Proceedings of the 2000 International Wildfire Safety Summit

Edmonton, Alberta Canada

October 10-12, 2000

Hosted by:

Alberta Environment Land and Forest Service

Sponsored by:

Proceedings

2000 International Wildfire Safety Summit

Edmonton, Alberta, Canada
October 10-12, 2000

Chair: B. Suenram

Produced by The International Association of Wildland Fire

Hosted by Alberta Environment Land and Forest Service

Edited by

B.W. Butler
USDA Forest Service

And

Kyle Shannon
USDA Forest Service

Published By
International Association of Wildland Fire
P.O. Box 2156
Montana City, Montana 59634

This Safety Summit made possible
by generous support from the following organizations:

Bombardier Aerospace

Air Tractor, Conair, Queen Bee Air Specialties

TYCO Wildfire Suppression Systems

Conference Materials and support provided by:

North Tree Fire International

NFPA

Fire Facilities Inc.

TriData Corp.

Natural Resources Canada

Additional support provided by the following organizations:

Travers
Rapid Fire & Rescue
Northern Titan
A&T Catering Ltd
Velcon Canada
Economy Carriers Ltd
Telus Mobility
Mercedes Textiles Ltd
Fulford Consulting

Individual papers can be accessed by clicking on the title below.

Table of Contents:

Key Observations & Recommendations
4th International Wildland Fire Safety Summit
October 10-12, 2000
Edmonton, Alberta, Canada

The breakout sessions have, traditionally, been one of the highlights of the Safety Summit conferences organized by the International Association of Wildland Fire (IAWF.) The conference includes breakout sessions to get people talking so that they may discuss their common safety problems, share information and approaches and generate new ideas using the conference presentations as fuel for ideas and discussion. We have documented key observations, recommendations and decisions that could advance the cause of firefighter or public safety regionally, nationally and internationally. The IAWF encourages you to distribute this document as widely as possible by all means possible.

1). SAFETY ZONES

Perhaps the most discussed issue of the Safety Summit, participants showed a great deal of interest in safety zones. Participants identified a critical need for a common understanding of safety zones and for common definition.

The apparent lack of understanding is due, in part, to confusion over fire shelter "deployment zones" vs. "safety zones." Given the difference in international approaches to fire shelter use, a common, international understanding of safety zones is needed.

Additional data (and additional funding) is needed to continue and reinforce practical research on safety zones. The Safety Summit participants identified numerous research needs, including:

- Guidelines, including safety zone requirements for varying slopes, fuel types, fire behavior and location on fire (head, flank or rear.)
- The apparent importance of separation from the flame front vs. overall safety zone size.
- A tiered approach (personal, crew, fireline evacuation.)

However, as has been the case since the safety summits began, participants called for a worldwide change in our fireline safety philosophy and culture. The desired change is one in which entrapment avoidance is emphasized over safety zones and fire shelters, risk to firefighter safety is weighed against values at risk and these concepts are emphasized in our training.

Participants also called for an effort to educate managers and line officers, believing that, when they understand why a safety zone must meet certain size parameters they will understand the need to reexamine strategy, tactics and the balance between firefighter safety vs. values at risk.

2). FIRE SHELTERS & FIRE SHELTERS/ENTRAPMENT AVOIDANCE

The fire shelter issue was widely debated with no consensus, or evidence that consensus in this forum is likely, consistent with past safety summits. The fire shelter issue evokes strong feelings. For example, there is a perception that the Province of Alberta is accepting and will adopt fire shelter use, evoking mixed feelings among participants from Alberta and across Canada.

Attitudinal differences regarding fire shelters remain stark, and many Canadian fire officers remain set against their use, regarding them as a safety hazard promoting risk taking and/or providing false security.

The issues surrounding “U.S. style” fire shelter philosophy generated familiar philosophical questions, including:

- How does protective equipment (fire shelters) influence firefighters’ risk perception?
- Do personnel who carry fire shelters take risks or become complacent?
- Does fire shelter training deter entrapment avoidance training?
- Do firefighters understand the limitations of the tool?
- No evidence seems to exist that “proves” whether firefighters are safer with or without fire shelters.

As with discussions of safety zones, participants used the opportunity to call for an emphasis, both in philosophy and training, on entrapment avoidance. Continued or growing international, interagency cooperation may demand that international consensus is achieved on fire shelter use.

3). <u>WILDLAND-URBAN INTERFACE</u>

There was a common perception among participants that society, and the fire community, has not completely come to grips with the reality that the wildland-urban interface is a people problem. Participants also cited concern that the fire community still does not fully understand that the complexities associated with wildland-urban interface fires make a significant contribution to firefighter safety problems.

The discussion revolved around many key issues, including:

- Compatibility – How do we live in fire dependent ecosystems?

- Confusion over the concept of defensible space. There exists widespread concern that we are confusing the public and firefighters. Common thoughts on “defensible space” (30 feet or 10 meters) may be a misnomer, and could give firefighters the wrong idea. Evidence from recent research shows that humans should not be in this zone in some fuel types.

- Whether, in a litigious society, U.S. fire agencies have made a mistake by accepting or taking responsibility for the wildland-urban interface issue?

- How we address the issue when insurance companies insure regardless of condition?

- How we change the attitudes and expectations of firefighters and the public regarding the priority and realities of structure protection? To understand how to make this change, requires that we examine firefighter and public thinking and the opportunities that exist for changing attitudes and the culture. This examination requires psychological and sociological study, which we are ill equipped to conduct.

- How do we reconcile structure protection with the value that firefighter safety is 1st priority?

- Where is the best investment in fuel modification or in the community? Some participants believe that our best investment is not in landscape fuel management, but in home construction/design, and in “making the community a fuel break, not making the fuel break around the community.”

- Evidence from Australia shows that fewer homes burn and people are safer if residents are not evacuated – given that the community/property/resident is prepared. U.S. fire authorities continue to focus on evacuation.

Many ideas were discussed to address the wildland-interface issue. Many sounded familiar themes that have been called for before. Ideas included:

- Leveraging the insurance and real estate industries
- Educating the public about the priority we place on firefighter safety
- Cleaning up government facilities as examples
- Increasing peer pressure in neighborhoods.
- Partnering with industry and local government.
- Providing tax breaks for property owner action and charging higher taxes or insurance premiums when standards are not met
- Increasing the budget, to a level that allows interface specialists in every field office
- Developing a new term to replace "defensible space."

4). EXPECTATIONS/ATTITUDES/CULTURE/SOCIAL SCIENCE

Reflecting the growing awareness of "human factors" in the wildland fire community, the safety summit participants engaged in substantial discussion of expectations, attitudes and culture. These discussions included attitudes, perceptions and expectations of individual firefighters, agencies and the public, and much of the conversation cycled around human factor issues, including cultural influences, public and media perceptions, personal accountability and responsibility and taking ownership of the safety issue.

As a piece of cautionary advice, one breakout group offered this piece of wisdom, "Firefighters, don't believe your No Fear tee shirt." Numerous participants believe that a "hero/glory seeker" mentality represents a major safety issue and attracts people with an undesirable attitude. Safety summit participants expressed particular concern regarding interface fires, where emotional concern, expectations and risk are simultaneously at their peak.

One breakout group summarized the issue well in saying "we are dealing with unreasonable expectations that arise from our previous successes." The wildland fire community is increasingly alarmed by how the public and media view firefighters and their responsibilities, and by their expectations. However, public perceptions are linked to how we view ourselves and how our actions effect public perceptions and media influence.

Approaches to the issue suggested by safety summit participants included:

- Get back to the realities of fire in the environment, and changing public attitudes. If we accept that we live in a fire dependent ecosystem, then we have choices to live compatibly or not. If people choose to not to live compatibly, property owners must be responsible for their own choices.

- We need to establish common expectations that are based upon mutually agreed upon risks and risk mitigations.

- Emphasize communication with the media, the public, elected officials and cooperators as a part of our concept of professionalism.

- Obtain the help of sociologists in developing and implementing the cultural changes we desire. We will need their assistance to change our culture and attitudes by identifying weak points in our community. Once done, we must then indoctrinate our new employees from their initial training.

- Engage social scientists to help us sort out how to deal with public and self-perceptions of firefighters as heroes and glory seekers, teach us to retain quality employees and develop psychological screening processes to weed out dangerous people and those who cannot make decisions.

- Understand the importance of team building and unit cohesion and how these concepts improve our resilience in stressful situations and chances for survival during crisis.

- Train people (firefighters & managers) in assertiveness, leadership and "no-go parameters"

5.) TRAINING AND EDUCATION

As usual, training was a major topic of discussion. Among major "findings":

- The video from the International Crown Fire Monitoring Experiment is incredibly valuable for teaching firefighters to recognize extreme fire behavior and potential for extreme fire behavior. People may not see this fire behavior for years, and the video can improve their knowledge.

- There is a need for quality safety training for contract operators.

- Canadian firefighters who served in the U.S. during the 2000 fire season observed that basic U.S. training focused on tactical safety references (orders, watchouts, LCES, etc) more than fundamental tactics and fire behavior.

- We are suffering from inconsistent terminology and definitions (see discussion of LCES/LACES.)

- The community needs to adopt, embrace and emphasize Crew Resource Management (CRM) concepts.

- Need to backup LCES/LACES training with data from current international research (i.e. ICFME, Safety zones.)

- We suffer from training that is inconsistent and over-complicated. We need to keep training consistent and simple.

- There is potential (and need) to develop an <u>international</u> fire safety communication network patterned on the use of SAFENET in the U.S.

- Establish an <u>international</u> fire training group or working team with its primary focus on safety and lessons learned (see above.)

- This group needs to endorse safety training, particularly safety training based in scientific data and standards developed using that data (as presented at the Safety Summit)

6.) NEED FOR ADDITIONAL DATA TO VALIDATE PRACTICAL RESEARCH

The safety summit participants were introduced to a wide variety of practical, applied research of importance to fireline operations. However, the need to validate that research was apparent, as was the need for additional funding to continue and reinforce safety related research. The Safety Summit participants identified continuing research needs, including:

- Increasing understanding of crown fire vs. surface fire behavior
- Improving practical understanding of fire behavior to improve firefighter safety
- Increasing emphasize on mitigating risk at initial attack vs. campaign fires
- Evaluating safety zones and fire behavior under a wider variety of topographic situations and fuels types

7.) LCES/LACES

Surprisingly, one of the most spirited topics of discussion revolved around cracks that have formed in the implementation of the LCES concept, widely regarded as a major advancement in firefighter safety. We labor under obvious inconsistencies in concept and terminology. For example, is it LCES or LACES? In LACES, is "A" for "anchor point" or "awareness?" If lookouts are critical to fireline safety, why are there no qualifications, standards or specific training for lookouts?

Key recommendations regarding this issue include:

- The LCES, situational awareness and risk management concepts must be integrated
- These concept(s) need to be taught in a stand-alone courses such as the LCES Workshop
- Need to establish qualifications & standards for lookouts, and provide guidance to them (what info to pass on, how to communicate, etc.)
- We can use video and situational case studies to effectively teach LCES/LACES

8.) STRATEGY

- The "no action" alternative/option needs to be an acceptable alternative/option
- We make too little use of the "trigger point" concept. For trigger points to work effectively, they must be flexible, changing by geographic area and used to consider values at risk when deciding whether to take action on fires or not. Fire behavior "triggers" have merit, but can also become "decision traps" We can use LCES/LACES as go/no go trigger.
- We need to update strategy, tactics, safety and IAP throughout shift and communicate those changes.
- Have main safety briefing in A.M. – Have smaller site-specific briefings during the day as situation changes.

9.) NEED FOR FIRE BEHAVIORISTS AND OPERATIONS STAFF TO WORK CLOSELY TOGETHER TO INFLUENCE DAY-TO-DAY SAFETY.

Participants in the safety summit identified the need for fire behaviorists and operations personnel to work more closely together to influence day-to-day safety. Principal concerns included:

- Operations chiefs and fire behavior analysts working together to identify escape routes and safety zones based on rate of spread and flame length respectively.
- An improved emphasis on firefighter safety in briefings, including providing safety zone size estimates in the incident action plan.
- Recognizing the need to update/change safety zones throughout the operational period.
- Operations/Safety need to conduct frequent, smaller, site-specific safety meetings

10.) SAFETY OFFICERS

Some participants discussed the safety officer position at length, with apparent consensus that the safety officer represents a valuable function for firefighter safety, and that experience, training and attitude of the individual are critical to their success. Among recommendations related to the safety officer position and function:

- Type I safety officers should be involved in national advanced fire behavior courses.
- Safety officers should be prepared with parameters to influence the decision process, such as when it is safe to deploy ground crews and when it is not, when fires should be actioned with aircraft, monitored or countered using aerial ignition.

11.) <u>PPE</u>

It appears that national and international PPE Standards many be needed. However, participants expressed some concern over the direction that the ISO standards are going, expressing a concern that there is an attempt to "armor" firefighters.

12.) <u>HAZARDOUS MATERIALS</u>

It appeared that hazardous materials (H2S "sour gas" and petroleum products are examples) represent an aspect of risk and hazard that are currently not well addressed in our standards and training, and an area that needs development.

DISTRIBUTION PLAN

The IAWF will distribute this document at the Association's website and by posting it at available listservs. The Association will also distribute this document in part or entirety, accompanied by a letter specifically requesting action, to each organization identified below. When possible, the Association will endeavor to tailor the document to reflect the interests of the target organization. The accompanying letter will note the composition of the 4th Safety Summit participants. In addition, the IAWF will explore options for television broadcast.

Australasian Fire Authorities Council (AFAC)
Canadian Council of Forest Ministers
Canadian Interagency Forest Fire Center (CIFFC)
European Fire Research Community (via D.X. Viegas)
Fire Equipment Working Team (Canada)
National Association of State Foresters (US)
National Wildfire Coordinating Group Steering Committee (US)
National Wildfire Coordinating Group – Safety & Health Working Team (US)
National Wildfire Coordinating Group – Training Working Team (US)
National Wildfire Coordinating Group – Wildland-Urban Interface Working Team (US)

An Introduction to the International Crown Fire Modelling Experiment[1]

M.E. Alexander

Canadian Forest Service, Northern Forestry Centre, 5320-122 Street, Edmonton, Alberta T6H 3S5. Phone: (780) 435-7346; Fax: (780) 435-7359; E-mail: malexand@nrcan.gc.ca

R.A. Lanoville

Department of Resources, Wildlife and Economic Development, Forest Management Division, P.O. Box 7, Fort Smith, Northwest Territories X0E 0P0. Phone: (867) 872-7700; Fax: (867) 872-7277; E-mail: Rick_Lanoville@gov.nt.ca

B.M.Wotton and B.J. Stocks

Canadian Forest Service, Great Lakes Forestry Centre, P.O. Box 490, Sault Ste. Marie, Ontario P6A 5M7; Phone: (705) 759-5740; Fax: (705) 759-5700; E-mails: bstocks@nrcan.gc.ca and mwotton@nrcan.gc.ca

Abstract. The International Crown Fire Modelling Experiment (ICFME) constitutes a major, cooperative, global undertaking involving coordination by the Canadian Forest Service Fire Research Network and the Government of the Northwest Territories' Forest Management Division combined with participation of collaborating scientists and operational fire personnel, principally from Canada and the USA, but with representation from several other countries as well. The initial impetus for the ICFME was oriented towards the testing and calibration of a newly developed physical model for predicting the spread rate and flame front intensity of crown fires. However, the ICFME has also provided the opportunity to examine other aspects or implications of crown fire behavior, without comprising this primary objective, including linkages to firefighter safety/personal protective equipment (PPE) and wildland-urban interface or intermix issues as well as certain ecological and environmental impacts or effects, including concerns about atmospheric chemistry from biomass burning. The 18 experimental crown fires that have taken place in the last four years (1997-2000) are providing valuable new data and insights into the nature and characteristics of crowning forest fires needed for dealing with the fire management problems and opportunities that will be affecting both people and ecosystems in the coming century.

This broad overview of the ICFME project will set the stage for the other presentations being made at the 4th International Wildland Fire Safety Summit dealing with specific ICFME studies. Some preliminary findings regarding community fire protection in the northern boreal forest, based on observations of the ICFME experimental crown fires, especially as they pertain to both public and firefighter safety, are also addressed.

Keywords: Canada; community fire protection; fire behavior; firefighter safety; fuel treatments; Northwest Territories; personal protective equipment; protective fire shelter; protective fire shelters; safety zones; wildland fire research; wildland-urban interface.

---

[1]For a complete copy of the paper presented at the 4th International Wildland Fire Safety Summit, Edmonton, Alberta, October 10-12, 2000, refer to the World Wide Web site for the International Crown Fire Modelling Experiment (http://www.nofc.cfs.nrcan.gc.ca/fire/fmn/nwt/).

A Pocket Card for Predicting Fire Behavior in Grasslands Under Severe Burning Conditions

M.E. Alexander
Canadian Forest Service, Northern Forestry Centre,
5320-122 Street, Edmonton, Alberta T6H 3S5
Phone (780) 435-7346; Fax: (780) 435-7359; email: malexand@nrcan.gc.ca

L.G. Fogarty
Berau Forest Management Project, C/O PT Inhutani I, JI Jend Sudiman 27, Balikpapan, Kalimantan Timur, Indonesia
Phone (62) 0542 395 889; Fax: (62) 0542-422-640; email: bfmpfire@indo.net.id

Abstract. The grassland fire behavior pocket card recently developed for use by wildland and rural firefighters in Canada and New Zealand is reviewed. The pocket card offers a practical field guide for quickly estimating the near worst case fire behavior potential in grasslands. At the same time it reinforces an awareness of the need for adopting safe work practices when attempting to contain grass fires in an effort to avoid burnovers and entrapments thereby eliminating firefighter injuries and fatalities.

Keywords:

Canada
Fire behavior
Firebreaks
Firefighter safety
Fire suppression
Fire weather
New Zealand
Safe work practices
Wildland firefighting

Many firefighters are surprised to learn that tragedy and near-miss incidents occur in fairly light fuels, on small fires, or on isolated sectors of large fires, and that fire behavior is relatively quiet just before the incident. Most of us believe that the high-intensity crown fire in timber or heavy brush is what traps and kills forest firefighters. Yet, with rare exceptions ... most fires are innocent-appearing just before the accidents.

Wilson and Sorenson (1978)

Introduction

In 1997, a pocket card entitled "A SIMPLE FIELD GUIDE FOR ESTIMATING THE BEHAVIOUR AND SUPPRESSION REQUIREMENTS OF FIRES DRIVEN BY WIND COMING FROM A CONSTANT DIRECTION, IN OPEN, FULLY CURED GRASSLANDS AT LOW FUEL MOISTURE" (Alexander and Fogarty 1997) was jointly developed by the Canadian Forest Service (CFS) and the New Zealand Forest Research Institute (Figure 1). This was followed by a technology transfer note (Fogarty and Alexander 1999) describing the derivation and use of the Alexander and Fogarty (1997) grassland fire behavior pocket card; a copy of this publication, as well as the French translation can be downloaded from the CFS Fire Research Network website (see Downloads at http://nofc.cfs.nrcan.gc.ca/fire/frn/).

Due to file conflicts, this figure cannot be viewed in acrobat reader. To see this figure please open the MS Word document.

Figure 1. The (a) front and (b) back sides of the Alexander and Fogarty (1997) grassland fire behavior pocket card. Actual dimensions are 11.5 x 17.2 cm (4.5 x 6.75 in.).

Why is the Grassland Fire Behavior Pocket Card Needed?

In comparison to free-burning fires occurring in other wildland fuel complexes, fires spreading through grass fuels are far more responsive to changes in wind and/or slope. This is especially so when the grasslands are in a fully cured state (Garvey and Millie 2000), and the fuels are critically dry due to high air temperatures, low relative humidity and a lack of recent wetting rain (Cheney and Sullivan 1997). This has important implications for firefighter safety with respect to the potential for burn injuries or even death (Figure 2). Grass fires can move surprisingly quickly, and so firefighters need to have a full appreciation and a healthy respect for this fact as evident by a significant number of fatalities associated with grassland fires in the United States (Wilson and Sorenson 1978; NWCG 1996; NWCG Safety and Health Working Team 1997). A major switch in wind direction can cause the relatively quite flank of a grass fire to suddenly become a much wider or larger and more vigorous high-intensity "head" from what previously existed. Similarly, any increase in wind speed above the average velocity will result in a corresponding escalation in a fire's overall rate of spread and intensity or flame size.

Figure 2. The emphasis of the pocket card is on providing basic fire behavior information in very simplistic terms to ensure safe wildland firefighting operations. Photos from NFPA (1992).

How Did the Grassland Fire Behavior Pocket Card Come About?

The inspiration for this field guide to predict grassland fire behavior under severe burning conditions came about as the result of one of the authors (MEA) undertaking an investigation of a burnover incident in grasslands that occurred near the town of Anerley, Saskatchewan, Canada, on October 2, 1993 (Alexander 1998; ETC 2000). A rural volunteer firefighter eventually died as a result of the burns he sustained while engaged in firefighting operations on this grass fire.

An initial draft of the grass fire behavior pocket card was prepared by the first author (MEA) as part of the technical review of a case study involving a "near miss" incident occurring on a wildfire in grasslands on New Zealand's North Island in early 1991 (Rasmussen and Fogarty 1997). The final version of the pocket card was completed by the second author (LGF) and is included as an appendix in Rasmussen and Fogarty's (1997) publication.

What is the Purpose of the Grassland Fire Behavior Pocket Card?

The principle intent of the pocket card is to provide wildland and rural fire suppression personnel with very basic information on grassland fire behavior such as forward spread distance and fire size (area and perimeter) in relation to elapsed time since ignition, in addition to flame front characteristics (Figure 1a), in as simple a manner as possible. However, at the same time it stresses the importance of adhering to traditional safe work practices and fire suppression strategies/tactics (Figures 3 and 4). The release of the 1996 California Division of Forestry video

"A Firefighter's Return From a Burnover: the Kelly York Story" (Anon. 1997) has reinforced the need for such a reminder in the form of a handy aid or guide like the grassland fire behavior pocket card. The concept of "making a stand" (Fogarty 1996) at a road, firebreak or other narrow barrier to fire spread (Figure 5) is certainly not recommended because of the potential for disastrous consequences, such as demonstrated by the major burn injuries sustained to a wildland firefighter on the 1989 Eagle Fire in northern California (NWCG 1993).

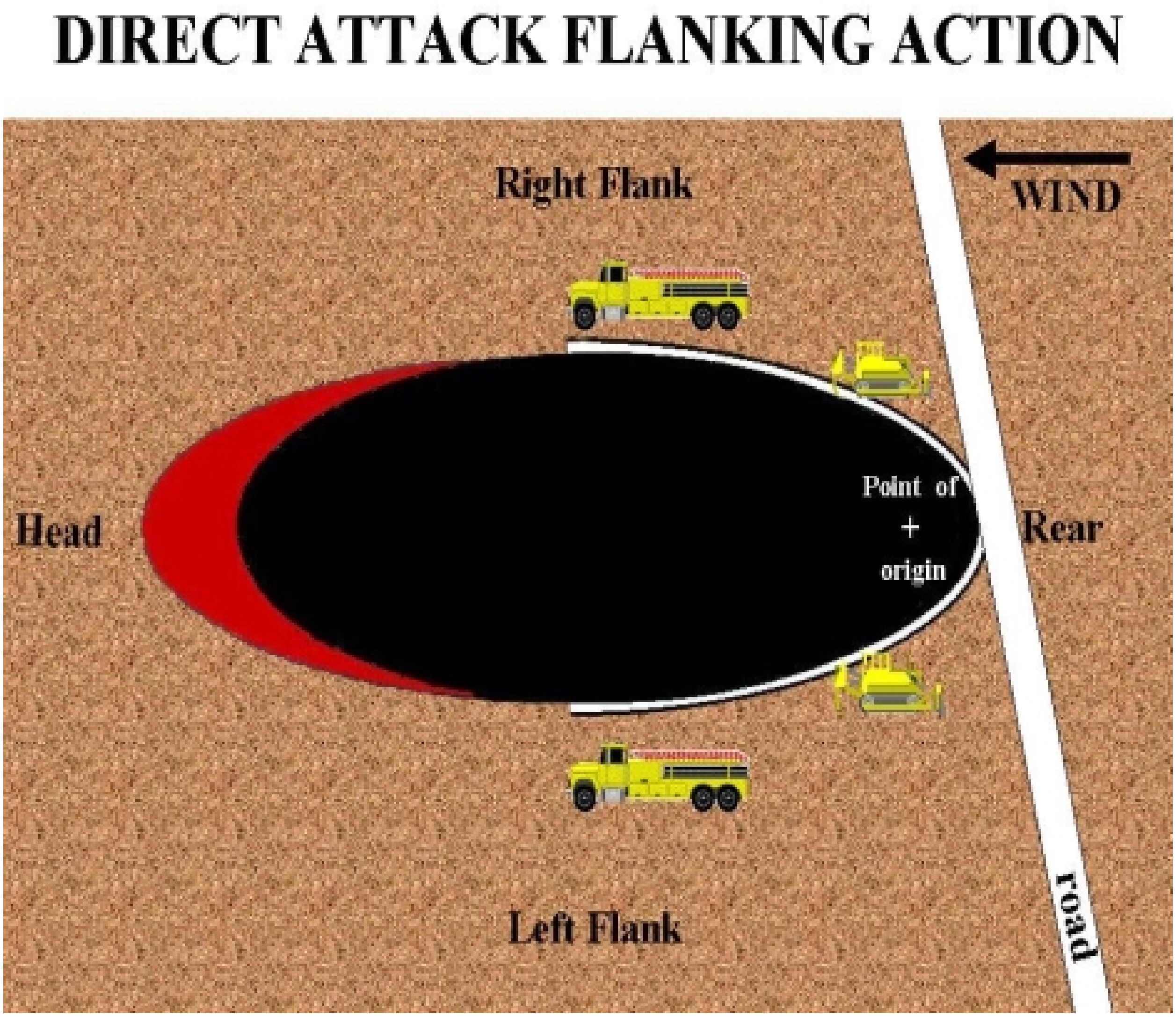


Figure 3. The pocket card explicitly states that the only safe fire suppression strategy/tactic is direct attack flanking action starting from the rear of the fire while being ever mindful of the possibility for rekindling, the value of a "black line", and the necessity for preparing a mineralized fireguard.

Figure 4. Safe work practices when engaged in grassland fire suppression include "anchor and flank" and "one foot in the green, one foot in the black". Photo from NWCG (1990).

Figure 5. The pocket card stresses that under no circumstances should a frontal assault on an advancing grass fire be undertaken. Photo from Clayton et al. (1987).

What is the Basis of the Grassland Fire Behavior Pocket Card?

The Alexander and Fogarty (1997) pocket card distills a large amount of research knowledge on wildland fire behavior in general and specifically as it pertains to grasslands (Wilson 1988; Cheney and Sullivan 1997[2]) that is both directly and indirectly relevant to the issue of firefighter safety (Figure 6). For example, the information presented on the front side of the pocket card (Figure 1a) enables one to judge whether or not a firebreak, a road or a prepared fireguard downwind of a spreading grass fire will stop the advancing flame front (Figure 7). Firefighters can accordingly develop or adjust their control strategy without jeopardizing their own well-being as a result of feeling compelled to take the fire "head on" in order to protect a value-at-risk (e.g., a farm house) or to stop the fire at all costs.

---

2 Cheney and Sullivan's (1997) book constitutes a tour de force in the field of wildland fire behavior and is recommended reading for anyone involved in grassland fire suppression.

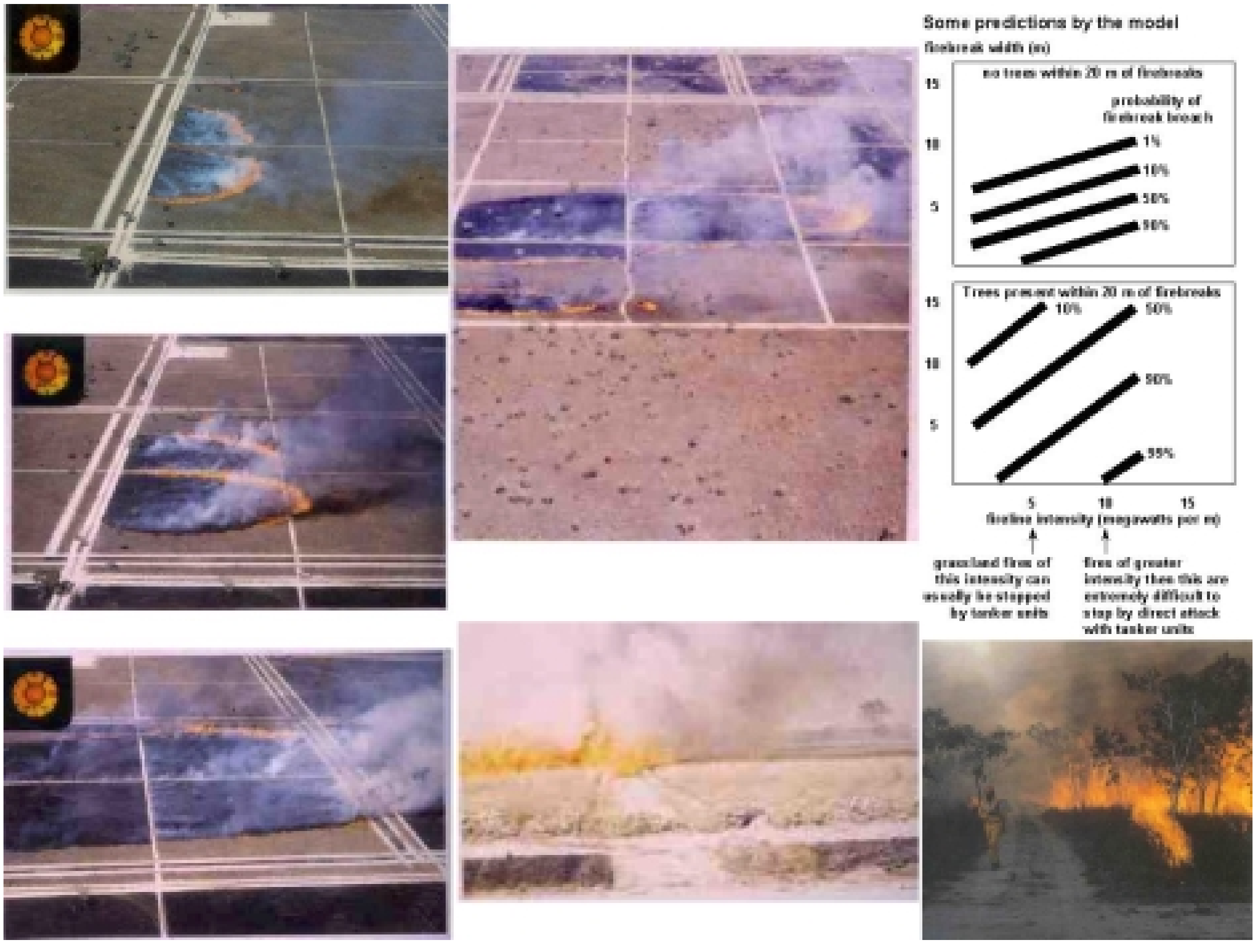


Figure 6. The pocket card has incorporated both the basic fire behavior data gathered from the experimental fires carried out in the Northern Territory of Australia by the CSIRO bushfire research group and the firebreak effectiveness model developed from this study. Photos from Davidson (1988) and CSIRO Division of Forestry and Forest Products Annual Report.

Figure 7. The pocket card provides guidance on the minimum firebreak width necessary to halt a grass fire's forward progress. Photo courtesy of D.R. Page, Woods and Forests Department of South Australia.

In contrast to the fire danger index climatology derived pocket card of Andrews et al. (1998), the estimates of the various fire behavior characteristics incorporated into the grassland fire behavior pocket card are based on the quantitative predictions obtained from the Canadian Forest Fire Behavior Prediction (FBP) System (Forestry Canada Fire Danger Group 1992). The predictions for fire spread and flame front intensity were obtained from the rate of spread model for the standing grass fuel type (O-1b) in the FBPSystem (Figure 8) assuming a constant fuel load (3.5 t/ha), degree of curing (100%),moisture content (Fine Fuel Moisture Code 93.2 equating to < 6% in fully cured grass), and a zero percent slope as stated on the back of the pocket card (Figure 1b). The fire area and perimeter estimates are based on the FBP System's simple elliptical fire growth model (Figure 9). For more information on the technical basis of the grassland fire behavior pocket card one should consult Fogarty and Alexander (1999).

Figure 8. The fire spread and intensity estimates in the pocket card are based on Canadian Forest Fire Behavior Prediction System Fuel Type O-1b (Standing Grass). Photo from De Groot (1993).

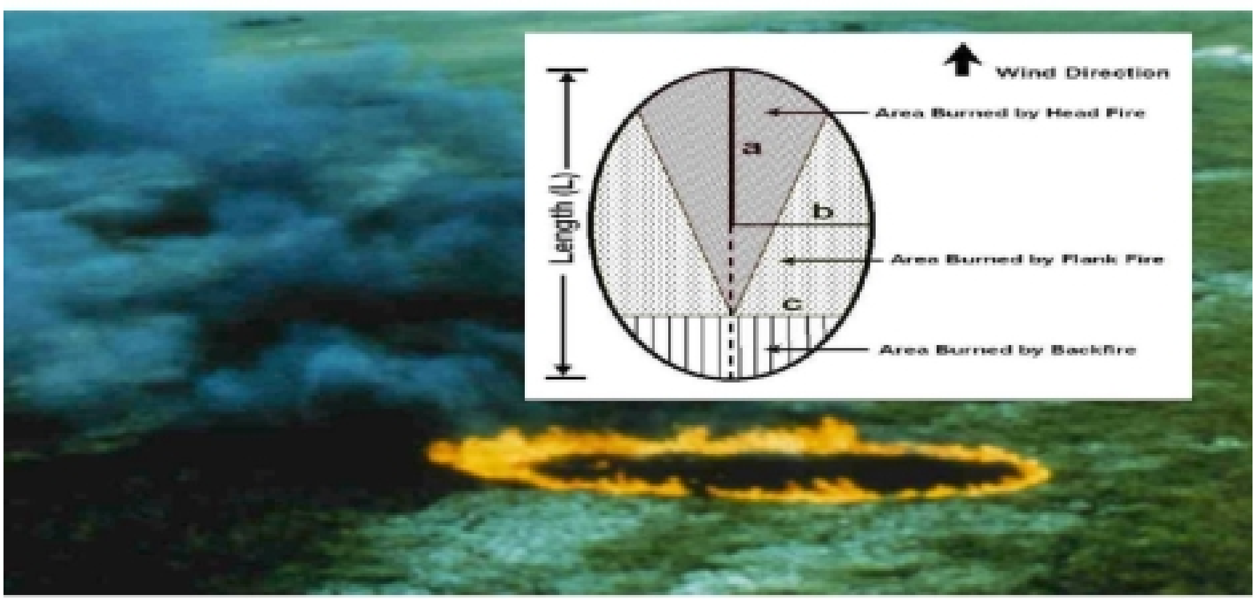


Figure 9. The fire growth projections in the pocket card assume an elliptical fire shape. Photo courtesy of D. D. Wade, USDA Forest Service.

How Does the Grassland Fire Behavior Pocket Card Work?

The pocket card requires only one input, namely an on-site estimate of wind speed (Figure 10) based on the Beaufort Wind Scale (List 1951, p. 119), which is reproduced on the back side of the card (Figure 1b); a measured or forecasted value could be used as well. Given the associated fire behavior predictions, a map and general knowledge of the area (e.g., road widths), and knowing what the prevailing wind direction is, fire suppression personnel are able to make assessments as to how far a grass fire is likely to advance. In turn, they are able to determine very early on whether warnings should be issued to residents and landowners downwind of the fire so that they can evacuate safely and/or make preparations to protect their assets. Simply put, the pocket card gives the initial attack fire boss or incident commander a means of making an initial estimate of potential worst case fire behavior which can be factored into the fire suppression strategy (e.g., the size or magnitude of the fire problem in terms of the resources that will be required to contain the fire). A detailed example of how to use the grassland fire behavior pocket card, suitable for training purposes, is given in Fogarty and Alexander (1999).

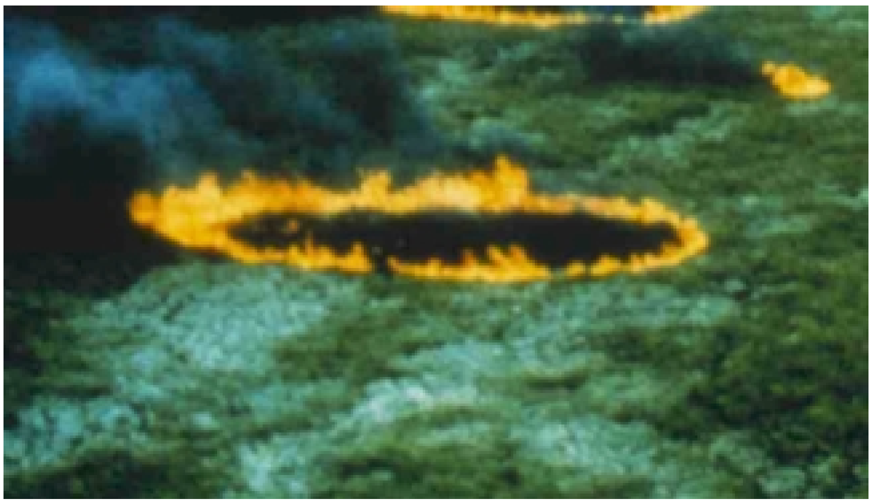


Figure 10. An estimate of the probable fire behavior characteristics in grasslands can be obtained from the pocket card based solely on an on-site estimate of the prevailing wind speed. Photo courtesy of J. McMecking, New Zealand Department of Conservation

Where Can I Get a Copy of the Grassland Fire Behavior Pocket Card?

Copies of the Alexander and Fogarty (1997) grassland fire behavior pocket card as well as the associated technology transfer note (Fogarty and Alexander 1999) and the publication by Rasmussen and Fogarty (1997) are available upon request from: Forest & Rural Fire Research Programme, ***Forest Research***, P.O. Box 29237, Christchurch, New Zealand (email: grant.pearce@forestresearch.co.nz). Furthermore, a poster on the grassland fire behavior pocket card that utilizes all the illustrations contained in this paper is available upon request from the first author (MEA).

Acknowledgements

At the time the grassland fire behavior pocket card was developed and the initial draft of the associated technology transfer note were prepared, the second author (LGF) was employed by the New Zealand Forest Research Institute (now called ***Forest Research***) in Rotorua. The review comments on this paper by G.J. Baxter of Forest Research are gratefully acknowledged.

References

Alexander, M.E. 1998. A wildland fire behavior researcher's perspective of firefighter safety in Canada. In: Proceedings Canada/US Wildland Fire Safety Summit. International Association of Wildland Fire, Fairfield, Washington, page 37.

Alexander, M.E. and L.G. Fogarty. 1997. A simple field guide for estimating the behaviour and suppression requirements of fires driven by wind coming from a constant direction in open, fully cured grasslands at low fuel moisture. New Zealand Forest Research Institute, Rotorua, New Zealand, and National Rural Fire Authority, Wellington, New Zealand. Pocket card.

Andrews, P.L., L.S. Bradshaw, D.L. Bunnell and G.M. Curcio. 1998. Fire danger rating pocket card for firefighter safety. In: Preprints Second Conference on Fire and Forest Meteorology. American Meteorological Society, Boston, Massachusetts, pages 67-74.

Anonymous. 1997. Video available showing the recovery of a severely burned volunteer firefighter. Wildfire 6(1): 64.

Cheney, P. and A. Sullivan. 1997. Grassfires: fuel, weather and fire behaviour. CSIRO Publishing, Collingwood, Victoria, Australia. 102 pages.

Clayton, B., D. Day and J. McFadden. 1987. Wildland firefighting. State of California, Office of Procurement, North Highlands, California. 136 pages.

Davidson, S. 1988. Predicting the effectiveness of firebreaks. Rural Research 139(Winter): 11-16.

De Groot, W.J. 1993. Examples of fuel types in the Canadian Forest Fire Behavior Prediction (FBP) System. Forestry Canada, Northern Forestry Centre, Edmonton, Alberta. Poster with text.

ETC. 2000. Wildland fire -- safety on the fireline. Environmental Training Centre (ETC), Hinton, Alberta. CD-ROM.

Fogarty, L.G. 1996. Two rural/urban interface fires in the Wellington suburb of Karori: assessment of associated burning conditions and fire control strategies. New Zealand Forest Research Institute, Rotorua, New Zealand, and National Rural Fire Authority, Wellington, New Zealand. FRI Bulletin 197, Forest and Rural Fire Scientific and Technical Series, Report No. 1. 16 pages

Fogarty, L.G. and M.E. Alexander. 1999. A field guide for predicting grassland fire potential: derivation and use. Natural Resources Canada, Canadian Forest Service, Ottawa, Ontario, Forest Research, Rotorua, New Zealand, and National Rural Fire Authority, Wellington, New Zealand. Fire Technology Transfer Note No. 20. 10 pages.

Forestry Canada Fire Danger Group. 1992. Development and structure of the Canadian Forest Fire Behavior Prediction System. Forestry Canada, Science and Sustainable Development Directorate, Ottawa, Ontario. Information Report ST-X-3. 63 pages.

Garvey, M. and S. Millie. 2000. Grassland curing guide. Victorian Country Fire Authority, Mt. Waverley, Victoria. 18 pages.

List, R.J. 1951. Smithsonian meteorological tables. 6th revised edition. Smithsonian Institute Press, Washington, D.C. 527 pages.

NFPA. 1992. Firestorm '91 case study. National Fire Protection Association (NFPA), Quincy, Massachusetts. 31 pages.

NWCG. 1990. Single resource boss – crew, S-230 slide set. National Wildfire Coordinating Group (NWCG), Boise, Idaho. National Fire Equipment System Publication NFES 2159.

NWCG. 1993. Look up, look down, look around. National Wildfire Coordinating Group (NWCG), Boise, Idaho. National Fire Equipment System Publication NFES 2244. VHS videotape.

NWCG. 1996. Common denominators of fire behavior on tragedy and near-miss wildland fires. National Wildfire Coordinating Group (NWCG), Boise, Idaho. National Fire Equipment System Publication NFES 2225. 23 pages

NWCG Safety and Health Working Team. 1997. Historical wildland firefighter fatalities 1910-1996. 2nd edition. National Wildfire Coordinating Group (NWCG), Boise, Idaho. National Fire Equipment System Publication NFES 1849. 38 pages.

Rasmussen, J.H. and L.G. Fogarty. 1997. A case study of grassland fire behavior and suppression: the Tikokino Fire of 31 January 1991. New Zealand Forest Research Institute, Rotorua, New Zealand, and National Rural Fire Authority, Wellington, New Zealand. FRI Bulletin No. 197, Forest and Rural Fire Scientific and Technical Series, Report No. 2. 18 pages + appendix.

Wilson, A.A.G. 1988. Width of firebreak that is necessary to stop grass fires: some field experiments. Canadian Journal of Forest Research 18: 682-687.

Wilson, C.C. and J.C. Sorenson. 1978. Some common denominators of fire behavior on tragedy and near-miss forest fires. U.S. Department of Agriculture, Forest Service, Northeast State and Private Forestry, Broomall, Pennsylvania. Publication NA-GR-8. 31 pages.

An Update on Fire Shelter Research and Design

Leslie Anderson
USDA Forest Service, Missoula Technology and Development Center,
Building 1, Fort Missoula, Missoula, MT 59804 USA
Ph. (406) 329-1043, FAX (406) 329-3719
Email: landerson@fs.fed.us

Abstract. The fire shelter is required personal protective equipment for all federal wildland firefighters in the United States. Since becoming required equipment in the 1970’s, the fire shelter has saved the lives of over 250 firefighters, and has prevented hundreds of serious burn injuries. The fire shelter is designed primarily to reflect radiant heat, rather than to insulate against convective heat. There are limits to the protection it can provide, especially when flames directly contact the shelter. A few injuries and even some fatalities have occurred when flame contact with the shelter was severe. Field and lab tests have been performed to determine the limits of the shelter’s protection and to obtain data that can be used to develop standardized performance tests for the fire shelter. During field tests at the International Crown Fire Modeling Experiments in 1999, ignitions occurred inside some shelters that were exposed to direct flame. Further testing by Mark Ackerman at the University of Alberta showed that the adhesive used to bond the layers of the shelter material can, under some conditions, volatilize and ignite inside the shelter.

The fire shelter program’s goal is to maximize the performance of the current fire shelter while seeking an improved fire shelter design. The three major components of the program are to improve firefighter training, to develop standardized tests and performance standards for fire shelters and to develop or acquire an improved fire shelter design.

This paper reviews recent fire shelter testing, and provides an update on the fire shelter program.

Introduction

The fire shelter is a tent-shaped device carried by wildland firefighters for emergency personal protection during wildfire entrapments. Every federal wildland firefighter in the United States is required to carry a fire shelter whenever he or she is on an uncontrolled fire. Although fire shelters have saved many lives and prevented many serious injuries, there is a limit to the protection they can provide. The Missoula Technology and Development Center (MTDC) is working through several avenues to provide improved fire shelter protection.

Background

Roughly 1,000 fire shelters have been deployed since the shelter was designated as mandatory personal protective equipment in the late 1970’s. In about 250 of these deployments the fire shelter is believed to have saved the life of its occupant. In at least 250 more deployments, the fire shelters prevented serious burn injury. While most of the remaining 500 or so deployments are considered to have been precautionary, some deployments may have prevented minor burns and smoke inhalation. About 13 persons have died with partially or fully deployed fire shelters. Some of the fatalities occurred when firefighters were unable to fully deploy their fire shelters before being overcome by heat and smoke. Others occurred when firefighters left their shelters when temperatures outside were still unsurvivable. Still others occurred when fire shelters were deployed in conditions so severe that the shelters were unable to provide adequate protection.

The fire shelter weighs about 3½ pounds and measures 3¼ inches by 5½ inches by 9½ inches when folded and in its case (Figure 1). It is carried on a belt or field pack so that it is immediately accessible at all times. The shelter is made of a laminate of a layer of fiberglass cloth and a layer of aluminum foil. The aluminum is the main protective layer in the laminate. The fiberglass cloth provides tear resistance and strength.

The fire shelter protects firefighters by reflecting radiant heat and trapping breathable air. The aluminum foil reflects about 95 percent of the radiant heat that reaches it, leaving only about 5 percent to be absorbed into the shelter material. Of the remaining 5 percent, part is reradiated back out of the shelter. The balance raises the temperature of the laminate and the air inside the shelter. When the shelter is exposed to nothing but radiant heat, it can provide significant protection against high temperatures.

The effect of convective heat on the shelter is far more problematic. As flames and hot gases move over the shelter, heat is transferred from the hot gases to the shelter material. The degree of convective heat transfer depends on the velocity of the air movement around the shelter and the difference in temperature between the gases and the shelter material. As the air velocity and the temperature difference increase, convective heat transfer also increases. Convective heat is easily transferred to the shelter material and can rapidly raise its temperature and the temperature of the air inside the shelter to critical levels.

If the temperature of the shelter material reaches 260 °C (500 °F), the glue that bonds the layers starts to break down. Without the glue, the foil can be blown out of place or tear in the turbulence that occurs with extreme fire behavior. If the material temperature reaches 650 °C (1200 °F), the aluminum itself can melt. Without the foil, the shelter offers virtually no thermal protection. In the extreme thermal environment of crown fires, temperatures can exceed 1100 °C. (2012 °F). In such environments, convective heat and flame contact can cause a fire shelter to fail within moments.

International Crown Fire Modeling Experiments: 1997 to 1999

The International Crown Fire Modeling experiments, held outside of Fort Providence in the Northwest Territories, offered excellent opportunities to test the fire shelter in high-intensity fire conditions. During the 1997, 1998, and 1999 experiments, the Missoula Technology and Development Center collected data on the performance of standard and prototype fire shelters (Figure 2). Each year we learned more about how best to instrument the tests and what data we needed to gather. By 1999, our highest priorities were to gather temperature and heat flux data, inside and outside of fire shelters, and inside and outside of the crown fire plots. Our intentions were to better define the fire environment to which fire shelters can be exposed to help us develop a controllable and repeatable lab-based thermal test. We were also interested in comparing total, convective, and radiant heat flux to temperatures inside the shelter in an effort to better define the size of effective deployment sites.

Our observations during the crown fire tests confirmed our fundamental understanding of the fire shelter's performance. As expected, the shelters did provide significant protection against high temperatures when exposed to radiant heat and minor levels of convective heat (Figure 3). Moderate to severe convective heat flux levels led to rapid damage if not outright destruction of the fire shelter. Because of limited data and because the radiant, convective, and total heat fluxes varied so widely, it was difficult to determine the heat flux levels at which damage to the shelters occurred or to compare heat flux to temperatures inside the shelters. There were too many variables and no way to control them. The results of the Crown Fire Experiments confirmed our need for a lab-based test for the fire shelter, and provided us with much needed information on the fire environment for developing such a test. With a lab test we hope to be able to better identify failure points for current and future fire shelters.

The most significant outcome of our testing at the Crown Fire Experiments was the discovery that flammable gases can ignite inside the fire shelter under certain conditions. This discovery has caused us to stand back and rethink our direction in the fire shelter program. Earlier tests done in cooperation with the Fire Behavior and Fire Chemistry Units of the Intermountain Fire Sciences Laboratory at Missoula, MT, showed significant downward spikes in oxygen levels and simultaneous upward spikes in carbon monoxide levels inside fire shelters exposed to direct flame. These troubling results led us to place video cameras inside some instrumented fire shelters at the crown fire experiments. Videotape from inside two shelters exposed to intense flames showed the shelters filling with smoke. The videotape could not show the flammable gases that were also in the shelter. Those gases ignited when flames entered the fire shelters (Figure 4). Immediately after viewing these tapes, the Center began an investigation to determine the cause of these ignitions and the conditions under which they can occur. Within 3 months of the discovery, Mark Ackerman of the University of Alberta (under contract with the Center) completed a detailed study of the ignition phenomena. The goals of this study were:

1. To identify the conditions under which a flammable mixture would form
2. To identify the composition of the flammable mixture
3. To review test methods and standards to identify potential performance tests.

Ignition Study Results

The University of Alberta study showed that the fire shelter ignitions were repeatable in a lab environment. Numerous tests were done on standard fire shelters using six, four and two propane burners, arranged around the foot end of the fire shelters. Depending on the number of burners, up to one-half of each side of the shelter was also exposed to flame. Each burner provided a heat flux of 60 to 85 kW/m^2. In one case, one-third, resulting in a reduced heat flux reduced the gas pressure. Temperatures were measured with thermocouples that were placed at distances of 3, 6, 9, 12, 15, and 18 inches from the floor of the shelter as well as outside the foot of the shelter near its peak. Given that a firefighter would lie in a prone position when using a shelter, the temperature 3 inches above the floor of the shelter is considered to be temperature at the breathing zone.

In each of shelters tested, off-gassing and internal flames were observed. Typically, the internal temperatures would climb at a steady rate until ignition occurred. After ignition the internal temperatures rose as much as 600 degrees in 1 to 2 seconds. Temperatures near the floor of the shelter were always much lower than those closer to the peak. As the exposure to flames was reduced, either by reducing the number of propane burners with flames directed at the shelters or by lowering the gas pressure, external temperatures, internal temperatures, and damage to the shelters decreased (See Table 1). In all cases, the flames extinguished themselves when the burners were shut off. This indicates that the flames inside the shelter are not self-sustaining, but require an external heat source that maintains flammable fuel mixtures.

Number of Burners	**Max. External Temperature* °C**	**Max. Internal Temperature* °C**	**Max. Breathing Temperature* (at 3 inches) °C**
6	>1150	900	100
Damage: Interior discoloration over ½ length of shelter. Delamination over foot end and >one-third length of shelter.			
6	>1100	>850	150
Damage: Interior discoloration over half the length of the shelter. Delamination over foot end and more than one-third the length of shelter. Foil broken open on both sides near foot end.			
4	>1050	750	80
Damage: Interior discoloration over one-third the length of shelter. Small amount of torn foil at foot end and minor delamination on sides near foot end.			
4 (w/ reduced gas pressure)	1070	300	60
Damage: Discoloration at foot end, less than one-fourth the length of the shelter.			
2	1200	>200	40
Damage: Discoloration limited to foot area.			
*Temperatures are approximate			

Table 1—Temperatures measured and damage to fire shelters exposed to direct flame from propane burners.

The findings from this study indicate that shelter ignitions can occur with relatively minor exposure to direct flame. However, the associated temperature traces and related shelter damage indicate that under moderate heat exposures, the ignitions do not necessarily signal shelter failure or conditions that cannot be survived. The greatest concerns associated with these ignitions are:

- Premature damage or failure of the shelters
- Flames inside the shelter—however brief—may directly burn the firefighter
- Flames may cause a firefighter to panic and attempt to escape, exposing the firefighter to the far more dangerous environment outside the shelter.

Tests run during the University of Alberta study show that the gases originate from the polyester adhesive used in the shelter material. The adhesive's decomposition rate is highly temperature dependent. Below 300 °C, decomposition is so slow that the quantity of gases produced is insignificant. At temperatures above 400 °C, the decomposition rate is rapid enough that combustible quantities of gases can accumulate inside the shelter. Radiant heat can cause the adhesive to decompose. Convective heat can cause the adhesive to decompose more rapidly because the shelter material's temperature rises more quickly when it is exposed to convective heating.

Samples of the gases produced when the adhesive decomposed contain a mixture of gaseous hydrocarbons. Because the specific compounds formed depend on the position on the long-chain polyester molecule at which the bonds break, the nature and concentration of these compounds will vary. However, the danger of flames inside the shelter exists regardless of the types of hydrocarbon compounds produced. A flammable hydrocarbon mixture can be ignited with a flame source, as might occur through an opening in a fire shelter, or by autoignition. Long-chain hydrocarbons can autoignite at temperatures as low as 200 °C.

Looking Ahead

Our new understanding of the fire shelter's performance and limitations led us to quickly define a new direction for the fire shelter program. This new direction is centered on some basic realities. First, we know that the current fire shelter has saved many lives and prevented many burn injuries. Second, although some new fire shelter designs are potentially excellent, our lack of an adequate performance test or standard has limited our ability to definitively compare new designs with each other or with the existing design. Our goal is to provide firefighters with an improved fire shelter, but we must know that the new shelter is indeed an improvement. Third, when the new fire shelter is identified, replacing the tens of thousands of shelters now in service will require a massive effort. It cannot happen overnight.

The goals of the new fire shelter program are to:

1. Improve training.
2. Develop performance standards for the fire shelter.
3. Test new shelter design options against the new fire shelter standards.

Let's examine these goals one by one.

Improving Training

Fire shelter training has always stressed avoiding flame contact with the fire shelter. However, updated training materials were needed to get the best performance possible out of the current shelter. The new materials do a better job of explaining the need for keeping the shelter away from flames and of helping firefighters recognize the differences between effective and ineffective deployment sites. New training is being developed that focuses on avoiding entrapment and escaping threatening situations.

The following is a list of new training products related to fire shelter deployment:

- <u>Avoid the Flames</u>: This color brochure includes descriptions of the conditions that can lead to ignitions inside the shelter, explanations of the need to avoid flame contact with the shelter, and advice on where and where not to deploy the fire shelter. Available in English and Spanish. This brochure can be obtained by calling the National Interagency Fire Center at 208-387-5512. It is also available on the Internet at www.fs.fed.us/fire/safety/deployment.shtml.

- <u>Your Fire Shelter: 2000 Update</u>. This booklet will cover escape, fire shelter deployment procedures, deployment site selection, fire shelter training, and fire shelter inspection. The booklet should be provided along with a facilitated training course. Available by November 2000***. NFES 1570.***

- <u>Deploying the Fire Shelter</u>. This video will cover escape, fire shelter deployment procedures, deployment site selection, fire shelter training, and fire shelter inspection**.** Available by November 2000.

Still to Come:

- Avoiding Fire Entrapments. Video and training package. Content will focus on procedures and concepts for avoiding fire entrapment. Expected release, November 2001.

Developing Fire Shelter Performance Standards

Currently there are no performance standards for the fire shelter have been approved by the National Fire Protection Association. The fire shelter standard listed in the Standard on Protective Clothing and Equipment for Wildland Fire Fighting (NFPA 1977, 1998 ed.) is a design standard *only*. This standard references the current Forest Service Fire Shelter Specifications. Only fire shelters that meet the current specifications can be certified as NFPA compliant. The positive effects of moving from a design standard to a performance standard are significant. Development and innovation are encouraged when manufacturers are freed from a restrictive design standard. When a new shelter design is selected, we *must* know -based on empirical data-that the new design is better than the current shelter. The availability of performance tests and standards will allow us to compare the performance of new shelter designs.

The first step toward developing these performance tests was the collection of heat flux, temperature, and air velocity data during the International Crown Fire Modeling Experiments in 1999. Additional data were collected during a prescribed burn in sagebrush near Dillon, Montana, in April 2000. Further data will be collected in the fall of 2000 during prescribed burns in southern California fuels. With this data we will have a better understanding of the fire environment to which the shelters can be exposed and in which we should be testing.

In January 2000, MTDC again contracted with Mark Ackerman from the University of Alberta for the development of a test protocol for full-scale thermal performance tests and for small-scale testing for material screening and component performance. The small-scale testing will include tests of flammability, durability, strength, and tear resistance. Through repeated tests of current shelters, the University of Alberta will be able to suggest failure criteria for testing standard and prototype shelters.

The new performance standard will also require designing a new toxicity test. The toxicity test used on the current fire shelter is not adequate for alternate shelter materials. The Center now has a contract with SGS-US Testing in Fairfield, New Jersey, for developing this test. The new toxicity test protocol is to be available to MTDC by April of 2001.

Developing and Testing New Fire Shelter Designs

A parallel effort in fire shelter development is taking place as we await delivery of the new performance tests. MTDC has contacted a wide variety of experts in thermal protection, including:

- Researchers from government agencies, the military, and universities.
- Manufacturers of thermal protective materials.
- Other experts in fire shelter development.

Our intention is to have numerous fire shelters ready to test as soon as the test and failure criteria are in place.

Conclusions

Any effective fire shelter must meet a demanding set of requirements. It must be lightweight and small enough to be carried at all times by firefighters who are performing difficult and exhausting work. It must be durable enough to withstand the harsh conditions and rugged treatment associated with wildland firefighting. Firefighters must be able to deploy shelters in a matter of seconds. And above all, the shelter must offer the firefighter protection in highly dangerous environments. The current fire shelter meets many of these demands and has saved many lives. It is unlikely that any fire shelter will ever be able to provide protection in the most extreme conditions. However, we do believe that a better fire shelter is possible and is something that wildland firefighters deserve.


Figure 1—The fire shelter is carried on a firefighter’s belt or pack so that it is immediately available at all times.


Figure 2—Setting up a fire shelter for testing during the International Crown Fire Modeling Experiments in the Northwest Territories during 1998


Figure 3—Fire shelters were placed at varying distances from the edge of the crown fire plots. The fire shelter in the foreground was 2 meters from the plot’s edge.


Figure 4—In some conditions, glue in the shelter laminate can volatilize and ignite inside the fire shelter.

BCFS Physical Fitness Standards – Challenges, Changes and Lessons Learned

S. Bachop

Abstract. It is generally accepted and supported by scientific research that individuals who perform the physically demanding and repetitive tasks associated with forest fire fighting require high levels of aerobic and muscular fitness.

Since the early 1980's, the British Columbia Forest Service Protection Branch has relied on a variety of pre-employment tests to help assess the physical capability of individuals who perform as fire fighters in BC. These have included the US Forest Service-designed step and smokejumper tests, the BCFS/University of Victoria designed "*Bonafide Occupational Fitness Test and Standards for B.C Forest Service Wildland Firefighters*" (1992-1999), and most recently a new pre-employment standard comprised of both the USFS pack test and existing BCFS pump/hose test.

Although the types of tests have changed due to emerging research and/or legal challenges in court, the underlying intent of these standards has always been the same. That is, to ensure that only people who are physically capable of performing the demanding tasks associated with fire fighting are employed to do this work.

This paper will summarize the experiences of the BCFS Protection Program with various fitness tests, up to and following the Supreme Court of Canada's *Meiorin** decision in September 1999. It will also explore some of the potential impacts of the *Meiorin* decision including the challenges currently facing the BCFS - and potentially other agencies in Canada - to ensure future employment standards are defendable and meet the intent of this Supreme Court decision.

*official *Meiorin* decision can be accessed at:

http://www.lexum.umontreal.ca/csc-scc/en/pub/1999/vol3/html/1999scr3_0003.html

Background – Challenges and Changes

The BC Forest Service Protection Branch (BCFS) has used organized physical fitness testing as a "condition of employment" for most fire suppression crews since the early 1980's. The initial test used by BCFS fire fighters for employment purposes was the US Forest Service designed "smokejumper" test, where candidates had to:

- Run a distance of 2.5 km on level ground in less than 11:00 minutes
- perform 7 chin-ups in less than 1 minute*
- perform 24 push-ups in less than 1 minute*
- perform 24 sit-ups in less than 1 minute*

*5 minutes rest allowed between test components

June 1991

The first significant challenge to this standard occurred when an initial attack fire fighter filed a grievance with the British Columbia Government and Services Employee Union (the "Union") after losing his job for failing this test. During the arbitration hearing for the case, an independent arbitrator upheld the validity of standard, quoting Dr. Brian Sharkey of the USFS in his decision:

"Taken as a whole, the standards seem to be reasonable and consistent with the results of our criterion-related field study. They are especially appropriate for an elite crew that is considered the first line of defense in the fire control

effort. The standards are well within the reach of motivated men and women interested in this strenuous form of employment."

"Dr. Sharkey's evidence makes it abundantly clear to me that there is a relationship between fitness and the work performance of a CIFFAC (Central Interior Forest Fire Attack Crew) fire fighter, and that the particular fitness test imposed by the employer is a reasonable one".

Consequently no changes were made to this standard, and it continued to be used as a condition of employment with a majority of crews. Around this time, the USFS "step test" was also adopted and used by BCFS sustained action "unit" crews as a condition of employment test.

August 1991

On August 01, 1991 a physically unfit logger, pressed into fire fighting duties near Sechelt on BC's sunshine coast, was fatally burned when he failed to escape an advancing fire. The British Columbia Coroner and Workers Compensation Board (WCB) stated as one of their recommendations:

"Regardless of previous fire fighting training, only workers who are physically fit and familiar with working in heavy brush conditions should be assigned front line fire fighting duties".

May - October 1992

In response to the coroner's recommendations and due to increasing concern regarding possible "systemic barriers" posed by components of existing tests, the BCFS and University of Victoria Sport and Fitness Center researched and established Bona Fide Occupational Fitness and Standards for Wildland Fire Fighters. The new "Bonafide" standard was the result of hundreds of hours of research, field and laboratory testing, and a comprehensive analysis of tasks regularly performed by BCFS fire fighters.

Designed to measure aerobic, muscular strength/endurance, and job specific fitness, the Bonafide test was introduced on a trial basis to all crews in 1993 and became a condition of employment for all new fire fighters in 1994. Returning fire fighters (hired prior to 1994) were given the option of attempting their original employment test (i.e. smokejumper or step test) if they failed the new Bonafide standard.

This "grandfathering" policy was adopted for a number of reasons: 1) the full impact of new standard was still unknown - there was concern about losing experienced fire fighters unable to pass it, and, 2) to reduce the number of costly and time-consuming employee grievances. It was felt that over time and through the simple process of attrition, the Bonafide test would eventually become the sole condition of employment test for all BCFS fire fighters.

May 1994

Tawney Meiorin, an initial attack fire fighter working in Golden, BC, was laid off from her position for failing to pass either the Bonfide test or her original condition of employment test* (she failed to complete the 2.5km run in less than 11:00). Meiorin immediately filed a grievance with her Union stating that the running test was "unfair" and discriminated against her. In anticipation of a lengthy grievance/appeal process, and based on legal advice, the BCFS immediately initiated follow-up research studies between 1994 and 1998 to reinforce the findings in 1992 Bonafide study.
*Contrary to existing policy and procedures, it was discovered that Tawney Meiorin's supervisor failed to test her (at any time) during her two previous seasons on the initial attack crew. This oversight would prove to have a significant impact on the outcome of the "Meiorin" case.

September 1996

Meiorin's grievance was ruled on by an independent arbitrator, who in his decision stated:

"I propose to make certain findings of fact:

Is the aerobic standard of 50 VO2 max, as adopted by the Employer, an appropriate standard that is reasonably related to forest fire fighting duties?"
"Turning to the first question, I am persuaded the employers position must prevail. I accept Dr. Wenger's evidence that the standard 50 VO2 max. for aerobic fitness for wildland forest fire fighters is one of the appropriate standards that measures the physical fitness of members of initial attack crews and further, that standard is reasonably related to forest fire fighting duties."* *U-Vic Professor and recognized expert in the field of exercise physiology

The arbitrator also cited sections of the earlier (June 1991) fitness arbitration decision:

"The Union does not challenge Dr. Sharkeys evidence", "The decision affirms the expert opinion of Dr. Sharkey and the validity of the 2.5 km run in 11:00 minutes or less as an appropriate measure of aerobic capacity that is reasonably related to the work in question…however, insofar as it measures with reasonable accuracy that standard of aerobic fitness for initial attack crew members, I am persuaded the standard and the test itself constitutes a valid measure of physical fitness for initial attack crew forest fire fighters to perform the requirements of the job."

Despite these comments - which appear to justify the use of the fitness test(s) used by the BCFS - the arbitrator ruled in favor of Meiorin. The arbitrator stated the BCFS discriminated against Meiorin and was obligated to *reasonably accommodate* her because of her gender. He failed to define what "reasonable accommodation" meant, and the BCFS appealed to the BC Court of Appeal.

July 1997

The fitness tests used by the BCFS were found not to discriminate by the BC Court of Appeal.

"{20} In our opinion, the appellant (BCFS) has established that the requirement that all forest fire fighters employed by the Ministry successfully complete what is called by the employer the Bona Fide Occupational Fitness Test does not discriminate on the basis of sex and that being so the appellant has not discriminated against Ms. Meiorin".

The Union then appealed this decision to the Supreme Court of Canada. In preparation for arguments in the Supreme Court, the BCFS submitted results of the additional studies done between 1994 and 1998. These included signed affidavits from male and female fire fighters, senior managers, and statistics supporting the theory that with consistent training a majority of women could meet the BCFS fitness requirements.

For no obvious reason this evidence was ruled *inadmissible* by one of the female Supreme Court justices.

February 1999

Arguments in the Meiorin case were heard before the Supreme Court of Canada, which resulted in national media attention in the case. Despite the BCFS's best efforts to justify the use of fitness test(s) for fire fighters, the majority of media coverage appeared biased towards Meiorin.

January - July 1999

In anticipation of the Supreme Court's forthcoming decision, the BCFS tasked a consortium of independent world experts (in the field of exercise physiology and forest fire fighting) to review and report on the research protocols and procedures followed to establish the Bonafide standard. The consortium, comprised of Dr. Brian Sharkey (USFS), Dr. Gordon Sleivert (New Zealand), Dr. H. A. Wenger (Canada) and Dr. Graham Budd (Australia), and Dr. Lynneth Wolski (Canada) reviewed relevant scientific literature on the physiological costs of wildland fire fighting, including the necessity of men and women to have the same aerobic fitness (VO2) to perform required fire suppression tasks at the same level.

The consortium overwhelmingly supported the recommendations made in the 1992 Bonafide study and confirmed validity of the BCFS standard. They stated that it accurately reflected the physiological costs of effectively performing fire fighting tasks in BC.

<u>September 1999 - Supreme Court of Canada Decision</u>

The Supreme Court of Canada ruled in favor of Tawney Meiorin, and upheld the initial arbitrators ruling that the BCFS failed to prove that the minimum aerobic component of the fitness test was "reasonably necessary to the accomplishment of that legitimate work related purpose."
The Court reached its conclusion by using a new three-step process to determine whether or not the employment standard was a true "Bonafide Occupational Requirement (BFOR)". In their decision, the Court recognized that the BCFS met the first two steps of this process, but not the third.

The Court also strongly implied in the *Meiorin* decision that all employers considering the use or introduction of employment (fitness) standards must be prepared to answer specific questions regarding the *validity* and *impact* of that standard to justify its "Bonafide" status. If an employer fails to do this, they risk having their test(s) struck down and could be forced to reinstate/compensate employees who have lost their jobs because of a non-Bonafide standard.

The following is a summary of the Supreme Court of Canada's new three step process for determining a BFOR:

1)"First, the employer must show that it adopted the standard for a purpose rationally connected to the performance of the job.
2) Second, the employer must establish that it adopted the particular standard in an honest and good faith belief that it was necessary to the fulfillment of that legitimate work-related purpose.
3) Third, the employer must establish that the standard is reasonably necessary to the accomplishment of that legitimate work-related purpose."

- In addition to ensuring that pre-employment standards comply with the above process the Court also asks each employer to consider the following:
- *Has the employer investigated alternative approaches that do not have a discriminatory effect, such as individual testing against a more individually sensitive standard?*
- *If alternative standards were investigated and found to be capable of fulfilling the employer's purpose, why were they not implemented?*
- *Is it necessary to have <u>all</u> employees meet the single standard for the employer to accomplish its legitimate purpose or could standards reflective of group or individual differences and capabilities be established?*
- *Is there a way to do the job that is less discriminatory while still accomplishing the employer's legitimate purpose?*
- *Is the standard properly designed to ensure that the desired qualification is met without placing an undue burden on those to whom the standard applies?*
- *Have other parties who are obliged to assist in the search for possible accommodation fulfilled their roles?*

Lessons Learned

BCFS Response to Supreme Court *Meiorin* Decision

Between September and December 1999, the BCFS developed a strategy (Implementation Plan) that would allow the continued use of a pre-employment standard with fire fighters in 2000 but would comply with the intent of the 1999 Meiorin decision. The remainder of this paper outlines in detail the BCFS Implementation Plan and how the new pre-employment standard will be validated in 2000.

This Implementation Plan received verbal support from the Union, BC Ministry of Women's Equality, and the Public Service Relations Commission (PSERC) in December 1999.

BCFS Implementation Plan

Proposed Physical Fitness Test for BCFS Fire Fighters (2000)

The following pre-employment standard complies with the September 1999 Supreme Court of Canada *Meiorin* decision. The proposed test is rationally connected to the performance of the job, has been adopted in an honest and good faith belief as being necessary for the fulfilment of this work, and is reasonably necessary to the accomplishment of safe and efficient forest fire suppression in BC.

The Pack Test (USFS) and Pump-Hose Test (BCFS) have been selected as the components for the revised pre-employment standard. They are both job-specific; have been extensively researched as legitimate measures of a person's ability to fight fire; and, do not show any adverse impact/discrimination based on age, height, weight, gender, or ethnic barriers.

Changes to Existing Fitness Tests

For the 2000 fire season, the BCFS Protection Program will:

- Eliminate the Shuttle Run (previously used to measure individual aerobic fitness (VO2) – this test involved running 20-metre segments back and forth within an increasingly shorter period of time. The minimum requirement was Stage 10, equating to about 13km per hour).

- Eliminate the Upright-Row component (previously used to measures upper body muscular strength and endurance. It required participants to lift a 51-pound bar a minimum of 18 times in time to a pace of 20 lifts per minute).

- **Maintain the Pump-Hose component. This task is job specific and is a direct measure of work capacity.** It requires a person to carry a 65-pound pump, non-stop, a distance of 100 metres, in no fixed period of time. A timed portion of the test then requires participants to carry 68 pounds of rolled hose 300 metres followed by the dragging of a water-filled hose for 200 metres (50 metres back and forth four times.) The work must be completed in four minutes and 10 seconds.

- **Introduce the USFS designed "Pack Test" which also measures work capacity.** This test involves carrying a 20.43 Kg. (45 lb.) backpack a distance of 4.83 km. (3 miles) in less than 45 minutes over level terrain.

- Maintain the current "grandfathering" provision for one more year (2000). Returning fire fighters hired using older fitness tests (i.e. step/smokejumper tests) will be required to attempt the new pre-employment standard on their day of re-call. If they do not pass they will be given the opportunity to fall back on their original condition of employment test to confirm their recall status for 2000.

Justification of Pack Test and Pump/Hose Tests

The Pack Test and Pump-Hose Test have been selected as the components for the revised pre-employment standard because:

- they are job specific;
- have been extensively researched and validated as a legitimate measure of a person's ability to fight fire and;
- they do not discriminate based on gender or ethnicity.

USFS Pack Test Development

Dr. Brian Sharkey of the United States Forest Service has conducted extensive research into the physical demands on, and requirements of, wildland fire fighters. Dr. Sharkey has gained an international reputation for his extensive testing, analysis of fire fighting physiology, and development of effective standards to test individuals for this demanding work.

In 1995, faced with concerns regarding inclusion of fire fighters of different weights, ages, heights, gender and ethnic backgrounds, Dr. Sharkey and the US Forest Service embarked on a comprehensive analysis of tasks associated with wildland fire fighting in the USA. Their review of this demanding occupation found that workers were required to:

- construct hand guard (fireline);
- use a variety of hand tools such as shovels, axes and chainsaws;
- lift and hike with light to moderate loads;
- work for long hours in rough terrain; hot/cold conditions; high or changing altitudes; smoky and stagnant air;
- work with limited fluids and sleep; and,
- be ready to respond to emergency situations such as quickly re-locating to a safe area, evacuating a threatened area, or assisting other (possibly) injured individuals.

***Albeit with minor differences, US Forest Service fire fighting tasks directly mirror the tasks performed by BC wildland fire fighters*.**

As a result of the work analysis, the US Forest Service developed the Pack Test to measure a person's aerobic and muscular "work capacity". The test involves carrying a 20.43 Kg. (45 lb.) backpack a distance of 4.83 km. (3 miles) in 45 minutes or less over level terrain.

Based on extensive analysis, Sharkey found that the effort required to carry the backpack over this distance was very similar to the energy expended fighting a fire. In addition, the duration of the test also measured a person's ability to perform prolonged, arduous work under adverse conditions while maintaining a necessary reserve to respond to emergency situations.

Importantly - the backpack-carrying test involves an actual fire-fighting task.

During a 1995 study of the Pack Test, Dr. Sharkey tested over 300 fire fighters (256 male, 64 female) of different ethnic backgrounds. A similar study was replicated in 1998 using a much larger population sample (4353 persons, of which 894 were women.)

The most significant outcome of the 1995 and 1998 studies/field trials was confirmation that the Pack Test was job related, highly correlated to the performance of actual fireline tasks, and showed no **adverse impact** associated with age, height, weight, gender, or racial/ethnic group.

For the purposes of the US Forest Service study, researchers drew on the US Department of Labor's definition of **adverse impact**:

"A *selection rate for any race, sex or ethnic group which is less than four- fifths or 80% of the rate for the group with the highest rate will generally be regarded by Federal enforcement agencies as evidence of adverse impact, while a greater than four-fifths (80%) rate will generally not be regarded by Federal enforcement agencies as evidence of adverse impact."*

Because no definition of adverse impact currently exists in Canadian Labor law or Human Rights Legislation, the BCFS has adopted and will be applying this definition when the impact of both the Pack and Pump/Hose tests are assessed thoroughly in the fall of 2000.

Table 1. Summary of 1995 USFS field study* demographics

Subject		Age	Height (“)	Weight (lb.)	Pack Test (SD)
			Gender		
Males:	(256)	28.4	70.6	178.7	41.4 (4.23)
Females	(64)	26.7	66.3	140.9	43.5 (3.58)
			Ethnicity		
Caucasian	(232)	28.2	69.5	166.5	41.8 (4.45)
First Nations	(45)	26.0	70.3	188.6	42.5 (3.58)
Hispanic	(27)	28.2	69.5	173.7	42.1 (3.21)
Visible Minority	(10)	25.4	71.0	169.6	42.8 (2.80)

* study involved majority of incumbent fire fighters

Table 2. Pass Rate on Pack Test (1995)

	Pack Test <45:00	F/M*	Pack Test < 46:00	F/M*
Gender				
Males	216/256 = 84.4%		229/256 = 89.5%	
Females	46/64 = 71.9%	(85.2%)	51/64 = 79.7%	(89.1%)

* Female pass rate relative to males fell within acceptable range of *adverse impact* guidelines (80%)

Table 3. 1998 Study* - Pass Rate on Pack Test (1998)

	Pack Test <45:00	F/M*	
Gender	**Total Participants**	**% Pass**	**Score(mins.)**
Males	3413	93.9%	41.5
Females	894	81.9% (*87.2%)	43.1
Unknown	46	93.5%	41.5
Combined	4353	91.5 %	41.8

*Female pass rate relative to males fell within acceptable range of *adverse impact* guidelines (80%). study involved incumbent fire fighters and potential fire crew applicants

BCFS Pump and Hose Test

The Pump-Hose Test has been used by the BCFS since 1994. Of the three tests formerly comprising the “Bonafide” fitness standard, this component is the only one that measures work capacity.

- During this test, a person is required to carry a 65-pound pump non-stop 100 metres in no fixed period of time.
- The second, timed portion of the test requires participants to carry 68 pounds of rolled hose 300 metres followed by the dragging of water-filled hose for 200 metres (50 metres “out and back”, twice).
- This task must be completed in four minutes and 10 seconds.
- The test involves common fire fighting tasks and requires the movement of equipment used by BC fire fighters on a regular basis.

Based on BCFS fitness results received so far in 2000, this test, like the pack test, does not show any signs of adverse impact based on gender or ethnicity.

Review Process – Assessment of Impact and Possible Adverse Impact

By mid October 2000, the BCFS Protection program will have completed a thorough assessment of the impact of the new pre-employment standard. It is anticipated that these results will reflect the findings of the 1995 and 1998 USFS field trials, showing that pack test and pump/hose test have no adverse impact based on gender and/or ethnicity.

Results from this study will be shared with the BCGEU (Union), Public Service Employee Relations Commission (PSERC) and other key stakeholders. The Ministry of Forests will continue to evaluate, monitor and adjust if necessary, the pre-employment standard to ensure that the safety and performance of BC’s fire fighters is not compromised.

Turner's Model to a Disaster as Applied to a Disaster Fire

Roddy K. Baumann
Regional Prescribed Fire Specialist, ph: 503-231-2075, Roddy_Baumann@r1.fws.gov

Abstract. This presentation is a safety lesson plan which is somewhat non-conventional. It does not address the "how to's" of general safety but rather the underlying societal (cultural) reasons for safety attitudes. When presented, the information has been well received. However, management in general has not been overly supportive of the concepts presented. I believe it is simply too non-traditional for most older fire personnel to assimilate. The original concept is adapted from a Bob Mutch presentation developed for the National Advanced Resource and Training Center in Marana, Arizona. Turner's Model to a Disaster is applied to a disaster fire which took the lives of 8 high school students on a prescribed fire in Ontario Providence, Canada.. The case study examines the stages of a disaster and the underlying societal (safety culture) reasons these junior foresters lost their lives. The safety lesson plan utilizes Turner's Model to a Disaster as the backbone but also incorporates several more recent works such as "The Challenger, Cockpit Management, Darker Shades of Blue, National Transportation Safety Board studies and general psychology. The purpose of the lesson plan is to educate personnel in two areas: 1) to recognize the safety culture which exists on their home unit and 2) to understand how safety culture is formed and changes over time. Currently, the plan is prescribed fire oriented, but is adaptable to any work environment.

Prologue

This paper does not represent a scientific study, but rather a compilation of several studies into a concept. A concept that a safety culture exist within each unit. Hopefully, this paper will stimulate the reader to recognize the safety culture of their respective home unit.

The ultimate goal of this paper would be to stimulate further research in the development of skills in culture recognition and the creation of managerial tools to modify existing safety cultures.

Adapted from a lesson plan of the Geraldton Prescribed Burn disaster, this paper may not be the easiest to read: my sincere apologies.

<u>Safety Culture: A primer for recognizing the Safety Culture of your local unit</u>.

By: Roddy K. Baumann
US Fish and Wildlife Service
Region 1 Prescribed Fire Specialist
Roddy_Baumann@r1.fws.gov

Too often we assume that serious, or even fatal, accidents are only the product of wildfire suppression actions. Experience, however, has sadly demonstrated a serious loss of life on prescribed burns as well.

An investigative report on one event cited several contributing factors to the fatalities, including a preoccupation with target accomplishment, haste, overconfidence, span-of-control problems, and deviations from the approved plan.

The passage on target accomplishment is worth repeating: "There has been a strong emphasis in recent years on the importance of prescribed burning in the forest regeneration and forest "health" programs. This has created a requirement to assign and meet targeted areas of prescribed burns. Undoubtedly the District staff, having been leaders in the prescribed burning program for over 10 years, feels this pressure keenly. These pressures were felt strongly and personally by the senior fire staff, who transmitted them to subordinate staff."

This case study is centered on a disaster, the loss of seven lives on a prescribed fire in 1979. These high school "junior forester's" lost their lives just seven minutes after ignition began. All of the above mentioned causal factors certainly contributed to this tragic loss of life. However, utilizing a different analysis model may shed new light on how the causal factors may be present on your home unit.

Defining the difference between a Disaster and an Accident is primary to developing the concepts presented.

An <u>Accident</u> may be defined as: An unwanted event(s) caused by individuals who do not adequately use shared beliefs to account for and cope with the hazardous situations they face.

In other words, an accident is simply a result of an individual's failure to conform to existing precautions (policy, procedures, and rules). The link between the failure and the result is short for an accident: If you do not wear saw chaps, you get cut!

A <u>Disaster</u> may be defined as: An event, concentrated in time and space, which threatens people with major unwanted consequences as a result of the collapse of precautions which had been culturally accepted as adequate.

The most important feature of this definition is its treatment of disaster as a social/cultural event instead of a biological or physical event triggered by destructive agents or individuals.

The links are in and of themselves a series of failures, which become accepted as the "norm" and accumulate slowly over time, ultimately leading individuals or groups toward an unwanted and unexpected event.

Here is an example: Think about a fender-bender involving a school bus, this would be an accident.

However, if the driver had a series of fender-benders over time, which became socially acceptable to the point of no one noticing the frequency had increased (you would hear at the town barber shop "did you hear Ole Joe had another fender-bender?" Followed by group laughter).

Then one day, word would come that a busload of children was involved in a serious accident with fatalities, this would be a disaster.

In this example, the normal accepted behavior had become for Ole Joe to be involved in fender-bender accidents, which became an acceptable social/cultural behavior. The surprise was, everyone became accustomed to the accidents only being fender-benders without serious consequences. Thus, this disaster caught everyone by surprise.

For example: Let's think about this in the context of prescribed burning. There are units that regularly experience small "slop-overs" on burn projects. They may be viewed as something that "comes with the territory", the old "light 'em and fight em" mentality. On the west slopes of the Cascades it would not be uncommon to hear someone say "Don't worry it will go out when it hits the shade line". These attitudes (social/cultural beliefs) allow us to become desensitized to the potential for extreme consequences.

Let us look at the six stages to a disaster: (Adapted to the prescribed fire situation from Turner's "The Development of Disasters - A Sequence Model for the Origin of Disasters", <u>Sociological Review</u> 24 (1976):753-774. After a brief overview, we will more closely examine and expand on stages I, II and VI.

> Stage I - Pre-disaster Starting Point: Initial culturally accepted beliefs about prescribed fire hazards. Associated precautionary rule set out in laws, guidelines, policies, etc.
>
> Stage II: Incubation period: the accumulation of an unnoticed set of events which are at odds with the accepted beliefs about prescribed fire hazards and the precautions to avoid these hazards.

Stage III: Precipitating Undesirable Event: Undesirable prescribed fire situation which forces a re-direction of attention and transforms general perceptions of Stage II.

Stage IV: Onset: The immediate consequences of the collapse of cultural precautions regarding prescribed fire become apparent.

Stage V: Suppression, Rescue, and Salvage - First stage adjustment: The immediate post-collapse situation is recognized in ad-hoc adjustments which permit the work of fire suppression, rescue, and salvage to be started.

Stage VI: Full cultural adjustment: An inquiry or assessment is carried out and beliefs and precautionary norms regarding prescribed fire are adjusted to fit the newly gained understanding of the character of prescribed fire hazards.

Was this case study and accident or disaster?

Was this tragic event simply the result of people not following established beliefs, guidelines, practices and policies related to prescribed fire? Or was there a subtle accumulation of unnoticed events, which were at odds with accepted beliefs about prescribed fire hazards and the precautions taken to avoid these hazards? The answer may well be yes to both questions.

Let's take a closer look to see how well the Geraldton Case Study fits Turner's model with respect to stage I? Answer the question: "What was the culture on the Geraldton District"?

Stage I - Pre-disaster Starting Point

The disaster sequence commences with a set of culturally held beliefs about prescribed fire hazards. The beliefs constitute the "normal" stock of knowledge, which is thought to provide the environment in which individuals and groups can survive successfully in a hazardous situation.

These normal beliefs are fundamental to the concept of an accident being caused by an individual. We would then simply look for a violation of laws, policies or guidelines to provide an explanation for the injury. Once fault is found we need look no further.

The focus has historically been placed on the individual, but in reality where is a collective attitude which establishes what are safe practices. This concept is, in and of itself, "the culture" and in this case, the culture of safety.

It is the common understanding that "We" understand the hazards and have the necessary precautions in place to abate those hazards. "We know what we are doing, we have done it before, and we do it right". The shift from "I" to "WE" tends to indicate the transition from individually held beliefs to those beliefs held by the collective, the culture.

The Geraldton District in Ontario, Canada, had used prescribed fire as a part of their resource management program since the late 1950's.

Knowing that they had been developing a prescribed fire program for approximately 20 years, we can make some assumptions that would allow us to agree that a culture with regard to prescribed fire had been established.

The fact is that there was a set of accepted beliefs, guidelines, and policies about prescribed fire hazards in Ontario, a few are listed below:

-Forest managers were committed to increasing the prescribed fire program.

-The program was taking advantage of advances in training and technology.

-Apparently burn plans were a matter of policy and included a burning prescription (which was tested using computer programs), firing patterns, and an organization. In addition, test fires were used as a normal procedure.

As in 1979 in Ontario, Canada, these same issues are present in most land management agencies today.

Let us take a closer look to see if we can gain some insight into the culture that existed prior to the Geraldton Incident, and compare this past culture to today's culture.

Key indicators may be:

-The apparent use of a test fire as a formality, rather than a true evaluation of expected fire behavior.

-The seemingly informal and ineffective briefing/communication that occurred prior to ignition.

-The numerous deviations from the approved plan. As contributing factors to the final outcome, were these actions and attitudes confined only to this project?

Stage II - Incubation Period

A prescribed fire disaster or cultural collapse occurs because of some inaccuracy or inadequacy in the accepted norms or beliefs. If the disruption is to be of any consequence the discrepancy between the perceptions of prescribed fire hazards and the way prescribed fire hazards really operate will not generally happen instantaneously. Instead, there is an accumulation, over a period of time, of a number of events which are at odds with the way things really are and the hazards represented by the norms and beliefs.

Within this "incubation period" events occur and accumulate unnoticed or it may be that they were not communicated.

Existing cultural precautions may be thought of as dealing with known and clearly defined hazards, but during the incubation period vague and unperceived hazards begin to be covertly delineated.

In order for events to build up in this way it is clear that they must fall into one of two categories: either they are not known to anyone; or they are known but not fully understood.

This incubation period may also be referred to as the "getting away with it" period which becomes culturally acceptable. This is a slow process where small incremental steps go unnoticed. There are five basic reasons for this to occur:

What we've been talking about are the ways in which events or the links accumulate. Remember the links to a disaster are like a slow motion wave, which when it finally crests, is overwhelming. There may well have been an accumulation of events from the late 1950's to 1979 that detracted from implementing normal prescribed fire precautions on the Geraldton District.

If we look at some of the details we may gain better insight to the development of the incubation period and the events that might gradually have accumulated to affect Geraldton's prescribed fire program in a detrimental manner.

The approved plan was not entirely duplicated in the actual preparations for the burn. This is apparent in a number of ways and is attributable to a number of factors.

<u>Target Accomplishment:</u> There was a strong province-wide emphasis on the importance of prescribed burning. This created a requirement to assign and meet targeted areas of prescribed burns.

Undoubtedly, the Geraldton District staff, having been leaders in the prescribed burn program for over 10 years felt this pressure keenly.

In the case of the PB3 burn, there was the added element of "time running out". With the probability of very few satisfactory burning opportunities left in the fire season and the certainty that most fire control staff would be lost within two weeks, the District was in a "now or never" situation.

The senior staff, who transmitted them to subordinate staff, felt these pressures strongly and personally.

Haste: The pressures referred to in the previous discussion coupled with the "time running out" problem, and the probability that an acceptable burn might be achieved immediately, inevitably led to haste. The burn was ignited less than 24 hours after Cameron and MacKay checked slash fuel conditions. Many evidences of haste, were exhibited:

- Examination of fuels at Fire 13 instead of at PB-3 to determine suitability for burn.
- Fuel volumes not computed, although sample plots were in place and the data had been collected.
- Hasty organization of staff (e.g., Morencie did not know his assignment until Wednesday morning).
- Key people not included in the briefing (e.g., members of Morencie's ignition crew).
- No detailed on-site briefing of the ignition crew.
- Not all staff briefed on safety measures and instructions were vague.
- Very little time spent on the test fire.
- Equipment was incomplete (e.g., no funnel to fill torches, no relative humidity tables, torches at the burn without fuel, etc.).
- Ignition started without waiting for all of the staff to reach the staging area.

Over Confidence: From the start and for a number of reasons, everyone involved thought that PB-3 would be easy to manage and would pose no problems except perhaps that the fire intensity would be too low.

As already pointed out, the Geraldton District had been an active participant in a prescribed burn program. The staff developed expertise through the process of planning and conducting many prescribed burn projects. It is understandable that there would be little concern about their ability to manage PB-3.

Reinforcing the district's confidence was the fact that this was a simple, safe burning opportunity which even under sever conditions would offer no fire problems. Furthermore, burning conditions were not severe and the forecast indicated rain no later than the evening of the day of the burn.

The final factor contributing to the lack of concern was the test fire set minutes before the ignition of the unit. Its initial slow rate of spread indicated that to the observers that the only problem they would have would be getting the main fire to burn.

Span of Control: It is obvious in hindsight that there were span-of -control problems with ignition. In fact, Morencie recognized the problem on Block C and drew it to MacKay's attention before leaving the base camp. Some evidence of the span-of-control problems are:

- There was not a completely clear picture of ignition sequences and details.
- Morencie, MacKay, and Cameron all gave some instruction about ignition. In itself, this is not necessarily bad, but it is an indication of the lack of "central" ignition control.
- The large number of ignitions made control difficult.

Deviations from Plans: Deviations of varying magnitudes were made from the original plan and from plans developed during the organizational stages. Most of the changes were reasonable, but rationale for others is questionable.

Inadequate staffing levels: Although the approved plan does not attach names to positions, the District policy would have indicated Herrington as Fire Boss and Quinney as Trainee Fire Boss. With Herringtopn on vacation and Quinney on a day-off and unable to be located, MacKay and Morencie were logical alternate choices. Cameron might have assumed the Fire Boss role if his knowledge of the burn area and plan had not been so limited.

The approved plan indicated a Safety Officer reporting to the Fire Boss, but this position was left vacant for reasons unknown.

Inadequate support staff: The most significant deviation was the number of ignition/suppression support staff assigned to the burn. A detailed comparison of the original plan and the final real situation can be made elsewhere in the report, but in general terms; there were more than twice as many people on the burn as planned. On Block C alone, there were 22 people compared with the maximum of seven implied in the plan.

The most serious product of this change was the assignment of seven inexperienced people to Wesley.

Equipment: Aerial ignition had originally been planned as a possibility for all or part of the burn, with alternate ignition methods to be used if a helicopter was not available. The fact that hand ignition was employed was, therefore, not a deviation from the plan.

Following the Geraldton Incident a Board of Review conducted an inquiry and precautionary norms regarding prescribed fire were adjusted to fit a newly gained understanding.

The Board of Review listed 21 recommendations following their analysis of the PB-3 burn. These recommendations were the foundation for their cultural readjustment.

Recognizing Your Local Culture

Now that we have an understanding of Turner’s model as it applies to the Geraldton Incident let’s apply the concepts of Stage I and Stage II to our own local environment.

It is important to understand where we are culturally and whether any of our standard operating procedures or adaptations that we carry out constitute an incubation period.

The above excerpts from the Investigation and Board of Review documents reflect a series of failures at the Geraldton District. The application for today is do these same issues remain today in your local unit? Furthermore, do these issues arise from current events and forces or are the origins of these issues have beginnings from years past?

More importantly, can we (the fire fighting community) utilize this historical event as a learning tool? Following are a series of thoughts, which hopefully, develop into a concept; a concept which may prevent repetition of a Geraldton type disaster on your local unit.

Cultures exist within agencies, within agency units and within sub-units. An example of an indicator clue may be overheard in the vehicle on the way to a prescribed burn project: Our unit “does it right” the other unit doesn’t have the know how”.

Unfortunately, when the disaster does happen, the age-old solution is to legislate additional rules or policies. Wide acceptance of these precautions is possible because people then to think that a violation of these norms and only a violation, can result in disastrous consequences. In other words, prescribed fire is only dangerous if violations occur.

Has this been true for the South Canyon Fire Review, the Cerro Grande review, Lowden Ranch review?

We are talking about culture, that part of society, which is seldom spoken but mystically understood by everyone. What are some of the cultural indicators on your particular unit? In particular, what is the culture on your home unit concerning safety?

Let us explore a few thoughts.

What is the general feeling about OSHA reviews on your unit? Would the reaction be something like “Why do we need to have these folks come review our work area? We have been doing this job for many years without a serious accident.”

Or: did you know that the State of Oregon requires 2400 hours of instruction to be licensed to cut hair? Yet zero hours of instruction are required to receive a drivers license. When was the last time someone was killed by a hair cut? Yet it is socially acceptable to allow someone to operate a lethal weapon (car) without any instruction. Is this a culturally accepted practice?

In the prescribed burning area we may wear nomex, but how about MSDS sheets and labels on the slash fuel containers or other materials like alumigel?

Do we follow DOT regulations for proper placards of the slash fuel during transportation? Or is this just another bothersome regulation?

When most folks are out doing prescribed burning, there is a fuel truck. Do folks install a fire extinguisher? Better yet is the extinguisher on the truck burred under a pile of empty drip torches? Or is the extinguisher set away from the truck a distance and easily available?

Is the written burn plan a quality document, which guides our actions in implementing a prescribed burn? Or is it just unnecessary paper work and we will go out and “do what’s right”?

Is the culture on your unit Nike or Oatmeal? Definitions: The Nike slogan is “Just Do It”, the Oatmeal slogan is “The Right Thing to Do”.

You have seen several examples of how culture can effect general “attitudes” about a number of areas. Psychologists tell us that we will learn most of our total knowledge by the age of 4, and that our core value system is reasonably solidified by the age of 12. How many years must be spent within an organizational culture for us to “imprint”? Is it 4 or 12 years? Well, there is no answer, but hold this thought, as we will re-visit this later.

Stage II - Incubation Period

A prescribed fire disaster occurs when culturally accepted beliefs and norms are found to be inadequate or inaccurate thus a discrepancy is revealed between the perceptions of prescribed fire hazards and the way prescribed fire hazards really operate. This has been fatally established over the years.

This does not arise instantaneously; there is instead an “incubation” period. Such discrepant events can only build up unnoticed if they remain unknown to most people or if they are known but misunderstood in such a way that their consequences remain unknown. This incubation period may also be referred to as the “get away with it” period. It may become culturally acceptable to take certain “short cuts” to job accomplishment. We also fail to recognize the warning signs and down play the significance of those warnings.

This is a slow process, small incremental steps along the way. So slow that change is unnoticed. The origins of a disaster may be 10 or 20 years prior to the event.

An example of a slow and incremental change process may be as follows. Think back 10 years ago, what type of material was contained in a "R" rated movie? Certainly violence and sexually explicit scenes, but not as graphic as today. Ask yourself "would society accept this amount of change in one year, or was acceptance gained in small incremental steps over a period of several years?

Another example as presented by Jerry Williams, Director of Fire and Aviation Management USFS Region 1, drawing a distinction between "Can Do" and "Make Do". The attitude of many fire fighters was that they "Can Do" the job. The comparison to more recent times with fewer suppression resources available is, are we in a "Make Do" situation?

There are five basic reasons for this to occur:

1-People are generally reluctant to fear the worst, with the result that they dismiss evidence of hazardous conditions and fail to notice warning signs of accumulating danger. In prescribed fire planning, RISK ANALYSIS and CONTINGENCY planning are inadequate.

How often do you share "near misses" during post-burn evaluations? Do they become the impetus for course correction or do they just become war stories? In today's fire environment, there is little opportunity to share these war stories except around the chow line in fire camp. Hopefully, the "Lessons Learned" program may help solve this information exchange gap.

2-Violations of prescribed fire policies and rules may become accepted as normal when people obtain misinformation or fail to learn appropriate beliefs and norms.

Examples may be:

The burning conditions today are fairly low, therefore, the danger element does not exist. The implication being, I can relax today and not worry about safety issues.

This unit is just like the previous 15 that we have done this year, no sweat.

One area within wildland firefighting which may provide an insight to this relaxation of standard operating procedures may be: When fire fatalities are taught in basic firefighter training it is often stated that 4 OR MORE of the 10 Standard Firefighting Orders are violated when a fatality occurs. The message received by the new firefighter is "I can violate 3 of the 10 Standards and not be killed"!

Have we developed similar "get away with it" attitudes in the arena of prescribed fire?

Safety habits are generally learned by leadership example. Are you setting an example, which may lead a lessor skilled person to think this is the real way to do the job (as they do not have the experience to recognize what level of danger they are being exposed to or the risk analysis undertaken prior to exposure)?

Examples:

Policy states that when you are out of the vehicle a hard hat must be worn. However, when you are in an open field, you may perform a risk analysis; no trees to generate falling material, thus no need to wear a hard hat. However, you always wear a hard hat when in timbered areas. If a new person were with you that day in the open field and observed you not wearing your hard hat, what would they conclude?

If you do not take the time to explain the risk analysis you went through to determine it was acceptable not to wear the hard hat in the open field, they would most likely conclude it is acceptable to not wear a hard hat and ignore policy.

When driving in mountainous terrain, it is often tempting to cross the center divider. While not legal, it remains common practice with many drivers. If you are driving in this manor, and your 15-year-old child observes this behavior, s/he may conclude that cutting corners is acceptable.

Again, the lack of realization that a risk analysis occurred (assuming this logic: it is acceptable to cut the corner with sufficient sight distance, otherwise, do not cut the corner).

3-Information overload in complex situations may be so much of a problem that people fail to see signs of danger. This is a "head down" situation, when folks become preoccupied with details and fail to step back and see the overall situation.

An example could be when a crew boss gets his/her head down digging fireline instead of maintaining an over view of the whole fire scenario.

On prescribed burns, fire behavior is important to meeting the burn objectives. If we become engrossed with fire behavior calculations (roughly 32 technical variables) and loose sight of the responsibility to manage the operation, we have allowed ourselves to become overloaded.

4-People's attention may be directed from warning signs by one problem that acts as a decoy to draw attention away from another more serious problem. These decoys may take many forms. They may be personal or professional and they may also be imposed by other individuals.

For instance, target accomplishment may divert attention away from a more basic need to conduct prescribed fires in a safe manor. Or we may be thoroughly convinced this prescribed burn has significant ecological importance and must be completed, so much so, that we ignore the warning signs of emerging danger. In other words, "We get too busy doing burns with our heart and not our head."

Or we may be preoccupied with getting finished with this unit so the next unit can be accomplished before expending too much overtime, cost management.

5-Prescribed fires escape at rather frequent intervals, tend to elicit the development of institutions suited to routine accidents rather than disasters.

We dismiss the escapes in the name of production, lack of funds or the lack of more skilled people, until at some point the escapes become culturally accepted. At this point the escapes become a "stuff happens" type of statement.

The Forest Service published a Prescribed Fire Review, which listed a number of commonalties among escaped prescribed burns. They are: escapes occur 3 days after ignition, there is a lack of adequate patrol planning and a lack of follow-up patrol documentation.

Again, the links to an accident are short; an error in judgement or knowledge leads almost immediately to a breakdown. Whereas, the links to a disaster are more casual, a slow motion wave, which when it finally crests, is overwhelming. Often referred to with comments such as "It would have happened sooner or later anyway," or "It was the final straw that broke the camel's back."

Stage III - Precipitating Event

The shock of a precipitating event is necessary to re-direct attention to the accumulation of unnoticed errors in the incubation period. The power of the precipitating event to transform beliefs and precautionary rules regarding prescribed fire is dependent upon total surprise.

> Although there may be a few "soothsayers" that predicted the event, general recognition of the underlying process, which gave rise to significant fire losses, will not occur unless it is unexpected.
>
> Was the fire community shocked in the wake of South Canyon? Many times and in many places the following words echoed through the fire fighting rank and file: "How could this happen, the Hot Shots are the best trained crews in existence?" or "The jumpers are the elite of the fire fighting world, how could this happen to these highly trained and motivated folk?" or "Who would have believed this could happen?" It is probably safe to say the fire fighting community was indeed shocked.

A transformation of culturally accepted prescribed fire beliefs and policies will occur only if a disastrous event is totally unpredictable.

Stage IV - Onset

The outbreak of a disastrous prescribed fire is followed immediately by the onset of unanticipated consequences, which force practitioners to face realities not accounted for by existing prescribed fire measures. The onset of the prescribed fire disaster is represented by high intensity burning, rapid rates of spread, large area burned, and lives and property lost.

How many times have you done a prescribed burn where all of the environmental parameters were aligned on the high side and gotten away with it? While most of the indices were well within the prescription parameters, there were seven fatalities and one serious injury on PB-3, which signaled the collapse of their cultural precautions.

Recent history continues to uphold the assertion that we (the fire community) seem to not possess "corporate memory". Many of the mistakes, errors in judgement, have been repeated Lowden Ranch – unexpected high intensity burning, Cerro Grande – unexpected high intensity burning.

Stage V - Suppression, Rescue, and Salvage

The onset of a disastrous prescribed fire is accompanied or followed by suppression, rescue, and salvage operations.

Major features of a failure in existing beliefs and precautions become evident as people go about meeting immediate problems of suppression, rescue, and mop-up. On the PB-3 burn immediate post-collapse adjustments were made in terms fire control and mop-up, in order to facilitate rescue and ultimately the recovery of those who perished in the fire.

Stage VI - Full Cultural Readjustment

After an agency has recovered from the immediate impacts of the onset of a disastrous prescribed fire, an assessment may be conducted to determine why culturally accepted precautions proved to be inadequate.

Readjustments can only take place if the investigation reveals major failure of the existing beliefs and precautions.

Storm King, Lowden Ranch and Cerro Grande shocked all of us. Have they changed our culturally held beliefs about safety in the fire environment?

Back to psychology and establishing your personal core value system by the age of 12. Psychologists also tell us that generally the only way to change your core beliefs is through a "significant emotional event". Was Storm King, Lowden Ranch or Cerro Grande a "significant emotional event" for you?

If we, the fire community, do not retain the corporate memory of these events, we will quickly fall back into the Incubation Period and allow history to repeat itself, with additional disasters.

Abstract

Prescribed fire activities are increasing in frequency and complexity for most resource management agencies. These prescribed fire programs also have included cases of serious loss of lives and property since 1979. Although often taken for granted, prescribed fires offer some of the most potentially hazardous situations that we undertake. The very continuance of such programs is closely dependent on the care and

skill we bring to this task. So that we don't become trapped, or surprised, by the unexpected, we have contrasted the terms "accident" and "disaster" and listed the six stages associated with a prescribed fire disaster.

A case study was employed to illustrate these six stages and to call attention to the accumulation of an unnoticed set of detrimental events during the incubation stage. Finally, we described and discussed how to begin to recognize the "Safety Culture" of your local unit.

The message is clear, we must always maintain a healthy respect for fire, apply the fundamentals that we know so well to prevent accidents, and be alert toward <u>changing</u> conditions, however small and incremental those steps may be, to prevent disasters.
References/Bibliography

References

"Attitudes", International Safety Institute, 1998 Version 8.0.

Alan E. Diehl, "Does Cockpit Management Training Reduce Aircrew Error?", Paper presented at the 22nd International Seminar International Society of Air Safety Investigators, Camberra Australia, November 1991.

Robert C. Helmreich, Ashleigh C. Merritt and John A. Wilheim, "Error and Resource Management Across Organizational, Professional, and National Cultures". The University of Texas at Austin.

Robert L. Helmreich, "The Evolution of Crew Resource Management", Paper presented at the IATA Human Factors Seminar, Warsaw Poland, October 31, 1996.

Major Tony Kern, USAF, "Darker Shades of Blue: A Case Study of Failed Leadership", 1995.

John K. Lauber, "Some Comments about Corporate Culture and Transportation Safety", NTSB Symposium on Corporate Culture and Safety, Washington, April 24-25, 1997.

Captain Daniel E. Maurino, "Safety Prejudices, Training Practices and CRM: A Mid-point Perspective", in press, International Journal of Aviation Psychology.

Ted Putnam, "Influences on the Risk Taking of Individuals and Groups", Fall 1998.

Ted Putnam, "The Collapse of Decisionmaking and Organizational Structure on Storm King Mountain".

James Reason, "Corporate Culture and Safety", NTSB Symposium on Corporate Culture and Safety, Washington, April 24-25, 1997. This paper was based on a chapter to appear in a forthcoming book:

James Reason. "Managing the Risks of Organizational Accidents", Aldershot: Ashgate (in press).

Barry A. Turner, "The Development of Disasters – A Sequence Model for the Analysis of the Origins of Disasters" ", <u>Sociological Review</u> 24 (1976):753-774.

Diane Vaughn, "Targets for Firefighting Safety: Lessons From the Challenger Case", Paper presented , 1996 Interagency Hotshot Crew Workshop, "Creating Standards that Insure Safety." April 1-5, San Diego, California.

A Method for Evaluating the Effectiveness of Firefighter Escape Routes

B.W. Butler, J.D. Cohen, T. Putnam3, R.A. Bartlette and L.S. Bradshaw
U. S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Intermountain Fire Sciences Laboratory, Fire Behavior Research Work Unit, P.O. Box 8089, Missoula, MT 59807
Tel. 406-329-4801; Fax 406-329-4825

Abstract. A general method of comparing escape route effectiveness in any terrain using any fire prediction method is presented. Information gathered from the South Canyon fire that burned in Western Colorado during July, 1994 and the Mann Gulch Fire that burned in central Montana during August, 1949 is used to estimate the average rate of travel of firefighters over rough terrain. This information is compared against predicted fire spread rates to gauge escape route effectiveness as a function of terrain slope, wind speed and fuel type. Type I, II and III track driven tractor travel rates are include in the analysis. It is intended that this analysis be used by firefighting crews to evaluate safety zone effectiveness for their specific situations. It is also envisioned that the method could be used by fire operations specialists to assess relative risk associated with alternate firefighting tactical options.

Introduction

The firefighting community is reminded of the importance of selecting adequate safety zones and escape routes all too often. Tragically, this reminder frequently happens due to the injury or death of fellow firefighters. Recently a relatively simple rule for estimating the size of safety zones was presented (Butler and Cohen 1998). The rule-of-thumb stated that the safety zone radius be at least 4 times the maximum observed or expected flame height. Unfortunately it may not be possible to find or build safety zones that are large enough and easily accessible from every location along a fireline. If firefighters do not carry the black with them, it is possible that they will be working some distance from their designated safety zone. It then becomes even more critical that they evaluate the effectiveness of their escape route relative to potential fire behavior.

In the course of completing a fire behavior case study of the South Canyon Fire (Butler and others, 1999) it became apparent to the authors that very little if any information existed for objectively evaluating firefighter escape route effectiveness. Beighley (1995) discussed the necessity for evaluating our personal “risk thresholds” in the context of the safety margins. He introduced the concept of “Safety Margins” and defines them as the difference between the time it takes a firefighter to reach a safety zone and the time it takes the fire to reach the same safety zone. A positive safety margin implies that the firefighter can reach the safety zone before being overrun by the fire, a negative safety margin implies that the fire catches the firefighter before he reaches the safety zone. Beighley’s “safety Margin” seems to provide an appropriate framework in which escape route effectiveness can be assessed. This study presents a method that could be used to quantify escape route effectiveness. The study consists of two parts. In the first part presents a method and the data used to quantify that rate at which firefighters travel over rough terrain. The second part presents a method for evaluating safety zone effectiveness using firefighter travel rate data and fire spread rate information. It is hoped that the analysis method described herein can be used by firefighting crews to evaluate safety zone effectiveness for their specific situations. It is also envisioned that the method could be used by fire operations specialists to assess relative risk associated with alternate firefighting tactical options.

3 Former Equipment Specialist (retired) with U.S. Forest Service Missoula Technology and Development Center Missoula, MT.

Part I-Firefighter Travel Rates

In the following, two fire case studies are evaluated to obtain information on the rates at which firefighters can travel over rough terrain.

South Canyon Fire July 6, 1994

The following information was taken from the South Canyon fire behavior case study (Butler and others, 1998).

Lightning ignited the South Canyon Fire on a ridge on the afternoon of July 2, 1994. For the next 48 hours, the fire burned downslope in the leaves, twigs, and cured grasses covering the ground surface. By 1200 hours on July 4 the fire had burned approximately 3 acres. It continued to spread downslope, covering approximately 50 acres by the end of July 5. Fire activity consisted of low intensity downslope spread with intermittent flare-ups and short duration upslope runs in the fire’s interior. The fire covered approximately 127 acres by morning on July 6.

On July 6 the fire continued to burn downslope through the surface fuels. At approximately 1520 hours a dry cold front passed over the area. Winds in the bottom of the canyon below the fire were estimated to be from the south (upcanyon) at 30 to 45 miles per hour. About 1555 hours several upslope fire runs occurred in the grass and conifers on a west-facing slope near the southwest corner of the fire's interior. Shortly after the crown fire runs, witnesses observed fire near the canyon bottom, directly west down the slope from the ridge where the fire had started. Pushed by the upcanyon windsthe fire in the drainage spread rapidly north. As this fire spread north and east, fuel, slope, and wind conditions combined to cause sustained fire spread through the live green Gambel oak canopy. The fire began burning as a high-intensity fast-moving continuous front. Steep slopes and strong west winds triggered frequent upslope (eastward) fire runs toward the top of the ridge. A short time later the fire overran and killed 14 firefighters. Figure 1 shows the west flank of Hellsgate Ridge, where the 14 firefighters were trapped and died. The firefighters were

Figure 1—Photograph of South Canyon Fire site (taken by J. Kautz USFS).

trapped in two separate groups. Twelve were caught hiking up the fireline to the designated safety zone (fig. 1). The 2 other firefighters were caught and died while trying to reach a rocky outcropping. In both cases the firefighters were not able to reach their safety zones before the fire caught them.

By 1607 all of the crews were moving toward their safety zones. The west flank fireline led diagonally off the top of a ridge to the southwest, down and across a west facing slope. 13 firefighters had been working on the lower portion of the line, when the decision was made to go to safety zones, they began hiking up the fireline toward the ridge top. The 13 firefighters on the fireline along the west flank of the fire were about 850 ft down the fireline. The trail they were hiking up varied from nearly flat to about a 20 percent slope. Their rate of travel was approximately 2.3 to 5.7 ft/s (1.5 to 3.9 mi/h) over the rough but relatively flat portions of the fireline they were using as an escape route. The fire was about 1300 ft southwest of the crew and was spreading at 3 to 7 ft/s (2 to 4.8 mi/h). The crew hiked over a few short but steeper sections (10 to 30 percent uphill slopes) where their rate of travel decreased to 2 to 4 ft/s (1.4 to 2.8 mi/h). Shortly after 1610 they started up the last steep pitch in the fireline (30 to 50 percent slope) their rate of travel decreased further to between 1 and 3 ft/s (0.7 to 2 mi/h). The fire was now 500 to 700 ft below them and was spreading at 6 to 8 ft/s (4 to 5.4 mi/h). A separate group of two helitack crewman traveled as fast as 6.9 ft/s (4.7 mi/h) over the approximately flat terrain near the top of the ridge.

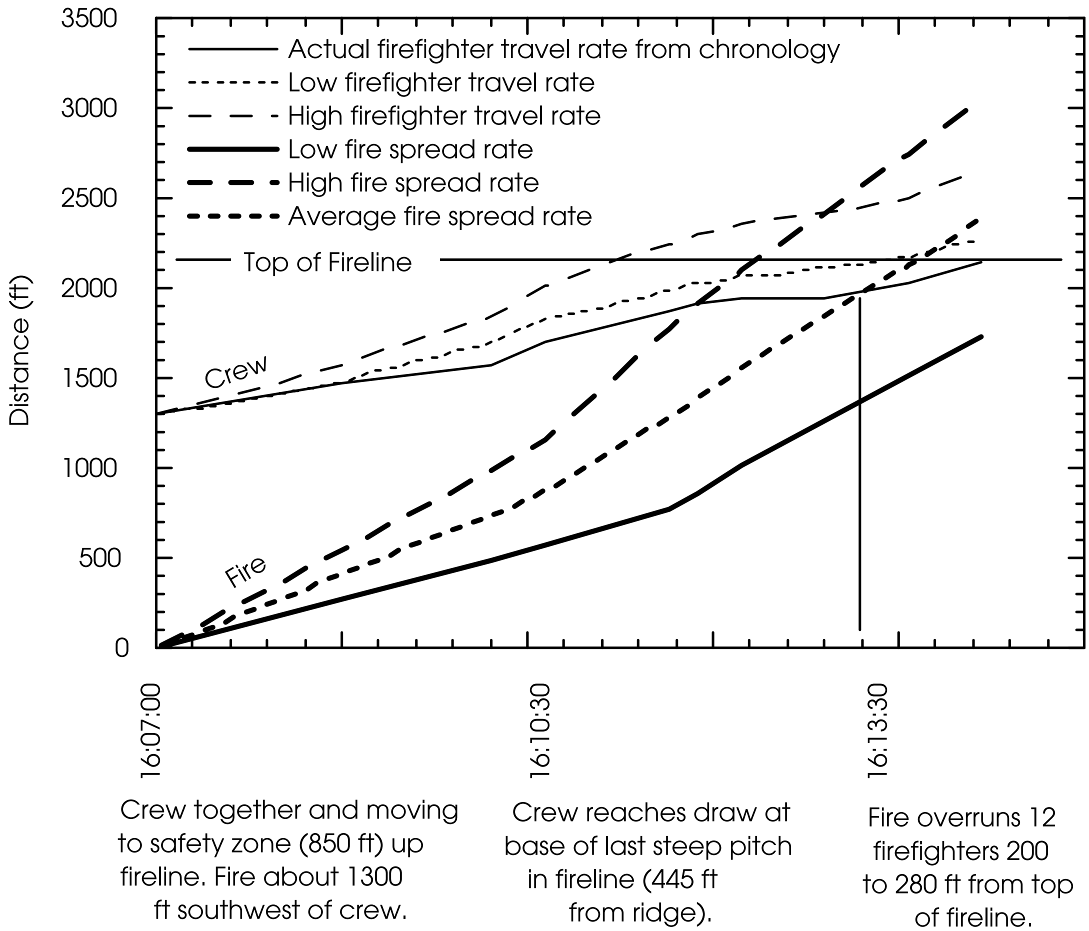


Figure 2--Fire spread rates and firefighter travel rates during blowup of South Canyon Fire(adapted from Butler and others, 1998).

At approximately 1613 the fire caught 12 of the 13 firefighters hiking up the fireline. One firefighter made it to the top. Two other firefighters died while attempting to deploy their fire shelters in a narrow draw.

Figure 2 shows the fire spread and firefighter travel rates during the afternoon of July 6, 1994. The 13 firefighters hiking up the fireline were moving uphill. Some sections of the trail exceeded 50 percent slope. The rates at which Type-1 firefighters can move over rough terrain are known (Sharkey 1994) and depend in large part on slope steepness. Firefighter travel rates over the fireline shown in figure 1 varied from as high as 5.4 ft/s on the nearly flat sections to as low as 1.0 ft/s on the 55 percent slopes. These were estimated from physiological factors and verified by actually retracing the crew's movements.

Mann Gulch Fire August 5, 1949

The following is a short summary of chronology and events that occurred on the Mann Gulch fire (Rothermel 1993).

The Mann Gulch fire started near the top of a ridge between Mann gulch and Meriwether Canyon approximately 20 miles north of Helena, Montana. Mann Gulch is a funnel shaped canyon, the narrow portion near the Missouri River is about one quarter mile wide. Vegetation on the south facing slope (located on the north side of Mann Gulch) was mature 60 to 100 year old ponderosa pine. The north facing slope was covered with 15 to 50 year old Douglas-fir, ponderosa pine, and juniper. Along the river was a stand of 60 to 80+ year old Douglas-fir. The lower portion of the canyon was covered with substantial shrub undergrowth which gave way to scattered timber and grass in the drier areas farther up the canyon. A crew of smokejumpers were dispatched to the fire and arrived on the site at about 1610. The jump plane encountered heavy turbulence at normal drop altitude and was forced to climb before dropping the crew's gear. After assembling their gear the crew started hiking down the canyon toward the river. Winds at this time were blowing up the canyon at 20 to 30 mi/hr with gusts to 40 mi/hr. Spot fires burning in the heavy timber and brush understory near the mouth of the canyon caused the crew to turn back up the canyon at approximately 1745. The spot fires developed into a crown fire that began spreading up the hill at 1.2 to 2 ft/s. The slope at the point were the crew turned back up the canyon was about 44 percent. As the fire burned into the less dense timber and grass its rate of spread increased to 3 to 4.4 ft/s. The crew were following a route that led uphill and across the slope at an average grade of 18 percent. They did not have a trail to follow and were hiking over broken and loose rock. Air temperatures were at least 97°F, possibly hotter. Their average rate of travel was 3 ft/s. Realizing they were in trouble, at approximately 1753 the crew dropped their tools. The fire was 75 to 100 yd down the slope below them. At 1755 Dodge (the crew foreman) lit an escape fire, the rest of the crew continued up the slope.

Estimates based on witness statements and fire behavior calculations indicate that from this point the crew traveled as fast as 6.5 ft/s. The four crew members that covered the most distance may have traveled nearly 7.5 ft/s, an amazingly fast travel rate (the equivalent of an 8 or 9 minute mile) over rough terrain up a 20 percent or greater slope. The fire caught and killed all but three of the firefighters within a couple of minutes after burning past the foreman who had lain down in the middle of the burned area left by his escape fire. Figure 3 is adapted from Rothermel (1993) and presents the fire progression and firefighter movements in a form similar to that shown in figure 2.

Discussion

These are just two examples of situations wherein safety margins proved inadequate. Several similarities exist between these two fires. In both cases relatively intense and fast moving fire developed downslope below the firefighters. These fires began burning up the slope under the influence of upslope winds. Both groups attempted to exit the area over rough trails and terrain. Both escape routes led uphill.

The 13 firefighters on the west flank of the South Canyon Fire traveled at an average rate of 4 ft/s (2.7 mi/h) over the rough but relatively flat portions of the fireline they were using as an escape route. Their average rate of travel decreased to 3 ft/s (2 mi/h) on the 10 to 30 percent uphill slopes and 2 ft/s (1.4 mi/h) on the even steeper (30 to 50 percent) slopes.

The smokejumper crew on the Mann Gulch Fire traveled across and up the slope (Rothermel estimates that their route followed about a 20 percent uphill rise across the slope) at a rate of 2.8 ft/s (2 mi/h). At the point where the crew dropped their tools and probably realized that they were in trouble, their rate of travel increased to between 6 and 8 ft/s (4 to 5.6 mi/h). While this last rate is possible for a short period of time it is probably not sustainable by most firefighters for any significant distance when traveling uphill over rough terrain.

These two cases suggest that average sustainable travel rates for firefighters over rough but flat terrain average about 4.4 ft/s (3 mi/h) with faster rates as high as 7 ft/s (about 5 mi/h) given stable footing. As the slope steepens the firefighter’s rate of travel decreases proportionally. For a relatively low slope (i.e. 10 to 20 percent) an average rate of travel is 3 ft/s (2 mi/h). The average sustainable rate decreases to 2 ft/s (1.4 mi/h) when the slope is 20 to 40 percent. For steep conditions (slopes of 40 percent or greater) the information presented in this study indicates that firefighter travel rates will be 1 ft/s or less.

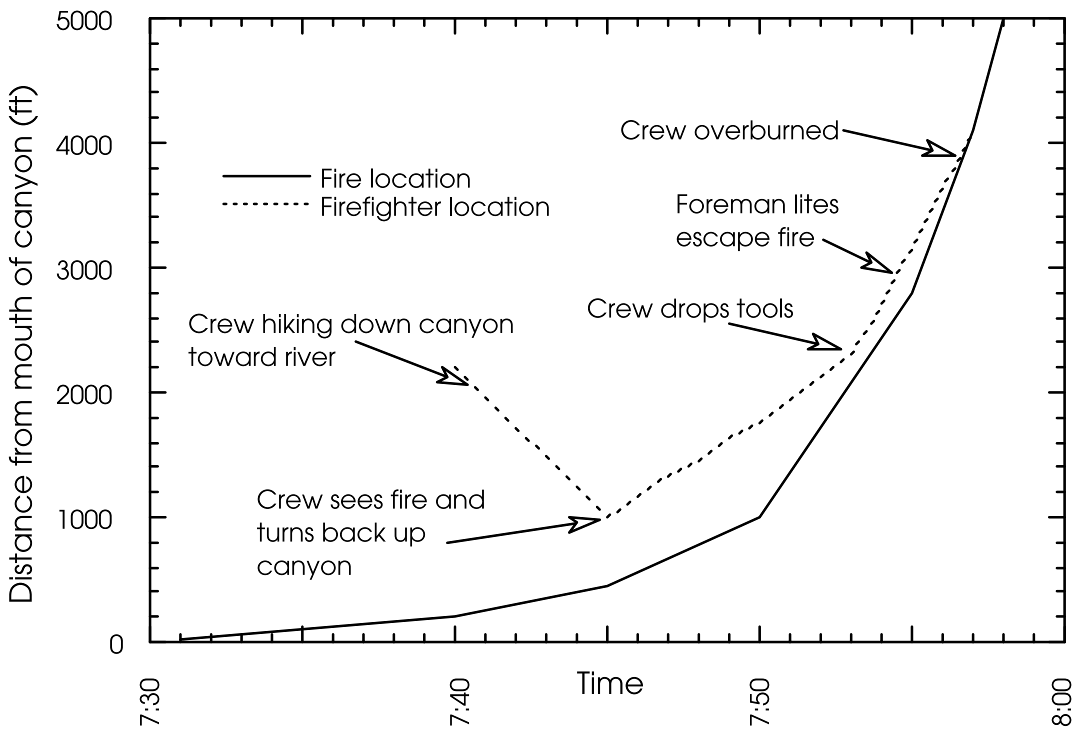


Figure 3--Firefighter movement and fire movement and location on the Mann Gulch Fire (adapted from Rothermel 1993).

Part II-Escape Route Effectiveness

The second part of this study compares the firefighter travel rate information obtained from Part I against fire spread rates. These comparisons are used to assess the conditions that may lead to negative Safety Margins. The analysis is applied to two sets of conditions, the first set may be considered moderate summer burning conditions, the second set is more characteristic of extreme drought in the western United States. The analyses are shown graphically in figures 4A-D and 5A-D.

Bulldozers are used on many fires to build firelines. Past firefighter entrapments have occurred when bulldozer operators were not able to outrun the fire. The speed at which type I, II and III bulldozers can travel over terrain has been documented (Fireline Handbook 1960 and 1969; Phillips, George and Nelson 1988; and Linane 2000a). In addition to comparing firefighter travel rates against predicted fire spread rates, Figures 4 and 5 include bulldozer travel rates as a function of slope.

For this study fire spread rates were calculated using the BEHAVE fire prediction system (Andrews 1986). Other systems could be used. We calculated fire spread rates for each of the thirteen standard fuel models over a range of slopes, wind speeds, and two different sets of fuel moisture values. It is assumed that the fire and firefighter are equidistant from the safety zone.

Moderate Burning Conditions

The first comparison was made for what may be considered moderate summer burning conditions: 0, 10, 20, and 30 mi/h (measured 20 ft above vegetation level) upslope wind speeds (midflame winds are also shown on the graphs), 8, 9, 10 percent for the 1, 10 and 100 hour dead fuel moisture contents respectively, and a live fuel moisture content of 100 percent. The process was repeated four times, once each for slopes of 0, 20, 40 and 60 percent. The thirteen models were separated into three categories: grass, shrub, and timber/slash. Figure 4 presents the fastest upslope fire spread rate from each fuel category at each upslope wind speed and the average firefighter travel rates as a function of slope. We also calculated the rates of spread for crown fires based on the model presented by Rothermel (1991).

Safety margins were defined earlier. Using the information shown in figures 4A-D it is possible to evaluate safety margins for each of the four fuel categories over a range of wind speeds and slopes.

Grass: Figure 4A compares fire spread rates in grass fuels. The data suggest that for fires spreading on flat terrain (slope < 10 percent) or downslope in grass under the influence of winds blowing less than 22 mi/h the Safety margin is positive for firefighters. When the fire is burning over moderate slopes (20 to 40 percent) and the firefighters must exit uphill a positive Safety Margin occurs only for fires subjected to winds blowing less than 15 mi/h. In the case of fires burning up steep slopes and uphill escape routes a positive Safety Margin occurs only for very low (less than 5 mi/h) or calm winds. At slopes less than 40 percent, bulldozers can travel much faster than firefighters. The data shown in figure 4A indicate that safety margins for bulldozers moving over flat terrain in grassy fuels are positive in winds of 30 to 40 mi/h. As the slopes increase to 40 percent or more the conclusions are the same as presented in the preceding paragraph.

Shrubs: Figure 4B suggests that for fires burning in shrub fuels over flat terrain (slope > 10 percent) positive safety margins occur only when the wind speeds are less than 15 mi/h. For moderate slope, uphill fire spread, and uphill escape routes positive safety margins occur only when the wind is less than about 10 mi/h. If the fire is spreading up steep slopes the safety margin positive only for low or calm winds.

Slash/timber surface fire : When the fire is burning in the surface fuels beneath timber or in slash figure 4C suggests that a positive safety margin is possible on slopes up to 60 percent and winds up to 30 mi/h.

Crown Fire: Figure 4D presents the predictions for crown fires burning in summer drought conditions. When the fire is burning over flat terrain a positive safety margin occurs only for winds less than 25 mi/h. When the fire is spreading up moderate slopes a positive safety margin occurs for winds less than 15 mi/h. If the fire is spreading up steep slopes the safety margin is negative for all but low or calm winds. When the escape route and fire are upslope in steep terrain (40 to 60 percent) the safety margin is negative even under calm conditions.

Type I and II bulldozers traveling over terrain with slopes less than 10 percent will travel faster than the fire as long as the winds are less than 30 mi/h. Type I dozers move slower and winds must be less than 25 mi/h to achieve a positive safety margin. When traveling over slopes of 20 to 40 percent the safety margin is positive only if winds are less than 10 mi/h.

Table 1 presents these data in tabular form. The shaded cells represent the conditions at which the fire's rate of spread exceeds the expected firefighter travel rate.

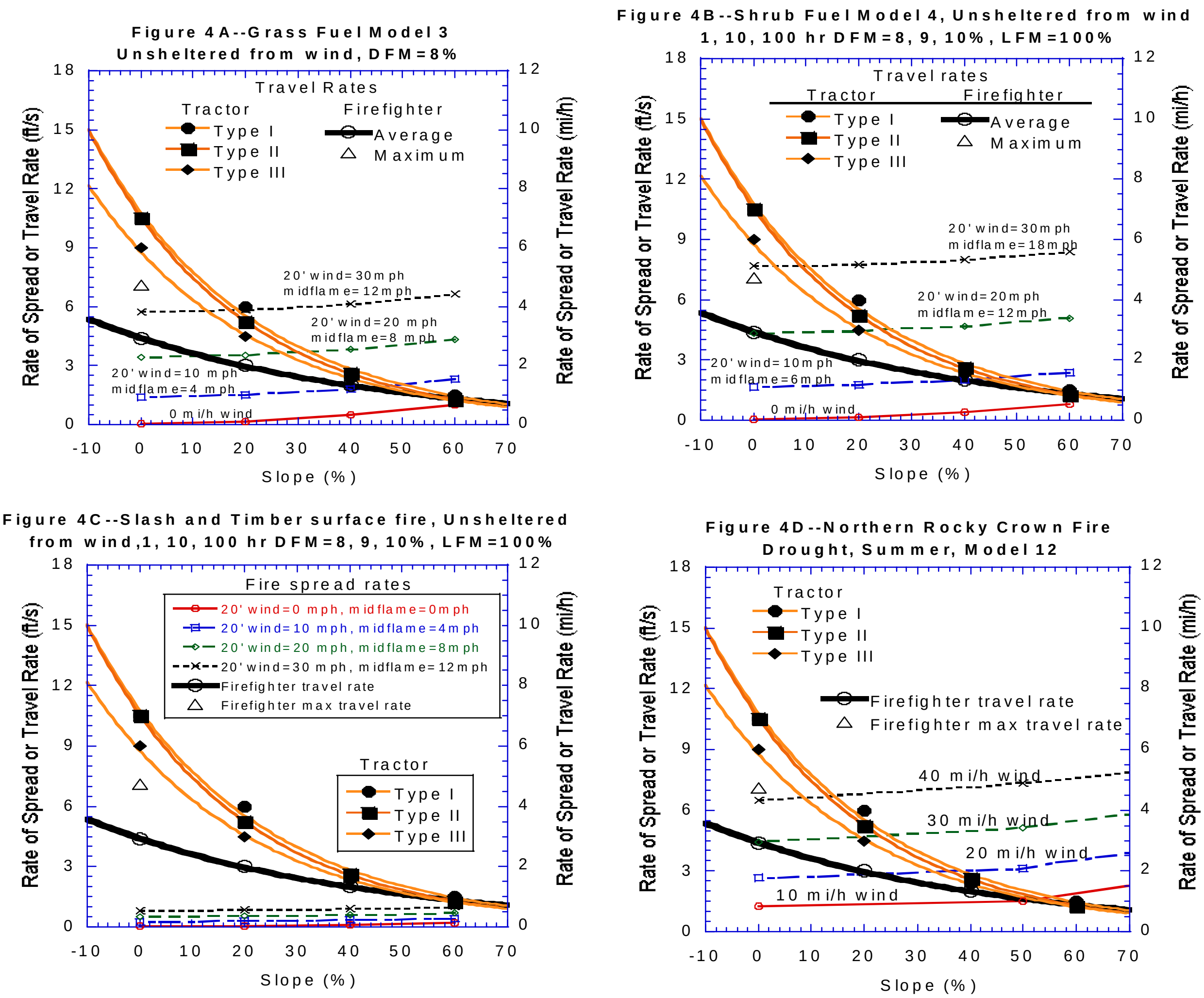


Figure 4--Exponential fits to the average firefighter travel rates derived from the South Canyon and Mann Gulch Fire case studies are shown by the heavy black lines. Maximum uphill fire spread rates obtained from the BEHAVE fire modeling system for various wind speeds are shown by the data points on the narrow lines (winds measured at 20 feet and midflame are shown). The fuel types were grouped into five categories, the grass fuels (4A), the shrub fuels (4B), the slash fuels (4C), the timber understory fuels (4C), and the crown fire fuels (4D). The slash and timber understory fuel fire spread rates were nearly identical and thus were lumped together in figure 4C. The maximum firefighter travel rate (depicted by the triangular symbol) was taken from the Mann Gulch case study. Dead fuel moisture contents (1, 10, 100 hour time lag fuels) for the calculations were 8, 9, and 10 percent respectively and live fuel moisture content was 100 percent. Crown fire calculations were made assuming drought summer conditions.

Severe Burning Conditions

A second set of fire spread calculations were conducted assuming fuel moistures that more closely resemble severe drought late summer burning conditions in the southwestern United States (Linane, 2000b). Fine dead fuel moisture contents of 4, 5, and 6 percent (1, 10, 100 hr time lag fuels respectively) and live fuel moisture content of 50 percent were used. Figure 5 presents the fastest upslope fire spread rate from each fuel category at each upslope wind speed and the average firefighter travel rates as a function of slope. We also calculated the rates of spread for crown fires, assuming severe drought late summer conditions (Rothermel 1991). Table 2 presents these results in tabular form.

Grass: Fire spread rates for the grass and shrub fuels were 50 to 80 percent faster than those for the moderate fuel moisture conditions. The data (see fig. 5A) indicate that for fires burning downslope or over flat terrain (0 to10 percent) in grassy fuels a positive safety margin exists only when the winds (measured 20 ft above the vegetation) are less than about 18 mi/h. As the slope increases to 20 percent a positive safety margin occurs only when the winds are less than about 12 mi/h. When burning up moderate slopes (20 to 40 percent) the safety margin is positive only when the winds are less than about 5 mi/h.

Table 1-Firefighter Travel Rate versus Fire Spread Rate for Dry Conditions

Slope (%)	FF Rate of Travel (ft/s)	Wind speed (mi/h) 20’	Fire spread rate, Flame length, Safety zone minimum size											
			Grass[1]			**Shrubs[2]**			**Crown Fire[3]**			**Surface Fire Beneath Tree Canopies[4]**		
			R/S (ft/s)	**FL (ft)**	**SZ (ft)**	**R/S (ft/s)**	**FL (ft)**	**SZ (ft)**	**R/S (ft/s)**	**FL (ft)**	**SZ (ft)**	**R/S (ft/s)**	**FL (ft)**	**SZ (ft)**
Flat (0)	4	0	.07	3	12	.07	5	20	.1	10	40	.03	4	16
		10	1.4	11	44	1.6	21	84	1.3	70	280	.2	10	40
		20	3	16	16	4	33	132	3	145	580	.5	14	52
		30	6	20	80	8	42	168	5	220	880	.8	17	68
Low (10-20)	3	0	.1	4	16	.1	7	28	.2	20	80	.05	5	20
		10	1.5	11	44	1.7	21	84	1.4	75	300	.2	10	40
		20	4	16	64	4	33	132	4	150	600	.5	14	52
		30	6	21	84	8	42	168	5	225	900	.8	17	68
Moderate (20-40)	2	0	.4	7	28	.3	11	44	.2	25	100	.1	6	24
		10	1.8	12	48	1.9	23	92	1.7	80	320	.3	11	44
		20	4	17	68	5	34	136	4	160	640	.6	14	56
		30	6	21	84	8	43	172	6	235	940	.8	17	68
Steep (40-60)	1	0	.9	9	36	.7	15	60	1.1	55	220	.2	9	36
		10	2	13	52	2	28	112	2	100	400	.4	12	48
		20	4	18	76	5	35	140	4	175	700	.6	15	60
		30	7	22	88	8	44	176	6	250	1000	.9	18	72

SAFETY MARGIN= (FIREFIGHTER TRAVEL RATE) - (FIRE RATE OF SPREAD)

Shaded areas represent a negative safety margin.

[*]Conditions are as follows: 1, 10, and 100 hour dead fuel moisture content=8, 9, 10%. Live fuel moisture content= 100%. For the Crown Fire Modeling late summer severe drought characteristics were used. The models that produced the most severe conditions are used. R-S is fire rate of spread, F-L is calculated flame length, SZ is safety zone radius.

[1]Fuel Model 3; [2]Fuel Model 4; [3]Fuel Model 12 and maximum rate of spread; [4]Fuel Model

Shrubs: The data for shrub type fuels are shown in figure 5B. These conditions and fuel type resulted in the highest overall fire spread rates. The data suggest that when the fire is burning over flat terrain the safety margin is positive only if the winds are less than approximately 12 mi/h. If the fire and escape route follow an uphill slope of 10 to 20 percent the safety margin is positive only for winds less than 8 mi/h. For fires and uphill escape routes on moderate slopes (20 to 40 percent) the safety margin is positive only if the winds are less than 4 mi/h. And if the fire and uphill escape route are on a steep slope (40 to 60 percent) the safety margin is negative even in calm winds.

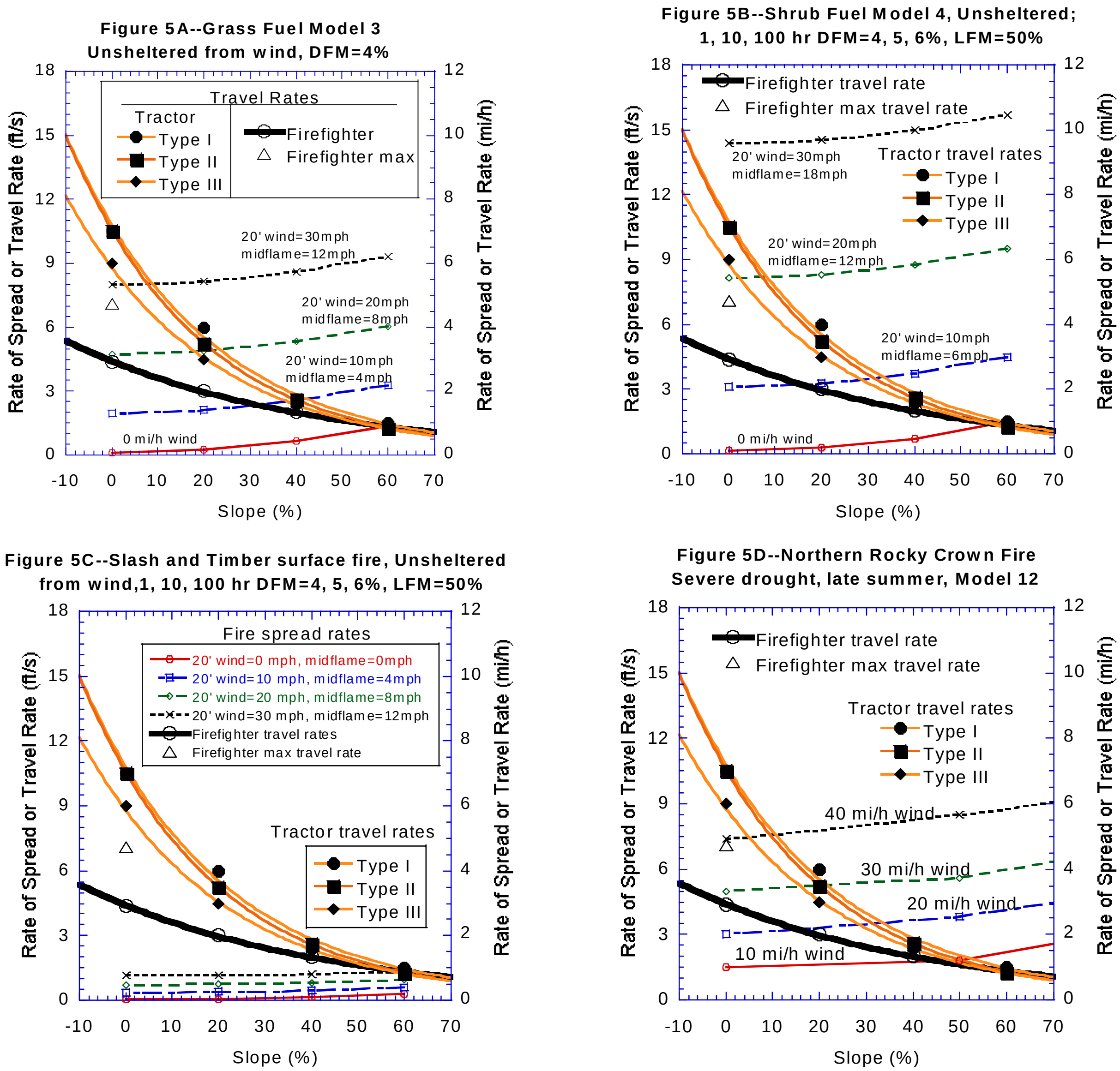


Figure 5--Exponential fits to the average firefighter travel rates derived from the South Canyon and Mann Gulch Fire case studies are shown by the heavy black lines. Maximum uphill fire spread rates obtained from the BEHAVE fire modeling system for various wind speeds (measured 20 feet above the vegetation and also at mid flame) are shown by the data points on the narrow lines. The fuel types were grouped into five categories, the grass fuels (5A), the shrub fuels (5B), the slash fuels (5C), the timber understory fuels, and the crown fire fuels (5D). The slash and timber understory fuel fire spread rates were nearly identical and thus were lumped together in figure 5C. The maximum firefighter travel rate (depicted by the triangular symbol) was taken from the Mann Gulch case study. Dead fuel moisture contents (1, 10, 100 hour time lag fuels) for the calculations were 4, 5, and 6 percent respectively and live fuel moisture content was 50 percent. Crown fire calculations were made assuming late summer severe drought conditions.

Positive safety margins for type I and II bulldozers on flat terrain are achieved only when winds are less than about 20 mi/h. At 40 percent slope the safety margin is positive only if winds are less than 5 mi/h. Even in calm winds the safety margin is negative at slopes greater than 55 percent.

Table 2-Firefighter Travel Rate versus Fire Spread Rate for Severe Conditions

Slope (%)	FF Rate of Travel (ft/s)	Wind speed (mi/h) 20'	Fire spread rate, Flame length, Safety zone minimum size											
			Grass[1]			Shrubs[2]			Crown Fire[3]			Surface Fire Beneath Tree Canopies[4]		
			R/S (ft/s)	FL (ft)	SZ (ft)	R/S (ft/s)	FL (ft)	SZ (ft)	R/S (ft/s)	FL (ft)	SZ (ft)	R/S (ft/s)	FL (ft)	SZ (ft)
Flat (0)	4	0	0.1	3	12	0.1	7	28	0.1	10	40	0.04	5	20
		10	2	14	56	3	31	124	1.3	70	280	0.4	12	48
		20	5	20	80	8	48	192	3	145	580	0.7	17	68
		30	8	26	104	14	62	248	5	220	880	1	21	84
Low (10-20)	3	0	0.2	5	20	0.3	10	40	.2	20	80	0.1	6	24
		10	2	14	56	3	31	124	1.5	75	300	0.4	13	52
		20	5	21	84	8	48	192	4	150	600	0.8	17	68
		30	8	26	104	15	62	248	5	225	900	1	21	84
Moderate (20-40)	2	0	0.7	8	32	0.7	16	64	.2	25	100	0.2	8	32
		10	3	15	60	4	33	132	2	80	320	0.5	14	56
		20	5	21	84	9	49	196	4	160	640	0.8	18	72
		30	9	27	108	15	63	252	6	235	540	1	22	88
Steep (40-60)	1	0	1.4	12	48	1.5	22	88	1.1	55	220	.3	11	44
		10	3	17	68	4	36	144	2	100	400	0.6	15	60
		20	6	23	92	9	51	204	5	175	700	1	19	76
		30	9	28	112	16	65	260	6	250	1000	1	23	92

SAFETY MARGIN= (FIREFIGHTER TRAVEL RATE) - (FIRE RATE OF SPREAD)

Shaded areas represent a negative safety margin. Conditions are as follows: 1, 10, and 100 hour dead fuel moisture content=4, 5, 6%. Live fuel moisture content=50%. For the crown fire modeling late summer severe drought characteristics were used. R-S is fire rate of spread, F-L is calculated flame length, SZ is minimum safety zone separation distance. [1]Fuel Model 3; [2]Fuel Model 4; [3]Fuel Model 12 and maximum rate of spread; [4]Fuel Model

Slash and timber surface fire: When slash and timber fuels are burning in severe drought conditions (fig 5C) the safety margins are positive for winds up to 30 mi/h and slopes less than 50 percent.

Crown Fires: Figure 5D presents the calculations and data for crown fires. The fire spread calculations from Rothermel's (1991) model and were made assuming late summer severe drought conditions. These data suggest that when the fire is spreading over relatively flat terrain the safety margin is positive as long as the winds pushing the fire are less than 25 mi/h. However as the slope increases to 30 percent, winds of 15 mi/h can result in negative safety margins. For slopes greater than 40 percent the safety margin should be considered negative even in low or calm winds.

For flat terrain, type I and II bulldozers maintain a positive safety margin if the winds are less than 40 mi/h. A positive safety margin for type III dozers requires winds to be less than 35 mi/h. Similar information at other slopes can be derived by examining the data present in figure.

Summary

Certainly many cases could be found that illustrate, often with tragic consequences, instances wherein firefighter safety margins were inadequate. Often the failure can be attributed to unexpected and rapid changes in fire behavior. Unfortunately, as Beighley (1995) states "firefighter's risk thresholds .... always have a degree of uncertainty because of inadequate or deteriorating information." This short analysis illustrates the fact that firefighters slow down while moving uphill and fires speed up. But the larger and more important issue is that the method demonstrated never provides a objective vehicle for assessing firefighter risk.

Appendix A contains a blank table similar to Tables 1 and 2. It is expected that firefighter crews could use information gathered from personal observations, Fire Behavior Analysts, or observations by others who have worked in similar fuels and conditions, to estimate fire spread rates in the different fuels that might be encountered as a function of slope, fuel moisture content, and wind speed. Once the fire spread rate information is completed and the crew has established that the firefighter travel rates are representative of their capabilities the table could be used to evaluate safety zone and escape route effectiveness with respect to potential fire behavior over a given burning period. It is anticipated that the method described herein could also be used by Fire Incident Management Teams when completing form 215A to evaluate the effectiveness of alternative safety zone and escape route options.

This study emphasizes the importance of firefighters constantly evaluating their position relative to that of the fire and the time that it would require them to reach their designated safety zone should the fire suddenly change direction and/or rate of spread. Methods of avoiding such situations are covered in the ten standard orders, the eighteen watchout situations, and LCES (Lookouts, Communications, Escape Routes, and Safety Zones Recognizing and predicting when threatening fire behavior changes are more likely to occur can allow variations in rates of escape (i.e. escape route length). The more uncertain the understanding and knowledge of the potential fire behavior the greater the safety margin should be. The evaluation method presented above assumes that the fire and the firefighter are the same distance from the safety zone. It is hoped that in most cases the fire would be significantly farther from the safety zone than the firefighter, this would increase the cases wherein a positive safety margin occurs. However, in some situations the reverse could be true in which case there is greater possibility that safety margins would be negative.

Literature Cited

Andrews, P. L. 1986. BEHAVE: fire behavior prediction and fuel modeling system-burn subsystem. Part1. Gen. Tech. Rep. INT-194. U. S. Department of Agriculture, Forest Service, Intermountain Research Station. 130 p.

Beighley, M. 1995. Beyond the safety zone: creating a margin of safety. Fire Management Notes. 55(4):21-24.

Butler, B.W.; Bartlette, R.A.; Bradshaw, L.S.; Cohen, J.D.; Andrews, P.L.; Putnam, T.; Mangan, R.J. 1998. Fire behavior associated with the 1994 south canyon fire on storm king mountain. Res. Pap RMRS-RP-9 U. S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Ogden, UT.

Butler, B.W.; Cohen, J.D. 1998. Firefighter safety zones: how big is big enough. Fire Management Notes. 58(1):13-16.

Fireline Hand Book, 1960 and 1969, U.S. Department of Agriculture, Forest Service.

Linane, M. 2000a. personal communication with John Feazelle, Santa Barbara Co. FD.

Linane, M. 2000b. personal communication with B. Butler

Phillips, C. B., C.W. George, D.K. Nelson. 1988. Bulldozer fireline production rates-1988 update. Res. Pap INT-392 U. S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Ogden, UT.

Rothermel, R.C. 1972. A mathematical model for predicting fire spread in wildland fuels. Res. Pap. INT-115. U. S. Department of Agriculture, Forest Service, Intermountain Research Station. 40 p.

Rothermel, R.C. 1993. Mann Gulch Fire: A race that couldn't be won. Gen. Tech. Rep. INT-299. U. S. Department of Agriculture, Forest Service, Intermountain Research Station. 10 p.

Sharkey, B. 1994. Personal communication with T. Putnam on physiological analysis of firefighter movement

Appendix A—Escape Route Analysis Table

Slope (%)	Type 1 Firefighter Rate of Travel (ft/s)	20' Wind Speed (mi/hr)									
			Rate of Spread (ft/s)	Flame length (ft)	Minimum Safety Zone Size*	Rate of Spread (ft/s)	Flame length (ft)	Minimum Safety Zone Size*	Rate of Spread (ft/s)	Flame length (ft)	Minimum Safety Zone Size*
Flat (0)	4	0									
		10									
		20									
		30									
Low (10-20)	3	0									
		10									
		20									
		30									
Moderate (20-40)	2	0									
		10									
		20									
		30									
Steep (40-60)	1	0									
		10									
		20									
		30									

SAFETY MARGIN= (FIREFIGHTER TRAVEL RATE) - (FIRE RATE OF SPREAD)

*Safety zone size is the minimum recommended distance between a firefighter and a fire. (Safety zone size = 4 x the flame length or flame height)

Field Verification of a Firefighter Safety Zone Model

Butler, B.W. and J.D. Cohen
U.S. Forest Service, Rocky Mountain Research Station, Fire Behavior Project, Missoula, MT,
bbutler03@fs.fed.us

Abstract. Safety zones are a primary component of firefighter safety. A theoretical study has been presented suggesting burn injury can be avoided if safety zones provide a minimum separation distance between the fire and the firefighter equal to 4 times the average flame height. In this study measurements of radiant energy emitted from crown fires burning through 12m tall stands of jack pine and black spruce are compared to predictions from the theoretical firefighter safety zone model. The comparisons suggest that the model underpredicts incident radiant flux near the flames (within a distance of about one flame height). The data also illustrate the effect of flame size (width and height) on the radiant energy distribution and required separation distance to prevent burn injury. If the effect of flame width is taken into account then it can be argued that the measurements generally agree with the model. Based on the data presented herein, the authors continue to support the general rule that safety zones should be large enough to provide a minimum separation distance equal to 4 times the expected flame height.

Key words: wildfire, safety, radiation, heat transfer

Introduction

Firefighter safety is a primary objective of all firefighting organizations. In North America, firefighters are taught to maintain adequate safety zones. These zones are areas to which firefighters working in the area can retreat to escape injury when threatened by the fire. Recently Butler and Cohen (1998) presented an analytical study comparing predicted radiant energy transfer from a 20m wide fire front as a function of flame height and distance from the flames. This information was compared against available data on burn injury by thermal radiation to humans wearing Nomex clothing. Based on this comparison it was concluded that in general firefighter safety zones must be large enough to provide a minimum separation distance between the fire and the firefighter equal to 4 times the flame height.

This study presents measurements of radiant energy emitted from crown fires burned as part of the International Crown Fire Modeling Experiment (Alexander and others, 2000). The measurements are compared against energy levels predicted by the safety zone model presented by Butler and Cohen (1998).

Experiments

The International Crown Fire Modeling Experiment provided researchers with an opportunity to deploy instruments and firefighter personal protective equipment ahead of an approaching crown fire. Descriptions of the site, environmental conditions, fuels and studies are provided elsewhere (Alexander and others 2000). Figure 1 is an aerial photograph of the experimental site.

Figure 1—Aerial view of experiment.

Figure 2 is a schematic of the site. Experiment plots were square with side dimensions varying from 75m to 150m. Vegetation consisted of 12m tall Jack pine with a black spruce understory. The vegetation was approximately 65 years old. A 1 to 10cm thick duff layer covered the mineral soil. The location was selected for its uniformity of fuel and accessibility. Once the instruments were deployed the environmental conditions were monitored until the target conditions were met. The fires were ignited using a truck mounted flame thrower developed for prescribed burning. The general procedure was to ignite the windward edge of the plots. In most cases the fire moved into the tree crowns within 15m of the ignition line.

The safety zone data where collected by deploying radiant heat flux sensors in the cleared area downwind of the fuel plot. Other sensors were deployed that measured air temperature, air velocity, radiant emission from the flames, and convective energy transfer, their data is reported elsewhere.

The safety zone sensors were located approximately 1.2m above the ground and were oriented with the sensing surface “facing” the approaching fire. The sensors used were of the Schmidt-Boelter thermopile design manufactured by Medtherm Corporation of Huntsville, Alabama USA. The sides and backs of the sensors were insulated with ceramic blanket material to reduce the effects of flame and solar heating.

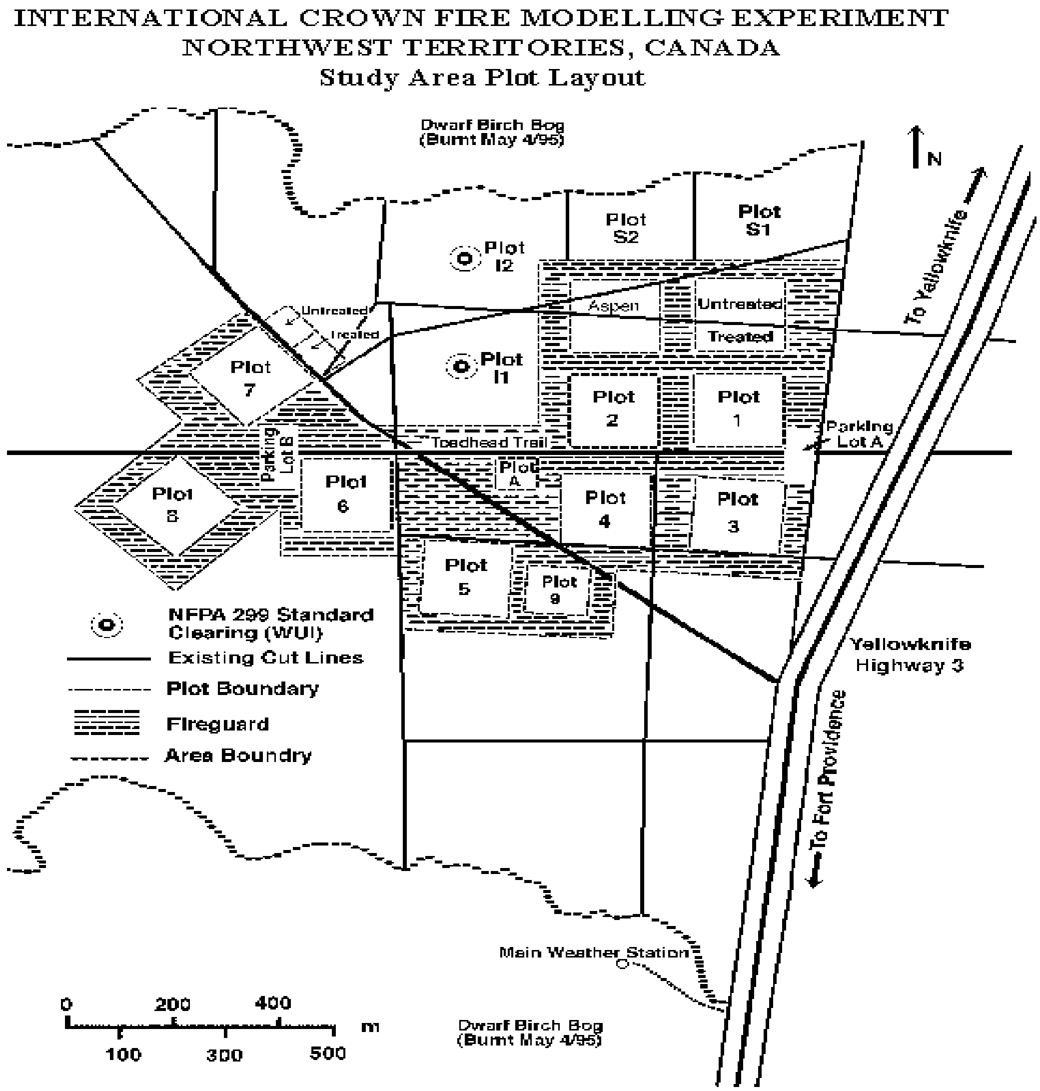


Figure 2—Schematic of experiment plots. This study focuses on data gathered from plots 1, 3, 4 and 9.

Four plots were instrumented with safety zone instrumentation. Table 1 summarizes the conditions and fire behavior for each experiment. Campbell Scientific CR-10X dataloggers collected the signals from the sensors at a rate of 1hz. The data were smoothed using a 10 second moving average. The peak incident radiant flux corresponding to each measurement location was selected from the smoothed data. The smoothed value was compared against the model. Figure 3 is a graph of a typical heat flux versus time signal and a smoothed trace. The rapid rise in measured flux is associated with the appearance of the flame through the intervening vegetation, followed by a peak and then rapid decline. Typical flaming combustion lasted approximately 30 seconds.

Table 1—Conditions and burning rates

Plot	Air Temp (C)	RH (%)	10m Wind Speed (km/h)	Rate of Spread (m/min)	Comments	Estimated Flame Height (m)
1	26	29	11	28	Fire did not reach leeward edge as uniform front.	17
3	31	23	11	24	Fire burned along one side only.	17
4	25	48	15	45	Fire burned center but not sides.	20
9	31	23	25	70	Fast burn, relatively uniform flame front.	30

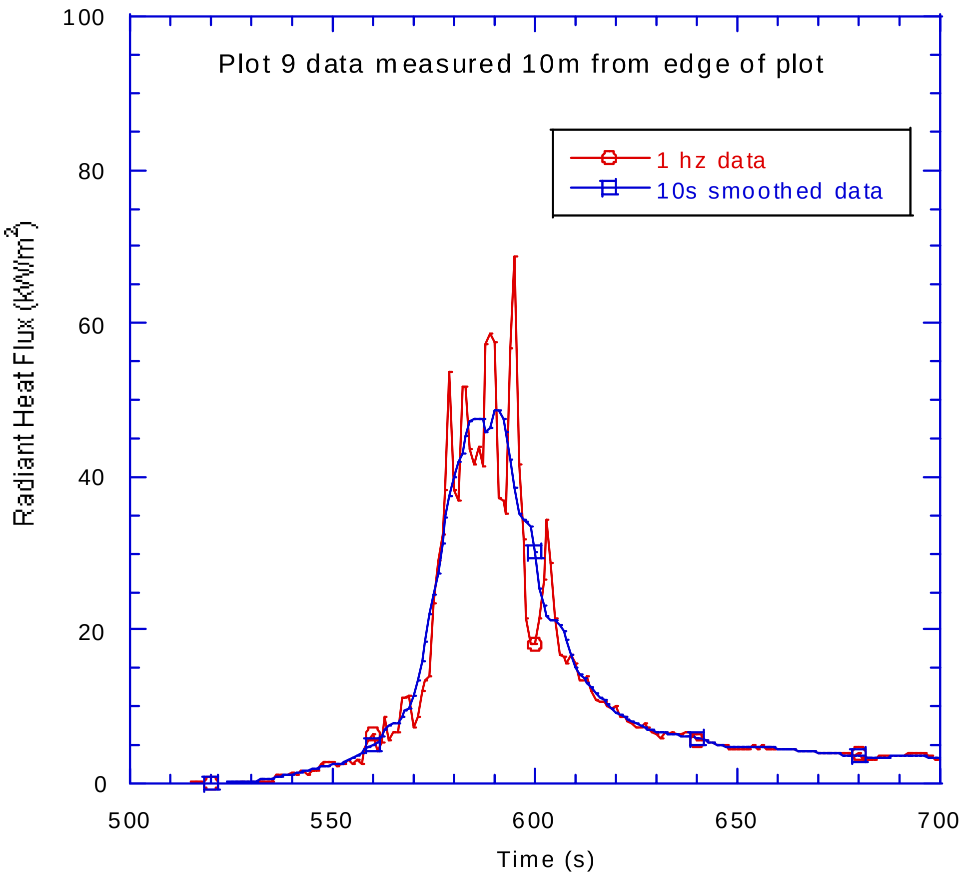


Figure 3— Thermal radiation measured at a location 10m from the downwind edge of Plot 9.

Safety zone measurements were conducted on plots 1, 3, 4 and 9. Wind speed, temperature, relative humidity, rate of spread of the fire, and estimated flame height are noted in Table 1.

Flame height is one of the primary factors affecting the amount of energy transferred ahead of the flames. For the purposes of this study, visual estimates of the flame height were made. These estimates were then applied to the model to predict the distribution of radiant energy ahead of the flame.

Discussion

The safety zone model presented by Butler and Cohen (1998) assumes a constant flame temperature of 1200K and a constant flame width of 20m. The model predicts the minimum distance between a firefighter and flame needed to prevent second degree injury through Nomex cloth as a function of flame height.

A comparison of model predictions against measured energy levels requires flame height information from the experiments. For these fires the vegetation height was approximately 12m. Figures 4-7 are photographs taken when the fire was burning along the downwind edge of the experiment plots. Using the vegetation height as a gauge, estimates of the height of the continuous flaming zone were made. These data are included in Table 1. Figure 8 graphically compares the predicted radiant energy flux profile versus the measured values. The separation distances shown in figure 8 are measured from the edge of the vegetation. The distances corresponding to the intersection of the horizontal solid black line at 7 kW/m^2 and the lines of constant flame height are the predicted separation distances required to prevent injury.

It is clearly shown that the data from plots 1, 3 and 4 are relatively consistent with each other in the region from 25 to 50m from the flame. However as noted in Table 1. These data do not agree with the predicted radiant energy distribution based on the estimated flame heights. In fact the data most closely

Figure 4--Plot 1 fire. This fire was characterized by torching rather than a coherent uniformly spreading flame as a function of separation distance.

Figure 6--Plot 4 fire. Note that the fire has nearly reached the edge of the fuel and is not forming a uniform flame front.

Figure 5--Plot 3 fire. Note that the fire is burning mostly on far right corner of the plot. The aluminum foil structures shown in the foreground are structure ignition sensor assemblies.

Figure 7--Plot 9 fire. Note that the flames are relatively large and uniform. The flame height was visually estimated to be 30 m.

match the distribution for a 5m tall flame. The initial impression is that the model overpredicts the distribution of radiant energy.

We believe that the disparity between the measured and predicted profiles can be explained by differences between the model assumptions and the actual flame size and behavior. The model presented by Butler and Cohen (1998) assumes that the flame is a uniformly radiating source of constant temperature and height and is 20m wide. Photographs taken of the fires in plots 1, 3 and 4 indicated an approximate flame height of 17 to 20m. Observers who watched the fires burn through these plots noted that when the fires reached the back edge of these plots, it did so along limited areas. Some of this behavior is shown in Figures 4-6 where flames are observed adjacent to unburned trees. Fgures 4-6 indicate that in general the fire did not exit plots 1, 3 and 4 as uniform front. In our opinion this was caused by the lack of alignment between the principle axes of the plots and the wind direction. Plots 1, 3, and 4 were oriented along north-south and east-west coordinates. Plots 1 and 3 were ignited under the influence of a quartering wind, the wind pushed the fire toward one corner of the plot. This resulted in a flame at the downwind edge of the plot that was much narrower than the actual width of the plot.

In the case of plots 1, 3 and 4 the lack of agreement between the model and measurements is attributed to the nonuniformity of the flame and narrow width of the fires as they exited the leeward edge of the plot. In support of this argument the authors note that the measured data compare very well against the predicted profile corresponding to a 5m flame height. Mathematically speaking, there is very little difference in terms of radiated energy between a flame that is 20m wide and 5m tall and another that is 5m wide and 20m tall. Therefore if one supposes that the 5m profile also represents a flame 20m tall and 5m wide then the data actually support the assumption that the flames exiting plots 1, 3 and 4 were very narrow (i.e. about 5 m wide and 20m tall).

Examination of the data collected from plots 4 and 9 indicate that for distances relatively close to the flames (within about 20m) the model agrees relatively well with the data in the 0-20m range. Video footage of the plot 9 fire indicates that the flames moved out the downwind edge of plot 9 a distance of more than 10m into the fire break. This convection of the flame into the fire break is one possible cause of the of the high measured radiant energy fluxes.

Conclusions

The theoretical model of radiant energy distribution in front of a solid flame was compared against measured values of the incident radiant energy. The model assumes an isothermal radiating source 20m wide. In general the shape of the measured flux distribution agrees reasonably well with that from the model. While there is a definite disparity between the measured and predicted flux distributions, the authors attribute these to differences between the assumed and actual values of flame width and height.

The model underpredicts the experimentally measured incident radiant energy within 10m of the flame front, this has been attributed to advection of the flames into the fire break area. The disparity between the data from plots 1, 3 and 4 and the predicted profiles can be attributed to the discontinuity in the flame as it reached the downwind edge of the plots. The result was a narrower radiant energy source than that assumed in the model. These data suggest that predictions assuming a narrower flame front would improve the agreement between the measured and predicted fluxes for these fires.

The authors believe that at this time there is no compelling reason to change the suggested rule of thumb that safety zones be large enough to provide a minimum separation distance between the

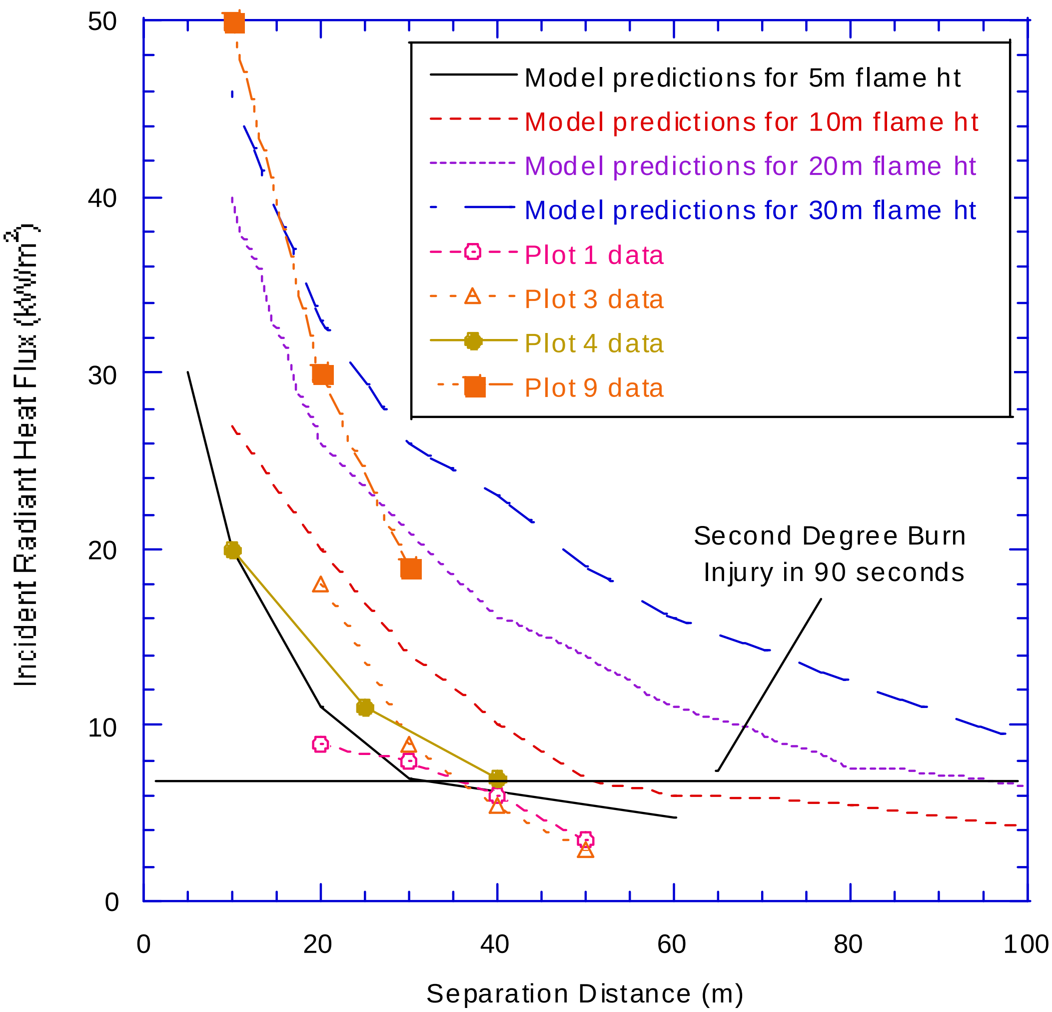


Figure 8—Predicted and measured distribution of thermal radiation ahead of a spreading flame front. The solid lines represent predicted values and the symbols and dashed lines represent measured values.

firefighters and fire equal to 4 times the maximum flame height for the current and expected fuel and environmental conditions.

These data provide a quantitative measurement of the duration and range of intensities that can be expected in crown fires burning through 12m tall forests. The data also are indicative of the variability that can be expected in field experiments, even when conducted under relatively uniform conditions. The instruments developed for this study provide a relatively robust method for quantifying the thermal environment in and around high intensity flames.

References

Butler, B.W. and J.D. Cohen. Firefighter Safety Zones: A Theoretical Model Based on Radiative Heating. Int. J. Wildland Fire 8(2):73-77, 1998.

Alexander, M.E.; B.J. Stocks, B.M. Wotton, M.D. Flannigan, J.B. Todd, B.W. Butler, R.A. Lanoville. The International Crown Fire Modelling Experiment: An Overview and Progress Report. Second Symp. on Fire and For. Met., 11-16 January 1998, Phoenix, AZ, by the American Meteorological Society, Boston, MA. Pages: 20-23

Alexander, M.E.; R.A. Lanoville; B.M. Wotton, B.J. Stocks. An Introduction to the International Crown Fire Modelling Experiment. In proceedings of 2000 Wildland Firefighter Safety Summit, International Association of Wildland Fire, Edmonton, Alberta Canada, October 10-12, 2000.

LCES Workshop, Do Basic Things Very Very Well

P. Chamberlin
US. Forest Service, Region 1, Missoula, MT, pchamberlin@fs.fed.us

Do Basic Things Very, Very Well

Lookouts, Communications, Escape Routes, and Safety Zones (LCES) are quickly becoming the dominant and most accessible safety standard for wildland firefighting. The LCES Workshop has demonstrated an instructional technique utilizing the many years of experience on our crews, while taking advantage of unbiased insights of new employees. The Workshop is fully accredited by NWCG as an alternative to required annual firefighter safety refresher.

This paper will introduce and outline the LCES Workshop, describing the history and values leading to this unique initiative. Next, the evolution to a methodical strategy to achieve thorough application (Paint in the Map), and finally a process to revisit and reinforce the workshop product throughout the field season (6-Minutes for Safety).

Appendices include sample workshop products (i.e. contracts), course evaluation data, a sample Paint in Map mailing, and a typical 6-Minutes for Safety package.

Current Situation

American wildland firefighters are directed by the agencies to operate using Ten Standard Firefighting Orders, 18 Situations that Shout Watch Out, the Downhill and Indirect Line Construction Guidelines, the Common Denominators of Fire Tragedies, and LCES. Over forty elements. All of them important.

These important topics are reviewed annually in required Standards for Survival training. While a great course, Standards for Survival's effectiveness is compromised by over use. Many firefighters are no longer mentally engaged by the videos. Conscientious instructors have independently added to and enhanced the course to maintain attention. Furthermore, as an agency we feel we have done our part once fire safety information has been delivered in the classroom. From then on the individual can be held accountable. In fact, even our best instructors fail to engage all class attendees, and even our best employees cannot always access all the rules.

Those of us in government agencies, no matter how sincere our concern, face an awkward wall in some communities where any authoritative direction is resented. Consequently, reaching the many volunteer and rancher firefighters is a critical safety challenge.

Workshop Genesis

The developers of the LCES Workshop are believers in the 10 Standard Firefighting Orders, the 18 Situations that Shout Watch Out, the Down Hill and Indirect Line Construction Guidelines, and the Common Denominators of Tragedy Fires. The effort, creativity and sincerity leading to these programs is as dedicated, profound and important as any other factor leading us to LCES. The Workshop actually serves these by providing effective review, and a mental map improving access.

LCES was invented by Paul Gleason, while Superintendent of the Zigzag Hotshot Crew. On June 26, 1990 the Dude Fire, on the Tonto National Forest, made a spectacular and tragic run. The Perryville Type II Crew was burned over, and 6 people lost their lives. Paul Gleason, his crew, and other crews and overhead were farther up the same hill in a pre-designated Safety Zone in the Bonita Creek Subdivision. Such a horrific experience changed the firefighting habits of everyone involved, and prompted Paul to conceive and publish LCES. Paul tells us that by doing a good job with Lookouts, Communications, Escape Routes, and Safety Zones, we are essentially accomplishing all the 10 Standard Firefighting Orders, and 18 Situations that Shout Watch Out.

After the South Canyon tragedy, Ted Putnam, an ex smokejumper, Missoula Technology Development Center expert on flame resistant clothing, and veteran of too many fire entrapment investigations, is also moved into action. Referring to his Ph.D. in Psychology, Ted brings to our attention aviation cockpit studies showing that sharp individuals can normally manage only 5 or 6 elements at one time, and when the situation becomes intense, we can focus on only one or two! Ted also organized the pivotal Human Factors Workshop in Missoula, Mt. in 1995. Many of the important concepts presented in the published findings are woven into the LCES Workshop.

Like many firefighters, Missoula Smokejumpers were also thinking of the complicated and "inaccessible" nature of the amassed Orders, Situations, Guidelines, and Denominators. The deaths of friends and coworkers on Storm King Mountain in 1994 impelled a self-evaluation and finally a deep commitment to LCES and firefighting safety. Mere lip service to the rules was over. The fire season of 1995 provided opportunities to test Gleason's theory, and the author, as a Smokejumper, IC3, Operations Section Chief and Safety Officer, held himself and others to a very literal and demanding commitment to LCES. Notice the Standard Orders say Post a Lookout When Necessary. LCES has shown we can have a lookout at all times, and the quality of the lookout is defined by the time it takes to get out the Escape Route to the Safety Zone.

Still, when wondering why, as a community, we were doing such a poor job with Lookouts, and Safety Zones, the thought dawned "We have no standards, no training of what a quality lookout is. We have no slide or video library of quality Safety Zones to aid in our studies". These ideas point to the fact that our actual commitment to these safety cornerstones was weak.

The Course

Making some important assumptions, that people are smart, that people demonstrate a greater commitment when participants in the plan, and that LCES is indeed a mitigation for the majority of the Orders, Situations, Guidelines and Denominators, a novel approach to fire safety training has emerged.

Unit I tests Gleason's theory. With scissors and tape, we reconstruct the Orders, Situations, Guidelines and Denominators and identify which of the L, C, E, or S categories best house each element. Participants decide for themselves whether LCES does or does not restate or mitigate most of the Orders, Situations, Guidelines, and Denominators. The nationally mandated review of Orders, Situations, Guidelines and Denominators becomes an exercise to focus attention on LCES. An unexpected compliment comes from many students: Unit I has been the best review of the Orders and Situations to date.

In Unit 2, the huge hole in our training and standards for lookouts, communications, escape routes or safety zones becomes the objectives and the product of each workshop. Instead of identifying a committee of national experts to create and publish a long list of what a good lookout should be, why not turn to the vast experience amongst our crews and firefighters, and empower people to be creative and design their own definitions and operating procedures. In small focus groups, participants brainstorm each element, and then, with the entire class, develop the LCES elements into a 'Contract' with each other, based on group consensus. Use of a laptop computer, projected with a video projector, facilitates the group editing process. The document is printed, copies made, and provided to each participant. The printing and copying is usually accomplished as participants review and practice fire shelter deployment.

In this four to five hour workshop, participants design and share ownership for their safety program. Pre-existing safety programs are an important tool, simultaneously meeting the nationally required annual review.

Unit 3, scenario exercises either provided by the course or locally produced, reinforce and demonstrate successful application. Scenario exercises are in addition to the four to five hour time frame, and are usually used the next spring. The course provides 5 scenarios (Initial Attack, Large Fire Crew Action, Urban Interface, Prescribed Fire, and Emerging Fire Engine Operations), each lasting about 2 hours.

Contract Ground Rules, Practice Success

The Workshop product, the 'Contract', is a consensus-achieved commitment, an agreement between all the participants. Nothing is allowed on the Contract that cannot be met everyday, on every fire. All the perfect world and fancy gadgets will not be counted. Straight forward and detailed group development of L, C, E, and S, cause individuals to expand theirs and the collective comprehension of what makes a quality Lookout, what our Communications responsibilities are, and crucial factors in managing Escape Routes and Safety Zones. By achieving a detailed look at these basics, and holding people to realistic expectations, firefighters are postured to practice success. When we practice doing things right every time, we avoid the situations where complicated and redundant rules are compromised. People will not become comfortable working in compromised situations.

The `Contract' is a nice touch, but the true value of this workshop is the high level of participation and engagement. That silent back row of macho firefighters become table-thumping sources of ideas and experience.

The Ultimate goal of the LCES Workshop is to move the entire firefighting community one solid, indelible step. Let's achieve a point where all firefighters are so familiar with L, C, E, an S, and their use so ingrained, that any time we find ourselves working without them, we will get very nervous, feel very comfortable speaking up, make the fix, and practice only success.

Deployment History

U.S. Forest Service Region One Smokejumpers and the Gila National Forest Guard School utilized the draft course in the spring of 1996. With funding and technical help from Nelda Vorce and the BLM, Billings and Reno, the latest version is now in Standard S-Course format and is available through NWCG. A digitized version is also available. The LCES Workshop has been reviewed and conducted on a multi-agency, multi-region basis. The author has traveled from Portland Oregon to Portland Maine, from Tallahassee to Fairbanks, and many locations in between, presenting either informational Power Point presentations, or Train the Trainer Workshops. The course is considered by many to already be in the 'Classic' category.

As envisioned, Standards for Survival, LCES Workshop, LCES Contract Review and Scenarios and other courses such as Jim Cook's Fatality Fire Case Studies may be presented in annual rotation to keep firefighter safety training fresh and engaging.

The LCES Workshop has proven to be an effective and popular tool to ingrain firefighter safety basics; however, even in the author's home region large gaps existed and many individuals were still unaware of this tool. It was time to engage a systematic strategy.

See: Appendix A, Sample Contracts
Appendix B, Course Evaluation Data

Source for the LCES Workshop:
Spring: 2001: National Interagency Fire Center
Att: Great Basin Cache Supply Office
3833 S. Development Ave.
Boise, Id, 83705
Immediately: Electronic Version
www.nv.blm.gov/2wgbcc

Paint In the Map

Utilizing existing interagency zones, which may be up to a quarter of an American western state, and achieving unanimity of purpose with partner agencies' leadership, we vowed to: 1) This Spring reach Federal, State, Tribal, Local, and Volunteer firefighters, 2) Utilize the LCES Workshop as an alternative to Standards for Survival annual refresher, and 3) Systematically move all firefighters within that zone to a deeper understanding and practice of LCES.

With interagency cooperation a modern reality, and fire trucks of all colors converging on fire starts, it is important to ensure all players are using the same sheet of music. The LCES Workshop achieves a consensus that has input and buy-in from all participants.

Only 3 zones were chosen in the Northern Rockies, and 3 in the Intermountain Region. Biting off only what can be accomplished well, remaining zones will be goals for subsequent years, until we “Paint In the Map”.

See appendix C, Sample “Paint In the Map” outline and package.

6-Minutes for Safety

The LCES Workshop has proven to be a very popular and effective tool to promote and build understanding of the basics, *in May and early June.* But how do we reinforce and ingrain *throughout the field season*? While pondering this question, the author was directed to develop something called 6-Minutes for Safety for Northern Region Forest Service firefighters. 6-Minutes has proven to be an ideal vehicle.

Risk Management speaker Gordon Graham is the inventor of 6-Minutes for Safety. Challenged with supervising young California Highway Patrol Officers, Graham recognizes that situations getting people in trouble fall into the High Risk Category, but happen infrequently (High Risk / Low Frequency). Much of the previous safety program focused on Low Risk / High Frequency. A careful analysis of how adults actually learn reveals a brief 6 minute review of key topics, one topic a day, had the biggest pay-off, with very little expenditure of money or duty hours.

Gordon creates a calendar identifying one topic each day, and the same topic is utilized at pre-shift briefings throughout the state of California. By the end of the month, each officer will have participated two or three times in a discussion of each of the High Risk / Low Frequency topics. Topics are repeated based on the degree of risk, and to work around days off schedules. At this rate, an agency would reap the equivalent benefit of three days of quality supplemental training per year, at little expense.

People feel empowered when knowing they are participants in a much larger force. In this case, officers know colleagues in distant parts of the state are discussing the same topic.

Graham presented to the national Forest Service FMO meeting in Orlando, as well as the national BLM FMO meeting in Boise. At these meetings he suggested the 6-Minute concept for firefighter adoption. U. S. Forest Service, Northern Region, developed a program, and invited cooperating agencies to participate. Before long, the two-week calendar found its way to crews and stations all over the U. S.

The firefighter 6-Minute Calendar is produced bi-weekly, and e-mailed one week in advance. Topic ideas and format suggestions have been solicited from the beginning, and ideas and trends were incorporated as the season developed.
A total of 9 calendars were produced, no negative comments were received, and many people reported great crew discussions, use on type II and I fires, staging areas, and team meetings. Numerous reports were received detailing how the topic timing was uncanny, as a related actual event occurred soon thereafter.

From teaching many LCES Workshops, the author was prepared to include a wide variety of perspectives to address basic L, C, E, and S subjects. A mix of vehicle, aviation, environmental, and other risks were assembled throughout the two-week period, as well as opportunities for each crew to choose topics unique to their mission.

See Appendix D, 6-Minutes for Safety Calendar and program information

And in Conclusion

Although originally developed for the wildland fire scene, LCES, and the LCES Workshop, is showing potential in structural fire safety, urban interface planning, hazardous materials, confined spaces, and any hazardous operation. LCES quickly provides a rock solid mitigation to these universal basics, allowing us to focus on the complexities unique to the situation. The Workshop provides the ownership and consensus, promoting commitment and compliance. This process capitalizes on peer pressure, which had previously been working against safe operations.

Paint in the Map has provided an ongoing methodical plan to bump the entire firefighting community up an indelible notch. By setting high interagency cooperation goals, and working with one zone at a time, chances of falling back into sloppy status quo habits are reduced.

6-Minutes for Safety provides critical mid-season reviews to reinforce knowledge and peer commitment to: Doing Basic Things Very, Very Well.

Ownership, Consensus, and Engagement are the core values behind the LCES Workshop. We work together, think hard and commit to our own, and our compadres safety.

References

Findings From the Wildland Firefighters Human Factors Workshop, November 1995, 9551-2855-MTDC, updated July 1996
USDA-FS, Missoula Technology & Development Center
Building 1, Fort Missoula
Missoula Mt. 59804-7294

Source for the LCES Workshop:

Spring: 2001:National Interagency Fire Center
Att: Great Basin Cache Supply Office
3833 S. Development Ave.
Boise, Id, 83705

Immediately: Electronic Version
www.wgbcc@nv.blm.gov

Contact for 6-Minutes:
pchamberlin@fs.fed.us

Appendix A

Sample Contracts

GILA NATIONAL FOREST

LCES performance standards for Gila National Forest firefighters as defined during the May 1996 Guard School.

LOOKOUTS

-LOOKOUTS MUST:

Have weather and fire behavior knowledge and experience.
Notice and report changes in weather and fire behavior.
Monitor radio traffic for:

- Air support.
- Adjoining crews or divisions communications.
- Communications relay.
- Completeness of monitored conversations.

Have own safety zones and escape routes.
Become familiar with surrounding topography.
Identify safety zones and escape routes.
Know location of firelines and anchor point.
Identify and report natural barriers.
Be a calm and capable communicator familiar with radio frequencies.
Be in good physical condition.
Monitor smoke color and direction.
Monitor fire.
Know location of crews and their proximity to safety zones.

STAY CALM IN EXTREME SITUATIONS AND BE ABLE TO COMMUNICATE WELL.

02-03-LCES-
IR
I of 4 pages

Tools:	Notebook
Flashlight	Signal mirror
Binoculars	Flagging
Radios	Weather kit
Fresh batteries	PPE
Compass	
Map	

COMMUNICATIONS:

A GOOD BRIEFING INCLUDES:

-Here's what I think we face.

-Here's what I think we should do.

-Here's why. -Here's what we should keep our eye on (this should include an LCES plan).

-Now, talk to me.

EQUIPMENT: (some of these are not required in all situations)

-Radios

-Maps

-Fresh Batteries

-Cell Phone

-Hand Signals

-Flagging

-GPS unit

GUIDELINES FOR EFFECTIVE COMMUNICATIONS:

Eliminate assumptions.

Ask questions.

Find out everything you need to know.

Relay updated information as soon as possible.

Stay in close proximity of communications with your crew.

Know all radio frequencies on fire and with other crews.

Speak clearly and concisely-- think before talking.

Relay information, ask questions, stay aware of your situation. Practice effective listening skills.

Pay close attention to verbal and NON-verbal communications.

ESCAPE ROUTES

Make sure everyone knows their escape routes.
Clear shortest path to the safety zone.
Walk out the escape route and note the time required.
Establish alternative escape routes.
Scout area. Consider fuels, weather, topography, fire behavior and spotting potential when evaluating an escape route.
Make routes known to adjoining forces and lookouts.
Communicate, re-evaluate, and reiterate.
You may need to change escape routes as weather, fire locaton or crew location changes.

EACH PERSON MUST TAKE PERSONAL RESPONSIBILITY, UTILIZE LOOKOUTS, AIR OBSERVERS.

EQUIPMENT: (some of these are not required in all situations)

Flagging
Notebook Paper
Compass
Chainsaw
Hand Tools
Radios
Heavy Equipment **(Dozers)**

SAFETY ZONES

Areas that all crew members can reach quickly.
Practical site needing little clearing or improvement.
Use natural barriers if available.
DO NOT CONFUSE WITH DEPLOYMENT ZONE.
Pick an area without re-burn potential.
Mark safety zone locations.
Note and use aerial view to find good safety zones.
Re-evaluate safety zone frequently.

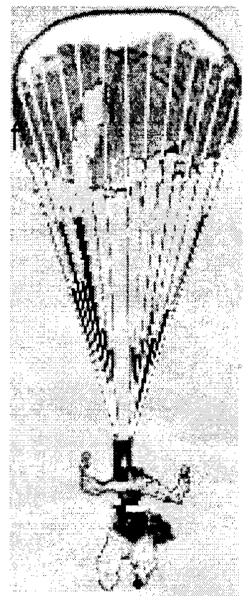
TOOLS: (some of these are not required in all situations)

PPE
Chainsaws
Lookouts, ground and aerial
Flagging
Radios
Fusees or other firing devices
Sprinkler system
Heavy equipment (dozers)
Camera (To record good and poor examples of safety zones for the slide library).

MISSOULA

SMOKEJUMPERS

LCES PERFORMANCE STANDARDS



LOOKOUTS

ATTITUDE-

A LOOKOUT SHOULD BE:

An alert self-motivated person

LOCATION-

PICK A GOOD VANTAGE POINT:

Identify fire related situations requiring special attention

Monitor other environmental hazards

Remember, you're responsible for LCES for yourself.

EQUIPMENT-

TAKE THE NECESSARY EQUIPMENT

PPE, compass, binoculars (if available), food and water.

Radio, extra batteries

Incident Action Plan

-Know the big picture and keep it updated.

Belt Weather Kit

-Take weather observations, SHARE THEM

HAVE ALL THE EQUIPMENT YOU NEED AND KNOW HOW TO USE IT.

COMMUNICATION

GIVE GOOD BRIEFINGS

COVER EVERYTHING IN A SENSIBLE,

STRAIGHTFORWARD MANNER

- Here's what I think we face
- Here's what I think we should do
- Here's why/when/where
- Here's what we should keep an eye on
- Now talk to me

HAZARD IDENTIFICATION

-Keep crews informed

-Spot weather forecasts

-Be pro-active, anticipate changes in weather and fire behavior

MAINTAIN CLEAR AND CONCISE COMMUNICATION.

KEEP OPEN LINES OF COMMUNICAITON WITH ALL RESOURCES YOU'RE RESPONSIBLE FOR OR WORKING WITH.

ENCOURAGE INTER AND INTRA CREW COMMUNICATION Up and down hierarchy Voice opinions, everyone, not just supervisors

CHECK-IN SCHEDULE SHOULD BE SET UP BEFORE HAND. HAVE SUPERVISORS UTILIZE THE 'SITUATION CHECK' MECHANISM TO RE-ASSESS WHETHER LCES IS COVERED.

-Listen for non-verbal clues; Are they really listening and am I?
-Recognize human factors and mitigate their impacts
-Confirm that information is understood

KNOW COMMUNICATION LINK PROTOCOL
FOR MEDICAL EMERGENCIES

ESCAPE ROUTES

SELECTING ESCAPE ROUTES CLEAR OBSTRUCTIONS

-Avoid uphill escape
-Route should be short/close enough to reach in a timely manner
-Often, the shortest route is your direct attack fireline, so use it
-Make sure the escape route is well scouted, well marked, and timed for all scenarios
-Provide for the lowest common denominator
-Error on the conservative side as to time needed to use escape routes

WELL IDENTIFIED AND COMMUNICATED TO THE CREW

-Input from all crew members, form a consensus
-Mark escape routes well enough so it's apparent, even under adverse conditions (smoke, dark, hurried, etc.)

HAVE ALTERNATIVES SELECTED SECONDARY ROUTES

-Use lookouts and aircraft to help identify escape routes

Appendix B

Course Evaluation Data

LCES Workshop
Course Evaluation Data

See attached sample Student Course Evaluation form

After each Workshop, students are requested to complete an evaluation form, which is designed to help instructors improve their presentation. The following data is from workshops that, for the most part, were facilitated by the author.

The Evaluation Form is in 4 parts: "Value of the Workshop to You", "Quality of Instruction", "Quality of Workshop Facilities", and "Quality of Scenarios (when used)". Comments are solicited throughout, and a later version asks pointed questions challenging people to consider their commitment to actualize the contract elements in the field.

The following Data reveals the participants post-workshop thoughts, and is limited to the first part related to the effectiveness of the Workshop in improving firefighter safety.

	Very (%)	Fairly (%)	Little (%)
Question 1 Is the Workshop pertinent to your needs?	880 (86%)	136 (13%)	11 (1%)

Interpretation
The compilation reveals 99% of participants feel the course addressed their job needs, and 86% are enthusiastic. Those saying the course does not address their needs usually included notes indicating they worked in support functions, or at a tanker base, etc. Interesting, most support people identify with the pulaski swinging and hose laying firefighter and spoke positively of the workshop process. They often comment that even though they may have been in fire camps for 20 seasons, and had on numerous occasions been in a rain of ash, this is the first time anyone suggested they also need to have an escape route and pre-designated Safety Zone.

	Very (%)	Fairly (%)	Little (%)
Question 2 Is it helpful in creating a safer worksite?	942 (94%)	55 (6%)	1 (.1%)

Interpretation
Almost everyone, 99+%, thought the LCES Workshop process will lead to a safer work site, 94% enthusiastically so. These numbers best reveal the level of engagement and new insights achieved by the Workshop. In any stack of evaluations written comments praise the involvement of all participants in a constructive dialogue, and the new clarity and straightforward approach to ingrain the basics. One Native American Crew Boss commented, "In 25 years of firefighting, this is the first time anyone has asked my opinion about anything".

Question 3 Did your group achieve a consensus?	730 (71%)	303 (29%)	2 (.2%)

USING ESCAPE ROUTES

-Re-assess

-All the time and as you move

-Use trigger points or situational awareness to determine when to use your escape routes - incremental changes may mean a lot

-Anticipate fire behavior so an orderly retreat is possible

-Account for all crew members

SAFETY ZONES

SELECTING A SAFETY ZONE PHYSICAL FEATURES

-Location

-Terrain

-Fuel Types

-Consider flame lengths, smoke

-Size of safety zone

-Free of other environmental hazards (snags, rocks)

-Consider reinforcing safety zones with retardant as last ditch measure

-As they change, that information must be passed along to everyone

ACCESSABILITY

-Can you reach it, can you be evacuated from it?

CHOOSE ALTERNATIVES IF POSSIBLE AND COMMUNICATE THEM TO EVERYONE

- The safest safety zone is usually 'In the Black'
- Don't totally trust black ground with aerial unburned fuels
- PERSONALLY VERIFY ALL SAFETY ZONES
- Try to ID safety zones from jump ship
- RE-ASSESS FREQUENTLY
- Assess the present situation while your last safety zone still exists

Interpretation
The drop in enthusiastic responses in relation to consensus reveals an area where the facilitator must be careful in finding the balance between exact agreement, and the risk of letting the discussion bog down in non-productive debate. When the objective is the deep consideration of LCES facets, a rigid consensus is not actually imperative. Rarely will any disagreement significantly affect field operations, and the existing ICS chain of command will carry the day.

Question 4
Is your Contract a useful guide?

	697 (70%)	283 (29%)	11 (1%)

Interpretation
Is the contract a useful guide? Again, the soft underbelly is exposed. An obvious comment, which emerges regularly, "Nice going Paul. We reduce 44 elements to 4 (LCES), and now we've expanded it to over 60 (the contract)!" Point well taken. The LCES Contract will not be pulled from pockets and packs any more often than the numerous cards and checklists promoting 10 Orders, 18 Situations, etc. Again, revisit the objectives. By participating in the contract editing process, we work to ingrain LCES to where just thinking of LCES will mentally access our deeper understanding and professional behaviors.

And added to the later form:

	Very (%)	Fairly (%)	Little (%)
Question 5 Will your field operations achieve this standard?	155 (69%)	68 (30%)	2 (1%)

Interpretation
When asked if they will achieve this standard, many people make comments such as "We'll See." And with that comments such as "I fully intend to". The total of 99% positive responses is promising, but the 30% less enthusiastic responses (fairly) often point to the cultural realities, supervisory commitments, and again, the drawn-out detail of the contract.

LCES WORKSHOP STUDENT COURSE EVALUATION

Workshop Location________________Workshop Date _______
Instructor(s)____

Value of the LCES Workshop To You

	VERY	FAIRLY	LITTLE
Is the Workshop pertinent to your needs?	______	______	______
Is it helpful in creating a safer work site?	______	______	______
Did your group achieve a consensus?	______	______	______
Is your contract a useful guide?	______	______	______
Will your field operations achieve this standard?	______	______	______

Comments: ____
____

What will impede you from fulfilling your Contract? ______________________________
____

What can supervisors and managers do to help firefighters practice quality LCES, as described in your contract? ____
____

Additional comments: ____
____
____

Quality of Instruction

	VERY	FAIRLY	LITTLE
Were your instructions clear?	______	______	______
Was the information & discussion lively/interesting?	______	______	______
Were student questions and ideas encouraged?	______	______	______

Additional Comments: ____
____
____

CONTINUED ON REVERSE SIDE

Quality of Workshop Facilities and Materials

	VERY	FAIRLY	LITTLE
Was the room appropriate for this session?	______	______	______
Are the handout materials easy to use?	______	______	______
Are the visual aids legible and useful?	______	______	______

Quality of Scenarios (when used)

Do the scenarios represent real life situations?	______	______	______
Are the scenarios well written?	______	______	______
Do the visual aids support the situations?	______	______	______
Was your contract a useful guide for the scenarios?	______	______	______

Comments about scenarios: ____

Any Additional Comments About the LCES Workshop? ____________
____
____
____
____
____
____
____
____
____

Appendix C

Sample Paint in the Map outline and package

Painting in the Map,
Bringing the LCES Workshop to the Bitterroot
White Paper, Paul Chamberlin, AFD

Contents-

Objectives-

- Systematically move all firefighters to a deeper understanding and practice of LCES.

- This strategy is being applied on two zones in Region-1 and two geographic areas in Region-4 for year 2000.

- Utilize the LCES Workshop as an alternative to Standards for Survival annual refresher.
    - LCES Workshop is a NWCG alternative to Standards for Survival annual refresher.

-Reach Federal, State, Tribal, Local, and Volunteer firefighters.

- Invite and encourage participation of dispatchers, line officers, and pilots.

- Achieve unanimity of purpose with partner agencies' leadership.

- Training Trainers, open to all comers, trainers or not, will begin with sessions put on by Paul Chamberlin. Paul is the author of the LCES Workshop.

- Individuals with a facilitative instructional style can then teach the class and additional trainers.
    -The LCES Workshop actually has a fairly simple format.

Our goal is the ***ingrained*** application of LCES. As we "paint in" a section of the map, we move on in subsequent years to additional areas.

And what is the LCES workshop? See the next page.

LCES WORKSHOP, AN INTRODUCTION

DO BASIC THINGS VERY, VERY WELL

Lookouts, Communications, Escape Routes and Safety Zones (LCES) are quickly becoming the dominant and most accessible safety standard for wildland firefighting. The LCES Workshop demonstrates an interactive instructional technique that utilizes the many years of experience on our crews, while taking advantage of the unbiased insights of new firefighters.

The Current Situation

Wildland firefighters are directed by the agencies to operate using Ten Standard Firefighting Orders, 18 Situations that Shout Watch Out, the Downhill and Indirect Line Construction Guidelines, the Common Denominators of Fire Tragedies, and LCES. Over forty elements, *all of them important*. However, aviation flight deck studies indicate an individual can manage only five to seven elements during normal activities, and one or two when the situation becomes extreme.

Furthermore, as an agency we feel we have done our part once fire safety information has been delivered in the classroom. From then on the individual can be held accountable. In reality, even our best instructors fail to engage all class participants, and even our best firefighters cannot access all the rules.

Those of us in government agencies, no matter how sincere our concern, face an awkward wall in some communities where any authoritative direction is resented. Consequently, reaching the many volunteer and rancher firefighters is a critical safety challenge.

Even before LCES, lookouts communications, escape routes, and safety zones have been cornerstones of safe operations; however, has anyone received formal training as a safety lookout? Is there training material available? How about effective communications? Or escape routes and safety zones? Up until the introduction of the LCES Workshop there has been precious little information or performance standards.

An Opportunity Within

Making some important assumptions, that people are smart, that people demonstrate a greater commitment when participants in the plan, and that LCES is indeed mitigation for the majority of the Orders, Situations, Guideline, and Denominators, a novel approach to fire safety training has emerged.

The nationally mandated review of Orders and Situations becomes the first exercise, Unit 1, to focus attention on LCES. Participants, working in small groups determine for themselves whether LCES does or does not restate or mitigate most of the Orders, Situations, Guidelines, and Denominators.

In Unit 2, the huge hole in our training and standards for lookouts, communications, escape routes and safety zones become the objectives and product of each workshop. Beginning in small focus groups, then the whole class, each of the LCES element are developed into a “Contract” with each other, based on group consensus.

This contract is a nice touch, but the true value of the workshop is the high level of participation and engagement. That silent back row of macho firefighters becomes table-thumping sources of ideas and experience.

Scenario exercises (Unit 3) provided in the course or locally produced, address specific risks and hazardous operations to reinforce and demonstrate successful application of the LCES Contract. (Scenario exercises are in addition to the five-hour time frame for Units 1 and 2, and are usually used the next year, after a review of the contract, Orders, and Situations.)

As envisioned, the Standards for Survival, LCES Workshop, and LCES Contract Review and Scenarios may be presented in annual rotation to keep firefighter safety training fresh and engaging.

OWNERSHIP, CONSENSUS, and ENGAGEMENT, leading to COMITTMENT and COMPLIANCE, are the core values behind the LCES Workshop. We think and work together, planning our own and our compadres safety.

As an example of LCES application, how about a quick look at the Sadler Fire, from one LCES perspective? Last page.

An LCES Review of the Sadler Fire

Region-4 was severely challenged by the Sadler fire. We all were. The following brief analysis demonstrates the usefulness of rigorous LCES application.

When the Hot Shot crews declined the original burnout, they elected to tie into the black and bring the black with them. It is my contention, that without solid LCES, the same event, *i.e. a burnout operation outpacing the creation of quality black*, and a 90-degree wind shift, would have put the Hot Shots, along the flank, in the same boat as Golden Gate, at the head.

Indeed, most tractor plow entrapments in the Southeast happen just this way.

I will go out on a limb and say that if the Safety Zone from which the Golden Gate crew commenced burning was a quality safety zone, and I understand it was, then the operation could have been carried out safely, if ultimately unsuccessful. *The trap occurred when the winds pushed their burnout faster than quality black was developed.* The same scenario was even more likely with the down wind burnout by the Hot Shots.

Question: Why didn't the Hot Shots over extend? Answer: Better application of LCES.

Truly good Safety Zones allow safe *aggressive* suppression. Safe aggressive suppression adds to our ultimate safety by containing the exposure. This is not to say, “Stop the fire at all risk”. No, this is “get after suppressing the fire, but practice rigorous LCES in the process”. We are too often sitting back in camp looking at predicted burning conditions and making conservative decisions when crews and Divs, *with solid Safety Zones from which to extend*, are in a better position to assess the situation.

Our management responsibilities include the education of firefighters, and then the oversight of rigorous LCES.

Land managers, ICs, Ops, Safety Officers, Crew Bosses, Squad Bosses, and individual Firefighters are empowered to ask, “Who is the Lookout, how are we Communicating with the Lookout and each other? And “Where are the Escape Routes and are they suitable for the assigned resources?, and question the location and size of the Safety Zones. With a commitment to these principles we will improve the quality of briefings, and encourage leaders to maintain an open communication environment.

This example demonstrates the values and potential benefit of the “Paint in the Map” strategy. Thank you for your interest

Appendix C

Sample 6-Minutes for Safety Calendar and program information

Northern Rockies & Beyond
6-Minutes for Safety

Here is our eighth 6 Minutes Calendar, for September 3 through September 16.

Help make the daily 6-Minutes briefing an important part of our culture.
Program information is also enclosed.
Send feedback and topic ideas to Paul Chamberlin (pchamberlin@fs.fed.us)

Six Minutes for Safety

Safety Briefing Discussion Topics Calendar
September 3 through September 16

Sunday, Sept 3 Discussion Leader Signature: _______________ Discuss firefighter safety along roads and highways.	Monday, Sept 4 Discussion Leader Signature: _______________ Discuss weather changes that must get our attention.	Tuesday, Sept 5 Discussion Leader Signature: _______________ What signs indicate fatigue, in others and in ourselves. How will we respond when the cumulative effects of a long assignment are taking a toll?	Wednesday, Sept 6 Discussion Leader Signature: _______________ Do we have individuals in our unit who have appropriate training and experience to be good lookouts?	Thursday, Sept 7 Discussion Leader Signature: _______________ What additional risks are acceptable to attempt saving someone's home? Review agency policy in regards to fighting structure fires.	Friday, Sept 8 Discussion Leader Signature: _______________ List and discuss typical priorities for fire suppression and prescribed fire.	Saturday, Sept 9 Discussion Leader Signature: _______________ Discuss common hazards encountered when working around sawing and falling operations.
Sunday, Sept 10 Discussion Leader Signature: _______________ (Choose a topic specific to your unique mission)	Monday, Sept 11 Discussion Leader Signature: _______________ Discuss the elements of a quality briefing. When are briefings necessary?	Tuesday, Sept 12 Discussion Leader Signature: _______________ Review the procedures and communications to evacuate a sick or injured person. When should we review this plan?	Wednesday, Sept 13 Discussion Leader Signature: _______________ Describe driver's driving and shift limitations.	Thursday, Sept 14 Discussion Leader Signature: _______________ Can the Meteorologist be considered a Lookout? Name the Communication elements related to weather information.	Friday, Sept 15 Discussion Leader Signature: _______________ With Fall's arrival, discuss preventing, recognizing, and treating Hypothermia.	Saturday, Sept 16 Discussion Leader Signature: _______________ What obstacles and impediments are often encountered when developing an Escape route?

6 MINUTES Invitation

To: All Our Fire Fighting Partners

The Forest Service in Region 1, inspired by the wisdom of Risk Management speaker Gordon Graham, is initiating a program called 6 MINUTES for SAFETY. A copy of the Format, Topic Input Form, and Initial Calendar are included.

In a nutshell SIX MINUTES for SAFETY is scheduled six-minute interactive review/briefing of one topic a day, the same topic being used throughout a large organization. Topics chosen are characterized by High Risk / Low Frequency, and have historically gotten people and the fire community in trouble. This is a technique to extend the key points of our spring training throughout the field season.

There is an empowering effect when we know we are participants in a much larger force, and with that in mind, the Forest Service welcomes the active participation of all our cooperators.

Active participation? This means not only receiving and using our topics for briefings, but also have input to the briefing calendar. We welcome input from individuals.

Bi-weekly re-evaluation and adjustment is part of the plan.

If you are interested in being included on the mailing list, have feed back or questions, please contact Paul Chamberlin at the Aerial Fire Depot, (406) 329-4965, or pchamberlin@fs.fed.us

Six Minutes for Safety

Daily Discussion Topics

-Safety discussion topics.

-A new topic each day, provided on a calendar

-On a given day, m*any* crews, from *many* agencies, will discuss the *same* topic.

-High Risk / Low Frequency, No Discretionary Time characterize most topics; those that "Historically get our people into trouble."

-Topic ideas come from individuals, supervisors, and managers.

-Will be in addition to tailgate and JHA safety briefings.

-Discussion format encourages "Non Punitive Close Call Reporting", shares knowledge, and reveals areas needing additional training.

-For all fire crews and resources, including:

Engine, helitack, hot shot, and smokejumper crews
Line officers and dispatchers
Lookouts, aerial observers, air attacks, pilots
Resources on fire anywhere, and visiting resources
Non-fire personnel on fire assignments or standby
Type 3, Type 2 and Type 1 incidents, and prescribed fire

-Topic calendar will be produced for two-week period, and distributed one week in advanced.

-Format and topics will be adjusted based on comments received.

-To stress key points, topics may be repeated.

-To work around days off, topics will be repeated.

-Use attached form to suggest topics for future use (e-mail preferred).

Six Minutes for Safety

Northern Rockies Geographic Area

Input and Suggestion Topic List

Send topic ideas to Paul Chamberlin, AFD, pchamberlin@fs.fed.us (406) 329-4965

Topic Code:

S= Strategic in nature
V= Vehicle related
T= Tactical in nature, including line construction
A= Aviation related
E= Entrapment related
H = Hot, in response to specific event

Code:	Suggested topics to be assigned to a calendar day, and repeated as appropriate.

Submitted By:_________________________ Unit________________
Phone: _________________ e-mail___________________

Examination of the Home Destruction in Los Alamos Associated with the Cerro Grande Fire

July 10, 2000

Jack D. Cohen
Research Physical Scientist
USDA Forest Service,
Rocky Mountain Research Station
Fire Sciences Laboratory
Missoula, Montana

Abstract An analysis of the burn pattern and fuel consumption that occurred on the Cerro Grande Fire is used to evaluate the effect of fuel management and home construction on vulnerability of homes to ignition. While the data are largely anecdotal the conclusions drawn can provide some indication of proper fuel management needs and home construction techniques to reduce the incidence of ignition and consumption of homes in the wildland urban interface.

I arrived at Los Alamos on May 14, 2000 to conduct an examination of the home destruction associated with the Cerro Grande Fire. My examination occurred between the afternoon of 5/14 and late afternoon on 5/16. I had contact with the southern command post incident management team, the Los Alamos Fire Department, and the Santa Fe National Forest.

The homes were destroyed as the main body of the Cerro Grande Fire burned past Los Alamos to the north-northeast and then toward the northeast between about 1700 on 5/10 to the early morning hours of 5/11. About 200 single and multi-family structures were totally destroyed or irreparably damaged. Although fire suppression actions saved homes, the high ignitability of most of the residential area allowed numerous simultaneous house fires that quickly overwhelmed the suppression forces.

1) Although the Cerro Grande Fire burned as an intense, continuously spreading crown fire (fire spread through the tree canopy) in certain areas, within several hundred yards or more of the Los Alamos residential area it burned as a surface fire—an under burn. The pictures show tree canopies that were variably scorched but not consumed next to totally destroyed homes.

Photo 1—The crown fire burned on the ridge (mid-picture) west of Los Alamos.

Photo 2—The fire burned only in surface fuels as it came from the wild land in the background toward the residential area. The wild land fire commonly burned through continuous fuels to encounter and burn through heavier residential fuels such as woodpiles (bottom right), flammable shrubs, heavy pine needle beds, and homes.

Photo 3—Within the residential area, separated by several streets from the wild land, the fire generally burned as an under-burn with scorched but unconsumed tree canopies. The surface under the trees in the foreground did not burn, but the house to the left was totally destroyed.

2) Commonly homes were totally destroyed with the tree canopies leading up to and adjacent to the structures remaining unconsumed. The canopy consumption that occurred adjacent to and downwind from homes occurred from burning homes. With the exception of two local and limited areas where crown fire occurred adjacent to the residential area, a surface fire spread into Los Alamos. The unconsumed vegetation surrounding destroyed homes indicates that these homes were exposed to a low intensity surface fire, not a high intensity crown fire. Many of the homes destroyed, particularly the 4-plexes on the northwest side (*Photo 6*), occurred from structure-to-structure spread (communication with Steve Coburn, LAFD). In general, the intense wildfire burned past the residential area to the west and north of Los Alamos. Scattered islands of destroyed homes at the community margin suggest low firebrand exposures and low spotting potential during the late night and morning hours during which much of the residential area burned.

Photo 4—The unconsumed, moderately scorched tree canopy along with the remaining wood rail fence indicate that this home was exposed to a low intensity surface fire. The high intensity wildfire burned on the hills in the background.

Photo 5—This totally destroyed home was within the residential area. A road separated it from other burning vegetation and homes. The unconsumed vegetation with little scorch indicates that the fire intensity surrounding the home was low. This suggests that firebrands (burning embers from other fires) ignited the home directly and/or in adjacent flammable materials that spread to the home.

Photo 6—Significant structure-to-structure fire spread occurred from flames and firebrands in an area of multifamily residences. The unconsumed vegetation surrounding the corridor of destruction indicates that the high fire intensities were due to the burning structures.

3) My examination suggests that the abundance and ubiquity of pine needles, dead leaves, cured vegetation, flammable shrubs, wood piles, etc. adjacent to, touching and or covering the homes principally contributed to the residential losses. Discussion with the Los Alamos FD indicated that few wood roofs existed and thus were not a significant factor. In many areas of home destruction a continuous ponderosa pine (*Pinus ponderosa*) canopy existed within the residential area. This produced a continuous pine needle fuel bed to the homes as well as pine needles deposited on the homes (roofs and gutters). An examination of surviving homes in areas of home destruction indicated that a low intensity surface fire in pine needles could burn to a home and ignite its wood siding. In several cases, a scratch line that removed pine needles from the base of a wood wall kept the house from igniting. Firebrand ignitions likely started fires in these pine needle fuels in areas within the community that were separated by streets.

Photo 7—The tree canopy, shrubs, pine needle bed, and woodpile adjacent to and touching this Los Alamos home represents a common situation.

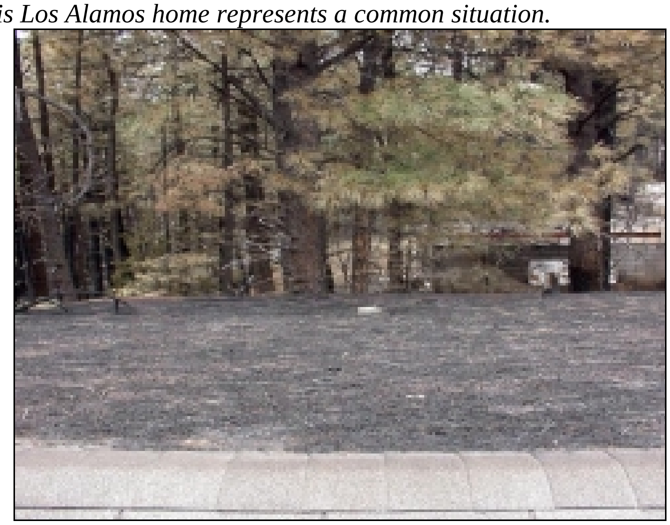


Photo 8—The surrounding ponderosa pine canopy deposited pine needles on this roof. The roof surface fire burned the needles without igniting the roof. The roof covering types were "built-up" gravel and composition shingle. The house did not have gutters to accumulate needles, potentially ignite and thereby ignite the eave edge. Although the neighboring home was totally destroyed (in the background) the tree canopies did not burn. The roof pine needle fire likely ignited from firebrands generated by the burning home next door.

4) That portion of the Cerro Grande Fire that burned into the community generally spread as a relatively low intensity surface fire, not as a high intensity crown fire. Homes ignited and burned from wildfire flames and firebrands that did not burn tree canopies and other vegetation in the same area.

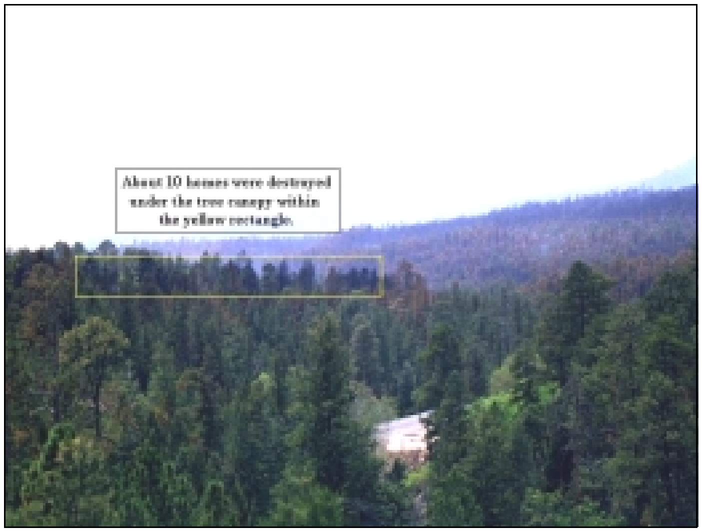


Photo 9— This is the Pueblo Canyon area looking southwest toward Ridgeway Road (within the yellow rectangle) with North Road visible towards the bottom of the photo. The Cerro Grande Fire burned as a crown fire on the slope in the background but as a surface fire in the foreground. Close inspection reveals torched trees within the yellow rectangle.

Photo 10—This is a portion of the area within the yellow rectangle shown in the previous photo. The trees burned from the burning homes. The homes ignited from the low intensity surface fire and adjacent burning homes.

1998 Results from the International Crown Fire Modeling Experiment Performance of Safety Equipment

Mark Y. Ackerman
Department of Mechanical Engineering
University of Alberta
Edmonton, Alberta, Canada

Gary Dakin
Alberta Environmental
Whitecourt, Alberta, Canada

Contact: Mark Y. Ackerman
4-9 Mechanical Engineering Building
University of Alberta
Edmonton, Alberta, Canada
T6G 2G8

Phone: 780-492-2822
Fax: 780-492-2200
Email: Mark.Ackerman@Ualberta.Ca

Abstract. The 1998 International Crown Fire Modeling Experiment presented a unique opportunity to examine the range of hazards that wildland firefighters might encounter when fighting fire. Several plots from a site near Ft. Providence, NWT were instrumented to measure incident heat flux at various distances from the edge of the fuels and ignited under conditions expected to produce a crown fire. In addition to heat flux measurements, personal protective equipment and both standard and prototype fire shelters were located near the edge of the fuels and instrumented to measure conditions during the exposures. In all two fuel blocks with three experimental sites were used.

The first block burned resulted in peak heat fluxes of more than 100 kW/m^2 at a 3 m distance from the fuel. Peak heat flux dropped rapidly with distance from the edge of the block with measured values of 12 kW/m^2 at a distance of 28 m. No attempt was made to separate the energy transfer mechanisms, convection or radiation. A standard fire shelter deployed 3 m from the block was destroyed and a shelter located 5 m from the block was damaged. Shelters located more than 5 m away from the fuels appeared undamaged. Coveralls located 3 m from the block were destroyed and peak temperatures were more than 800^{o}C.

The second block burned was instrumented at two locations: on the down wind edge and a cut line adjoining the plot. Based on measurements from the first block sensors were placed no closer than 5 m from the fuels. As a result peak heat flux measurements were much lower at less than 40 kW/m^2. Fire shelters located at a distance of 5 m from the fuel appeared to be undamaged. Measurements within a 6 m wide cut line were quite different in character than those obtained on the lee edge of the block. More than one distinctive peak in the measurements was obtained as the fire progressed parallel to the cut line. Depending on the location, peak flux measurements varied between 10 kW/m^2 and 20 kW/m^2. Based on the geometry of the test block and the progression of the fire parallel to the cut line it is not known whether a cut line of 6 m width would provide any sort of safety zone for firefighters. One would need to examine conditions where a fire burned across a cut line to assess the hazard.

Data sets of peak heat flux as a function of distance were combined from both test plots and fitted with an empirical relationship, shown below.

$$Q_{\max} = \frac{300}{X+1}$$

In this relationship Q_{max} has the units kW/m^2 and distance, X, is expressed in m. The relationship describes the data set well but is should be pointed out that the data set is in fact quite limited and it is not known if the function will hold with other fuel types or environmental conditions.

Introduction

Wildland firefighters necessarily work in an inherently hazardous environment while attempting to prevent the spread of forest fires. While equipped with safety related equipment, boots, hard hats, gloves and fire resistant clothing the paramount concern is the avoidance of situations that would exacerbate an already hazardous situation. This means that firefighters must continuously monitor their surroundings, not only for potential hazards, but also for areas of refuge or “safe zones”. Unfortunately it is very difficult to determine what constitutes a “safe zone” other than an area where the fuels have been previously removed by fire or mechanical means. Training firefighters as to what constitutes a safety zone means that educators must be clear in their own minds as to the meaning and unfortunately at present the concept is not well understood. It is the purpose of the present study to present heat flux measurements made in the proximity of crown fires to attempt to define the concept of a safety zone.

The International Crown Fire Modeling Experiment presented an opportunity to lay instrumentation to measure spatial variations in energy transfer during the progression of a controlled fire. The experiment also allowed the evaluation of the performance of personal protective equipment such as fire resistant coveralls and fire shelters. It was hoped that a visual examination of the condition of personal protective equipment placed in proximity to the fire could be correlated with energy transfer measurements and aid in the definition of safety zones.

Experimental Site

The International Crown Fire Modeling Experiment site is located approximately 50 km north of the town of Fort Providence in the Northwest Territories. Various governmental agencies have cooperated in the formation of the site which consists of a number of fuel blocks separated by 50 m wide fire breaks as depicted in Figure 1. The activities in June 1998 concentrated on plots 7 and 8 in the northwest corner of the site.

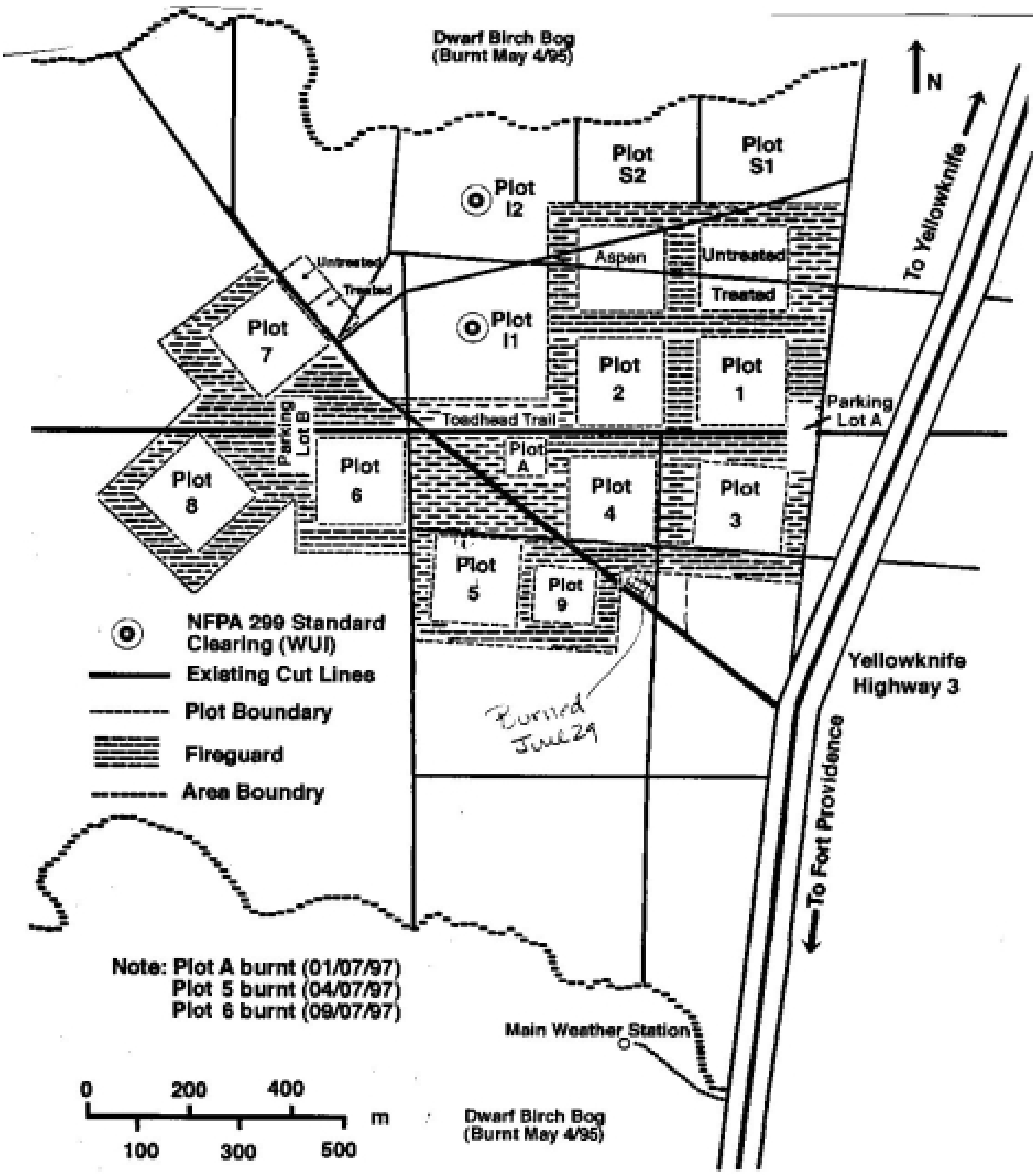


Figure 1. Site Map for International Crown Fire Modeling Experiment

Instrumentation

The sensors used to measure incident heat flux are made from a material with thermal properties similar to human skin with a temperature sensor (usually a thermocouple) bonded to the surface. The determination of energy transfer to the surface is made by recording the surface temperature history of the sensor. By knowing the properties of the sensor, thermal conductivity, heat capacity and density, the sensor can be modeled as a semi-infinite solid for limited time periods. If the sensor is insulated from the surroundings on all sides but the front face (exposed to the incident heat flux) the sensor is usable until the initial temperature wave caused by the incident heat flux reaches the back side of the sensor. At this time the sensor can no longer be considered a semi-infinite solid and the solution for surface temperature and heat flux no longer is applicable. The sensors used in the present study were made from a material known as Colerceran with a type T (copper- constantan) thermocouple bonded to the surface with high temperature cyanoacrylate adhesive. The sensors were individually calibrated using a high intensity lamp and any that did not fall within 10% of the mean calibration were discarded. This calibration method allowed a single calibration constant to be used with all sensors while still maintaining a measurement accuracy of approximately 10%. Five sensors were installed in the faces of a sheet metal cube and the sensor leads run to a custom made data logger which could be buried near the sensor package. The surface temperature on each sensor was recorded once per second and the logger had sufficient memory to operate continuously for about 12 hours. After each fire the information contained in the data logger was down loaded to a laptop computer for later analysis.

Experimental Results

The following sections detail the experimental results obtained during the three weeks spent in Fort Providence.

4.1 Plot #8 - July 4, 1998

Plot 8 was a large (300 m by 300 m) area located on the western side of the experimental site. Plot 8 was the first full sized plot burned during the 1998 season. Because of the orientation of the plot it was suitable for burning with a south-east wind. Since the winds were favorable and the fuels were sufficiently dry the site was instrumented as indicated in Figure 2, which shows in detail, the location of fire resistant coveralls, fire shelters and instrument packages. As indicated in Figure 2, three rows of coveralls were placed in a standing position over steel tube frames at distances of 3 m, 8 m and 13 m from the edge of the block. The first two rows consisted of Proban™[4], non-FR Cotton, and Nomex™ coveralls while the third row had only Nomex™ and non-FR Cotton. Sensor packages were placed within each row as well as at distances of 18, 23 and 28 m. Thermocouples were placed on the front and back surfaces of the Nomex™ coveralls in the first two rows and on the front of the coverall in the third row to get some indication of the temperatures of the exposed material. Four standard aluminum fire shelters were placed as shown in Figure 2 with the closest shelter foot end approximately 3 m from the edge of the block. The remaining three were staggered and spaced so that the foot end of one was at the head end of the previous shelter. The fire shelters were placed in a staggered formation so that they would not be sheltered from the effects of the fire by closer shelters. A

[4] Nomex is a trademark of DuPont Corporation and Proban is a trademark of Westex Fabrics.

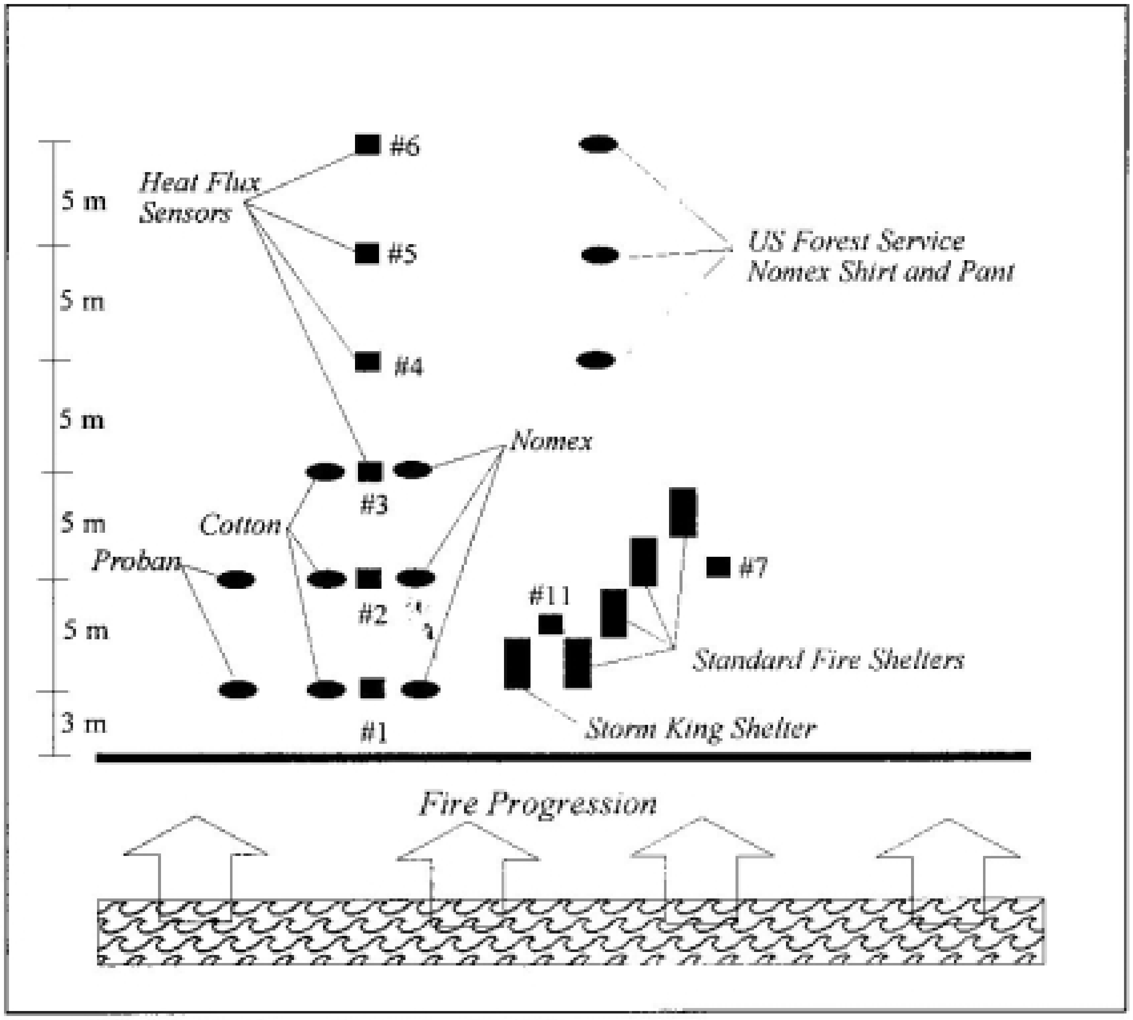


Figure 2 Detailed Equipment Layout on Plot #8

fifth shelter, manufactured by Storm King Technologies, was placed at a distance of 3 m from the block; essentially the same distance as the closest aluminum shelter. A sensor package (#7) was placed with the grouping, approximately 8 m from the edge of the block. Figure 3 shows the flames emerging from the block at the location of the experimental setup and Figure 4 is a photograph looking along the block edge after the fire. Note that the first row of coveralls is no longer there and that the first two aluminum fire shelters were visibly damaged. The foot end of the shelter 3 m from the block was destroyed while the shelter at 5 m showed localized damage but remained largely intact.

Figure 3 Flames Emerging on Down Wind Edge of Plot 8, July 4, 1998

Figure 4 Post Burn Photograph of Equipment Setup

4.1.1 Coverall Temperatures

As was stated previously, the first three rows of coveralls were instrumented to measure fabric temperature during the fire. Thermocouples were placed at chest height on the front (facing the fire) and back sides (away from the fire) of the coveralls. Figure 5 shows the temperatures measured during the exposure. Measurements on the first coverall showed that the temperatures on the front side reached more than 800°C while the back side reached about 700°C. Since the aramid fiber used in Nomex™ coveralls pyrolizes at less than 400°C it is not surprising that all the coveralls placed a 3 m from the fuel were destroyed. At a distance of 8 m from the edge of the block temperatures on the coverall peaked at nearly 200°C and at a distance of 13 m the peak temperature recorded was more than 200°C. It is not known if the high temperatures observed at 13 m were a result of exposure to the hot products of combustion or radiation from the fire.

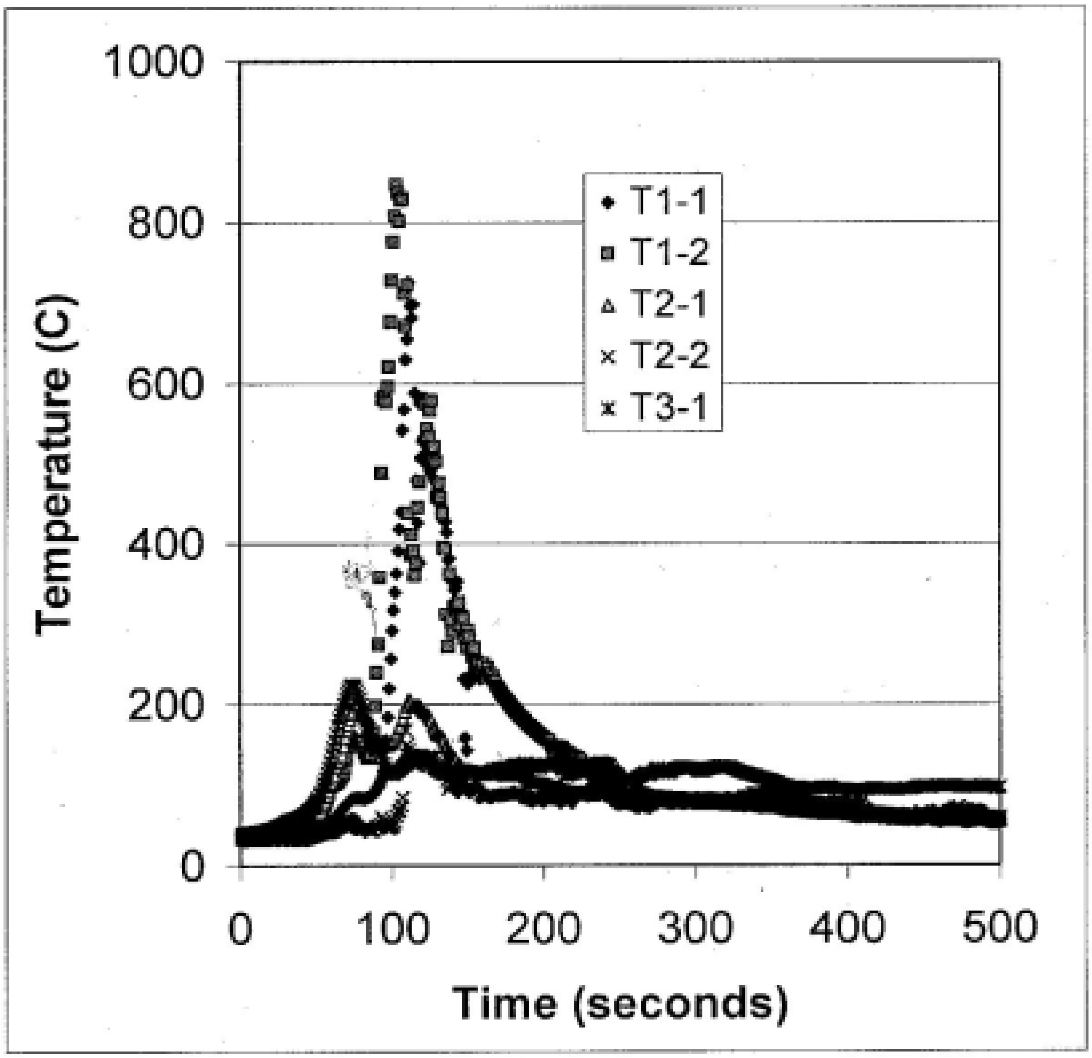


Figure 5 Coverall Temperatures Measured During Exposure to Fire, July 4, 1998

4.1.2 Measured Heat Fluxes

The results from sensor packages placed at 3, 5, 8, 13, 18 and 23 m from the edge of the block were analyzed and a typical result is shown in Figure 6. Figure 6 shows that the package placed closest to the fuels received peak exposures of more than 100 kW/m^2 on the upper face and more than 80 kW/m^2 on the side facing away from the fire. The fact that all faces of the sensor indicated such high fluxes would indicated that it was engulfed in the hot combustion products produced by the fire.

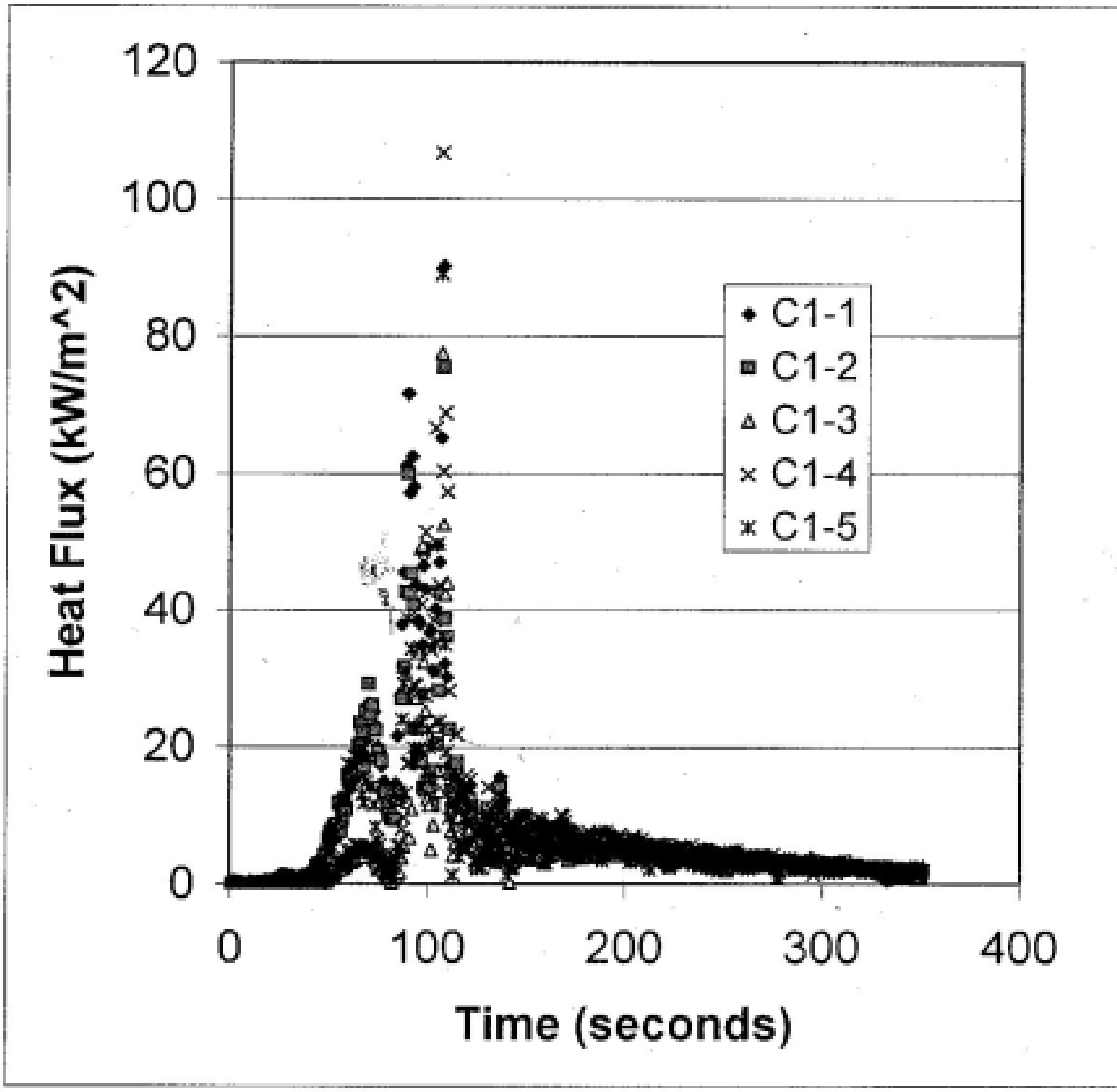


Figure 6 Heat Flux Measured at 3 m from the edge of Plot 8, July 5, 1998.

Measurements made at distances further away from the block showed a decline in peak values as indicated in Table 1. Note that the values in the table represent the peak reading from the sensor facing Plot 8. There is an apparent discrepancy shown in Table 1 where a second sensor package placed 8 m from the plot indicated a peak heat flux nearly a factor of 4 higher than a second placed at the same distance from the fuels. This apparent discrepancy illustrates the problem associated with a single measurement location: while a measurement may be obtained there is no way to determine if that measurement is representative. The only means of determining the range of expected exposures is to extensively instrument the test site spatially or to repeat the experiment many times on many test plots.

Table 1 - Measured Peak Heat Fluxes

Distance From Edge of Block (m)	Measured Peak Heat Flux (kW/m^2)
3	90
8	32
13	22
18	18
23	16
28	12
8	135

4.1.3 Fire Shelter Performance

None of the standard aluminum fire shelters was instrumented other than to measure heat flux in the vicinity. Figure 7 shows how the standard shelters fared when exposed to the fire. As indicated, the shelter closest to the fire was destroyed, the second was visibly damaged and the remaining two standard shelters were apparently unharmed. This would seem to indicate that a deployment at a distance of 8 m from the fuels would allow the shelter to survive even if the peak heat flux were in excess of 100 kW/m^2 for one or two seconds and was largely radiative in nature.

Figure 7 Post Burn Photograph of Fire Shelters Deployed on the Down Wind Edge of Plot 8

The Storm King Mountain shelter was instrumented to measure temperatures inside and outside at the foot end as well as air temperatures at 50 mm and 300 mm above the ground. In addition a skin simulant sensor was placed in an insulating block and laid on the ground in the shelter so that the sensing face Alooked@ up. As indicated in Figure 8, temperatures measured near the surface of the fabric reached maximums of more than 450^{o}C outside and 200^{o}C inside. Air temperatures peaked at about 100^{o}C at 2" and 150^{o}C at 12" above the floor of the tent. Measured heat fluxes were low at less than 1kW/m^2 at the floor level of the tent. If the entire interior of the shelter were at 200^{o}C and the ground at 35^{o}C the expected radiant energy transfer would be approximately 2kW/m^2. Since the interior surface temperature was measured at the end of the shelter facing the fire it is likely that most of the interior surface of the shelter was at a temperature less than 200^{o}C and hence the radiant energy transfer to the floor would be something less than 2kW/m^2 as indicated by the simulant measurements. Whether the conditions within the shelter would be survivable is unknown but would largely depend on the duration of the exposure.

The literature [Webb, 1959] suggests that one would experience discomfort breathing through the nose at about 100^{o}C and through the mouth at about 135^{o}C. Figure 9, taken from Webb=s paper shows that temperatures in excess of 100^{o}C are tolerable for several minutes and since the time scales for the exposure was of the same order (approximately 5 minutes) it is unlikely that high temperatures would result in the demise of the occupant. It is not known at this time if other conditions within the shelter (smoke, O_2, CO, or hydrocarbons) would have made staying within impossible as these measurements were not made.

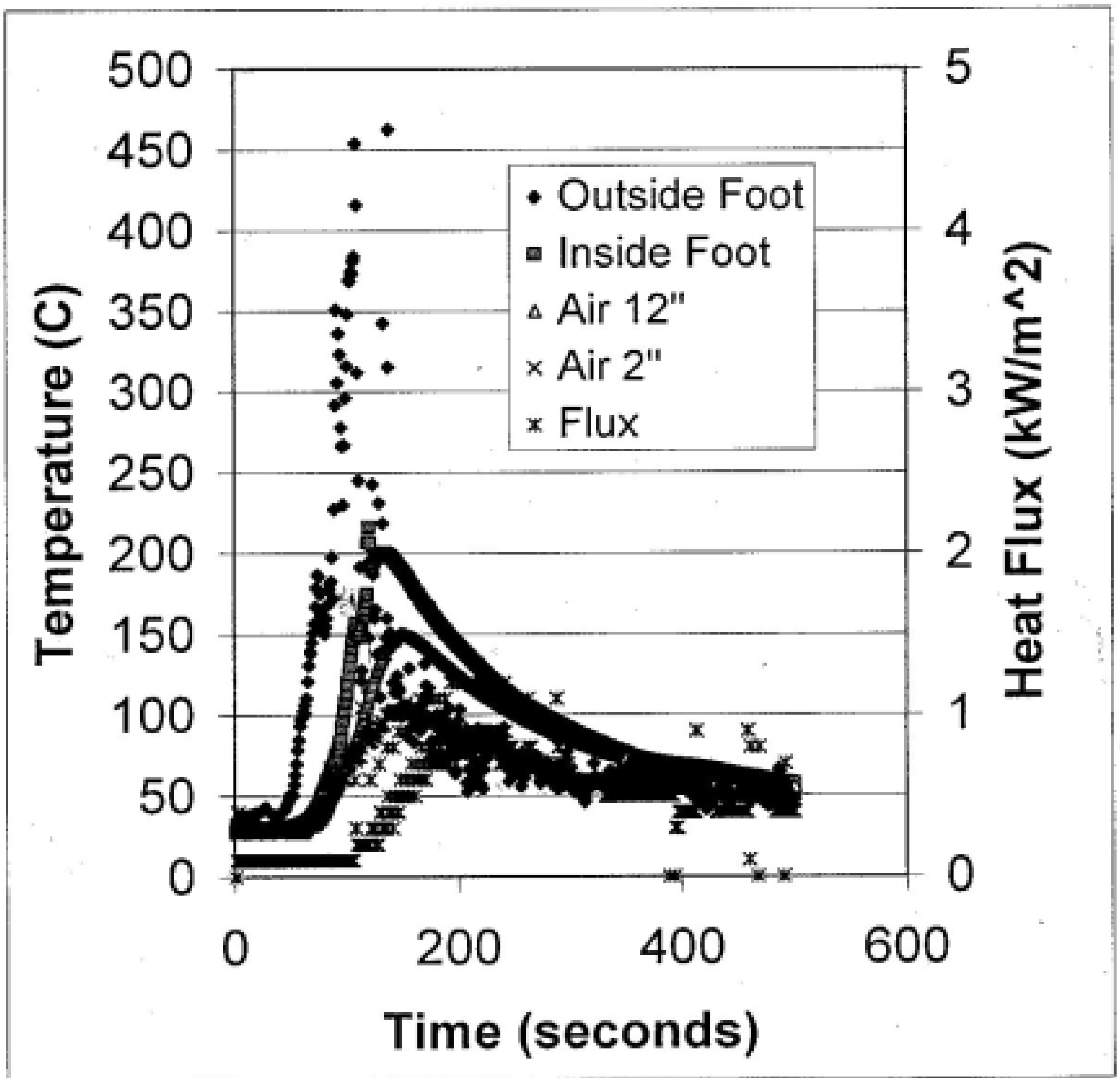


Figure 8 Measured Temperatures in and around a Storm King Mountain Shelter During the Burning of Plot 8, July 4, 1998

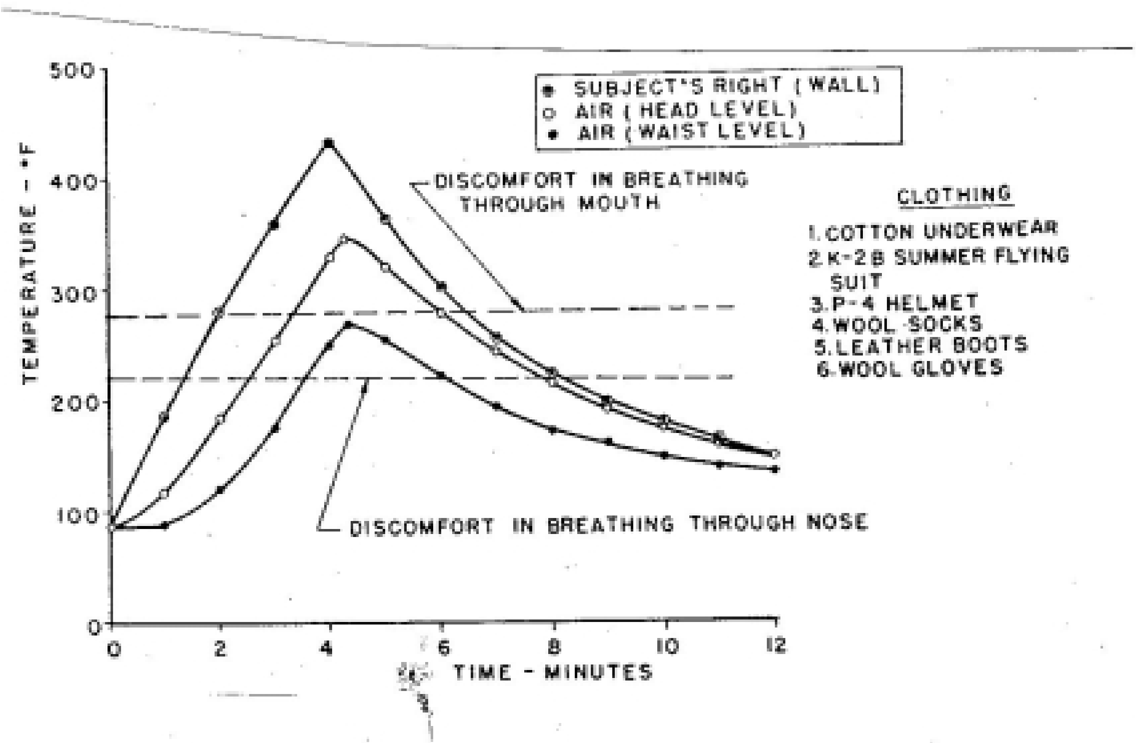


Figure 9 Human Tolerance to Slow Heat Pulses (Webb, 1959)**4.2 Plot #7 - July 5, 1998**

Plot 7 was the second full sized plot burned during the 1998 season. As with Plot 8, Plot 7 was on the north-west corner of the site and because of its orientation was suitable for burning with either a north-west wind or a south-east wind. Unlike Plot 8, Plot 7 was adjoined by an unburned block separated only by a 6-7 m wide cut line. This presented a good opportunity to examine the conditions within a cut line or seismic line during a fire. For this reason the plot was instrumented at two separate locations as indicated in Figures 10 and 11.

On the down-wind edge of the block coveralls were again suspended on steel frames at distances of 5, 10 and 15 m from the edge. As more closely positioned coveralls were destroyed in the previous fire it was felt that little would be learned by placing clothing closer than 5 m. The first row of coveralls consisted of Nomex™, Proban™ and a Natural Resources Standard coverall of unknown material. The second row again consisted of Nomex™ and Proban™ but in this case the third coverall was a Forest Service Forester. The third row of coveralls had only Nomex™ and Proban™. Sensor packages (#1-#4) were placed as shown, in line with each row of coveralls. Two standard shelters were deployed, one with the foot end 3 m from the edge of the fuels and the second with the foot end aligned with the head of the first. A single sensor package (#5) was placed at the foot end of the shelter farthest from the fuels. Fire shelters and sensor packages were placed within the cut line as indicated in Figure 11. Four shelters, three standard aluminum and one Storm King fabric, were placed in the approximate center of the 6 m wide cut line with the foot end of each approximately 2 m from the fuels. Three sensor packages (#6, #7 and #8) were placed as shown. After ignition the fire jumped into the crowns of the trees and proceeded rapidly down the block.

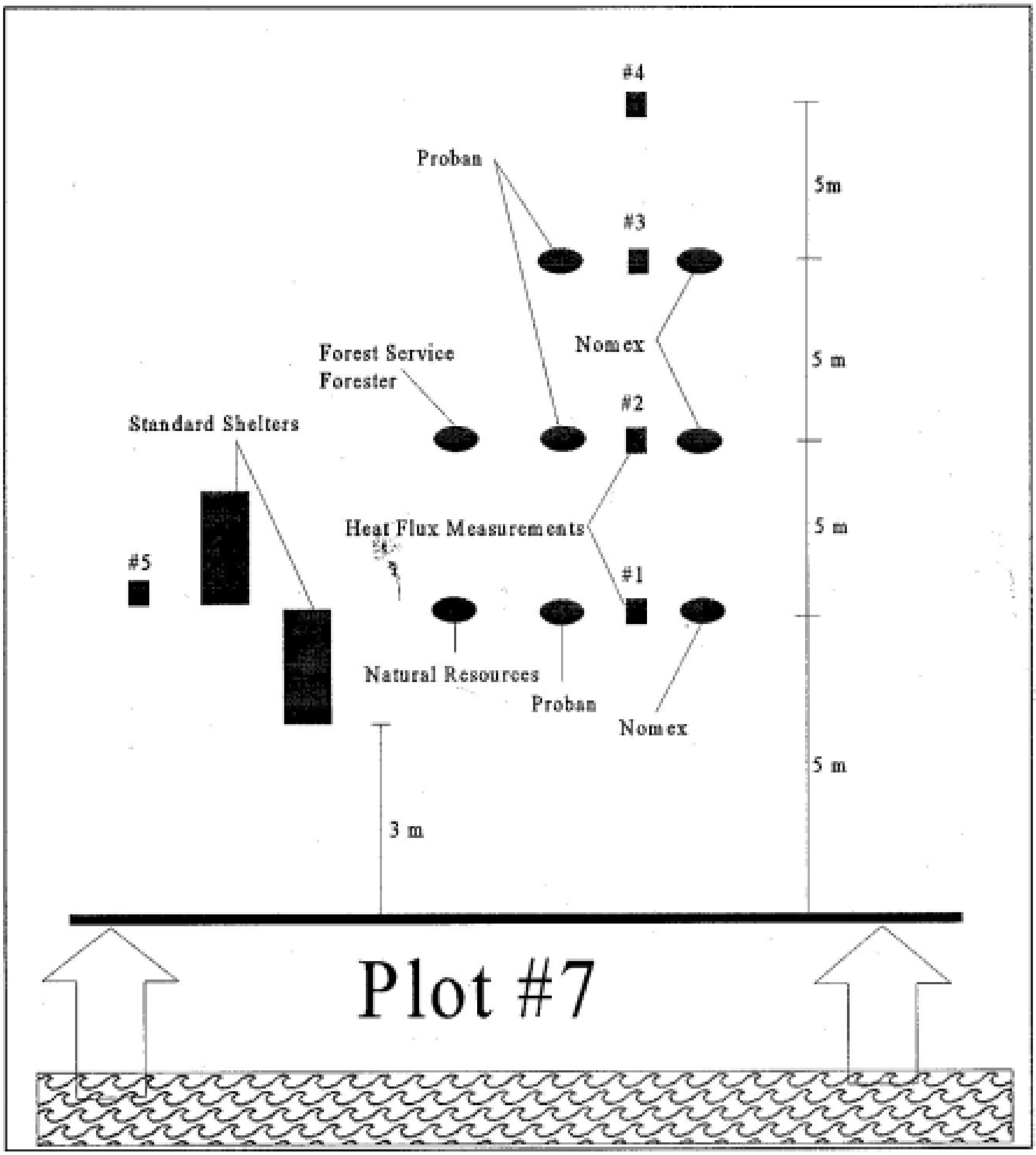


Figure 10 Equipment Deployed on the Leeward Side of Plot 7, July 5, 1998

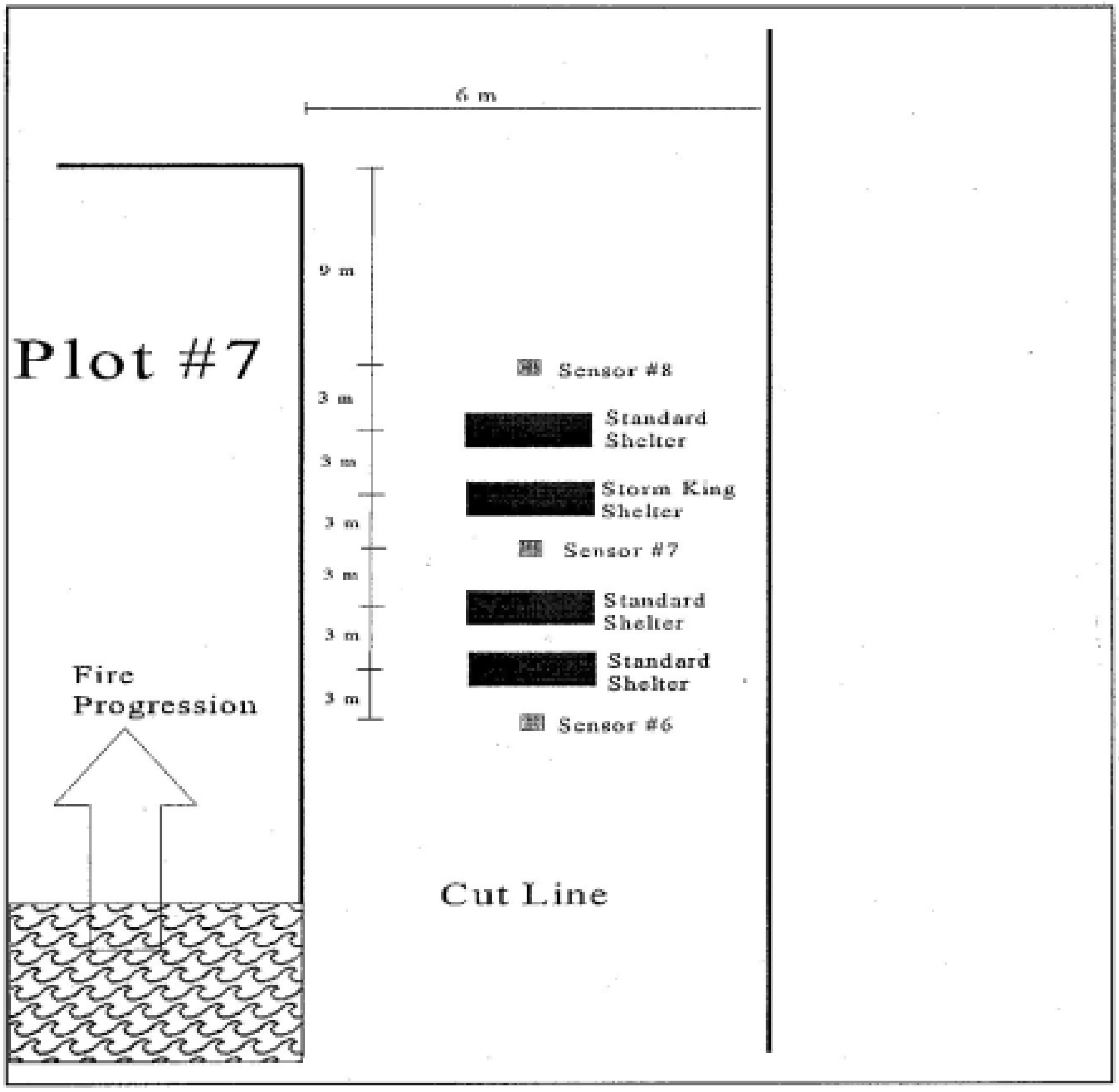


Figure 11 Equipment Deployed on a Cut Line Adjoining Plot 7, July 5, 1998

Because of the positioning of the block with respect to down wind fuels it was not possible to observe, in person, either the emergence on the down wind side or the progression within the cut line. Cameras placed in insulated cases showed that the emergence of the fire on the down wind edge was not as vigorous as it had been on Plot 8 and that the fire never really emerged on the cut line but ran more or less parallel to the line. As a result there was little damage to any of the equipment with the exception that within the first row of coveralls (5 m from the fuel) the Natural Resources coverall and the Proban™ coverall were destroyed. The Nomex™ coverall in the same row showed some discoloration on the side facing the fire but was largely undamaged. No damage to any of the standard aluminum fire shelters deployed on either the down wind edge or the cut line was observed. Some discoloration of the Storm King shelter deployed in the cut line was observed.

4.2.1 Measured Heat Fluxes

4.2.1.1 Leeward Edge Measurements

Sensor packages 1 through 4 were placed at distances of 5, 10 , 15 and 20 m from the edge of the plot. Figure 12 again shows a sample of measurements obtained using the sensor packages. Each sensor package was placed so that simulant #1 was facing the plot and simulant #3 was facing away from the plot. As such, simulant #1 in each case would be exposed to combined radiant and convective heat transfer while simulant #3 would only experience convective heat transfer as it could not Asee@ the fire. As shown in Figure 12 heat fluxes peaked at less than 35 kW/m^2 at a distance of 5 m from the fuels. This is approximately the same level that was measured at a distance of 8 m from the fuels during the burning of Plot #8.

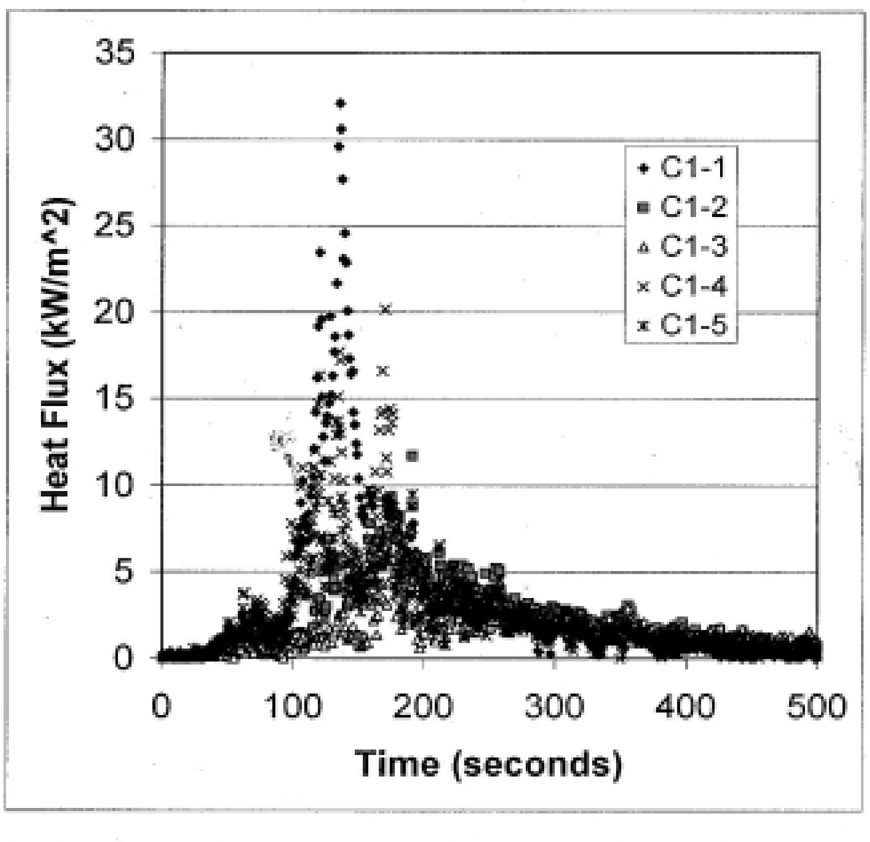


Figure 12 Measured Heat Fluxes on the Lee Side of Plot 7, Location 5 m from the edge of Plot 7, July 5, 1998

Energy transfer rates measured on the side facing away from the fire peaked at about 7 kW/m^2.
As summarized in Table 2 the peak energy transfer rates dropped rapidly with distance, falling to less than 10 kW/m^2 at a distance of 20 m.

Table 2 Measured Peak Heat Fluxes - Plot #7

Distance from Block Edge (m)	Peak Heat Flux (kW/m^2)
5	32
10	17
15	13
20	9
5	39

4.2.1.2 Cut Line Measurements

Measurements of heat fluxes within the cut line were quite different from those obtained in the lee of Plot 7. Three sensor packages were placed in the cut line with approximately 7 m separating each. As before the packages were place with Simulant #1 facing the direction of the approaching fire. Figure 13 shows the measured heat fluxes at one location in the cut line. Note that in all cases the measurements are quite different than those obtained on the leeward side of the plot. In each case there are two distinct peaks separated in time by about 3 minutes and the peak heat fluxes were 20 kW/m^2 , 9 kW/m^2 and 8kW/m^2 for sensors #6, #7 and #8 respectively. That the peaks were lower for sensors 7 and 8 would indicate that the fire had died down somewhat before reaching that location.

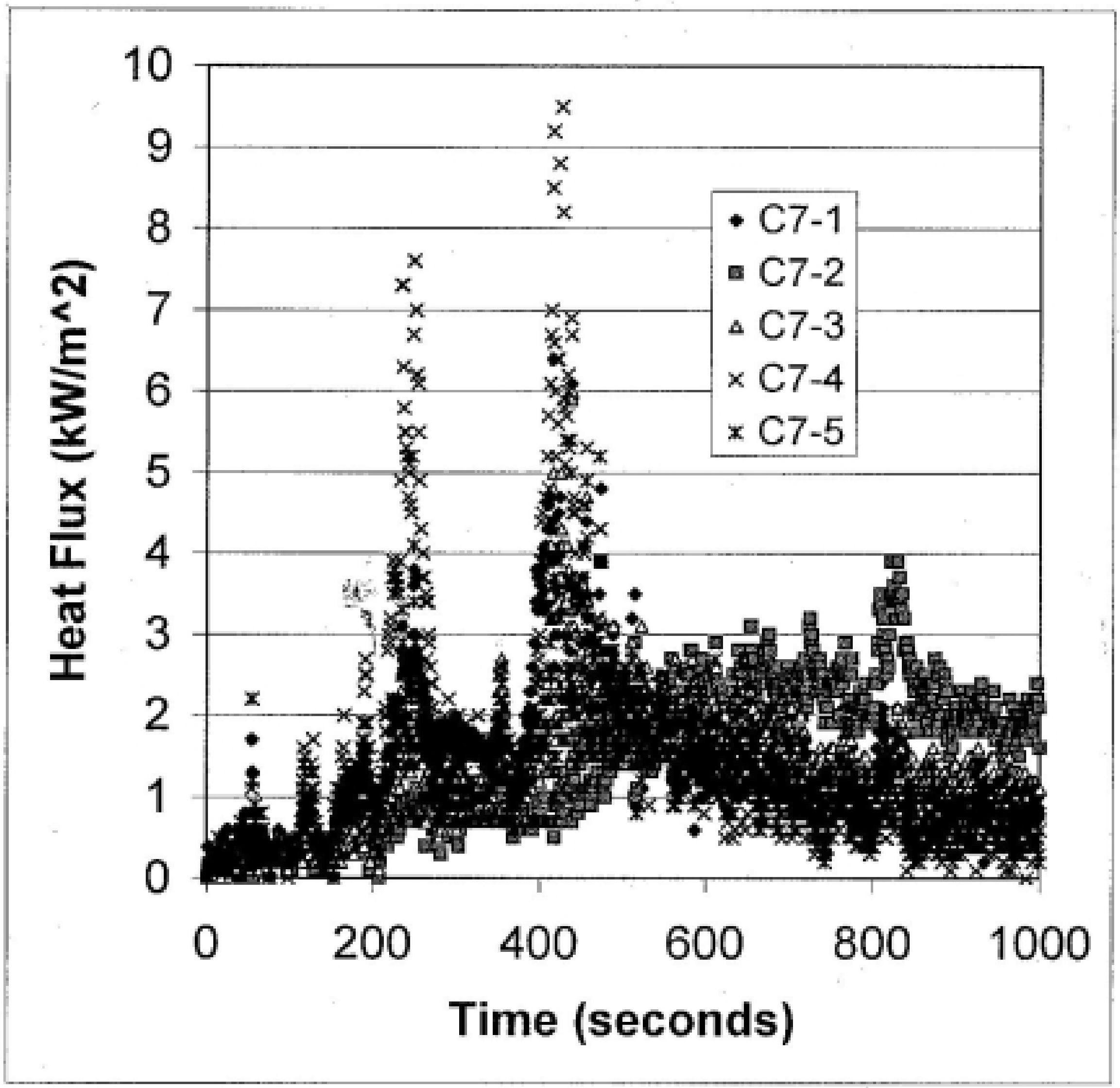


Figure 13 Measured Heat Flux within a Cut Line Adjoining Plot 7, July 5, 1998

4.2.2 Fire Shelter Performance

The two standard fire shelters placed on the lee side of the block were instrumented to measure material temperatures inside and outside at the foot as well as interior air temperature at 50 mm and 300 mm above the ground. In the case of the shelter closest to the fuels the outer surface temperature peaked at just over 200^{o}C. Inner surface temperature at the foot of the shelter rose to approximately 120^{o}C while air temperatures at both the 50 mm and 300 mm level were below 75^{o}C for the duration. Measurements were made at the same locations in the shelter placed about 7 m from the fuels. Outer surface temperature was a little lower, peaking at about 150^{o}C while the inner surface reached almost the same value as the previous case, 120^{o}C. Air temperatures measured at 50 mm and 300 mm were lower, peaking at between 60^{o}C and 70^{o}C. As was stated previously, the literature would indicate that air temperatures below 100^{o}C can be tolerated for periods of several minutes; comparable to the durations measured in these fire studies. Whether smoke, oxygen level or unburned hydrocarbons would make the shelters uninhabitable was not measured during the study.

5.0 Safety Zones

The purpose of the study was to evaluate the thermal conditions in close proximity to fires deliberately set in blocks of mixed spruce and pine to attempt to determine the range of conditions that might reasonably be encountered. To examine the concept of safety zones one must be cognizant of the sources of danger. Thermal exposure can take three forms: energy transfer by either convection, conduction or radiation. Conduction exposure depends on contact with a hot object while convective exposure depends on contact with a hot gas. Radiation exposure is a little more difficult to quantify as it depends on the temperature of the surroundings, the properties of the surfaces and the shape factor between the objects. In this case the Aobjects@ may be a fire or the hot sooty gases within the fire and the human form. Because radiation exchange requires one object to be able to Asee@ the other its calculation can be more difficult. The level of exposure that can be tolerated depends on the duration as well as the protective equipment worn. In laboratory testing it was estimated that when clothed in 6 oz Nomex^{TM} the exposure time to the onset of second degree burns was 3.6 seconds with a radiant exposure of 84 kW/m^2 and a little over 16 seconds at an exposure level of 21 kW/m^2. The measurements made within this study allow the estimation of the total thermal exposure at varying distances from the fuel. In this case the total thermal exposure refers to the total energy transfer to a surface whether it occurs by conduction, convection or radiation. The data sets were examined for maximum and minimum thermal exposures by examining the results from the simulant which faced the fire and the one that faced away from the fire. These results are plotted in Figure 14. The line shown on the figure, equation 1, represents a relationship that closely describes the maximum exposure at any given distance from the edge of the fuels where the fire emerges into a cleared area. In this relationship Q_{max} has the units kW/m^2 and X has units of

$$Q_{\max} = \frac{300}{(X+1)}$$

meters.

Equation 1 has some physical basis if one realizes that the maximum expected energy transfer rates within a forest fire are approximately 300 kW/m^2 with the majority of the flux as a result of hot gases and soot particles at about 1200^{o}C acting as black body radiators.

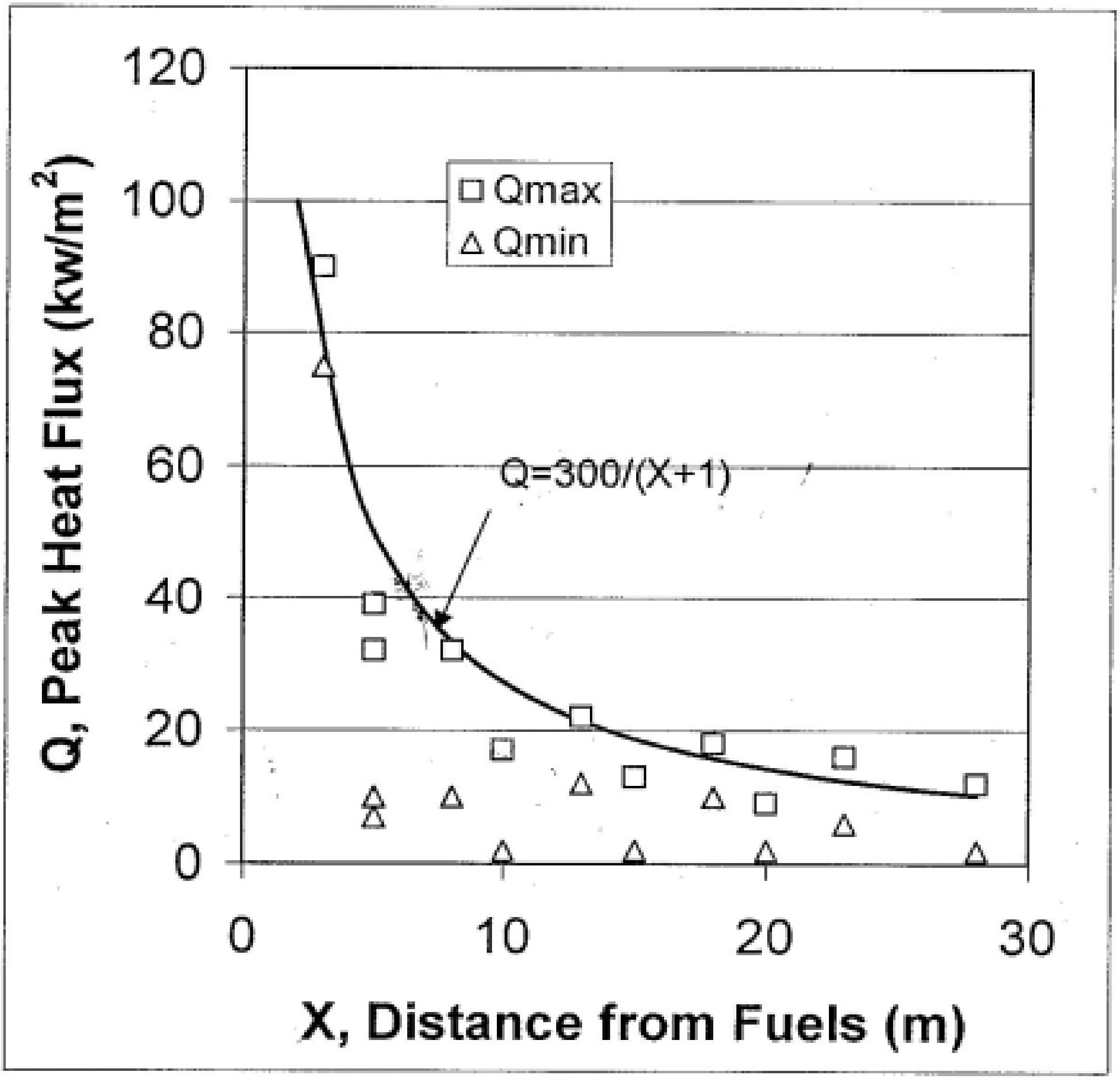


Figure 14 Variation in Total Heat Flux as a Function of Distance from the Edge of the Fuels

The remainder of the energy transfer is a result of convective heat transfer. The one in the denominator of the equation is simply to prevent the relationship from predicting infinite heat flux when X is zero, that is within the fire. What this means to wildland firefighters is that the exposures near the fuels can be extremely high and given the limited protection afforded by FR clothing the time to serious burn injury is mere seconds.

6.0 Further Work

While the study reported here presented the opportunity for measurements within and around two controlled fires there are some limitations that should be addressed prior to attempting to establish guidelines for safety zones for wildland firefighters. The data presented was gathered from two controlled fires and at a limited number of locations within each. While one might hope that the results are indicative of those that would be obtained in Atypical@ fires there is some evidence to suggest that this may not be the case. This comes primarily from the results that showed that heat fluxes could be quite different spatially even through the distances from the fuels were approximately the same. In the present study it was found that measured heat fluxes varied by a factor of 4 at two locations laterally separated by a few meters. It is not know at this time if this is an anomalus result but examination of the data set showed no obvious problem with the raw data. Because of this result it would be desirable to obtain measures of energy transfer at many more locations around controlled fires as well as near other fuel types. This would entail additional sensor packages be set along the edges of plots as well as spatially down wind from the edge of the plot. In this manner one would hope to capture the range of heat fluxes a wildland firefighter could expect to be exposed to.

The second area that was not addressed in the present study deals with the environment inside a fire shelter during a deployment. Limited measurements of temperatures inside shelters deployed near the fuels indicated that the thermal conditions were not severe enough to force an occupant to vacate a shelter if the shelter were deployed more than 5 m from the fuels. No measurements of the air quality inside a shelter were made. It would be desirable to measure oxygen, carbon dioxide, carbon monoxide and hydrocarbons inside a shelter during an exposure to determine if the conditions would be severe enough to force an occupant to vacate in spite of the obvious danger.

The third area that was not completely addressed deals with the size of an opening or cut line that could reasonably be expect to behave in a fashion similar to the down wind edge of the test blocks. Instrumentation placed in a cut line parallel to the fire movement indicated heat fluxes that were quite a bit lower than those measured where the fire emerged. It would be extremely valuable to be able to instrument a cut line where the fire would have to cross to continue its down wind progression rather than running parallel. This would give some indication as to whether a cut line or seismic line would afford a firefighter any additional safety margin. It may be that typical cut lines are simply too small to afford any protection relative to a deployment within the fuels but at this point in time the answer is not known.

7.0 References

1. Webb, Paul, AHuman Thermal Tolerance and Thermal Protective Clothing@, Annals of the New York Academy of Science, Volume 82, Art. 3, pp 714-723, 1959.

2. Ackerman, M.Y., AInternational Crown Fire Modeling Experiment 1998 - Safety Zones for Wildland Firefighters@, Final Report to Alberta Environmental Protection, February 1999.

Toward a Healthier and Safer Wildland Firefighter Workforce

Richard J. Mangan
U.S. Forest Service
Missoula Technology & Development Center
Missoula, Montana USA

Wildland fire fighting activities take place in a high-risk environment. The firefighters involved in these activities are often at risk, both in the short term and the long term, from illnesses, injuries, and sometimes infrequently even death, in the process of performing their jobs. In the United States, 133 individuals died in activities associated with wildfire suppression during the period from 1990 – 1998. Australia has also experienced numerous fire related fatalities during the same period, and other firefighters around the world have died in Greece, Mongolia, Russia and South Africa.

This paper will discuss those factors that are critical to both firefighters and fire managers to insure a safe and productive workforce. First, we will discuss such items as the work environment, the firefighter workforce, physical fitness, nutrition, work/rest cycles, lifestyle choices and job requirements. In addition, we'll review firefighter illnesses, injuries and fatalities, with the purpose of identifying mitigation measures that can be implemented to reduce and/or eliminate the risks from the fire environment. The mitigation measures suggested are applicable to both the volunteer and full-time firefighter workforce.

The Work Environment

A wide variety of environmental conditions exist in the world of wildfire suppression: from the Arctic tundra to the Florida Everglades; from the Eucalypt forest of Australia to the chaparral fields of southern California; and from the Pine forest of Montana to the Pine barrens in New York and New Jersey, the extent of ecosystems that experience fires is truly world-wide. There are numerous factors compounding the already stressful work of suppressing fires: elevations that range from sea level to over 2000 meters; steep, uneven ground; high ambient air temperatures that often exceed 35C; and above average levels of smoke and dust. All these conditions have the potential to affect the on-the-ground performance of the bushfire fighter, and may ultimately result in illness, injury or even death. These factors, especially for individuals not acclimated to them, can have a cumulative effect on a firefighter's ability to resist these exposures and risks.

The Firefighter Workforce

The individuals that participate in wildland fire fighting operations are a varied as the fuel and terrain types that they fight fire in: females and males of all racial backgrounds, at least 18 years old, but often into their 60's and 70's, weighing less than 50 kilos, but sometimes more than 100, and less than 5 feet tall to more than 6.5 feet. The fire fighters are truly a cross-section of the population that they serve. While some fire agencies have physical fitness requirements (especially among the career departments), firefighters often come to the fire environment with the same physical conditions as the general population: allergies to smoke and dust; trick knees; sometimes overweight and out of shape; and with other untold pre-existing conditions that may surface on the fireline.

The Firefighting Job

Besides the environmental and human factors already described, the other critical factor that contributes to the illnesses, injuries and deaths that affect wildland firefighters is the actual job itself. Long hours of arduous work under difficult physical conditions, coupled with reduced sleep and dietary changes, plus working closely with a new group of individuals in a less than hygienic setting, with the potential for exposure to previously unseen infections in a period of reduced immunity: all these are prime conditions for illness and/or injury to strike the firefighter, especially on multi-day fire assignments.

Demands of the Job

Fighting wildfires has unique physical fitness requirements unlike most other jobs in the civilian workforce: both lower and upper body strength are needed to complete the necessary tasks, and endurance is essential to work the extended periods of time required to control the unwanted fires. In addition, there is always the unexpected action of responding to a flare up on the control line, or even worse, the need to make a rapid retreat when a fire threatens the firefighter's personal safety, especially after long hours on the line. Studies at the University of Montana Human Performance Laboratory have shown that aerobic fitness, as measured in max VO2, is the primary limiting factor in the firefighter's ability to sustain hard work throughout the long work shifts.

Like athletes, serious firefighters realize that physical activity and training are a year-round commitment if they are to successfully meet the demands of the job. This is often difficult to achieve, especially in a workforce that has many other conflicting demands on their available time.

Individual Factors in Firefighting Health and Safety

There are a number of factors that affect the ability of an individual to perform wildfire suppression activities in a safe and efficient manner: some are beyond the individual's ability to influence, but many are well within the individual's total control. Those factors that are inherited, or those controlled by the environment (heat, humidity, elevation), are interesting to contemplate, but are beyond the scope of our ability to affect in the context of bush firefighting.

There are, however, a number of items that the individual firefighter, whether volunteer or full-timer, can affect through their own actions and attitudes. While physical height is a genetically inherited factor, an individual has a range of options regarding their lean body weight, physical fitness level, and muscular endurance. These factors are a direct result of the firefighter's choices regarding nutritional choices, exercise regimes, and motivation to prepare themselves for the job at hand.

While these factors are generally considered as long-term in nature, there are other factors that tend to be affected more by short-term actions: acclimatization for both heat and elevation can be changed within a relatively short time frame. As temperatures heat up during the early stages of a fire season, firefighters should begin moderate levels of outside activity to prepare themselves for the inevitable fires that will require extended physical activity. Similarly, higher levels of hydration and nutrient supplements will be necessary during prolonged periods of strenuous activity during periods of high heat loads, both from the ambient air and from the fires.

Firefighter Illnesses

The illnesses that fire fighters are subjected to are not that unique from those suffered by other large groups of individuals thrown together in a close environment – such as sailors at sea, or teachers and students in a classroom – for extended periods of time. The introduction of endemic levels of infection and disease in any one individual has the potential to cause visible signs of illness among other individuals who have not had previous exposure, and the opportunity to develop an immune response. In addition to bringing a large group of individuals together, wildfires also complicate the equation by requiring long hours of hard work, coupled with a change in diet and sleep patterns. These factors, and the exposure to smoke and dust, result in a variety of illnesses among, especially as the duration of a fire assignment progresses beyond the first week.

The short-term and long-term exposure to high levels of environmental smoke from wildfires was most apparent in the 1987 and 1988 fire seasons: in those years, long duration smoke inversions plagued not only the immediate fire area, buy also impacted the incident base camps and surrounding communities for days on end. For firefighters spending multiple 21 day assignments under those conditions, the incidence of upper respiratory tract infections was wide spread, and lasted for periods as long as 3-4 months after the fire operations were over. As a result, the Health Hazards of Smoke project sponsored by the National Wildfire Coordinating Group (NWCG) was undertaken at the Missoula Technology and Development Center (MTDC). The six-year project culminated in 1997 with a Consensus Conference in Missoula, Montana that summarized the research findings, and developed mitigation measures for on-the-ground fire operations to reduce exposure to smoke.

The long duration fire season in Northern Idaho and Western Montana in 1994 offered another opportunity to look at the incidence of illness among firefighters on large fire incidents managed by fire overhead teams. An informal review of medical records conducted by Mark Vore from the Idaho Panhandle National Forest showed that nearly 40% of the visits to the Incident Medical Units were documented as respiratory problems. These findings are consistent with the problems that surfaced in 1987 – 1988, and have the potential for future occurrences as well, given the mountainous terrain and inversion potential that exist on many large wildfires and prescribed burns in the western U.S.

Another illness issue that appears to be on an upward trend on wildfire operations in the incidence of heat stress injuries. Under conditions of both high ambient air temperatures and high radiant heat flux, the firefighter can easily become dehydrated and a heat stress casualty if positive preventative measures are not implemented as a normal way of doing business on a daily basis. A recently completed Australian study on work productivity among bushfire fighters indicated that the personal protective clothing was a key factor in reducing heat stress. Project “Aquarius” noted that 2/3 of the firefighter’s heat load was generated internally, with only 1/3 coming from the radiant heat of the fire. They recommended that the design of protective clothing should be to “let heat out, not keep heat out.” Additionally, they recommend that wildland firefighters consider the need to consume as much as one liter of fluids per hour under high temperature and heavy workload conditions. The logistics of supporting this level of fluid replacement during a 12-hour operational period can be challenging, but is certainly essential to prevent heat stress illness. Dehydration and heat stress illness can be the result of a progressive deterioration that occurs over several days of reduced fluid intake, and can be compounded by other factors such as other illnesses or medications being taken be the individual.

Fire managers and crew leaders should take positive actions to minimize working firefighters to the point of exhaustion, or exposing them to excessive levels of smoke. Additional actions that can help reduce firefighter illness include reducing both physical and emotional stress; enhancing rest and recuperation periods, with a target of a 2-to-1 work/rest cycle (16 hours work/8 hours rest); and, providing adequate energy and nutrients to meet the special requirements of the arduous fire job. Firefighters each have an individual responsibility to insure their own ability to perform the job by getting and staying in good physical condition; making correct nutritional choices to sustain them on multi-hour and multi-day fire assignments; and making healthy lifestyle choices (such as not smoking) that will help them remain on the job during periods of reduced immunity to illnesses.

A recent paper by Dr Steve Woods from Abbott Laboratories identified “immune friendly nutrients” that enhance the function of the human immune system. They include Vitamins C and E, which both stimulate and enhance immune response; Beta carotene, which stimulates natural killer cells; Vitamin B6, which promotes white-cell proliferation; selenium, promoting anti-bacterial activity; and zinc, which promotes wound healing. All these nutrients can be helpful in reducing the risk of firefighter illness in the bushfire environment.

Firefighter Injuries

In difficult terrain, under conditions of long hours and arduous work, injuries are one of the major perils that wildland firefighters are subject to. Although no documented records exist showing trends of firefighter injuries, on-the-ground observations by experienced personnel shows several major areas where injuries occur:

* Vehicle accidents	* tool use
* Slips/trips/falls	* muscle strains

By inference, several of these injury areas can be related back to the casual factors of fitness levels and fatigue. As an individual fire firefighter becomes more fatigued from the long hours and arduous work, they become less attentive to the small things that prevent injuries under different circumstances: walking on steep slopes, over logs, down cut slopes; clearing obstacles and using full muscle control when swinging hand tools; failing to use proper lifting techniques for heavy objects; and not keeping full attention on driving techniques on windy, steep, unsurfaced roads.

Although these accidents are not well documented to show their rate of occurrence on fire operations, experienced personnel are well aware of these risks. Better documentation will more clearly define the problems, and lead to mitigation practices for their ultimate reduction. The MTDC publication “Fitness and Work Capacity” documents many of the conditioning techniques that can reduce firefighter fatigue by increasing work stamina.

Fitness and Injury

A number of recent studies have documented the relationship between fitness levels and injury rates. In the U.S. Army, a study of 861 female and male trainees indicated that the fittest soldiers (measured by their pushups, setups and 2 mile runs) experienced the lowest injury rates. Another study showed that the most fit individuals, as indicated by running speed, experienced the least injuries in sports training. Finally, a 1999 Australian Army study of their recruits a negative relationship between fitness and injuries. The implications of these studies to the firefighter ranks are obvious, especially in such a physically demanding activity.

Firefighter Fatalities

The first half of the 1990’s decade saw two major wildfire fatality events that riveted the attention of the Nation in the U.S.: the Dude Fire in 1990 killed six (6) firefighters, and fourteen (14) firefighters died on the South Canyon Fire in 1994. Although these tragic events were horrific reminders of the risks inherent with wildfire suppression activities, they were on a portion of the total deaths that occurred in the 1990 – 1998 period. In those years, 133 fire fighters and others involved in wildfire operations died from a variety of causes. A recent MTDC Technical Report documents those causes, including aircraft accidents (30 deaths), heart attacks (28 fatalities) and vehicle accidents (25 deaths). Numerous opportunities exist to reduce firefighter fatalities off the immediate fire ground, through many of the same actions that will reduce illness and injuries. Reduction of deaths from heart attacks offers the best opportunity to reduce a sizeable number of deaths, but will require a major life style change to accomplish in many firefighters.

In the progression of events, it could be surmised that fatalities on wildland fire operation are, in many cases, the logical extension of early failures to address issues of illness and injuries that manifest themselves throughout the fire season. It is imperative that we break the chain if we are to ultimately reduce firefighter fatalities.

Toward a Safer and Healthier Firefighter Workforce

The safety and health of the bushfire-fighting workforce is critically important to the firefighters and their families, the fire management organization, and the community being served. There are numerous opportunities, both short-term and long-term, to improve the health and safety of the bushfire workforce for both volunteer and career firefighters:

- First and foremost, individual firefighters must take positive and affirmative actions to insure their own health and safety. This includes maintaining an appropriate height/weight ratio, participating in an exercise program, and minimizing high risk activities that threaten good health;
- Fire agencies have a major obligation and responsibility to provide the environment for their firefighters that fosters a safe and healthy workforce. This can include health screening programs, exercise facilities, and in some cases, work capacity testing;
- Provide specialized training in high risk activities, such as emergency vehicle operation, and create a culture that does not condone or tolerate unsafe work practices, even on a bushfire emergency;
- On multi-day bushfire operations, insure that fluid and nutritional needs are met, and that work/rest cycles are managed to prevent unnecessary fatigue among both firefighters and fire managers.
- Develop, maintain and monitor an "Illness and Injury" database, preferably at the National level, to identify health and safety trends occurring among the bushfire community.

References

Budd, Grahame, et.al. 1996. Safe and Productive Bushfire Fighting with Handtools. Australian Govt. Publishing Service, Canberra, ACT, Australia.

Davis, Paul O. 1999. Individual Factors Related to Health, safety and Performance, in Wildland Firefighter Health and Safety: Recommendations of the April 1999 Conference. MTDC, Missoula, MT.

Mangan, Richard J. 1999. Wildland Fire Fatalities in the United States: 1990 – 1998. MTDC, Missoula, MT.

Mangan, Richard J. 1999. Illness, Injuries and Fatalities Among Wildland Firefighters, in Wildland Firefighter Health and safety: Recommendations of the April 1999 Conference. MTDC, Missoula, MT.

Sharkey, Brian, ed. 1997. Health Hazards of Smoke: Recommendations of the April 1997 Consensus Conference. MTDC, Missoula, MT.

Sharkey, Brian. 1997. Fitness and Work Capacity, second edition. MTDC, Missoula.

Sharkey, Brian, ed. 1999. Wildland Firefighter Health and Safety: Recommendations of the April 1999 Conference. MTDC, Missoula, MT.

Management of Safety on the Fireground

Paul Macmichael
Training Services Officer Operations
New South Wales Rural Fire Service – Australia

Abstract. Many have been killed or maimed throughout the world at wildfires and much has been written to improve the safety of our firefighters. In New South Wales - Australia, we in the Rural Fire Service continue to pursue the safe management of our mainly volunteer force by learning from past incidents. The operational management aspects of fireground safety are taken into account as well as equipment design and other issues.

This presentation is an attempt to highlight key management factors that controllers and commanders must take into account to pursue safety in the inherently unsafe wildfire environment.

Many wildfire commanders have experienced a wildfire management situation where chaos seemed to prevail and recognise they could be in a similar situation in the future. How can we assist these commanders to face their next major wildfire with greater confidence to manage safety on the fireground? Operational managers who face serious wildfire only once or twice in a lifetime need support.

As well as the competence of the individual and the team, the effectiveness of the operational management tools and procedures are vital. These tools and procedures must be as simple as possible so they can be understood through all levels of the command structure and to the firefighters on the fireground.

Introduction

For the purpose of this paper, management is described as the effective command and control of resources to combat bushfires.

(Note: in Australia 'bushfire' is the common term for 'wildfire').

In New South Wales (NSW), Australia, many deaths to bush firefighters have occurred on the fireground, so the efficient management of the fireground is vital for fireground safety. Most of the total combat effort must be directed at supporting the firefighters in their endeavour on the fireground.

> "Fighting bushfires more than any human experience resembles the fighting of a pitched battle".
>
> **C.E.W Bean**

C.E.W. Bean, an Australian First World War historian said:

After we analyse all the facets of a large threatening bushfire including its combat, this statement is probably true. One difference however is that a bushfire is considered more predictable than the average human enemy.

If we consider that a bushfire might present as large a management task as a 'pitched battle', then we must put as much management effort into the bushfire as should be given to the military battle. Our firefighters deserve the highest level of safety in an inherently unsafe environment. We should not draw too many other comparisons between soldiering and firefighting. Soldiers might expect to die, firefighters must expect to live.

This paper highlights bushfire operational management issues and focuses on a bushfire management sequence used by the NSW Rural Fire Service. My aim is to highlight the complexity of providing competent operational management for the firefighters. I understand that this paper is *a ripple on the surface* and that it will take considerable effort to condense all the present knowledge into a comprehensive set of tools to continue supporting competency development in the volunteer services.

The NSW Scene

In NSW and the rest of Australia there is a large proportion of unpaid volunteer firefighters and fire managers at all command levels. This presents many advantages, with competencies and experience gained in civilian life being directly transferable to firefighting operational management. However it also presents a challenge. We must maintain a unified management system to safely combat bushfire within an environment that includes lack of time for training and large distances to travel.

In NSW there are 2500 Rural Fire Brigades and in excess of 40,000 active firefighters. These brigades are responsible for structural fires and for support at other incidents. The time volunteers have for training must be balanced between all their responsibilities, so time for training and exercising is often limited for bushfires.

Some Safety Considerations

Before starting on the main aim of this paper let us review some relevant factors.

Human Factors

One competent commander at a small incident has the luxury of processing all the required data in one processor, his or her brain, to manage the incident. At a large bushfire there can be dozens of personnel making decisions. Computers can be linked effectively. Linking human brains at any time is difficult, during a threatening bushfire it is extremely difficult, especially if time for developing team competence is short. The aim is to develop individual and team competence and to put in place operational management tools and procedures which can be readily understood by all.

> "--- the teamwork which he developed in war was of the highest order of efficiency. Each man understood his part and understood also that the part which the others had to play depended upon the proper performance of his own"
>
> *Lt. General, Sir John Monash. Commander 1st Australian Corp 1918-19*

Knowledge

It is of course impossible for all personnel in a large volunteer force to achieve competence in all facets of bushfire management. The emphasis must be on making sure that the required knowledge is available within the appropriate levels of the operational management structure or within teams. The development of team competence needs to be given as high a priority as individual competence. Modern tools such as training on the 'web' will reduce the time required for face to face sessions. Dynamic experiential learning, followed by operational exercising, is required to lock key knowledge and skills into the long term memory. However we need to balance these training needs with volunteers available time.

Personal Protection Equipment

Firefighters must be provided with effective clothing and accessories. The problem is to balance the requirement between gear for bushfire and structural fires. For bushfires the requirements in order of priority are radiant heat protection, body ventilation, comfort and economical supply. The best available personal protection equipment will be of little benefit if firefighters are in the wrong place at the wrong time.

Vehicle Design

Firefighters must be provided with safe vehicles and equipment to give them the best chance of survival if they get caught in the wrong place at the wrong time. It is now generally understood that the best designed vehicles will not provide safety during the extreme heat generated at some bushfires. The disposition of resources in regards to safe location under the current fire behavior must have the highest priority.

Research

Developments in bushfire behaviour research will make the fire analysis task more accurate, however the challenge is to make good use of it. Collecting and disseminating all the fire behaviour intelligence in a timely manner is still difficult for a large bushfire. Research into operational management systems for communications, information management, resource tracking and other requirements needs to keep pace with technology. Research into human factors is as important as research into technical aspects of safety on the fireground. Leadership and teamwork training must not be based solely on ancient military doctrine, however military research and practice has much to offer.

Principles

Principles for managing emergency and military operations have been around for centuries and are relevant for the management of safety on the fireground. These principles must always be taken into account during pre-planning and during incident operations planning.

The principles are: *Foresight, Simplicity, Speed, Flexibility, Safety, Sound Administration, Morale, Mobility, Concentration, Economy, Co-Operation, Effective Communications, Span of Control and Management by Objectives.*

These principles could all relate to safety on the fireground. For example *Mobility* relates to the ability to deploy and re-deploy resources in a timely manner. It involves having effective command, communications and equipment. Lack of mobility is obviously a safety issue.

Pre-incident Planning

An efficient and safe reactive phase for bushfire suppression relies on effective planning well before the fire ignition (pre-incident planning). Without effective pre-planning, operational management will usually be chaotic until at least commanders have time to develop their operational management systems. By this time the fire suppression activity might be winding down.

The pre incident planning requirements include:

OPERATIONAL PROCEDURES

Developing procedures for all facets of fire management and having these understood and owned by all is a key factor. Continual development of these procedures is a key focus in our volunteer service.

ORGANISATION STRUCTURE - PLANNING

The structures for command and for command facilities should be pre-planned so that they can be developed pro-actively during the developing fire situation. This will allow commanders to be in front of the fire, not the fire in front of commanders. Commanders at all levels should have a high level of competence and support. They should work from secure locations as close to the fire as practicable.

> "I have always been a firm believer in having H.Q. well forward, it makes the job easier, saves a great deal of time, in fact it has every possible advantage"
>
> *Lt. General, Sir Leslie Morshead. Commander of the Australian 9th Division at el-Alemaine*

COMMUNICATIONS PLANNING

These days we have incredibly smart technology that might give the inexperienced the notion that with good communications equipment efficient information flow results. This of course is not the case. Getting accurate messages between humans throughout the fire organisation structure is difficult to say the least.

As well as sound technical planning and implementation, developing the communications structure to fit the organisational structure as the situation develops requires careful consideration. Also, the message handling systems must be designed with simplicity, as well as efficiency, in mind. Personnel must be able to talk directly over systems when necessary, as well as being able to handle written messages. Implementing an efficient fire fighting language is also necessary for efficient information flow.

> "Commanders at all levels must be able to provide themselves with the means to command even when direct communications are not possible"
>
> *Anon*

COMMAND & CONTROL FACILITY PLANNING

Although effective building design is important, it is the effective facility planning and resourcing of all operational levels that is more important. If the tools for communications, message handling, resource management and mapping are well catered for in a tent, then better safety management will result than if poorly catered for in a grand building.

Effective mapping, communications equipment and other operational tools are vital for crew leader, sector, divisional and incident management team facilities.

RESOURCE MANAGEMENT PLANNING

The safe management of resources on the fireground requires a resource tracking system and procedures that is clearly understood by all before the fire starts. The procedures must include the responsibilities that crew leaders, through to fire controllers, have in resource tracking.

MAPPING

A system to provide maps and map information to firefighting crews and commanders at all levels, as well as for the control facility, is a key focus for the operational management of bushfires. Complete local knowledge is rarely available to all involved so maps are an important tool throughout the firefighting effort. Mapping factors include suitable scales, standard operational symbols, distribution etc.

> "A picture speaks a thousand words"
>
> **Anon**

LOGISTICS

The following quote sums up the need to plan logistics requirements, many of which are directly relevant to safety on the fireground.

EXERCISING

> "----, it is no exaggeration to say that tactics – the art of winning battles – is no more than the art of the logistically possible"
>
> *John Keegan (Soldiers)*

Testing new operational management competencies, procedures, systems and tools at large bushfires is fraught with danger. However using them at small incidents, where they may not seem necessary to the uninitiated, will be useful. The competencies, procedures, systems and tools should be in place before large scale exercises are conducted. Small exercises are useful for training in components of operational management, (experiential learning). Developing and conducting sound operational exercises will result in improved safety.

There are of course many other pre-planning requirements such as fuel management which I won't discuss here.

Safety on the fireground relies initially on competent pre-planning.

An Operational Sequence

The NSW Rural Fire Service and other authorities use the following operational sequence to plan the response to bushfires. This sequence has been around for many years and was probably developed by military strategists but has been slightly modified by the NSWRFS. I will use this sequence as a format for discussion.

RRAPIDE

R	**Reaction**	**agers, commanders and firefighters to the fire suppression activity.**
R	**Reconnaissance**	**The gathering of information from the fire. May include obtaining pre-incident data.**
A	**Appreciation**	**The consideration of essential information and the consequent decisions for the fire combat objectives.**
P	**Plan**	**Development of a plan to combat the fire.**
I	**Issue Orders**	**Communication of the plan to the firefighters.**
D	**Deployment**	**The safe and timely movement of resources to the fireground.**
E	**Evaluation**	**The continual evaluation of the implemented objectives, strategies and tactics.**

This operational sequence is not necessarily carried out step by step. For example some deployment will be occurring before a plan of action is developed and quick appreciations will be made during the reaction, or response, to the fire. It relies on effective information flow between all levels.

RRAPIDE **The Reaction Phase**

The efficient reaction, or response to a fire, will require minimal orders to crews if necessary information is contained in known procedures. Crews might automatically go to a designated assembly area, or start fire suppression from the point of origin. The reaction must be planned. If unplanned, safety of crews could be in jeopardy.

R**R**APIDE **The Reconnaissance**

If a complete picture can be made available to firefighters and their commanders, about what the fire is doing and what is effecting it, they will have the best chance of acting safely.

Reconnaissance can be obtained from firefighters, special ground reconnaissance and from air observers. As with any information flow in an emergency situation, standard message formats and language, active listening and procedures are necessary if important reconnaissance information is going to get to the right place.

Firefighters and commanders should understand what fire behaviour and other information must be passed on to adjoining units and to higher command. If this happens, and can be achieved without clogging communications systems, then better safety will result.

Often firefighters and commanders will not be able to obtain a clear picture of their area of the fire due to smoke, terrain restrictions, lack of suitable mapping and, more importantly, lack of local knowledge. Under these circumstances special ground observers might be the answer, however the use of competent air observation will often be necessary to obtain the required information.

Air observers must be competent in a number of tasks, have effective communications and have personnel on the ground that they can relate to. Their competency requirements include a high level of fire behaviour knowledge, mapping / navigation skills and an understanding of bushfire operational management. Often an individual will not possess all these competencies however this can be overcome by making sure that the team in the aircraft has them. The tasks of the air observer are demanding so task sharing is beneficial.

Real time imagery, amalgamated with global positioning data, is now a possibility and will afford improved management on the fireground. However it will not completely take the place of competent human air and ground observation of the bushfire.

RR**A**PIDE **The Appreciation Phase**

All the information collected for fire management will be useless if it is not acted upon correctly. The appreciation is the term used for analysing the information, relevant to combating the fire and then deciding what to do with it. It is a decision making process which, although automatic to the effective commander, should be practised at times in written form. The appreciation is exercised in our service to make sure important information is not forgotten and to enable effective co-operative decision making where necessary.

> "Nothing is more difficult and therefore more precious than to be able to decide"
>
> *Napoleon 1, (Maxims 1804-1815)*

The format for the appreciation used by the NSW RFS is:

- **Consider all the factors.**
- **Consider what the fire could do.**
- **Consider what our control options are.**
- **Select the most appropriate control option.**

The factors to consider include:

- The fire location and status.
- The weather both current at the fireground and forecast.
- The ground, i.e. the topography and relevant factors on it.
- The resources available and what might be required.
- What is threatened.
- Time and space considerations.
- Safety considerations.

In considering what the fire might do, for a written appreciation, a comprehensive fire analysis is made as follows:

- The current and forecast weather is extrapolated into fire behaviour detail.
- The possible fire runs are placed on a map overlay.
- One of the mapped fire runs is selected to base the plan of action on.
- One or more other runs are selected for alternate plans of action.

In considering what the control options are, for the immediate action plan, possible options for control are based on the most likely fire run as selected:

- The control options are worked out on a map overlay.
- The most appropriate control option is then selected to base the action plan on.

For a large fire management operation a written appreciation is carried out by a planning team, as described above. There is every advantage however in using this process for training those commanders who will only be in a position to make quick appreciations followed by immediate orders.

Commanders who have a sound appreciation process locked in their long-term memory, will be more likely to make safe operational decisions in chaotic fire environments. If their long term memory is reinforced by aide-memoirs (checklists etc) all the better.
Some might notice the AIM has been left out of the above process. This is because the aim is to save life and property and is always known. However affording particular protection may be identified as one of the control objectives.

Once the appreciation is made then a plan of action can be put into place. The selected control option becomes the OBJECTIVE/S.

RRA**P**IDE **The Planning Phase**

Once the objectives are decided on, then a plan of action can be developed. It is called an Incident Action Plan (IAP). The IAP follows a format for giving briefings (or orders) that has been around for many years (SMEAC). SMEAC covers all the operational information required throughout the command structure to conduct operations for the designated period.

Using SMEAC, for both the incident action plan and for giving orders throughout the command structure, is a key to effective operational information flow. The SMEAC format is the same for a quick set of orders given verbally, to a complicated written IAP for handing over to the next shift of commanders.

A format for the incident action plan is: *SMEAC*

S	Situation	**The current and predicted situation relating to the fire, resources, the weather etc.**
M	Mission	The Objectives, **both current and alternate (from the appreciation).**
E	Execution	The General Outline: **strategies and tactics, groupings, tasks and coordinating instructions for firefighting units.**

A	Administration	The Logistics: **supply, ground support, catering, medical, finance and facilities.**
C	Command, Control & Communications	**The command structure, coordination with supporting agencies and the communications plan for the incident.**

This simple approach to plans and orders enables commanders to effectively develop and communicate their plans through all command levels. SMEAC might simply be used direct from a commanders memory, used as a checklist or used in special forms for a written incident action plan.

The responsibility for components of the IAP by commanders and functionaries will depend on the complexity and type of bushfire. These responsibilities should be worked out in pre-planning. For example, for fast running grassland fires the objectives might be the responsibility of the Incident Management Team (IMT), the strategies delegated to the Divisional Commanders and tactics to the Sector Commanders. For situations where the IMT has close command & control then they might be fully responsible for the entire Incident Action Plan, but of course will consult with field commanders.

Throughout the combat of a large bushfire, two distinct, but linked areas of incident action planning occur: that co-ordinated by a planning team for prediction planning and that managed by operations personnel for the ongoing planning required to immediately react to the fire situation. If this is not thoroughly understood then unnecessary restrictions and lack of timely orders could result in safety problems.

> " His orders were models of conciseness. Nothing was overlooked. What he did was to think out all things and detail officers to work out the detail and report to him as to their satisfactory development."
>
> *(about) General Monash, 8/1/1916*

The issuing of orders is often referred to as briefings. In the NSWRFS the term 'issue of orders' is for command IAP communication, 'briefings' is the term for communications of a co-ordination nature. Briefings might use parts of the SMEAC sequence however all of it will be required for orders.

With all presenters and recipients understanding the SMEAC format, effective communications and implementation of the IAP should follow. This standard procedure for plans and orders, is one of the vital operational management tools for promoting safety on the fireground.

There is a need for our personnel to exercise this structured delivery of orders, because it is not normal to communicate in this formal way. If it is not done correctly all important communication between humans in an often chaotic environment might fail with a detriment to safety.

RRAPI**D**E **The Deployment Phase**

Commanders and crews should not be deployed unless they have enough information. Deployment should only occur if either full orders are given, components of orders are known beforehand or missing components can be communicated in a timely manner after deployment. Consideration should be given to using the term *warning order.*

A warning order is about communicating enough information so personnel can be mobilised or can prepare for mobilsation. A warning order could be given for crews to organise their logistics and to move to a staging area by a certain time.
Deployment during the initial reaction to a bushfire should still be planned for using SMEAC, or relevant parts of it. Reaction to a situation at a bushfire, such as a break out, should be given special attention by commanders. A well executed quick appreciation, followed by immediate but safe orders is usually the requirement for the breakout.

"He was the master of the quick appreciation which he followed with immediate orders" (about) Major General George Vasey

RRAPID**E** **The Evaluation Phase**

All commanders must continually evaluate the effectiveness of their operations and report as necessary to higher and adjoining commands. Working with competent air observers will often be necessary to obtain a good picture of the developing fire situation. Firefighters could find themselves in unsafe situations if the evaluation phase is not managed.

“Order marches with weighty and measured strides;
disorder is always in a hurry”

Napoleon 1 (Maxims, 1804-15)

Operational Communications Planning

From the moment the first crews are deployed until the last ones stand down, fire managers must attend to operational communications planning. This planning like all operational planning must be pro-active. The communications structure and facilities must be set up to cope with the predicted growth of the fire. This means the communications planners should work closely with the fire prediction planners. A large fireground structure will require an operational communications plan that complements the structure.

Information Management

The effective management of information over the various communications mediums, is a must for safety. The crew around the tanker must be able to communicate with one another in a noisy, stressed and smoky environment. The crew commander must be able to communicate to sector commanders when communication systems are stressed. The sector commander must be able to communicate to divisional commanders as well as their crews. Divisional commanders must be able to communicate to the Incident Management Team and to their sector commanders. All these will need to communicate to their adjoining equivalents. The Incident Management Team will often have a large number of personnel who will find difficulty in maintaining efficient communications within their complex. Without a sound information system to handle written and unwritten communications safety of crews could be jeopardised.

Resource Tracking

From the moment the first crews are deployed until the last ones stand down, fire managers must keep track of resources (personnel and appliances). All commanders and designated staff need to know the part they play in resource tracking. At a large fire, with more than a thousand personnel and numerous appliances deployed, this can be an onerous task, so must be thoroughly prepared for in pre-incident planning. It is my guess that many commanders have, at least once, lost track of their resources.

Changeover Planning

The changing over of crews during a campaign fire (long duration fire) requires considerable planning. The aim is to change over crews so they can obtain enough rest for their next shift and so the fire suppression operation continues unabated. Many things can go wrong during changeover: it takes hours instead of minutes, crews get lost, the fire escapes, transport fails and so on. An efficient changeover will result in rested crews, continuous fire suppression and enhanced safety.

Conclusions

- The efficient operational management of bushfires is as important for the safety of our firefighters as other safety factors.
- Operational management is complex and warrants considerable research and development.
- Simplicity and consistency of operational management systems is especially important for large volunteer organisations like our NSWRFS.
- Having the format of the Incident Action Plan the same as for the Giving of Orders is an example of this consistency.
- The effectiveness of operational tools and procedures is as important as the competency of personnel.
- The competency of the team is more important than individual competence.
- Operational exercises are vital for combined operational competence.

This paper is a short overview on what I consider to be a very complex subject. No doubt there are other considerations. I understand there is excellent work being done on the subject and that a comprehensive appreciation would be necessary to arrive at the best options for sound operational management on the fireground. Our volunteers and full time firefighters deserve the best.

The NSWRFS is committed to the principle of continuous improvement. We are currently more focused than ever on the need to reduce firefighter deaths and injuries as far as is humanly possible. Continuous analysis, evaluation and revision of operational management is a vital part of the process.

References

The content of this paper is derived from Australian and international training material over many years. I would like to thank my mentors, volunteers in my local area (Mulwaree Shire) and my colleagues in the Service as well as associates in other agencies from whom I have gleaned much useful information.

Paul Macmichael
New South Wales Rural Fire Service
Goulburn Training Office
PO Box 701

GOULBURN NSW
Australia 2580

paul.macmichael@bushfire.nsw.gov.au

Non-Traditional Resources and Safety in Wildland Fire Management: The Unified Command Safety Team

Gene Madden
Division Safety Officer
Florida Division of Forestry

Florida suffered through its third year of significant wildfire in 2000. In order to understand what occurred this past year, one must look back to 1998, when Florida experienced one of the worst wildland fire seasons ever recorded. Major loses in forest land and structures occurred. The severe fire weather conditions experienced in 1998 were unprecedented. Significant improvements were subsequently implemented by the Florida Division of Forestry both strategically and in available resources as a result of enhanced funding.

The 1999 wildfire season proved to be another critical event.

The 2000 wildfire season also developed into a critical event with a spring drought that was more severe than the one experienced in 1998. Property and acreage losses however, in 2000 were far less than that of 1998.

In each one of the past three years Florida had to turn to a wide variety of in-state and out-of-state resources to meet the conflagrations that were so abundant.

With so many different types and kinds of resources, concern arose as to the level of safety that was actually out there on the fireside at the local, state and federal levels in Florida.

In response to this and the continuing wildfire occurrence and extreme wildfire danger the Florida Unified Command instituted Unified Command Safety Teams.

The purposes of the Safety Teams were to:

- ❑ Serve as an extension and liaison for Unified Command
- ❑ Provide timely safety information
- ❑ Facilitate safe wildland fire suppression behavior
- ❑ Assist certain incidents as needed
- ❑ Provide timely reports and communication to Unified Command

Two teams were formed. One team “roved” north of Interstate 4. The second south of Interstate 4. The North Team covered DOF field units 1-11. The South Team covered DOF field units 12-18.

Each Safety Team consisted of three experienced safety officers. Each team had representatives from the Florida Division of Forestry, the USDA Forest Service and the Florida Fire Chiefs’ Association.
Simple operational guidelines were developed. Each Team was asked travel to together, in uniform and in a marked vehicle. In addition, they were asked to have daily communication back to Unified Command, complete appropriate forms as needed.

The Teams contacted the following agencies included: The Florida Division of Forestry field units, USDA Forest Service Ranger Districts, Florida National Guard, Florida Fire Marshal’s Office, Bureau of Land Management, Georgia Forestry Commission, North Carolina Forestry Service, South Carolina Forestry Service, and 25 county and local paid and volunteer fire agencies as well as many private and commercial landowners.

A short *Safety Questionnaire* was developed and used by both Safety Teams which was used to document their visits and aid in capturing consistent data at every site visited which could then be correlated. Interviews were not limited to only the listed names but other agency members.

Recent Overall Safety Record

Safety records were all excellent, with the exception of one fire department that reported a burn-over incident. Most contacts displayed a high awareness to ongoing safety concerns. Some heat-related concerns, close calls with civilians assisting in suppression, and several concerns with the urban-interface challenges were reported.

Personal Rest Cycle

All of the contacts were providing adequate, if not regular days off and rest cycles. This also appears to be the case even throughout the period of high-volume wildland fire incidents. There were some reports of long hours and signs of fatigue–mostly in the wildland group.

Rehab

All agencies appeared to be insuring that all personnel were in good shape. No major problems or concerns were noted.

Established SOP's & Safety Officers

There was a varied response to this issue. Several Fire Departments had existing SOP's for wildland fire. Some structural firefighters did not recall seeing safety officers but received daily safety messages in IAP's. Fire Departments generally had SOP's in place for deploying safety officers to wildland fires. Wildland fire agencies tended to have assigned SOF's on incidents.

LCES

The LCES acronym program was not widely known or recognized by structural fire departments. All wildland firefighters were aware of the program, but thorough knowledge was not consistent.

Lookouts: Often there are too few responders or adequately trained personnel as lookouts.

Communications: Much concern over inconsistent radio communications. Incompatible systems between cooperating agencies and neighboring jurisdictions (especially during Initial Attack). ICS and fire terminology sometimes poses a problem (training issue). ICS is generally used but not consistently.

Escape Routes: Not much feedback. Dozer lines and roads were generally used. Often brush trucks do not have adequate escape routes or safety zones in wildland situations (training issue).

Safety Zones: Dozers can create them as they work. Engines need to be more aware of them.

PPE

Fire departments are largely without wildland gear. A few have some gear, however, everyone wished for additional gear. Some fire departments in process of obtaining wildland gear. Budget issues rather than policy issues, seem to be biggest barrier. There was found to be much interest and willingness in acquiring and use of proper PPE.

Training

It was found that structural fire departments have very limited wildland fire training. All expressed an interest in further training. All were interested in “Train-the-Trainer” programs, if available. Some identified obstacles included: large numbers of firefighters that would need to be trained in each department, especially considering all of the required refresher training structural firefighters are now required to take annually (ISO 20 hrs/mo. + EMS - CEU’s).

Traffic

Highway safety and travel were recognized and addressed in most safety briefings. Some concerns identified in particular were the urban interface and the problems associated with these areas (limit access, “near misses” smokey-limited visibility. All fire vehicles should be provided with red/yellow flashing lights for safety (National Guard). EVOC training should be given to all drivers.

Tactics

Respondents indicated that they had concern over changing tactics as the urban interface areas expand especially with new communities with limited access. This has led to a departure from the historical or traditional tactics employed (saving structures vs. putting out the fire). Some recognized that tactics have to be modified during drought conditions and knowledge of fuels and fire behavior is a must. Personnel without wildland fire training often take dangerous risks during drought conditions. Often during drought conditions, structural personnel were called on from other areas that have little brush fire problems–and little brush fire training and experience. Some departments had SOP’s to determine tactics.

Equipment

Generally found to be adequate in most areas. There were some isolated requests for more specific tools. Some equipment is in need of replacement, but all equipment of the line appeared to be safe. There is a need for additional Type II dozers in some areas. With increasing interface areas, there is a greater wildfire occurrence in dried up swamps and a greater need to mop-up these areas quickly and completely. Existing equipment is often unsuited for task. Class A foam is used frequently on these situations. Some departments using “PASS” accountability devices on firefighters during wildland fires.

Routine Critiques

Nearly every agency conducted routine critiques on most incidents, either formally or informally.

Daily Shift Briefing

Daily shift briefings were consistently done by all agencies.

Access to Safety Information

Numerous methods being used by different agencies. All indicated a good flow of information. Internet was commonly used. Nearly all cooperators were going to the DOF website for daily information. Several fire departments were broadcasting daily fire weather forecasts on alpha numeric pagers.

General Safety Issues

Physical Fitness:	Several different standards used. Including the Work capacity Test a.k.a. "Pack Test."
PPE:	Personal protective equipment not always available or used by personnel.
Policy Differences:	Some conflict with routine policy and procedures, i.e., North Carolina Forest Commission uses a "blackline" policy–FL DOF doesn't.
Lack of wildland firefighters:	More wildland firefighters are wanted by structural firefighters.
Wildland refresher training:	Wanted more often, weekends, evenings and in local areas
Radio/Communications:	Portable radio caches needed. Some areas have a VHF vs. 800 MHZ issue.
ICS:	Needs to be consistently adopted and used by all agencies
Training:	Standardize and require
Out-of-Area Resources:	Should come "prepared," e.g. radio frequencies, and typed and matched properly as per request.

Conclusions

The Unified Safety Teams were very well received. Nearly all of the individuals contacted willingly took the time to visit and were candid with their responses. The overall safety environment appeared to be positive at all sites visited, especially when qualified safety officers were assigned to an incident.

The Safety Team concept achieved all expectations. The two Teams helped to provide important safety information and advice to resources on where to go and how to get it done in Florida.

The Safety Teams provided critical daily information back to Unified Command and also provided "unified" model of all levels working together for local resources.

Recommendations

The Unified Safety Team approach worked and is something that will be used again. Possibly year-round. The handouts given to each contacted party were very well received and efforts should be made to increase the dissemination of wildland safety information to structural fire agencies. They served as a safety tool for personnel to learn and build from.

The standardized data form was an excellent tool for Team members to be consistent and serve as a guide for them so key points were covered. Safety Teams worked through local DOF and USFS contacts to arrange meetings and interviews. No surprise visits.

A firm procedure especially involving logistics and finances should be worked out ahead of time.

Finally, the Unified Safety Team worked in Florida last year. The benefits were clear and it is recommended that this approach to safety be used again..

Dangerous Tree Assessment - British Columbia's Wildland Fire Safety Module

T. Manning[1], P. Taudin-Chabot[2], M. Dunleavey[3], D. Rowe[4] and N. Densmore[5]

Abstract. British Columbia has a standardized dangerous tree assessment process recognized by the provincial Ministry of Forests, Workers' Compensation Board, and the Ministry of Environment, Lands and Parks. This process is considered the "standard of care" for determining tree hazards in forestry and wildland fire operations in B.C. Recently, a new training module was developed to provide information and technical procedures for assessing tree hazards and establishing safe work practices where workers are involved in wildland fire fighting. This danger tree assessment process uses level of disturbance (type of work activity), site conditions, and tree defect failure potentials in order to reach a safety decision for any given tree(s). Benefits of this assessment process are: i) a tree defect failure potential rating system which uses visual indicators --- this process is quantifiable and repeatable; ii) reduced downed wood fuel loading and maintenance of wildlife tree habitat as a result of fewer trees being felled (i.e., previously all snags were routinely felled --- now upon assessment, some trees will be determined to be safe to work around); and iii) improved worker safety in situations where workers may be exposed to dangerous trees. These guidelines and associated training will be of interest to persons involved in wildland fire fighting activities where determination of tree hazards is required.

Background

In British Columbia, the historical definition of a standing dead tree or "snag" has been – "*any standing dead or dying tree over 3 meters in height*". New Workers' Compensation Board Occupational Health and Safety regulations (WCB 1998) were adopted into law effective April 15, 1998. With these new regulations, the term snag has been replaced with *"dangerous tree"*. According to section 26.1 of these regulations, a dangerous tree is defined as:

> "*any tree that is hazardous to workers because of location or lean, physical damage, overhead hazards, deterioration of the limbs, stem or root system, or a combination of these*".

Recently, dangerous tree assessment guidelines and technical criteria were developed by the Ministry of Forests Protection Branch and the Wildlife Tree Committee of British Columbia (WTC), in conjunction with the above changes to the WCB regulations. The guidelines were reviewed and pilot tested by fire protection officers and others with practical experience in wildland fire fighting and occupational health and safety. The information was then incorporated into the provincially sponsored "*Dangerous Tree Assessor's Course - Wildland Fire Safety Module*" (WTC 2000), which provides technical information and practical field skills to persons who wish to assess trees for hazards in wildland fire fighting situations.

Determining Tree Danger

The determination of a tree's failure potential (i.e., the likelihood of all or a portion of a tree breaking, rated as low, medium or high), and ultimately whether or not it is dangerous, involves a four step process:

Step 1 - determine the level of ground or tree disturbance (i.e., type of work activity around the tree);

Step 2 - conduct a site assessment overview;

Step 3 - conduct visual tree inspection (determine tree failure potential); and

Step 4 - make the appropriate safety decision.

These four steps are described in detail below.

Step 1 - Level of Disturbance

Various activities are associated with differing levels of ground or tree disturbance. Work activities rated as low disturbance, such as recces/patrolling, tree marking and fire guard layout, involve very little ground or tree disturbance and as a result, expose people to minimal danger. However, as the level of disturbance and exposure increases, for instance with tree falling or use of heavy machinery during construction of fire guards, the potential danger and risk of injury also increases. Consequently, potentially dangerous trees considered for retention in these operations must be carefully assessed for any hazards in order to determine tree failure potential and reach an appropriate safety decision. A summary of various activities and associated levels of disturbance is shown in Table 1.

Table 1. Levels of disturbance for unprotected workers in various fire-related work activities

Level of Disturbance	Type of Work Activity
1 (Low)	• surveys • tree marking • fire guard/control line layout • road travel with light vehicles
2 (Medium)	• fire control with hand tools and/or water hoses • road travel with heavy vehicles • tree bucking • slashing
3 (High)	• tree falling • use of heavy equipment (without adequate FOP) • use of light and intermediate helicopters for transport, aerial recces and aerial drops*****
4 (Very High)	• use of medium and heavy helicopters for transport and aerial crops*****

*** Note**: a dangerous tree assessment is only required if there is exposure to workers on the ground (e.g., aerial work with no workers on the ground does not require an assessment unless ground workers are subsequently scheduled to work in this area).

Step 2 - Site Assessment Overview

The determination of a tree's failure potential begins with a site assessment overview. This involves an assessment of site factors which suggest tree decline or potential tree failure. These can be forest health agents (e.g., root rots, insect damage), stand condition (e.g., age, tree species, presence of heart rots), soil profile and condition, and other site variables (e.g., wind conditions, build-up index, fire severity/burn intensity, slope). A partial list of the site factors which indicate potential tree failure concerns is found in Table 2.

Table 2. Site Assessment Overview (for all tree species)

Site/Stand Factors	Hazard Indicators/Influences
Stand history and condition	• evidence of past tree failure • stand age and structure • tree species composition • disturbance history (e.g., old burn, root rot area) • soil or slope instability • sites where air tanker or water scooper aerial drops have recently occurred
Windthrow potential	• topography (e.g., steep slopes) • shallow soils or restricted rooting depth (e.g., bedrock, clay hardpans) • evidence of significant windthrow • stems with height:diameter ratio >90
Crown condition	• small live crown (<20%) • crown imbalance (majority of branch weight on one side)
Resinosis	• higher than normal stem or basal pitch flow
Tree lean	• trees recently leaning due to windstorm, root damage, shifting root mat or other causes
Severity of fire/burn	• build up index (BUI) as per Fire Behaviour Prediction System (FPB) guide for fuel types • damage to major roots or anchoring soil layer affects tree stability
Time since fire (the 3 day time frame should only be used as a cautionary indicator relative to assessment of site hazard)	• ≤ 3 days since fire → minimal effect • > 3 days since fire → significant effect. Daily assessment if BUI is above threshold value

Step 3 - Visual Tree Inspection

The third step in the danger tree assessment process is the visual tree inspection. This inspection results in determination of a failure potential rating (low, medium or high) for a given tree. Failure potential rating thresholds have been developed for eight general tree defects, as well as tree lean and root condition. These are:

- hazardous tops
- large dead limbs
- split trunk
- stem damage (fire or machine scarring, butt rot)

- thick sloughing bark
- fungal fruiting bodies (conks and mushrooms)
- butt and stem cankers
- large witches' brooms.

The above defects are rated according to tree species group. Consequently, failure potential thresholds for a given defect such as stem fire damage, may be different based on the tree species grouping (e.g., cedars have a larger permissible stem scarring threshold than the other tree species groups). The defect indicators have been arranged into four tree species groupings, as follows:

i) Douglas-fir - larch - pines - spruces

ii) western redcedar and yellow cedar

iii) hemlocks and true firs

iv) deciduous trees (hardwoods).

The visual tree inspection identifies visual defect/hazard indicators which are used to predict tree failure potential. With adequate experience and training, this is an efficient process which usually requires only a few minutes per tree.

Step 4 - Making a Safety Decision

Once a failure potential rating (low, medium or high) has been determined from the visual tree inspection (step 3), then the tree can be rated as either safe (S) or dangerous (D) dependent on the level of disturbance or activity around that tree. This procedure is illustrated in Table 4 below.

Table 4. Overall Tree Danger Rating

Level of Disturbance	High Defect Failure Potential
1 (Low)	S*
2 (Medium)	D
3 (High)	D
4 (Very High)	S - class 1 trees S - class 2 cedars with low failure potential defects S - class 2 and 3 trees with NO defects D - all other trees

*** Note**: for level 1 disturbance activities, only trees which have one of the three "significant hazard indicators", are rated D (dangerous)

If a tree is determined to be dangerous (D) for a particular type of work activity, then the appropriate safety procedures must be implemented. These include removing the tree or any hazardous parts (e.g., hazardous limb), or establishing an appropriate size safe buffer area (called a *no-work zone*) around the tree to eliminate exposure of workers to the hazard. However, if a tree is assessed as safe (S) for a given type of activity, it can then be worked up to regardless of whether it is dead or live.

Inherent to the implementation of any safety decision is an understanding of the concept of *"risk"*. Expressed as a simple product, *RISK = HAZARD x EXPOSURE*. For example, if there is exposure of workers to a dangerous tree or a *"target"* exists (e.g., facilities or equipment which are within striking distance of a dangerous tree), then an inherent risk of injury or property damage also exists. On the other hand, if there is no hazard (i.e., the tree is not dangerous) or there is no target exposure, then there is no or very minimal risk. An example of risk management is illustrated by the following situation. In very specific instances where it is not practicable to remove danger trees because of site factors or operational problems (e.g., steep slopes, high stem densities, falling difficulties, fire behaviour), alternate and approved safe work procedures may be implemented. These might be the use of people trained to look out for tree hazards and changes in wind condition, with radio and/or air-whistle communication to ground crews.

Benefits of the Danger Tree Assessment Process

The danger tree assessment process is considered the "standard of care" for determining tree hazards in forestry and wildland fire operations in British Columbia. The major benefits of the assessment process are:

i) a tree defect failure potential rating system which uses visual external indicators --- this process is quantifiable (i.e., a numerical value or threshold is used to rate tree defects such as stem damage or hazardous tops) and repeatable (standardized training helps ensure people are assessing trees using the same criteria);
ii) reduced downed wood fuel loading --- fewer trees have to be felled as danger trees because many trees will often be determined to be safe to work around for activities such as mop up --- this increases operational efficiency of fire suppression activities;
iii) improved safety to workers on the ground where there may be exposure to potentially dangerous trees --- having a standardized danger tree training and awareness program permits active and concurrent integration of danger tree assessment, identification and associated safety procedures into operational wildland fire fighting. This also increases the overall awareness and level of "heads-up" to those crews working in burned stands. In addition, by falling less trees prior to mop up activities, the incidence of tripping hazards to ground workers will be significantly reduced.

The dangerous tree assessment process described in this paper has been incorporated into an Operational Safe Work Directive governing safety procedures for fire crews who may be exposed to dangerous trees. This process is also compatible with previous danger tree assessment criteria developed in British Columbia by the WTC for forest harvesting and silviculture operations, and supports the wildland fire safety program of "LCES" (look-out, communicate, escape routes, safety zones).

Acknowledgements

The authors would like to thank the members of the Wildlife Tree Committee of British Columbia who have contributed to the development of the Wildland Fire Safety Module, as well as the various Ministry of Forests protection staff who have provided ongoing operational feedback concerning the implementation of the danger tree assessment process.

References

Wildlife Tree Committee of British Columbia (WTC). 2000. Dangerous Tree Assessor's Course - Wildland Fire Safety Module. B.C. Min. Forests., Workers' Compensation Board, Min. Environ., Lands and Parks, Victoria, B.C. March 2000.

Workers' Compensation Board of British Columbia (WCB). 1998. Occupational Health & Safety Regulation. Parts 20-33. Richmond, B.C. April 1998.

1. Wildlife Tree Committee of British Columbia and BRANTA Forestry and Tree Assessment. 5148 William Head Rd., Victoria, B.C. V9C 4H5. Canada. ph. (250) 478-7822. Email tmanning@islandnet.com

2. British Columbia Ministry of Forests, Protection Branch. Coastal Fire Center, 665 Allsbrook Rd., Parksville, B.C. V9P 2T3. Canada. ph. (250) 951-4222. Email phil.taudinchabot@gems2.gov.bc.ca

3. British Columbia Ministry of Forests, Protection Branch. Quesnel Zone, Box 14, Airport Site, RR8, Quesnel, B.C. V2J 5E6. Canada. ph. (250) 992-2144. Email mel.dunleavey@gems3.gov.bc.ca

4. Workers' Compensation Board of British Columbia, Prevention Division. 1066 Vancouver St., Prince George, B.C. V2L 5M4. Canada. ph. (250) 561-3799. Email drowe@wcb.bc.ca

5. British Columbia Ministry of Forests, Forest Practices Branch. P.O. Box 9513, Stn. Prov. Govt., Victoria, B.C. V8W 9C2. Canada. ph. (250) 356-5890. Email nancy.densmore@gems2.gov.bc.ca

H2S (Sour Gas) Awareness in Regards to Safety of Crews On the Fireline

Steve Matlashewski
email:steve.matlashewski@gems6.gov.be.ca

The need to develop a H2S (sour) gas operational awareness package in relation to wildland fire fighting has been identified due to increasing amounts of oil and gas exploration and development in North Eastern B.C..

The goal of this package is to raise awareness of the inherent risk of sour gas and it's exposure effects on firefighters. Safe Work Directive #10 has been established in conjunction with the Workers Compensation Board of B.C. and the Protection program. This Directive provides clear procedures to be followed when initial attack fires occur within our"oil patch".

To better understand the reasoning behind these procedures an operational awareness package has been developed in conjunction with the Safe Work Directive. This package consists of 1) general knowledge and charactericts of sour gas also including other related hazards such as heliportable programs and windrowing of seismic slash.2) recognition of facilities and operational areas. 3) communication procedures.4) glossary of terms.

OPERATIONAL SAFE WORK DIRECTIVE # 10
March 3, 1999

H_2S & Geophysical Operations

Definition: Geophysical operations refer to all work sites and facilities involved in the exploration, acquisition, processing, and transportation of oil and gas.

All Protection staff will review and be familiar with the"H_2S & Geophysical Operations Awareness" guideline before actioning fires where exposure to H_2S may occur. While actioning a fire on or near an Oil and Gas operation, all guidelines contained in the"H_2S & Geophysical Operations Awareness" package will be adhered to.

Personnel will request a gas detector from zone staff or industry personnel when working in proximity to oil and gas installations. Ensure the detector is on and monitored closely, zone staff will maintain proper calibration of detectors. Detectors will be equipped with 2 different audible alarms set for 5 PPM and 10 PPM.

Procedures:

1. Any person approaching a fire that is adjacent to a Geophysical operation will identify the type of operation or facility, and communicate this back to the F.C.O., *before* commencing any suppression activities.

2. Any site that has the *potential* to expose a crew to H_2S will be treated as if it were a "sour gas" site until determined or notified otherwise.

3. Crews will be educated on detector use and operation.

4. H_2S Detectors will have alarms set at 5 PPM extreme caution to be emphasized and spotter required. An Alarm will also sound at 10 PPM withdrawal from area. Professional personnel will be brought in to determine the size, source, and detailed location of contaminated area.

5. While assessing the site, personnel will stay upwind, and not fly within 100m of the site/structure.

6. If the site is a facility or structure, the access or entrance road will be checked for a sign indicating ownership, type and location of the facility. This information will be passed on to the F.C.O..

7. If it is determined that the fire is in a location that could expose personnel to H_2S, the fire should not be actioned, and an alternative suppression strategy should be developed in conjunction with the F.C.O. and the applicable Zone Protection Officer.

8. If contact has been made with an Industry representative, any instructions given should be communicated back to the F.C.O. and followed explicitly.

9. Scheduled check-ins must be strictly adhered to.

10. If any personnel show signs or symptoms of H_2S exposure, all personnel will be immediately evacuated from the site. (Symptoms may include: irrational or out of behavior character, complaints of headache or nausea, loss of balance, loss of smell, eye or respiratory tract irritation.)

** 24 hour ph. # for Westcoast Energy (Ft.St.John) 1-250-262-3400 or 3466**
** 24 hour ph. # for Oil and Gas Commission (Ft. St. John) 1-250-262-3300**
** These contact numbers will engage industry and government personnel in providing: gas flow control, value at risk assessment, identification and ownership of infrastructures, and assistance where required.**

H_2S & Geophysical Operations Awareness

The Oil & Gas, or geophysical industry is most common in the NE corner of British Columbia, however, sporadic activity may occur in other areas of the province. This industry poses some unique hazards to forest firefighters. One of the most prominent of these hazards is the potential for exposure to Hydrogen Sulphide gas (H_2S or "Sour" gas).

What does this *mean* to you the firefighter? *Exposure to this gas can kill you.* Situational awareness is all-important when working in an area with Oil and Gas installations and activity. You must develop some familiarity with recognizing industry installations, both active and inactive. The process of familiarization has been broken down into 5 steps:

1. Safe Work Directive
2. General knowledge and training
3. Recognition of facilities and operational areas
4. Communications
5. Glossary of terms

General Knowledge and Training

Hydrogen Sulphide is a naturally occurring gas formed by the decomposition of organic material in the absence of Oxygen. The important properties of this gas that firefighters must understand and respect are:

- I.D.L.H. (Immediately Dangerous to Life and Health) is 100 parts per million
- Colorless
- Rotten egg smell at low concentration levels (1 to 2 PPM)
- Lethal exposure concentrations will not be smelled
- Soluble in water

- Denser than air
- Flammable

There are gas industry courses that spend 8 hours and more describing the details and effects of this gas. The industry standard for entry-level training is the H_2S Alive course. This one day course is specifically tailored to the oil & gas industry. This course outlines properties of the gas, use of Self Contained Breathing Apparatus (S.C.B.A.), detection in conjunction with level of gas concentration, and rescue techniques. The nature of our work is quite different compared to a gas plant facility or installation, therefore the H_2S course is not specifically tailored to our needs. Our operations are mobile, crew weight (restriction factors) and operations do not lend themselves well to the use of this specialized equipment. In addition, the Forest Service does not want firefighters working in areas where they could be exposed to lethal hazards.

H_2S & Geophysical Operations Awareness

Situational awareness and avoidance is the best protection from H_2S exposure. Exposure may occur in and around lease sites, flare stacks and flare pits, compressor stations, gas plants and exposed pipelines. In short, almost any facility or structure can pose a threat.

H_2S gas is soluble in water and heavier than air. This means low lying areas around gas sites, including small bodies of water, should be treated with caution as they could become concentrated with this gas. Walking into one of these low-lying areas could expose a firefighter to this gas. Disturbing water (i.e. *priming a pump intake*) that is saturated with this gas could also cause exposure.

H_2S affects the Central Nervous system. Symptoms of H_2S exposure include: irrational or out of character behavior, complaints of headache, loss of balance, loss of smell, nausea, eye and respiratory tract irritation. Ultimately exposure to high enough concentrations will lead to death.
When working around gas facilities fire fighters will monitor for gas exposure with a gas detector and observe each other's actions carefully. If any symptoms are noted you must leave the site uphill and upwind.

** 24 hour ph. # for Westcoast Energy (Ft.St.John) 1-250-262-3400 or 3466**
** 24 hour ph. # for Oil and Gas Commission (Ft. St. John) 1-250-262-3300**
These contact numbers will activate an established emergency response system from industry personnel. Nature of emergency will be assessed and measures of control will be undertaken ie: gas flow control. These numbers will also provide for logistical support when needed in fire control operations.

Gas sites and facilities are known as "sweet" if H_2S is not present, and alternatively as "sour" when H_2S is present.Treat all sites as sour until notified or determined otherwise. Do not assume your pilot has familiarity with this industry. Upon approaching a fire that have adjacent gas facilities consider the following points:

- Look for a windsock. Stay upwind of the facility.
- Fly the entrance road and look for a sign denoting ownership and location
  (I.e. Petrocan YoYo, d-27-H / 94-O-10 or lat. / Long.)
  PASS THIS INFORMATION & SITE DESCRIPTION ON TO THE F.C.O.
- Look for a DANGER or H_2S sign, which denotes a sour site, individual *structures* may also be labeled.
- Take note of the structures on site. A flare stack or flare pit generally indicates H_2S.
- Observe the personnel on site. Are they wearing SCBA gear? This is a sure sign of H_2S.
  If there are personnel on site not wearing SCBA gear, it should be safe to land and consult with the Safety officer or site supervisor for safe working distances and specific hazards.
- If the site potentially has sour gas present, consider other suppression strategies and advise the F.C.O. (I.e. Non action, Air Tanker or high level bucketing action). Values at risk should be carefully evaluated.

- Is there Industry personnel available to assist with monitoring and detection of H_2S while the crew works in the area?
- Look for an "airshack" on site. This indicates sour gas could be present.
- Avoid being in or near the emissions from a flare stack. They contain Sulphur Dioxide ($S0_2$) which is also hazardous to your health.
- If actioning the fire, maintain scheduled check-ins with the F.C.O. and monitor frequently and carefully for gas exposure. Act immediately if symptoms appear.
- Avoid being downwind from the site, or travelling in low lying areas. Plan escapes routes uphill and upwind.
- Do not use flare pits, sump pits, or standing water in adjacent low lying areas for pumping.
- If you suspect someone has become unconscious from exposure to H_2S, you cannot rescue the person without exposing yourself to the same hazard.

H_2S & Geophysical Operations Awareness

Other Hazards

Most exploration activity takes place in the winter months. This is because much of the ground worked on is saturated soils and muskeg. However, in recent years there has been an increase in summer activity. This can occur on dry or wet sites with the use of "Heliportable" operations. This is the use of helicopters to transport equipment to help minimize the environmental impact on the site. The specific hazard with this operation is the aircraft. The pilots will be slinging or longlining expensive equipment, often to a site where a high degree of precision is required. Consequently, they may not be monitoring an F.S. radio frequency. Firefighters and pilots need to be aware of this. Give these operations a wide safety zone. While working in proximity to a heliportable operation ensure contact is established, and both parties are aware of each other's flight paths and activities.

Seismic lines are laid out and cleared to provide paths from which sounding signals can be sent and received back to establish the potential for presence of oil or gas. These lines are referred to as source or receiving lines.

A two dimensional program (2D) is a number of cleared lines of varying width set out parallel to one another or with some degree of crossover. A three dimensional program (3D) is a more intense survey and involves lines laid out in a grid (perpendicular) pattern which are typically closer together than that of a 2D program.

After the lines are cleared, dynamite charges are laid out in series of drilled holes on the source lines. Specialized receiving equipment is set up on the receiving lines, which then record reflected shockwaves sent out from the explosive charges.

If a seismic line is active it will appear freshly cleared and may have equipment and personnel on site. An active source line will appear to be freshly cleared and have a row of drilled holes containing explosive charges, usually visible down the center of the line. It may be possible to observe wires running between the holes. Do not land on or near an active source line. Do not handle wires or other devices on the line, there may be undetonated charges still on the line.

While working fires on or near a seismic line, be aware of any windrowed slash left on the line from construction. If this material is dry, an advancing fire can be "wicked" along these lines quite quickly, posing an escape hazard and possibly creating an entrapment situation.

Flare stacks are often the source of ignition for fires as they may be ignited with a flare gun. If the flare overshoots the site, It may start a fire.

Do not assume that lease sites with a capped well head are safe to work around (wellhead may be old with possible gas leaks). These sites are generally fairly immune to fire damage because lease sites generally have grass as their predominant fuel type hence the heat generation will not be sufficient to damage the wellhead. Do not work directly on the lease site. Consider values at risk wind conditions and escape routes carefully before actioning.

H_2S & Geophysical Operations Awareness

3. RECOGNITION OF FACILITIES AND OPERATIONAL AREAS

In light of the types of hazards involved in this industry, the firefighter must be familiar with general industry operating areas. The vast majority of this activity is contained in the NE corner of the province in three zones: Dawson Creek, Fort St. John, and Fort Nelson. This area also includes all the adjacent land bordering these zones in Alberta and the Territories. Firefighters who are dispatched to these areas should *expect* to be in working proximity to this industry. Crews base changed to one of these areas should ensure zone staff or senior I.A. personnel provide a briefing or review on this subject. Take the time to find out where the major plants or facilities are, as well as any summer exploration activities. Mark these points on all working maps. These points will indicate areas of potential hazards to crews, and are valuable for navigation and orientation in the vast expanse of the open muskeg.

Zone staff or Industry personnel will issue firefighters a H_2S detector. Firefighters will ensure that they are fully briefed on its use and that the unit is calibrated. While working in an area with the potential for H_2S exposure, crews should ensure that they have formulated an escape plan that considers wind direction, terrain, and time to reach a safe area.

Communications

All communications with regards to this topic should be as precise and forthwith as possible. Although lat / longs and a geographic location are given on the IFR, further information will be useful to the F.C.O. The Industry map designator (petro-can yo-yo d-27 H 94-O-10) if available, along with the location and proximity of the fire with respect to the industry operation, should also be communicated. If there are tanks or other structures on site, pass on the colour that they are painted. The industry routinely has “company colours”, so this may be useful for identification purposes.

If personnel are unsure of the type of structure or facility they are near, the Industry map designator or a brief description of the site may assist the F.C.O. in identifying the site and hazard.

If a person has been designated a spotter as per the Safe Work Directive, that person will maintain ½ hour check ins with crew along with lookouts, base camps, zone staff or Fire Centre, whichever is most applicable. Monitor for appropriate behavior and listen carefully for any signs which could indicate H_2S exposure (changes in behavior or speech pattern, irrational conversation, any complaints which may indicate exposure.) If symptoms appear or the level 10 (PPM) alarm sounds, have the crew leave the area uphill and upwind immediately, and advise the F.C.O. A professional consultant will be brought in to determine the extent of the affected area. The fire control plan will then be adjusted accordingly based on his/her findings.

H_2S & Geophysical Operations Awareness

5. GLOSSARY OF TERMS

Airshack - A small airtight “shack” found on sites which may have sour gas present. These buildings closely resemble a shipping container or small mobile trailer.

Battery site - A collecting site where gas from several sites may be pressurized, de-iced or. have additives introduced, and then sent into the main pipeline system

Capped well - A cutoff stem and control valve that is placed at the top of a producing well.

Christmas tree - A wellhead or capped well.

Compressor Station - A facility on a pipeline used to compress and accelerate gas flow.

Dehydrator station -A Facility used for removing moisture from gas flowing through Pipelines.

Flare stack -A vertical pipe where sour gas is bled off to and ignited to "flare" off or burn.

Flare pit -A horizontal pipe that dead ends into a pit where sour gas is bled off to and ignited.

Geophone - A portable electronic listening device used on seismic lines to sense and record reflective signals.

Heliportable - An exploration operation that uses helicopters to transport equipment from site to site. These are usually low elevation, sling and longline operations, where it is quite probable that the pilot will **not** be monitoring an F.S. frequency.

H_2S. -"Hydrogen Sulfide". A naturally occurring gas formed by the decomposition of organic material in the absence of Oxygen.

Lease site - See well site.

Map Designator - Geophysical operations utilize National Topographic Series Maps for base maps. Each map is divided into 12 blocks (designated with capital letters A-L). Each block is divided into 100 units. Each unit is divided into 4 quarters (designated with small letters a-d)
I.e. NORCEN LEASE SITE: d-27-H/94-O-10

Pigging station - A station or site along a pipeline where the pipeline can be opened and a cleaning ram introduced ("pig") to clean the pipeline of residues and impurities.

Pipeline -A pipe carrying gas or oil.

Receiver line - A seismic line utilized for receiving and recording seismic signals generated from source lines used in 3D type operations.

H_2S & Geophysical Operations Awareness

Rig - The drilling platform and tower for the drilling operation.

Rollback - Slash that has been spread out or "rolled back" across the seismic line. Generally reserved for areas of open muskeg, willow, Aspen, and Black Spruce with timber diameters under 10 cm.

SCBA - **"**Self Contained Breathing Apparatus" utilized by the gas industry for work / rescue in an environment with hazardous levels of H_2S .

Seismic line -A four to seven metre wide cleared right-of-way of variable length, where

explosive charges are detonated. The recorded "Seismic wave" produces a picture of underground strata which aids in locating sources of oil and gas.

Source line - A seismic line that dynamite charges are drilled and placed in at about 30m Intervals used in 3D type operations**.**

Sour gas **-** Gas that contains Hydrogen Sulphide (H_2S) in concentrations above 10 PPM.

Spraycut - A Slash treatment performed in areas with < 500 stems per hectare. Trees are felled and bucked, with branches lopped and scattered. All slash should be "flat to the ground"

Sump - A cleared pit on a lease site where water containing drilling clays and impurities from the drilling operation is allowed to settle out.

Sweet gas **-** Gas that does not contain Hydrogen Sulphide (H_2S).

Tight hole - A term used to refer to a drilling operation that is under tight security. The parent company of this drilling operation does not want *any party* knowing any of the particulars of this operation (i.e. how deep, or in what direction they are drilling). These sites are marked on the access road. If a crew notices this designation on any site, they should diplomatically explain their presence to the first worker they encounter.

Wellhead - A capped well.

Well site **-** A square clearing where a drill rig is used for drilling for oil or gas. These openings are approximately 1 ha in size and can be a valuable reference for estimating fire size by comparison.

Windrow - Slash from clearing lines, placed in rows that can be up to 400m in length.

Application of Aviation Human Factors to the Fire Service: A New Opportunity for Safety

Randy Okray and Thomas E. Lubnau, II

Crew Resource Management, is a force multiplier – that is to say it acts to energize and synergize elements that already exist in the individual – and multiplies them into a "whole is greater than the sum of its parts.[5] This paper will describe how the aviation concepts of crew resource management can be applied to the fire service to achieve greater efficiency and safety.

Generally, crew resource management refers to the effective use of all available resources, people, equipment, time and information. By effective utilization of these resources to their fullest potential, all of the talents of all of the people and equipment associated with a fire can be used more effectively and efficiently. More efficient utilization of resources enhances the safety, suppression and morale of the crew.

History of CRM in the Aviation Industry

In the late 1970's, an L-1011 crashed in the Florida Everglades. The plane crashed when the flight crew became preoccupied with changing a burnt-out nose landing gear indicator lamp. While they were all working on changing the indicator lamp, they failed to notice that the altitude hold function had been accidentally disengaged, and the plane simply flew into the ground killing all on board.[6] In the same month, a B-737 crashed while attempting a go-around on an approach from Chicago's Midway Airport. The crew became preoccupied because the flight data recorder light became inoperative, and they lost track of where they were. On the initial approach, the crew deployed speed brakes because they were too fast and high and not configured for landing. The pilot decided to go around, but as a result of extreme time pressure, forgot to deactivate the speed brakes, and crashed the airplane.[7] These two crashes served as a wake-up call to the airline industry.

For many years prior to these two incidents, the cause of crashes was equipment failure. But as the equipment became more and more reliable, it became apparent that the human animal was also a cause of accidents in the air. With the leadership of Robert Helmreich from the University of Texas, Richard S. Jensen from Ohio State University, NASA, the FAA, the Air Carriers, and others, uncounted hours of research and millions of dollars have been spent in developing a program which optimized a crews' interactions in times of high stress, little information, where the lives of many people are at stake.

History of CRM in the Fire Service

On July 6, 1994, fourteen firefighters lost their lives on Storm King Mountain, near Glenwood Springs, Colorado. The United States government empanelled a group of high level firefighting experts to examine the cause of the deaths. According to the official report, the direct causes of entrapment on South Canyon were:[8]

---

5. *Major Tony T. Kern, email to CRM Developers Group. April 17, 1998*

6. *Lauber, Cockpit Resource Mangement: Background and Overview, Cockpit Resource Management Training, NASA/MAC Workshop, May 6-8, 1986, p. 6.*

7. *Id at 7*

8. *Report of the South Canyon Fire Accident Investigation Team, August 17, 1994, p. 35-7*

FIRE BEHAVIOR

Fuels

- Fuels were extremely dry and susceptible to rapid and explosive spread.
- The potential for extreme fire behavior and reburn in Gambel oak was not recognized on the South Canyon fire.

Weather

- A cold front, with winds of up to 45 mph, passed through the fire area on the afternoon of July 6.

Topography

- The steep topography, with slopes from 50 to 100 percent, magnified the fire behavior effects of fuel and weather.

Predicted Behavior

- The fire behavior on July 6 could have been predicted on the basis of fuels, weather, and topography, but fire behavior information was not requested or provided. Therefore, critical information was not available for developing strategy and tactics.

Observed Behavior

- A major blowup did occur on July 6 beginning at 4:00 p.m. Maximum rates of spread at 18 mph and flames as high as 200 to 300 feet made escape by firefighters extremely difficult.

INCIDENT MANAGEMENT

Strategy and Tactics

- Escape routes and safety zones were inadequate for burning conditions that prevailed. The building of the west flank downhill fireline was hazardous. Most of the guidelines for reducing the hazards of downhill line construction in the Fireline Handbook (PMS 410-01) were not followed.
- Strategy and tactics were not adjusted to compensate for observed and potential extreme fire behavior. Tactics were not adjusted when Type I crews and air support did not arrive on time on July 5 and 6.

Safety Briefing and Major Concerns

- Given the potential fire behavior, the escape route along the west flank of the fire was too long and too steep.
- Eight of the 10 Standard Firefighting Orders were compromised.
- Twelve of the 18 Watch Out Situations were not recognized, or proper action not taken.
- The Prineville Interagency Hotshot crew (an out-of-state crew) was not briefed on local conditions, fuels, or fire weather forecasts before being sent to the South Canyon Fire.

Involved Personnel Profile

- The “can do” attitude of supervisors and firefighters led to a

compromising of Standard Firefighting Orders and a lack of recognition of Watch Out Situations.
- Despite the fact that they recognized that the situation was dangerous, firefighters who had concerns about building the west flank fireline questioned the strategy and tactics but chose to continue with line construction.

Equipment
- Personal protective equipment performed within design limitations, but wind turbulence and intensity and rapid advance of the fire exceeded these limitations or prevented effective deployment of fire shelters.
- Packs with fusees taken into a fire shelter compromised the occupant's safety.
- Carrying tools and packs significantly slowed escape efforts.

The investigation was very extensive, but Ted Putnam, PhD, felt the report omitted his concerns regarding human factors, and he refused to sign the investigation report.[9] His conclusion, issued in a separate report was as follows:

> The fatal wildland fire entrapments of recent memory have a tragic common denominator: human error. The lesson is clear: studying the human side of fatal wildland fire accidents is overdue.
>
> Historically, wildland fire fatality investigations focus on external factors like fire behavior, fuels, weather, and equipment. Human and organizations failures are seldom discussed. When individual firefighters and support personnel are singled out, it's often to fix blame in the same way we blame fire behavior or fuels. This is wrong headed and dangerous, because it ignores what I think is an underlying cause of firefighter deaths – the difficulty individuals have to consistently make good decisions under stress.
>
> There's no question individuals must be held accountable for their performance. But the fire community must begin determining at psychological and social levels why failures occur. The goal should not be to fix blame. Rather, it should be to give people a better understanding of how stress, fear, and panic combine to erode rational thinking and counter this process. Over the years, we've made substantial progress in modeling and understanding the external factors in wildland fire suppression and too little in improving thinking, leadership and crew interactions.[10]

Dr. Putnam also pointed out the results of an extensive 12-year study of Forest Service field crews conducted by sociologist Jon Driessen (1990) showed there is an inverse correlation between crew cohesion and accident rates. The study also identified factors fostering cohesion. Driessen found it takes about 6 weeks for good crew cohesion to take affect. So firefighting crews are predisposed toward accidents until they become cohesive units. Unfortunately, this type of information is not normally considered even when sending crews to more risky fires.[11]

---

9. *MacLean, John, Fire on the Mountain, William Morrow & Company, Inc., 1999, p.231*
10. *Ted Putnam, Ph.D: The Collapse of Decisionmaking and Organizational Structure on Storm King Mountain, February 15, 1995*
11. *Id.*

Dr. Putnam's recommendations served as a wake-up call to the wildland branches of the fire service. And although the service is slow to wake up, the movement is gathering steam.

In 1995, the Forest Service, under the direction of Dr. Putnam, convened the Wildland Firefighters Human Factors Workshop. The recommendations of that workshop include, amongst other items, to contract to have CRM course materials adapted to the fire service, to identify skills necessary that are unique to the fireground environment, develop decision making examples suitable for wildland firefighters, examine how stress and other environmental and psychological factors affect decisions, develop a situational awareness class and determine critical cues and how to accelerate the training of inexperienced firefighters; develop a leadership course for IC's and crew supervisors, implement assessment and develop methods to speed up crew cohesion and work practices before fireline assignments, and contract to have professionals provide guidance in setting procedures for collecting and disseminating lessons learned from fireline duties and entrapments.[12] After the Human Factors Workshop, the United States Forest Service, the Bureau of Land Management, the Bureau of Indian Affairs, the Fish and Wildlife Service and the National Park Service, through NIFC, commissioned the Tri-Data study. With 86 goals and over 200 specific recommendations for improving the organizational culture, leadership, human factors, and external influences that affect wildland firefighter safety, the Tri-Data Study has met the requirements of the NWCG for identifying what needs changed in the underlying organizational culture of wildland fire.

Quotes that came from the survey of 1,000 mostly federal firefighters included:

> "We understand the science of fighting fires, but we do not understand the science of people fighting fires."
>
> "One in five division supervisors is really scary."

This study attempted to identify the good and the bad of our current Wildland Fire Organizations and Operations and then plot a course for a 'Future Culture.' With the results of this study, we have the tools to make the culture of wildland firefighting a self-learning, self-correcting system.[13]

The recommendations of the Tri-Data Study with respect to CRM are very clear:

This report contains several references to Crew Resource Management (CRM) Training as a potential solution to several problems, including improving crew dynamics. CRM is a model for cultural change that has been used in the aviation environment since the 1970's; it has been effective in improving operational efficiency and reducing safety problems. It is one of many tools the agencies should employ as part of a comprehensive strategy to change their organizational safety culture.

Participants of the 1995 Wildland Firefighter Human Factors Workshop devoted a considerable amount of their effort to exploring the wildland fire applications of CRM and recommended that CRM-type training remedies be applied to strengthen crew and crew member performance in the wildland fire environment. CRM training directly addresses many aspects of human performance and crew dynamics, including communication, decision-making, leadership, situational awareness, and barriers to these processes such as conflict and potentially hazardous attitudes. The goals of CRM training are to improve crew effectiveness, reduce the occurrence of error, and improve safety.

CRM training focuses on individual performance and attitude. The resulting attitude changes are effective because they both directly assist the crew member in working within the crew and present an example for others. CRM training helps each crew member think about his or her individual situation, including job

---

12. *Findings from the Wildland Firefighters Human Factors Workshop, USFS, November 1995, p. 17-18*
13. *Wildland Firefighter Safety Awareness Study-Highlights of Recommendations, Tri-Data Corporation, March 1998*

duties and barriers to performing those duties. They help them develop individual strategies for combating potential safety problems caused by human error.

History of CRM—CRM originally stood for Cockpit Resource Management. It was first coined for training crews to reduce pilot error, and make better use of human resources. A NASA research project found that many air crashes resulted from failures in interpersonal communication, decision-making, and leadership, and this training concept was a response.

The first comprehensive CRM course was started by United Airlines in 1981. It was derived from corporate management development training. It emphasized changing individual styles and correcting deficiencies in individual behavior such as a lack of assertiveness by juniors and authoritarian behavior by captains. Starting about 1990, the airlines included other aircraft crew members in the training, and renamed it CREW Resource Management.

CRM then was adapted to other industries, including medicine, engineering testing, maintenance, and offshore oil exploration. CRM also became more specialized in aviation, addressing problems such as flight deck automation. The Federal Aviation Administration now requires that CRM concepts be integrated into the airlines' technical training curricula. This resulted in the development of aircrew target behaviors and skills, which the airlines now include in operational procedures and checklists.[14]

The Tri-Data Study clearly encourages the development of CRM programs for the fire service.

In response, and a part of Phase IV of the Tri-Data program, and the SAFE initiative, NIFC is currently in the process of developing and testing a "Human Factors for the Firefighter" course. Jim Cook with the National Park Service has developed a very good four-hour course, which is presently up for NWCG approval. The plan is to offer it to all line-level firefighters.

There are other CRM training efforts in the fire service. Most of the information on those programs has not been made available to us. Chief Jack Rutledge is developing a communications program for his department. Dr. Patrick R. Veillette, a smoke jumper pilot has written extensively about the topic and has offered training on the subject. IAFC has started a CRM for the Fire Service Initiative, and NFA has begun to address the topic. There are others, we believe, who are training on these concepts, but a unified effort nationwide to adapt these principles to the firefighting service has yet to be made.

History of CRM in the Campbell County Fire Department

The 1994 tragedy at Storm King Mountain had a deep and lasting effect on the psyche and personality of the firefighters of the Campbell County Fire Department. Firefighters on this department had fought fires side by side with those who are now dead. Their loss was not going to be without meaning. Dr. Putnam's independent report, and the findings of the Wildland Firefighters Human Factors Workshop caused the department leadership to think about these new aviation concepts and their application to the day-to-day firefighting routines.

After some extensive lobbying with the Campbell County Fire Board, members of the department were allowed to attend the Ninth and Tenth International Symposiums on Aviation Psychology, held by Ohio State University in Columbus, Ohio.

Gradually, CRM concepts were introduced into the department. The introductions were made slowly, at first. Real life examples served as lessons.

---

14. Wildland Firefighter Safety Awareness Study, Phase III, Tri-Data Corporation, March 1998

For example, one of the behavioral concepts embodied in CRM principles is when a leader becomes overloaded with information and input, that leader reverts to prior over learned behavior to cope with the situation. When such reversion occurs, it is a clue to other firefighters on the team that the leader is losing situational awareness, and needs to take a step back and evaluate what is happening. On one particular fire in our department, apparatus on a particularly nasty and remote fire suffered mechanical difficulties and road blockage as a result of fallen trees. The command officer of the fire, a former hotshot for the USFS, became overloaded with information and stress as a result of the equipment breakdown. Instead of maintaining control of the overall fire scene, he reverted to his prior over-learned behavior, and took a chainsaw and began to cut the trees blocking the road. While other people on his crew were perfectly able to cut the trees, he reverted to this behavior.

In a debriefing after the fire, this behavioral manifestation gave credence to the principles the training department was trying to teach. As more real-life examples developed, there became more and more buy-in by the department.

In 1999, the department leadership authorized a five module course be developed, covering situational analysis, communication, leadership, followership, and decision-making. The five modules were offered and the organization began to adopt the principles as part of the organizational culture. Now, the concepts are intermeshed with training on other subjects. No specific CRM training is offered or is necessary, now, because the principles are ingrained in other department courses, and are becoming a part of the organizations culture and language.

In our initial Situational Awareness class, the command level officers were amazed to learn junior firefighters would not tell a command officer about a dangerous situation even though there was great risk of life or serious bodily injury. The day the CRM training proved that it was ingrained into our organizational culture was when, on a recent wildland fire, a command officer made a tactical decision to go direct on a fire. One of the probationary firefighters asked the command officer if he would like to rethink his decision in light of the fuel model and the wind. The command officer took the suggestion, evaluated it, and changed the tactic. For this interaction to have occurred, both parties had to divest themselves of ego and status, and to focus on the good of the overall mission, not on the position within the service. When this type of interaction can truly occur, then, the culture of the department has changed from a group of individuals working to fight a fire, to a team, utilizing all of their resources and talent, to work as a team to accomplish a task.

Elements of a Crew Resource Management Program

A properly structured Crew Resource Management Program focuses changing individual behaviors so that the group of individuals can operate more effectively as a team. CRM is designed to optimize the interpersonal interaction to facilitate problem solving, decision-making, situational awareness and team building. The elements of a CRM course are Situational Analysis, Communications, Leadership, Followership and Decision Making.

Situational Analysis

Situational Analysis is the skill of becoming aware of the situation, as it actually exists. Usually, there is a huge difference between how someone perceives the situation and how it actually exists. Situational awareness training teaches the skills necessary to utilize resources to determine how the situation actually exists, and more importantly, teaches the signs and symptoms of when situational awareness is being lost.

The wildland firefighting community does a good job of teaching its firefighters the dangerous situations for which to look on the fire ground. All firefighters are given basic courses on weather, fuel models, terrain, and fire behavior. The eighteen watchout situations are ingrained in every firefighter, and are carried on the inside back cover of the Fireline Handbook.[15] Firefighters are trained to have lookouts, communications, escape routes and safety zones, and until all of those elements are adequate, the firefighting operations should not be conducted.

But even with all that training, there are still burn-overs~~burnovers~~ and accidents, and people are hurt and killed because they failed to follow the standard fire orders.[16] CRM training of the firefighters should not only include what the dangerous situations are the firefighters should avoid, but also, what the clues are to loss of situational analysis. Factors like complacency, high stress level, ambiguous instructions, unresolved discrepancies, lack of experience, lack of communication or coordination, fatigue, lack of adequate weather information, emotional pressure, fixation, and just a bad gut feeling are clues that situational awareness is being lost.

The firefighter should be taught when these elements start to arise, it is time to take a step back and evaluate what the situation is and what the plan is if things start to go wrong. Periodically, throughout any operation, the firefighter should ask 1) am I aware of what is going on around me; 2) are things happening like they are supposed to happen, 3) if they are not, why aren't they, and 4) if things go really wrong, what is the plan; 4) does the leader know the answers to all of these questions?

If the answers to the above questions are unsatisfactory, all firefighters should be given the authority to completely stop any operation in which they are participating until satisfactory answers to the questions can be given.

Communications

As emergency workers, we depend on a system of communications. Not actual hands-on systems like radios, repeaters, etc., but the way we communicate. We should have systems that deal with how, what, and when this transfer of information takes place. Keep in mind that all the equipment in the world won't cure a bad communicator. Crew Resource Management has addressed a system of communications that includes: Inquiry, advocacy/challenging, listening, conflict resolution, and critique. This is the basis of all cockpit communications among pilots and now is adapted to the Fire Service.

When humans communicate there are some 'agendas' that we all have and need to be aware of:

- We tend to protect, maintain, and enhance ourselves when we communicate.
- We defend against looking ignorant or foolish for fear of ridicule.
- We wish to maintain consistency; we tend to support our opinion even when we suspect that we may not be totally correct.
- We wish to feel valued, worthwhile, belonging and meaningful. This means that we must be acknowledged with respect and trust.
- Reality is second to perception—and our mind set may be very difficult to change.
- People behave according to their perceptions; may not be aware of the level of risk.
- Emotions always take first place, feelings are the facts.
- Commitment comes from self-determination, people have their own motivations.

15. *NWCG Fireline Handbook, January 1998*
16. *Id.*

The key elements to Effective Communications are:

Inquiry: In the fire environment we gather information many different ways. We feel what the weather is doing, we look at the flame lengths, and we hear the winds and fire. We also look to other firefighters to build our information base. Never be embarrassed to ask a question no matter what level of training or what rank you have. What you don't know could kill you. Your pride will often be restored when a fellow firefighter reinforces information or corrects misinformation and respects you even more for asking them for input. To clarify an order or expected action is always a right of any firefighter at any level. If I don't understand what I'm supposed to do, how am I supposed to do it?

Advocacy: This is the part that makes everyone nervous. For years we've been told, or told someone else, "Don't talk back to me." Now, we're changing the rules of the game and saying to everyone who disagrees with a decision (course of action) to advocate their position. We must do this respectfully. A skilled firefighter knows that they don't have all the information or the proper perspective on the incident all the time. Therefore, they should expect some feedback on decisions. In fact, in the last discussion our department had regarding Advocacy, numerous Command Officers expressed personal concern that firefighters didn't feel like they could advocate their position.

Feedback/Monitoring: The process of keeping track of your actions. This is especially important to do after an Inquiry or Advocacy statement or discussion. If you make a mutual decision and then nobody monitors the outcomes or the process it is very likely that the outcome will not turn out as expected.

Conflict Resolution: Conflict is a normal part of group interaction. All personnel in the team must expect that conflict will occur, even in highly organized and effective teams. The number one item to remember is; "What is right, not who is right." Respectful interaction and rational thinking, void of any inappropriate influences (such as race, culture, religion, personal feelings, etc.), will lead to a successful resolution to any conflict.

For example: You are on a wildland fire and you notice a large column of smoke just over a small rise. The terrain and the wind could push that fire right up to where you and your partner have your truck. You call your division and ask what is happening. **(INQUIRY)** He states that they started a blackline operation. You speak up and tell the Division that you are between the main fire and the set fire. **(ADVOCACY)** Division says he's not sure where you're at but that you should be alright. You state that you are in a difficult spot and the fire is going to come your way due to the terrain and the winds. **(ADVOCACY)** Division still says that it should probably be alright. You state that you feel that if you stay there you will be trapped due to the access and the fire behavior; and, that you'll be pulling back to a safe area. **(ADVOCACY, Self-directive)** After you state that you are leaving your assignment it finally sinks in to the Division that you are not comfortable. He tells you that he is stopping the blackline operation and that you should be alright to stay where you are. You agree and stay. Fifteen minutes later you still see a large column of smoke. **(MONITORING)** You call Division and ask if he can see it and what's going on. **(CHALLENGING)** He states that they just had to finish up this little corner and they are almost done. You get in your truck and leave immediately. **(ADVOCACY, SAFETY ISSUE, VIOLATION OF SOP'S—LCES)**

Leadership

The militaristic methods of 'I command and you just shut up and do it' do not provide for the complexities that we see today—especially in the Fire Service. As a matter of fact, one of the leading war fighting agencies in the world is now training the exact opposite. The United States Marines are training their personnel to discuss objectives instead of giving 'orders.' This is called Mission Emphasis. They allow their teams to perform what they call an 'OODA Loop'—Observation, Orientation, Decision, and Action. By allowing teams to make decisions to meet a Mission Objective they have a quicker OODA Loop, which

Command is about Authority.
Leadership is about people.
Management is about things. 18

translates into victory on the battlefield. Basically, the Marines have de-centralized their command structure and given leadership responsibilities to their working teams instead of their 'Brass.'[17]

In a world—and a profession, full of shifting paradigms, it is essential that we utilize Crew Resource Management to encourage and support the Leaders in the Fire Organization. With so many duties, so much training, the increasing complexity of incidents, the continued request for more services, and dwindling time for any of it, we must support Leadership in an entirely different way than we have in the past. As members of a Wildland Fire Organization we must all adopt the philosophies of CRM Leadership.

Before we go much further we need to set something straight. Leadership is a far cry from Management and Command. In a nutshell:

Although many Command Positions depend largely on Leadership Skills and Abilities it is not necessarily a direct correlation. There are people who are in command of incidents who have no leadership training, experience, or skills. Competent commanders utilize many different Leadership Styles to accomplish their goals. Inexperienced Commanders usually utilize only one or two styles of Leadership no matter what the situation. That creates team problems because the style doesn't fit the event.

At the heart of Crew Resource Management is effective Leadership. Each member of the Fire Organization must realize that they have a leadership responsibility that is important to effective decision-making, incident stabilization, and safety. No matter what role or position you occupy on the incident you must learn to become a leader, and perform, like a leader.[19] Most people believe that Leaders are born, not made. That is untrue in many respects. Many 'Great Leaders' are in the right place at the right time and the particular situation fits their Dominant Leadership Style.

A leader is a person whose ideas and actions influence the thought and the behavior of others.
This is accomplished through the use of examples, persuasion, and an understanding of the goals

Effective Leadership on the fireground is one of the keys to safely accomplishing the firefighting mission. Utilization of all of the talents and resources of the team, through leadership, is the heart of CRM training. But a leader is only as effective as the followers.

Followership

Perhaps the most under trained aspect of the fire service is how to become an effective follower. Recently, we conducted training for our department. Eighty percent of the junior firefighters reported they would not report a dangerous condition to command, even though it might affect firefighter safety. Ninety five percent of the command officers developed ulcers. The reason for failure to report was that the junior firefighters believed command already knew, and did not want to hear input from a junior firefighter.

The aviation industry has found junior officers on flight crews tend to wait too long to report dangerous situations, and when they do report, the tend to either overestimate or underestimate the consequences

We have found this situation to be true in the departments to which we have offered training. Followership training teaches a junior firefighter how to maintain situational awareness, and when a dangerous situation is developing, to speak up. Followership training spreads the responsibility for outcomes from the leader to the whole crew, and teaches the regulation of information flow so important information gets to the command officer while weeding out extraneous information.

[17.] *Hayden, Lt. Col. H.T., Warfighting: Maneuver Warfare in the U.S. Marine Corps, Greenhill Books, 1995*
18 *Loeb, Marshall & Kindel, Stephen, Leadership for Dummies, IDG Books Worldwide, Inc., 1999*
[19.] *Wildland Firefighter Safety Awareness Study, Phase III, Tri-Data Corporation, 1998*

The effective follower should complete a thorough self-examination, including a complete self-evaluation of physical condition (illness or physical conditioning), mental attitude (am I prone to hazardous attitudes that will get me in trouble), psychological conditions (do I have any personal problems which will interfere with my performance), and an evaluation of the leader for the same condition. Additionally, the good follower needs to be adept and receiving and interpreting information and instructions, teamwork skills and making decisions together.

Finally, the follower should be trained in the communications skills necessary to interact with a leader, that is the advocacy/feedback/conflict resolution communication model explained above. The follower should have enough information and training to recognize the leader's authority, but to question decisions and point out critical pieces of information to the leader. By utilizing the eyes, ears and brains of the leader, by effective use of the follower, the team becomes synergistically more efficient and effective.

Decision Making

As more research is conducted, accidents and incidents investigated, and people attempt to accomplish more on the fire ground, we are beginning to understand that our old way of looking at how people make decisions are probably wrong. Many new theories are being applied to firefighters and other high-risk professionals. Most notably is the Theory of Naturalistic Decision Making (NDM).

"The study of NDM asks how experienced people, working as individuals or groups, in dynamic, uncertain, and often fast paced environments, identify and assess their situation, make decisions and take actions whose consequences are meaningful to them and to the larger organization in which they operate."[20]

Klein describes the problem situation as having four important characteristics: dynamic and continually changing conditions, real-time reactions, ill-defined goals and tasks; and the knowledgeable participants.[21]

We must train our firefighters to utilize their training and experience to first judge one critical factor—Time Pressure. Many times firefighters make decisions based on NDM because of a perceived lack of time. When, actually, they had enough time to gather more information, come up with options, and discuss the decision with peers. Many decisions are made 'from the hip' because of the perceived time constraints. But, when time pressures are real, NDM is a great idea.

Future of CRM in the Fire Service

Crew resource management has been mandated, by law, for the aviation industry. The time has come for it to be adopted by the fire service. However, for CRM principles to be adopted by the fire service, a whole new mind set and organizational culture will need to be instilled, from the top, down. Modifying an organization from a military and authoritarian leadership style, to that of a team takes extensive training and a courageous release of control by those in command. The application of the old saying, "Only the lead dog has a good view" to the fire service has had its time, come, and go. The fire service needs to take on a new, and tried approach, that takes advantage of all the skills and senses of the entire team, not just that of the leader. For the adoption to be effective, leadership will need to buy into the concepts completely. We have been fortunate in our department because we have that leadership buy-in. What our leaders have found is their workloads have become more manageable, because the team members are making their own tactical decisions. The leaders focus on strategies.

However, we are perfectly aware of the fire service motto, "Two hundred years of tradition, unimpeded by progress." We expect the transition to CRM thinking will be a difficult, but necessary road to travel.

[20.] *Zsambok, C. (1997) Naturalistic Decision Making: Where are we now? In C.*
[21.] *Klein, G.A. (1993), A Recognition-Primed Decision model of rapid decision making. In G. Klein, J. Orasanu, R. Calderwood & C. Zsambok (eds.), Decision Making in Action. Models and Methods. Norwood, NJ: Ablex.*

In addition to leadership buy-in, there is a need for additional scientific research on the psychological impact and behaviors of firefighters in firefighting situations. Firefighters are constantly placed in a rapidly changing situation, with all types of information, where the information is incomplete, time pressure is great and the consequences of the decision are dire. These types of situations are not common to the human experience.

Finally, a training in these concepts for all firefighters, as well as reinforcement from leadership, is necessary.

The time for CRM application to the fire service has come. Additional delays will cost lives and property.

Vehicle Burnovers: Design of Protective Fire Curtains and Enclosures for Crew Protection

Dr. Bruce R. Paix[1] and Jim E. Roth[2]

[1]Country Fire Service, Macclesfield Brigade, Box 72, Echunga, South Australia 5153, Australia
e-mail 461616@picknowl.com.au
[2]Storm King Mountain Technologies, 2311 W. Silver Lake Drive, Los Angeles, CA 90039
Tel. +1.323.666.6784; Fax +1.323.665.2201; e-mail j_roth@stormkingmtn.com

Abstract: Vehicle “burnovers”, or the over-running of fire apparatus by wildfires, are periodic occurrences in fighting fires with engines, tankers, bulldozers or tractors. Such incidents regularly kill or injure crews throughout Australia and North America. Crew safety in these situations can be improved if suitably designed protective fire curtains or enclosures are used to prevent the entry of flames, radiant and convective heat into the firefighters cab or Roll Over Protection System (ROPS) area. This paper discusses the design and proposed performance requirements for protective window curtains and enclosures for use during fire apparatus burnovers. A result of this paper will be the ability for fire fighting organizations to provide potential manufacturers of firefighting apparatus, the needed specifications for burnover protection curtains and enclosures.

This paper discusses the vulnerability of windows in real world burnovers and provides a review of experimental data in various fuel types in wildland fires. Based on this documentation, the paper discusses the alternative technology for burnover protection, and illustrates several examples of using protective fire curtains and enclosures to increase firefighter survivability. It also provides a recommended specification for fire curtains and enclosures for wildland firefighting vehicles, which is shown below.

To review the complete paper on line, view it at the conference home page at:

Or at :

www.stormkingmtn.com

Fire Curtain Specifications

Rationale

a) Experimental and real world data suggest that large amounts of thermal energy may enter the cabin of a fire appliance during a burnover via the window apertures because:

1. Approximately 50% of radiant heat incident on a pane of automotive glass is transmitted through the glass.
2. Fracture of the window glass is possible during a burnover.
3. Rubber or aluminium window mouldings can give way in extreme heat, allowing the window to fail.

b) Experimental and real world data have also shown that suitably designed reflective and thermal insulating curtains inside the vehicle cabin can reduce the entry of heat via the windows by:

1. Reflecting radiant heat back out through the glass.
2. Stopping flame entry through the window openings even if the window glass does fracture.

Therefore, suitably engineered window curtains may significantly improve the chances of survival for crew members sheltering within the cabin of an appliance during a burnover. Such protective curtains should be designed and constructed so that:

a) They are both flame resistant and reflective of radiant heat.
b) They are sufficiently flame and heat resistant that, when the outer surface is exposed to flames with a thermal loading of $100kW/M^2$ for 2 minutes:

    1) the fire curtain cool side, inner surface temperature must be less than 500°F (260°C) during the test.
    2) no burn through of flames occurs through to the inner curtain side.
    3) during the first thirty (30) seconds of running this test, some smoke is allowable to remove residual oils and sizing compounds added during the manufacturing process.
    4) the curtains are to be designed to minimize any out gassing or toxic smoke occurring in the inner layer.
    5) the use of adhesives, rubber or silicones are not permitted on the inner curtain layer.

c) The window curtains should be sufficient in number and large enough that, once deployed, they must overlap all of the glass window, window mouldings, and any adjacent door seals of the vehicle cabin/crew refuge area.

~~d)~~They are able to be fully deployed from within the cabin/crew refuge area within less than 30 seconds while wearing gloves, with final securing of minor air gaps afterwards by crewmembers.

e) Once deployed, the curtains must be affixed to the vehicle structure so there is no air gap above or to the sides of the curtains which may allow smoke or flames to reach around the curtain. The curtains are to be designed so that when deployed, curtains must be attached and secured to block flames from reaching around the curtains.

f) Curtains are to be flexible to allow a side to be slightly unsecured and folded back to allow a crewmember to look outside to monitor fire conditions, without having to raise the entire curtain and be exposed to unnecessary heat and flames.

g) when not in use, they can be stowed so as to allow largely unimpeded vision through the window concerned.

h) Curtains designed to be installed on the exterior of the vehicle in weather conditions are to have a protective flame resistant outer cover, or apron to provide long life.

i) The curtains are to be designed to provide long life with normal “wear and tear” in service and with periodic use in safety training with no allowable delamination of the outer reflective layer, or degradation of the thermal insulating performance due to the use of age sensitive materials.

* * *

Wildland Firefighter Load Carriage: Effects on Transit Time and Physiological Responses During Simulated Escape to Safety Zone

B.C. RUBY[1], G.W. LEADBETTER III[2], and D. ARMSTRONG[3]

[1]THE UNIVERSITY OF MONTANA, MISSOULA, MT
[2]MESA STATE COLLEGE, GRAND JUNCTION, CO
[3]NATIONAL NAVAL MEDICAL CENTER, BATHESDA, MD

Address for correspondence:

Brent C. Ruby, Ph.D.
Director, Human Performance Laboratory
Department of Health and Human Performance
McGill Hall
The University of Montana
Missoula, MT 59812
(406) 243-2117
ruby@selway.umt.edu

Abstract. The purpose of this investigation was to determine the effects of load carriage on transit time during simulated escape route evacuation. Subjects (8 males, 82.2 kg; 5 females, 65.8kg) completed two maximal field hikes in random order on two successive days; one with (35 lb line gear pack and one without a field pack. Field trials were completed on a dirt trail 2,172.2 ft (660.5 meters) in length with a vertical gain of 450.7 ft (137 meters; average grade = 20.75%) on Storm King mountain. Each trial required subjects to carry a calibrated portable metabolic system (Cosmed K4 orAerosport VO2000), a fire shelter, and a Pulaski. Blood samples were collected prior to and 2 minutes post exercise for lactate analysis. Data were analyzed using a 1 between, 1 within (2x2, gender x trial) mixed design ANOVA with repeated measures and planned comparisons.

	Time Min	Mean VO2 ml/kg.min	Peak VO2 ml/kg.min	HR bpm	Lactate peak-rest (mmol)
Pack					
Male	10.7	41.1	48.6	181	9.8
Female	13.7	32.5	42.5	188	5.8
No Pack					
Male	8.4*	46.0*	52.1*	177	5.8*
Female	10.1*	35.1	41.1	188	5.8

* p<0.05 vs pack trial

Transit time was significantly faster during the no pack trial, representing a 21.5 and 26.3% faster transit time for males and females respectively. For the males, mean VO2 was higher during the no pack trial. The difference in blood lactate (peak - rest) was significantly higher during the pack trial for the male subjects. Similarly, ratings of perceived exertion (RPE) were significantly higher for males during the pack trial (19.8 vs. 18.7 for the pack and no pack trials). In contrast there were no differences in RPE for the females (20.0 vs. 19.6 for the pack and no pack trials). High correlation's between peak VO2 and transit rates were noted (r = 0.82 for the pack trial and 0.87 for the no pack trial), indicating the contribution of aerobic fitness to transit time. These data indicate that load carriage will significantly impede ground travel during a forced evacuation. Finally, the results support the recommendation that wildland firefighters should abandon their packs during emergency escape to an established safety zone.

Introduction

Since 1975 the United States Forest Service has required a minimal level of fitness for those employees actively involved in wildfire suppression (Sharkey, 1999). Initially, the step test was used to assess job readiness. In 1998, the pack test was introduced as a more job-specific standard of work capacity. This physical standard is meant to serve as a minimal level of work capacity (including muscular strength and endurance) for the wildland firefighter. Regardless of the physical standards, wildfire suppression remains a high-risk occupation. During 1990 – 1998 there have been 133 fire related deaths. These deaths have included aircraft accidents (30), heart attacks (28), motor vehicle accidents (25) and the burnovers of ground crew personnel (Dude Fire – 6, South Canyon – 14).

Fire behavior researchers, firefighters and authors have noted parallels between two of the major fire tragedies in the west. These fires include the Mann Gulch Fire (1949) in Montana and the recent South Canyon fire on Storm King mountain (1994) near Glenwood Springs, CO.

Although there have been official investigations surrounding the two fires (including fire behavior, the use of the fire shelter and the human element of decision making), the metabolic cost of "escape" has received little attention. Indeed the combination of the two disasters has altered policy and stimulated extensive research in the area of fire behavior. The goal of recent and current research has been to reconstruct events, improve tactical strategies and to develop safer techniques so that future tragedies can be prevented.

The lessons learned from the South Canyon fire have lead to a more comprehensive understanding of fire behavior, ground fuels, and the ever present human factor. In the aftermath of South Canyon, crews and supervisors became more particular regarding assignment of personnel and expressed a new enthusiasm for the standard fire safety orders.

In the wake of the South Canyon fire, controversy surrounding human factors surfaced again and again. Many of these are discussed in the executive summary and even in the book by John N. Maclean, , "Fire on the Mountain: The True Story of the South Canyon Fire." One of the issues that haunted investigators included a minimal sense of urgency among the firefighters during the early evacuation of the west flank line, and the fact that the attempted escape to a defined safety zone was done while carrying full line gear (pulaski or chainsaw, pack and fire shelter). The Missoula Technology and Development Center contemplated the effects of retaining line gear

Figure 1. **South Canyon layout of the west flank line and other landmarks. Image from executive summary.**

(pack and hand tools) during an escape. The additional load may hinder their progress along the escape route and ultimately affect their survival.

Concerned investigators estimated the energy demands associated with load carriage. Sharkey and Putnum (MTDC) originally estimated that the hiking speeds would be significantly slower (by 15-20%) in response to carrying a standard line gear pack (Roth, 1968). They further suggested that the decrement could be as high as 30% with an increase in speed and slope.

The purpose of this investigation was to determine the effects of load carriage on the physiological responses to a simulated escape to safety zone in males and females.

Methods

Location

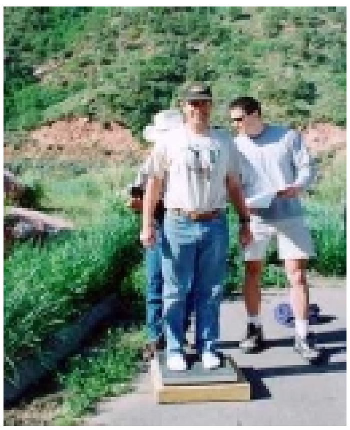


Figure 2. Subject Weighing

The present investigation included eight males (82.2±8.4 kg) and five females (65.8±6.5 kg). All subjects were weighed the morning upon arrival to the base parking area near Storm King Mountain (0730) using a digital laboratory scale. After an initial hike into the west drainage, a base camp was established on the established hiking trail near the location of the 1610 spot fire (see Figure 3).

Using the established trail, a course was measured and marked ending near the original H-2 (see Figure 3). The course measured a distance of 2,172.2 feet (660.5 meters) with a vertical gain of 450.7 feet (137 meters; average grade = 20.75%).

Testing Protocol

Subjects completed two maximal field hikes in random order on two successive days over the course described above. One field trial was completed carrying a 35-pound pack, a pulaski and a fire shelter (Pack). The second trial was completed over the same course without the pack but with the pulaski and fire shelter (No Pack). Subjects were instructed to maintain a maximal effort for the duration of the hike and were encouraged along the course by two to three spotters. During each trial, subjects wore a calibrated portable metabolic system (Cosmed K4 or Aerosport VO_{2000}). Subjects completed both trials with the same metabolic system. Expired air samples were continuously monitored and averaged using breath by breath (Cosmed K4) or 15 second averaging collection cycles during the entire test. Prior to each trial, the metabolic samples were calibrated using medically certified calibration gas (16.2% O_2, 5.17% CO_2). Pneumotach flow (for measures of expired volume) was calibrated prior to each trial using a 3 liter calibration syringe.

Figure 3. **View of the west drainage near the established base camp for data collection. Each field trial was initiated near the location of the 1610 spot**

Heart rate was continuously monitored using a chest strap heart rate monitor (Polar) set to average 60 second values for the entire trial. Arterialized blood samples were collected from a finger tip prior to and at 2-minutes post exercise for blood lactate concentration.

Figure 4. **Blood lactate measurements were conducted before and after each trial.**

A

B

Figure 5. A) Subject nears completion and approaches the designated finish spot near H-2. **B)** Subject completing a "No Pack" trial. Rating of perceived exertion and blood lactate were collected immediately after and 2-minutes post exercise, respectively.

Blood lactate was analyzed on site using a portable lactate analyzer (Accusport). At the end of each trial, subjects were instructed to provide a rating of perceived exertion using a standardized 6-20 scale (6 = very, very light to 20 = maximal effort).

Statistical Analyses

All data were analyzed using a 1 between (sex), 1 within (trial) mixed design ANOVA with repeated measures and planned comparisons.

Results

For both males and females, the additional load carriage during the Pack trial resulted in a significantly slower total time (minutes) and average hiking pace (ft/sec) compared to the No Pack trial (see Table 1). With the pack, males had a finish time that was 2.3 minutes slower compared to the No Pack trial. Similarly, the females demonstrated a 3.6 minute deficit with the added carriage weight of the pack. Although the decrement in finish time was slightly higher in the females (likely a function of body size), it was not statistically different from the males ($p=0.0653$).

Table 1. Variations in finish time and calculated rates of travel during the Pack and No Pack trials.

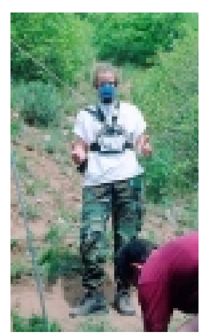
	Pack	**No Pack**
Males		
Finish Time (min)	10.7±1.4	8.4±0.7*
Average pace (ft/sec)	3.42±0.44	4.35±0.37*
Females		
Finish Time (min)	13.7±1.3	10.1±0.6*
Average pace (ft/sec)	2.66±0.24	3.60±0.23*

* $p<0.05$ vs. Pack

The average rates of oxygen consumption during the trials were higher for the males during the No Pack trial compared to the Pack trial. In contrast, there were no differences in average oxygen consumption between the trials for the female subjects.

Table 2. Variations in mean and maximal oxygen consumption (VO_2) and energy expenditure (kcals/mn) during the Pack and No Pack trials.

	Pack	**No Pack**
Males		
Average VO_2 (ml/kg/min)	41.1±6.0	46.0±6.1*
Peak VO_2 (ml/kg/min)	48.6±6.7	52.1±5.8
Average kcal/min	16.8±2.7	18.5±2.9*
Females		
Average VO_2 (ml/kg/min)	32.5±6.6	35.1±4.7
Peak VO_2 (ml/kg/min)	42.5±6.2	41.1±4.8
Average kcal/min	10.6±2.3	11.5±1.8



* $p<0.05$ vs. Pack

There were no significant differences in the average heart rates during the Pack and No Pack trials for the males (Pack=181±6 bpm, No Pack=177±4 bpm) or the females (Pack=188±12 bpm, No Pack=188±15 bpm). Similarly, there were no differences in the peak heart rates during the trials for the males (Pack=188±6 bpm, No Pack=185±4 bpm) and females (Pack=196±14 bpm, No Pack=195±16 bpm). It is interesting to note that there were minimal differences between the average and maximal heart rates for both trials.

Ratings of perceived exertion were significantly higher for the males during the Pack trial (19.9±.3 and 18.8±1.0 for the Pack and No Pack trials, respectively). However, there were no differences in the RPE across trials for the females (20.0±0.0 and 19.6±.5 for the Pack an No Pack trials, respectively).

Figure 6. **Subject prepared for Pack trial**

For the measures of blood lactate, pre trial values were subtracted from the 2-minute post exercise values to obtain a change in the blood lactate concentration for the Pack and No Pack trials. The difference in blood lactate (post-rest) was significantly higher for the male's Pack trial versus the No Pack trial (9.8±4.8 and 5.8±2.2 mmol/L for the Pack and No Pack trials, respectively). However, there were no observed differences in the change in blood lactate for the females across the two trials (5.8±1.7 and 5.8±3.1 for the Pack and No Pack trials, respectively).

The relationship between peak oxygen consumption (VO_2 peak) and average hiking speed (ft/sec) was determined using a simple linear regression analyses. For the Pack trial there was a significant positive correlation (r=.82, p=0.001) between the measure of peak VO_2 and the average hiking speed. A similar positive correlation between peak VO_2 and average hiking speed was also noted during the No Pack trial (r=.87, p=0.0003).

Discussion

Figure 7. **Subject completes the Pack trial.**

The purpose of this study was to determine the physiological variations associated with common load carriage during escape to an established safety zone. The main findings of this study indicate an obvious need to maintain a minimal level of fitness to ensure job preparedness while enhancing overall safety. Our data further supports the current recommended minimal level of aerobic fitness (required minimum of 45 ml/kg/min) established for the step test and the current work capacity test (pack test). Using the regression equation associated with the strong positive correlation between aerobic capacity (VO_2 peak) and finish time, it is possible to calculate the estimated finish times for subjects of varying levels of fitness (See Table 3).

Table 3. Calculated estimates of finish times during the Pack and No Pack trials considering low, current minimal USFS standard, and high levels of aerobic fitness.

Regression equation (Pack trial): y = 22.953 - .223x, r=.82, p=0.0012 where y=finish time (min)	
Low (40 ml/kg/min)	14:02
Current minimal USFS standard (45)	12:55
High (50 ml/kg/min)	11:48
Regression equation (No Pack trial): y = 15.153 - .123 x, r=.85, p=0.0004 where y=finish time (min)	
Low (40 ml/kg/min)	10:14
Current minimal USFS standard (45)	9:37
High (50 ml/kg/min)	9:00

This analyses clearly indicates that escape route evacuation is dependent on two primary factors **1)** level of aerobic fitness (peak VO_2), and **2)** load carriage. With the pack, the difference in finish time from a low level of fitness (40 ml/kg/min) to the USFS minimal is over one minute. The disparity is even greater if you consider a low versus a high level of aerobic fitness (just over 2:00). However, when the No Pack test is considered, the disparity is less dramatic (1:14 faster for the low versus high). The variations between the Pack and No Pack trials are likely a function of the energy systems involved and the interaction between the demands for muscular strength and endurance. With a 35 pound pack in place, there appears to be an increased demand for absolute muscular strength as indicated by the larger margin of time between the low, minimal and higher levels of aerobic fitness. These regression analyses indicate that load carriage incorporates a large muscular strength component as well as an aerobic capacity component. This was originally reported by Sharkey et. al (1994 and 1996) during the development of the work capacity test. Sharkey noted a high correlation between strength measures and pack test performance times.

The purpose of a minimal fitness or work capacity standard is not a new concept for the wildfire community. It has been estimated that the average energy expenditure during wildfire suppression is approximately 7.5 kcals/min. Previous research by our laboratory has further indicated the unique energy demands of the job. Using the doubly labeled water methodology, calculated rates of total energy expenditure ranged from approximately 3000 – 6500 kcals/day (Ruby, 1999 a, b). These studies were conducted over a five to seven day work period further indicating the extreme energy demands of the work environment and the necessity for a high level of aerobic capacity.

Additional research in our lab (Ruby, 1997) has documented the measured values of peak oxygen consumption (ml/kg/min) during a treadmill test before and after the fire season of 1997. Twenty-three subjects (15 Hot Shots – 6 F, 8 M and 8 Jumpers – 4 F, 4 M) were tested prior to the fire season. Pre-season VO_2 peak for the Hot Shots was 52.15±5.6. Pre-season VO_2 peak for the Jumpers was 52.4±3.2. Considering Table 3 and the USFS minimal standard, this sample was clearly “fit for duty.” Of the 23 subjects tested, 12 of the Hot Shots returned for post season for testing. Peak VO_2 increased to 56.5±4.7 after the season. If a subject is unprepared and untrained prior to the season, Table 3 indicates a clear deficit in job related performance.

Our data indicates a clear and significant decrease in hiking speed when a common line gear pack is carried during escape to an established safety zone. This strongly suggests that fire safety officials and incident commanders should recommend that line gear be abandoned to allow a faster escape (21-26% faster without the line gear pack). These data also indicate that if the line gear pack is retained, perceptions of fatigue are higher and the contribution of the glycolytic energy system increases (indicated by the higher blood lactate concentration noted in the current study). In combination, these will slow the escape, lead to premature muscular fatigue and exhaustion, and may decrease the chance of survival.

Our data strongly suggests that the current minimal level of aerobic fitness should be considered just that: **a minimal standard**. Considering our 1997 data on the Hot Shots and Jumpers, the average VO_2 prior to the season was well above the minimal standard. However, laboratory data has not been collected on Type II crews. The correlation data presented in the present study indicates that the performance of the wildland firefighter during an escape to safety zone is enhanced with a higher level of aerobic fitness (VO_2 peak). Conversely, when the aerobic fitness level is low, performance is clearly impaired.

References

Roth, E. (Ed) (1968) Compendium of human responses to the aerospace environment, vol 3.

Ruby B.C. (1997) Unpublished data.

Ruby B.C., T.W. Zderic, C.A. Burks, S. Tysk, B.J. Sharkey FACSM. (1999). Total energy expenditure (doubly labeled water) and bone resorption during wildland fire Suppression. Medicine and Science in Sports and Exercise 31:s366.

Ruby and B.J. Sharkey. (1999). Young Men and Women and Fire: Young Men and Women and Fire: Total energy expenditure (doubly labeled water) during acute wildfire suppression in males and females. National Symposia on Wildland Firefighter Health and Safety, Missoula MT.

Sharkey, B.J, Rothwell, T. and DeLorenzo-Green. (1994). Development of a job-related work capacity test for wildland firefighters. Medicine and Science in Sports and Exercise 26:S88.

Sharkey, B.J., Rothwell, T. and Jukkala, A. (1996). Validation and field evaluation of a work capacity test for wildland firefighters. Medicine and Science in Sports and Exercise 28:S79.

Sharkey, B.J. (1999). Demands of the Job. MTDC publication 9951-2841, Wildland Firefighter Health and Safety, Recommendations of the April 1999 Conference.

Storm King Mountain Research Team – May 2000

Supported by the Missoula Technology and Development Center and a collaborative research grant from Mesa State College, Grand Junction, CO

We would like to thank the student subjects who volunteered to participate.

We hope our research program can enhance the overall safety, health and performance of the wildland firefighter.

Effective Firefighter Safety Zone Size: A Perception of Firefighter Safety

Jim Steele
Bureau of Indian Affairs – National Interagency Fire Center
Training Specialist – Northern Rockies Training Center
Aerial Fire Depot, 5765 West Broadway
Missoula, Montana 59801

jsteele01@fs.fed.us
james_steele@bia.gov

Abstract. Our professional direction for safe practices during fire suppression assignments are guided by established and accepted safety paradigms. Our assessment of risk to health and welfare, during wildfires, usually guides how we implement these tactical safety paradigms to achieve a measurable range for personal safety. Using a simple exercise to measure consistent understanding of effective safety zone size, it becomes apparent our views on being safe are dangerously different. Understanding fire behavior, being able to visualize future fire behavior, emphasizing good human behaviors to assure we meet the intent of our safety paradigms, and use of new data to achieve this, appears to be reasonable solutions to correct this shortfall.

Introduction

One of the major risk factors firefighters must mitigate is the threat of a burnover caused by intense fire behavior. Routinely we instruct and expect firefighters to mitigate these risks by using safety zones. As a cornerstone of our safety standards, they offer us a safe environment from the dangers of intense fire.

Our attempts to emphasize the importance of safety zones, and other possible mitigations, may have overlooked our cultural subjective understanding of safety zone standards. What we recognize as being safe may have conflicting perceptions throughout the firefighter community.

As an example, our fire suppression skills' training does not address effective safety zone size standards. The actual designation of a safety zone for a specific number of firefighters is a complex decision based on several factors, such as, size for a specific number of firefighters, location, access, site condition, and site integrity. When there is reference to these safety zone attributes, they are in grocery list format without details and are not tested prior to actual field use.

Consequently, experience and information sharing are the only methods we have to establish or maintain a consistent understanding of effective safety zone size. My question is, how divergent are our perceptions of safety zone standards?

Current State of Knowledge

Safety Zones are imbedded in our safety parables. The Standard Fire Orders, Eighteen Situations That Shout Watch Out, LCES, Downhill/Indirect Line Construction Guidelines are a few examples. We are good at reciting these paradigms. However, when implementing them in the field, many seem less understood. Safety zones, for example, can be ignored, inadequately located or constructed, under-sized or over-sized. Some are inaccessible, either because of poor escape routes or the zone itself cannot be entered because of live fuels. The point is, inconsistent and poor information promotes poor and contradictory understanding.

If we have such a poor understanding of effective safety zone size, then why aren't there more incidents with injuries or fatalities? Good timing with poor tactics. In many cases we walk a fine line thinking our mitigations are successful, when actually, the fire environment is not conducive to the large-scale intense fire behavior that would catch us unaware. Time allows us to perfect this misunderstanding until conditions do change, and we are oblivious to the change, and ultimately someone gets caught.

It wasn't until 1998 that the NWCG Fireline Handbook included qualitative guides for safety zone selection, not inclusive of size. The Bureau of Land Management, in their 1999 Standards For Fire Operations included a guide for safety zone size based on radiant heat flux research by Butler and Cohen (1998). Yet with these new data entries to our base of understanding, we as a fire community continue to foster inconsistent notions of safety, in this case, inconsistent notions of effective safety zone size.

Study Methods

To demonstrate a divergent understanding of "being safe" an exercise was developed that eliminated all but one of the considerations for determining an effective safety zone. Size was the only criteria being tested, and how size was influenced by our ability to perceive fire intensity changes over time.

Exercise participants would view a fuel type without fire. They would estimate effective safety zone size for 20 firefighters wearing standard issue personal protective equipment without having to deploy a fire shelter. Two tables were provided at the bottom of the exercise data sheet that related circle radius, or square feet dimensions to size in acres. Each participant worked alone, and had about 10 – 15 seconds to review the fuel slide and estimate effective safety zone size. They would then view a second slide of the same fuel type, only this displayed fire behavior. They were again asked to estimate effective safety zone size for 20 firefighters. Their estimates would take into account the fuels and topography as depicted by the slides. Weather was considered hot and dry, consistent with the 3rd year of a regional drought during late summer. Eye level winds are 5-12 mph. Participants viewed 2 slides per fuel series, and they viewed 4 fuel series (see figures 1-4). Their estimates were entered into a standard Microsoft EXCEL spreadsheet per fuel series and estimates averaged. Participants that changed their first and second estimates are shown as percentages changed with an average increase or decrease. Values for each fuel series were graphed to display the range and frequency of size estimates from the first to second entries.

Various groups of firefighters were sampled as part of formal courses, workshops, and conferences. The minimum experience level represented was Firefighter 1 (Squad Leader), the highest Type 1 Incident Commanders, Operations Section Chiefs, and Safety Officers. The most common experienced personnel were Strike Team Leaders and Division Supervisors. Years of experience were not sampled, nor was years of experience in their highest tactical position.

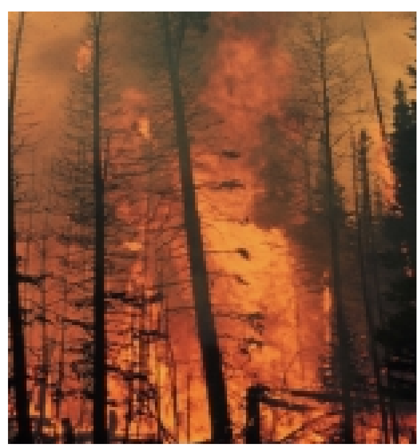


Figure 1. Fuel series 1 depicts a mature stand of lodgepole pine with 50% standing dead. Slide 1 shows the fuel type without fire, and slide 2 shows it with fire behavior.


Figure 2. Fuel series 2 depicts a mature stand of sagebrush associated with pinion juniper and understory grasses and forbs. Slide 1 shows the fuel type without fire, and slide 2 shows it with fire behavior.


Figure 3. Fuel series 3 depicts a mature stand of ponderosa pine with an understory of seedling/saplings with incense cedar. Ground cover is antelope bitterbrush, grasses and forbs, and pine needle litter cast. Slide 1 shows the fuel type without fire, and slide 2 shows it with fire behavior.


Figure 4. Fuel series 4 depicts a mature stand of high elevation subalpine fir and lodgepole pine. Ground cover shows a high biomass mix of forbs and shrubs. Slide 1 shows the fuel type without fire, and slide 2 shows it with fire behavior.

Results

The results in general show us a wide range of estimates (see figures 5-8). Looking at the data we can see firefighters do not have a standard understanding or approach to determining effective safety zone size. Table 1 lists the average estimates for all participants. Column 3 displays their average estimates based on viewing the fuel type, column 4 shows their estimates after viewing that same fuel type with fire behavior. The groups increased their second estimates in every case. The spreads displayed with the first estimates show a wide range of perceptions. Equally far ranging are the arrays of the second estimates. The increase of the range for fuel series 2 and 3 are not significant, which might suggest a higher confidence level predicting fire behavior in non-complex fuel types.

Table 1. Average acres for 1st and 2nd estimates of effective safety zone size with low and high estimate ranges for four fuel series.

Fuel Series	No. Participants	Average 1st Est. Acres	Average 2nd Est. Acres	Overall Average Acres	Range 1st Estimate Acres Low	High	Range 2nd Estimate Acres Low	High
1	332	14.4	17.8	16.1	0.25	100	0.5	150
2	385	2.9	3.6	3.2	0.01	51	0.01	51.6
3	374	8.4	10	9.2	0.06	100	0.06	100
4	377	16.5	28.1	22.3	0.15	100	0.2	640

Table 2 displays the impacts of estimate changes. For example, fuel series 1 showed 51% of the participants increase their second estimate, over the first, by an additional 8 acres. For the same fuel series, 8% decreased their second estimate by an average of 8.5 acres, and 41% of the participants did not change their second estimate from the first for an average estimate of 16.8 acres.

Table 2. Show change in size estimates influenced by fire behavior for four fuel series.

Fuel Series	2nd Estimate Increased by %	Acres	2nd Estimate Decreased by %	Acres	No Change %	Acres
1	51	8	8	8.5	41	16.8
2	40	2.3	11	2.1	49	2.8
3	34	5.6	11	3.1	54	9.2
4	66	17.8	1	10.2	33	25

If we stratify the fuel types, we see fuel series 1 and 4 are multiple level timber stands that experience surface and crown fires. Fuel series 2 and 3 are low continuous fuels that would be considered surface fuel oriented. The complex fuel types had the greatest number of participants change their minds after viewing the fuel type with fire behavior in it, and they showed the greatest average increase over the less complex fuel types. The percentage of those that did not change their minds from the first to second fuels' slide was closely grouped with the exception of fuel series 4. What was not tracked was if these participants made their final determination on the first or the second slide.

This information indicates we have a substantial number of firefighters that have difficulty visualizing fire intensity changes over the course of a burn period. Because we only had 2 fuel slides per series, it is not legitimate to assume these firefighters were more sensitive to slides with fire in them, however, in this exercise their changes did correspond to that kind of additional information. If this does prove to be true, it would indicate we are likely designating ineffective sizes earlier in the burn period when intense fire behavior is absent. It might also indicate, we are underestimating the effects of fire intensity on our locations for escape route use, identifying trigger points for escape, or estimating probabilities of success for chosen tactics.

Conclusions

We can use this exercise as a barometer of safety perception, rather than just our ability to estimate safety zone sizes. Then we can question how consistent we understand a lot of the safety paradigms that drive our tactical decisions. Recently, the work of Butler and Cohen relating radiant heat flux to firefighter safety gives us a standard to work with and to verify with different conditions. It would also give us the necessary information for teams to consider actual sizes when devising tactics.

Tactical decisions must be based on realistic fire behavior predictions. What we often overlook is how fire behavior and safety zones are integrated into the tactical decision. That is, if firefighters require access to safety zone/s then we realistically have to determine safety zone presence by exact location, effectiveness in size, occupant size limitations, and firefighter access throughout the burn period. All of this ties to the networking of crew position, lookouts, defined fire behavior trigger points, a communications system that is preplanned and functional, and crew movements that are based on real travel times.

Recommendations for the near future would include:

1. A profession wide distribution of accepted safety zone sizes for a predetermined number of occupants, based on fire intensity.

2. Publication of a guide to effective safety zone standards.

3. Publication of a guide for determining effective escape routes considering slope, location, escape route condition, crew fitness and travel timing.

4. Develop an approach to recognizing fire behavior trigger points and their relationship to crew personnel escape route use.

5. Instruct fireline tactics when safety zones are necessary, and when not available.

6. Base tactical decisions during training and fire assignments on data, not perceptions. If safety zones are in place, verify they are adequate for the plan; if they are not available, verify the plan.

7. Reinforce technical fire behavior understanding with visualization. Know what the numbers mean in terms of the physical presence of fire from intensity buildup, through peak intensities, fire movements (head to flanks, spotting kinds and distances), and momentum (mass, positioning).

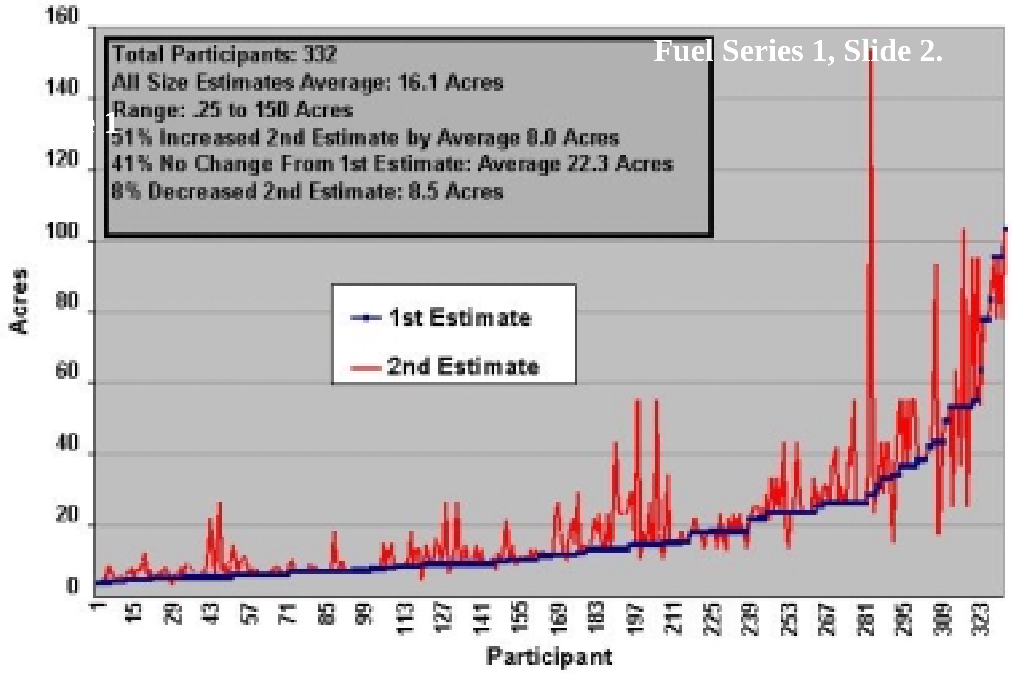
8. Further define the roles and characteristics of an effective lookout, including: fire behavior knowledge and experience, ability to communicate, effects of vigilance, and safety considerations.

References

Butler, B.W. and J. D. Cohen. Int. J. of Wildland Fire 8(2):73-77, 1998.

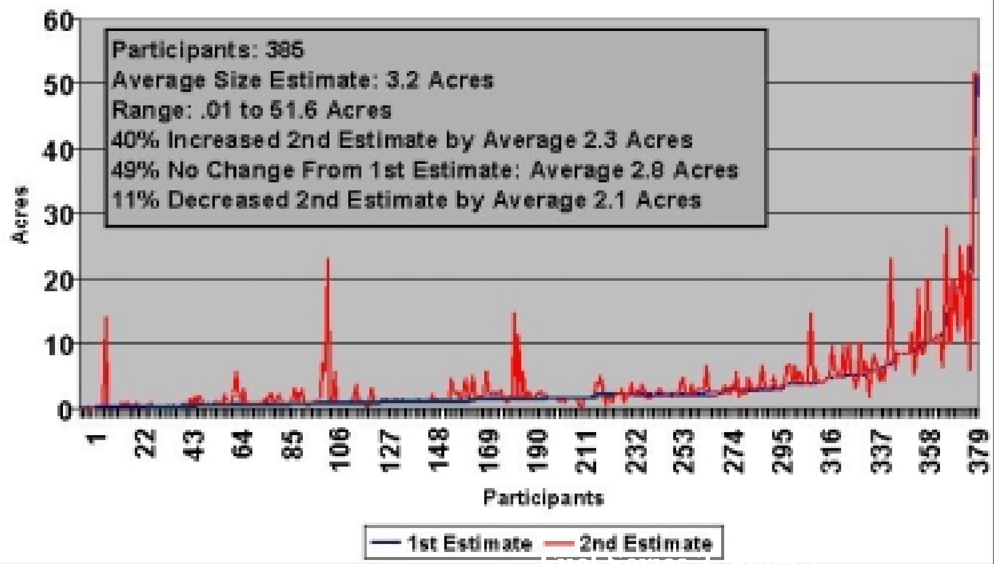
Safety Zone Size Recognition for Fuel Type 1, 50% Dead Lodgepole, High Elevation

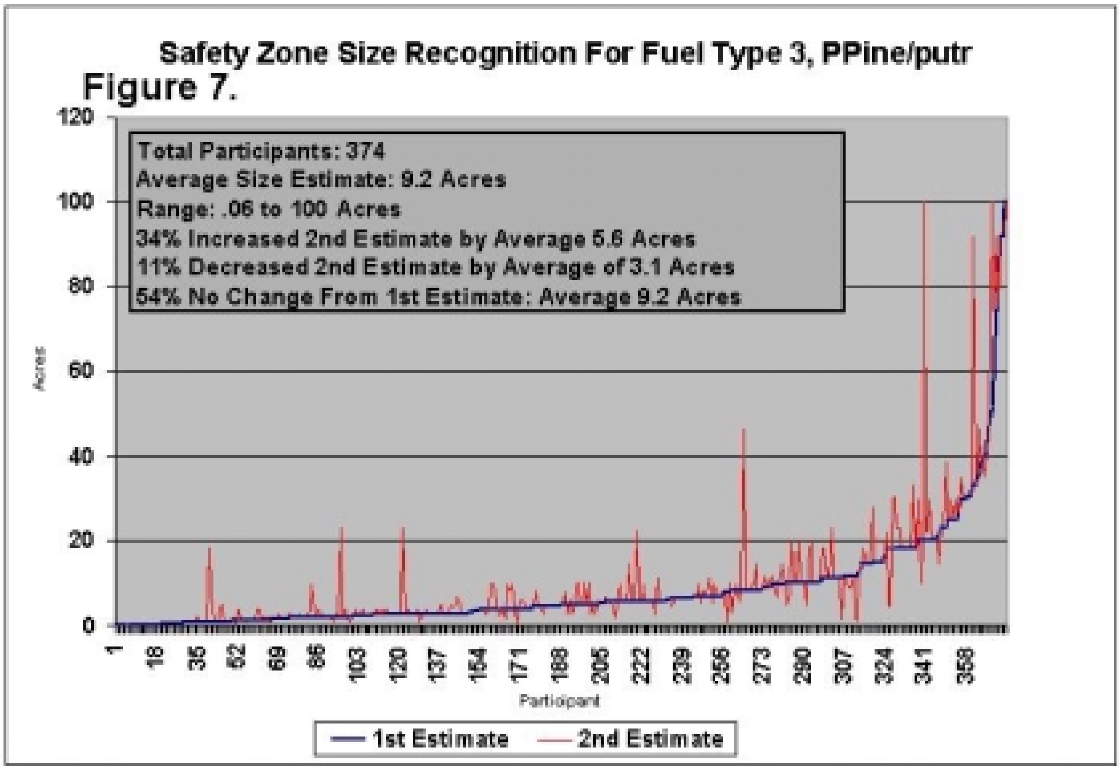
Figure 5.

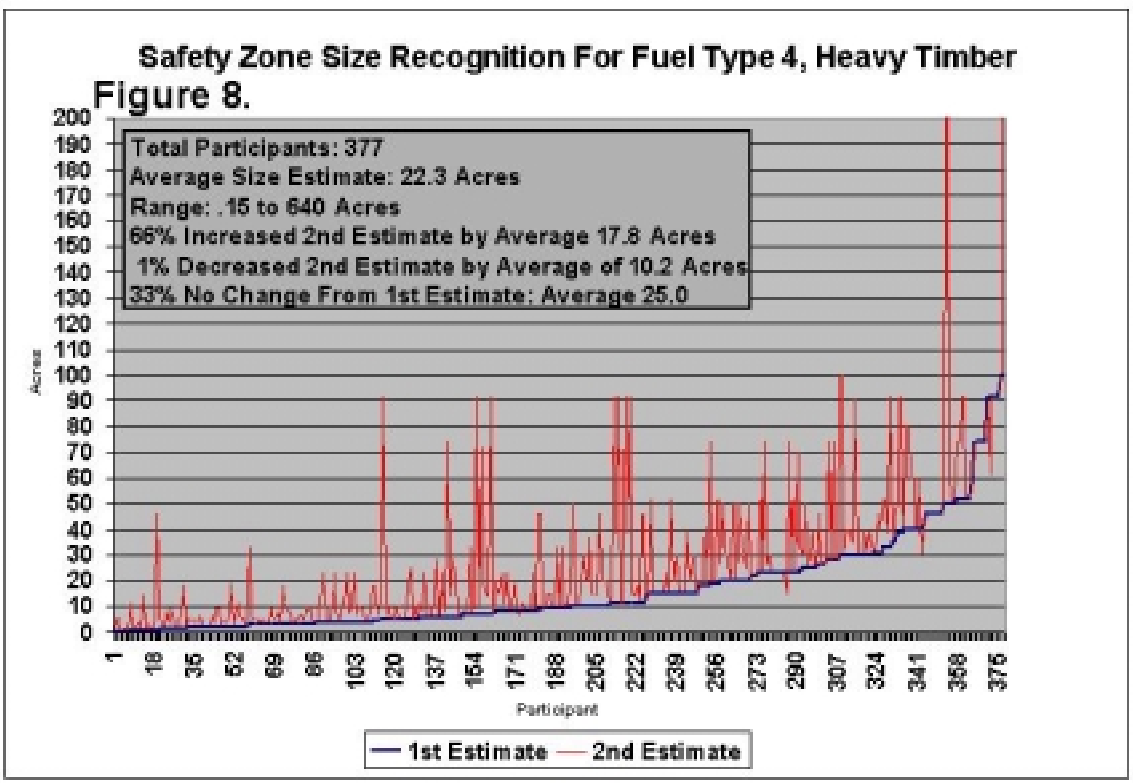


Safety Zone Size Recognition For Fuel Type 2, Sagebrush

Figure 6.




Safety Zone Size Recognition For Fuel Type 3, PPine/putr
Figure 7.
Total Participants: 374
Average Size Estimate: 9.2 Acres
Range: .06 to 100 Acres
34% Increased 2nd Estimate by Average 5.6 Acres
11% Decreased 2nd Estimate by Average of 3.1 Acres
54% No Change From 1st Estimate: Average 9.2 Acres
Acres
Participant
1st Estimate
2nd Estimate


Safety Zone Size Recognition For Fuel Type 4, Heavy Timber
Figure 8.
Total Participants: 377
Average Size Estimate: 22.3 Acres
Range: .15 to 640 Acres
66% Increased 2nd Estimate by Average 17.8 Acres
1% Decreased 2nd Estimate by Average of 10.2 Acres
33% No Change From 1st Estimate: Average 25.0
Acres
Participant
1st Estimate
2nd Estimate

The Wildland Fire Problem in Strathcona County, Alberta and Its Impact on Firefighter Safety

Stewart, L.[22], P.M. Woodard[23], K. Hirsch[24], D. Polinski[25], and L. Burton[26]

Strathcona County is located immediately east of the city of Edmonton and is bordered on the east by Elk Island National Park. It is in the aspen/parkland region of Alberta but does contain small fragments of a boreal forest. Poplar sp. are dominant in forested areas though there are spruce dominated sections in the northern and southern portions of the County. The major urban center, Sherwood Park, has a population of 45,000 people. The rural area, which is about 1000km^2, has a current population of 23,000. The population growth rate averages 4%.

There are 5 fire stations located throughout the County. One in the northern section at Josephburg, another in the south at South Cooking Lake, one in the central portion at Ardrossan and the remaining 2 are located within Sherwood Park.

Wildland fires commonly occur in Strathcona County. Grasslands, short-lived poplar forests, and wetlands are the dominant vegetation types in this County. In the absence of fire and other disturbances, poplar forests are replaced by white spruce on dry sites and black spruce on wetter sites, when a seed source is available. Wildfires occur most frequently in the spring, but fall fires are possible after leaves have fallen and the grass has cured. Fires will spread is quickly when cured grass fuelbeds, which are usually well aerated, are dry and wind speeds are high. The danger of these conditions is further complicated by the fact that human development and occupancy in the more remote areas of this County are increasing. Further this urban/wildland interface problem is increasing yearly.

Strathcona County Emergency Services Department employs 58 full-time fire fighters/EMTs and about 100 part-time. Equipment used in fighting wildland fires includes 4 brush trucks, 3 tankers and numerous types of small equipment. In 1999, Emergency Services responded to 250 fires in rural Strathcona County. This includes structural fires, wildland fires and vehicle fires. There have been 6 fire fighters/EMTs trained in fighting fire occurring in the wildland.

In May, 2000 a survey was sent out to 385 randomly selected residents of the wildland/urban interface and had an overall response rate of 38%. The survey was designed to ascertain how much knowledge a typical resident of the WU/I in Strathcona County has about potential fire hazards. Information about building materials, presence/location of fire pits or barrels, location of firewood, visibility, signage, vegetation modification and property cleanliness was obtained. 51% considered the flammability of materials when building though 74% did not consider the risk of wildfire when they moved into their home. On a scale of 1-7, with 1 being no danger, 53% felt that there was no fire danger on their property, 5% felt it was extreme. 52% have made modifications to the vegetation to reduce the fire hazard. 78% have a fire pit with over half located within 10m of vegetation. 46% locate their firewood away from all buildings. In

22 M.Sc. Student enrolled in the Department of Renewable Resources, University of Alberta, Edmonton and an employee of the Strathcona Parks and Recreation Department, Sherwood Park.
23 Professor, Forest Fire Science and Management, Department of Renewable Resources, University of Alberta.
24 Fire Researcher and Team Leader (fire Environment), Canadian Forest Service, Edmonton.
25 Manager, Strathcona County Parks and Recreation Department, Sherwood Park.
26 Fire Chief, Emergency Services, Strathcona County

regard to building materials, 69% have asphalt shingles, 15% have unrated wood shakes, and 26% have wood siding. When asked to rate events that pose a risk, wildfire destroying the home was ranked 3rd, behind a car accident and being a victim of a robbery. 98% have never explored any of the fire information sites available on the internet.

Field assessments were performed in August 2000 at 322 homes along 4 randomly selected rural roads within the County. It was found that 50% had an address sign that was perpendicular to the road, 35% had a sign that was parallel to the road, and 15% had no signage at all. Of the 50% perpendicular, 34% only had numbers on one side of the sign therefore only visible from one direction. 76% had numbers that were greater than 5cm in size. 97% had adequate road width leading to the home meaning a large emergency vehicle could access the home. 75% of the homes had full or partial visibility though the trees were in full leaf. There was an access gate located at 32% of the homes.

The results found from the survey and field assessments can indicate the average conditions fire fighters will be subjected to when responding to a fire. Of concern were the homes that were equipped with entrance gates. Although these gates can be forced, this causes a delay in the response of the Emergency Services Department. Another concern was the amount of homes that had address signs parallel to the road or only on one side of a perpendicular sign. This can cause delays for emergency vehicles, as they may not be able to find the home immediately. Efforts should be made to educate the residents to ensure that emergency personnel can perform their duties with all speed and efficiency.

Wildland Fire – Safety on the Fireline: An Application of Interactive Multimedia CD-ROM Technology to Wildland Firefighter Safety Training

R.W. Thorburn
Alberta Enviornmental Protection, Environmental Training Centre, 1176 Switzer Drive, Hinton, Alberta T7V 1V3
Phone: (780) 865-8216; Fax: (780) 865-8266; email: Rob.Thorburn@gov.ab.ca

A. MacMillan
Christie Communications, #1002 10611-98 Avenue, Edmonton, Alberta T5K 2P7
Phone: (780) 424-4433; Fax: (780) 424-4888; email: lex@christie.ab.ca

M.E. Alexander
Canadian Forest Service, Northern Forestry Centre,
5320-122 Street, Edmonton, Alberta T6H 3S5
Phone: (780) 435-7346; Fax: (780) 435-7359; email: malexand@nrcan.gc.ca

Abstract. There have been very few fatalities resulting from wildland firefighting in Canada. However, in spite of what appears to be a near spotless safety record, there have been some documented and many undocumented "near misses". In an effort to avoid becoming complacent when it comes to wildland firefighter safety, the Environmental Training Centre received the mandate from the Canadian Interagency Forest Fire Centre (CIFFC) Board of Directors and in turn the CIFFC National Training Working Group to develop an interactive multimedia CD-ROM for the delivery of wildland firefighter safety training. This led to the development of the ***Wildland Fire – Safety on the Fireline*** course which was completed in July 2000. The ultimate goal of ***Wildland Fire – Safety on the Fireline*** is to teach anyone who is involved in fighting wildland fires to work safely on the fireline, regardless of their position within the wildland fire community. Interactive multimedia technology allows delivery of training to a large number of students on a consistent basis. In addition, cost savings can be achieved through reduced learning time, reduced travel, minimal use of instructors, and most of all, through retention of knowledge as a result of using multimedia. The course ***Wildland Fire – Safety on the Fireline*** was developed and reviewed by a national team of specialists in wildland fire behavior and wildland fire safety with the intent of reducing and/or eliminating injuries and fatalities associated with the suppression of wildland fires. ***Wildland Fire – Safety on the Fireline***, which contains 72 video clips, over 250 audio clips and some 500 graphics/photos, on-line help, a glossary and a SI-to-imperial unit conversion calculator, focuses on due diligence, situational awareness, entrapment survival, health, equipment, and hazards encountered when working on the fireline. Each of the four sections comprising the course is followed by a board game test in preparation for a final test that is tracked by the computer.

Keywords:

Canada
Computer applications
Fire behavior
Fire entrapment avoidance
Firefighter fatalities
Firefighter physiology
Fire suppression
Fire survival
Personal protective equipment

Risk management
Safe work practices
Situational awareness
Wildfire case studies
Wildland firefighting
Wildland-urban interface

Introduction

There have been very few fatalities resulting from wildland firefighting in Canada in comparison to the United States (who have probably ten times or more fires than Canada). Consequently, burn-overs and entrapments on wildland fires in Canada are a relatively rare occurrence. However, in spite of what appears to be a near spotless safety record, there have been some documented and many undocumented "near misses" or "close calls".

It would be quite easy to become complacent when dealing with firefighter safety based on documented statistics. Some senior managers and policy makers alike may perceive fireline safety to be a non-issue. Nevertheless there are a number of reasons to be vigilant over safety issues that apply not only to Canada but the United States as well. Some of these issues are:

- reduction in senior fire personnel in recent years;
- mounting wildland-urban interface fire problems;
- "implied" pressure to keep area burned in commercial forest areas to a minimum;
- possible escalation of the "gung-ho" approach to firefighting largely due to romanticizing by the media and fire management agencies themselves
- fuel buildup in short-interval fire regime fuel types
- difficulty in accessing standardized fire safety training

While there are some very good safety training materials available within the wildland fire community such as "Look Up, Look Down, Look Around" and "Standards for Survival" (Anon. 2000b), most of this material is oriented to traditional classroom training approaches (i.e., lecture style teacher-student interaction).

Given that the current generation of wildland firefighters have strongly developed skills in the audio-visual area, an interactive multimedia training CD-ROM approach is a natural and more current way to approach the issue of fire safety training and education for wildland firefighters. What is multimedia? Multimedia is a carefully orchestrated interaction of video, audio, text, graphics, slides, and animation. When you enable users to control the pace and direction of information presented with a computer thorough this media, the program becomes "interactive multimedia".

About the New Course *Wildland Fire – Safety on the FireLine*

The Environmental Training Centre in concert with a multimedia producer (Christie Communications), has undertaken a number of multimedia training projects in the area of wildland fire over the last several years (Anon. 1997, 1998; Hirsch 1998). As a result, the Environmental Training Centre received the mandate in late 1998 from the Canadian Interagency Forest Fire Centre (CIFFC) Board of Directors and in turn the CIFFC National Training Working Group to develop an interactive multimedia CD-ROM for the delivery of wildland firefighter safety training.

With the assistance of a national content team* comprised of wildland fire behavior and fire safety specialists, the CD-ROM ***Wildland Fire – Safety on the Fireline*** (Anon. 2000a) has now been completed following alpha and beta testing and is available for general distribution (Figure 1).

Figure 1. Cover plate for the ***Wildland Fire – Safety on the Fireline*** CD-ROM.

What's the Course About?

The ultimate goal of the ***Wildland Fire – Safety on the Fireline*** CD-ROM training course is to teach wildland firefighters how to work safely on the fireline. To teach this critical information, this multimedia program uses the interaction of video, audio, text, graphics, photos, and animation***. Wildland Fire – Safety on the Fireline*** contains 72 video clips, over 250 audio clips and some 500 graphics/photos. In the tools menu, the program includes on-line help, a course map, a glossary, SI-to-imperial unit conversion, references, and an electronic index.

Wildland Fire – Safety on the Fireline was developed and reviewed by subject matter specialists in wildland fire behavior and wildland fire safety. This quality expertise can now be delivered to a large number of students on a consistent basis, using the CD-ROM interactive training approach. ***Wildland Fire – Safety on the Fireline*** is primarily aimed at the on-the-ground wildland firefighter although anyone involved in fighting wildland fires will find it of value.

In addition, cost savings in training can be achieved through reduced learning time, reduced travel, minimal use of instructors, and most of all, retention of knowledge. However, the bottom line benefit of this training program is to reduce and/or eliminate injuries and fatalities associated with the suppression of wildland fires.

What's in the Course?

Wildland Fire – Safety on the Fireline is divided into four main sections, each containing a "board game" section test to help learners review material and ensure they are ready to proceed (Figure 2).

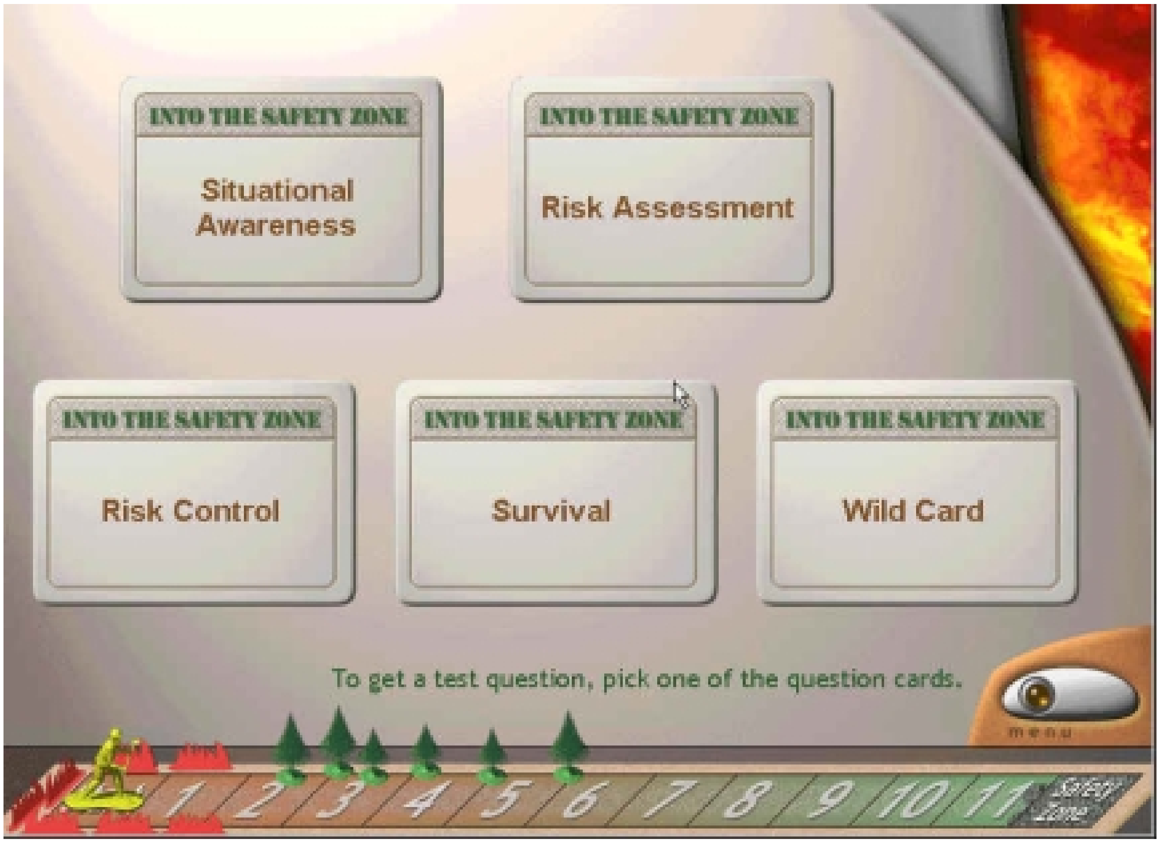


Figure 2. Sample window from the ***Wildland Fire—Safety on the Fireline*** CD-ROM illustrating a board game.

Section 1: Introduction – the *Introduction Section* has two activities. The *Course Introduction Activity* includes information on help/controls, acknowledgements, learner objectives, a course map, and prerequisites to the course. The *Safety Introduction Activity* teaches areas such as risk management, safety responsibilities, due diligence, leadership, adaptiveness, personal ability, reinforcement, and continued training.

Section 2: Entrapment– the *Entrapment Section* contains three activities. In these activities, learners also get to try scenario-based interactions that give them an opportunity to apply the theory. *Entrapment Avoidance* teaches situational awareness, the 10 standard fire orders, the 18 situations that shout 'watch out', tactical watchouts, downhill checklist items, lookout requirements, fireline communication, escape routes, safety zones, and the common denominators of fireline incidents and fatalities.

Indicators of Potential Fire Behavior Hazards is all about identifying the fuel, topographical, weather, and fire behavior indicators. This activity contains a "flash card" exercise that lets learners practice identification. *Entrapment Survival* describes heat radiation hazards, methods of preventing exposure, escaping an entrapment situation, and the procedures for vehicle and heavy equipment entrapment.

Section 3: On-the-Job – The three activities in this section are *Your Body*, *Equipment*, and *Working with Others*. The activity *Your Body* focuses on the effects of heat stress and fatigue, prevention methods, and basic treatment. In a "try-it-out" exercise, learners can experiment with firefighter fluid levels to see the results. The *Equipment Activity* describes the key considerations for personal protective equipment (PPE), including working with and caring for hand tools. In *the Working with Others Activity,* learners are taught the safety intelligence flow on the fireline, the importance of safety briefings (tailgate meetings), employee and supervisor safety responsibilities, and the incident reporting process (Figure 3).

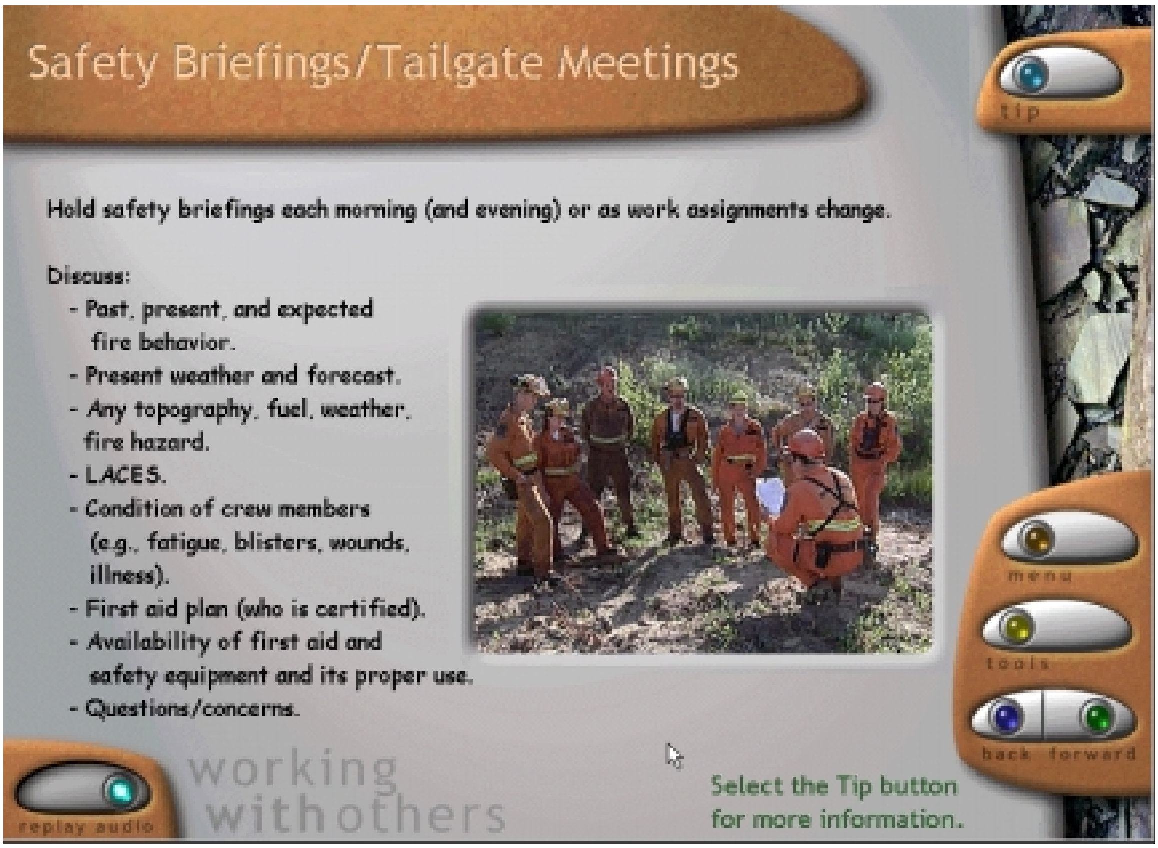


Figure 3. Sample window from the ***Wildland Fire – Safety on the Fire line*** CD-ROM illustrating a user interface.

Section 4: On the Line– this section contains the final three activities. The *Fireline Concerns Activity* describes the safety procedures for working on the fireline. It includes hazards such as getting lost, falling rocks and/or logs, snags, heavy equipment, thunderstorms, fixed wing and rotary wing aircraft, retardant drops, and nighttime firefighting. Each learner is asked to pick out the snags by using his/her cursor as a flashlight in this activity's exercise. The *Urban Interface Activity* provides an overview of the pitfalls of fighting wildland fire near or around burning structures.

This activity includes wildland firefighter responsibilities, urban/wildland watchouts, high voltage powerline concerns, and safety considerations for dealing with vehicle fires. A "try-it-out" exercise asks learners to pick the wildland/urban interface watch out situations from a graphic. In the *Course Summary* Activity, learners are given the opportunity to apply knowledge from all sections of the course in four interactive wildland fire case studies. These include the 1994 South Canyon Fire in Colorado (Butler *et al.*

1998; Maclean 1999) and three fatality fires that are used in national fire behavior training courses, Advanced Wildland Fire Behavior and Wildland Fire Behavior Specialist, involving a logger on a slash fire in coastal British Columbia in 1991, a rural volunteer firefighter on wind-driven grass fire in southern Saskatchewan in 1993, and a rappatack crew member on a forest fire in north-central Alberta in 1995 (Alexander 1998).

Once learners have successfully completed these sections, they are given a final test (Figure 4). Scores on all tests are recorded by a performance tracking system, which can be used by course administrators for certification purposes. It takes learners 6-8 hours to complete the course; however learners can take the course in shorter time duration, using the modular tracking system.

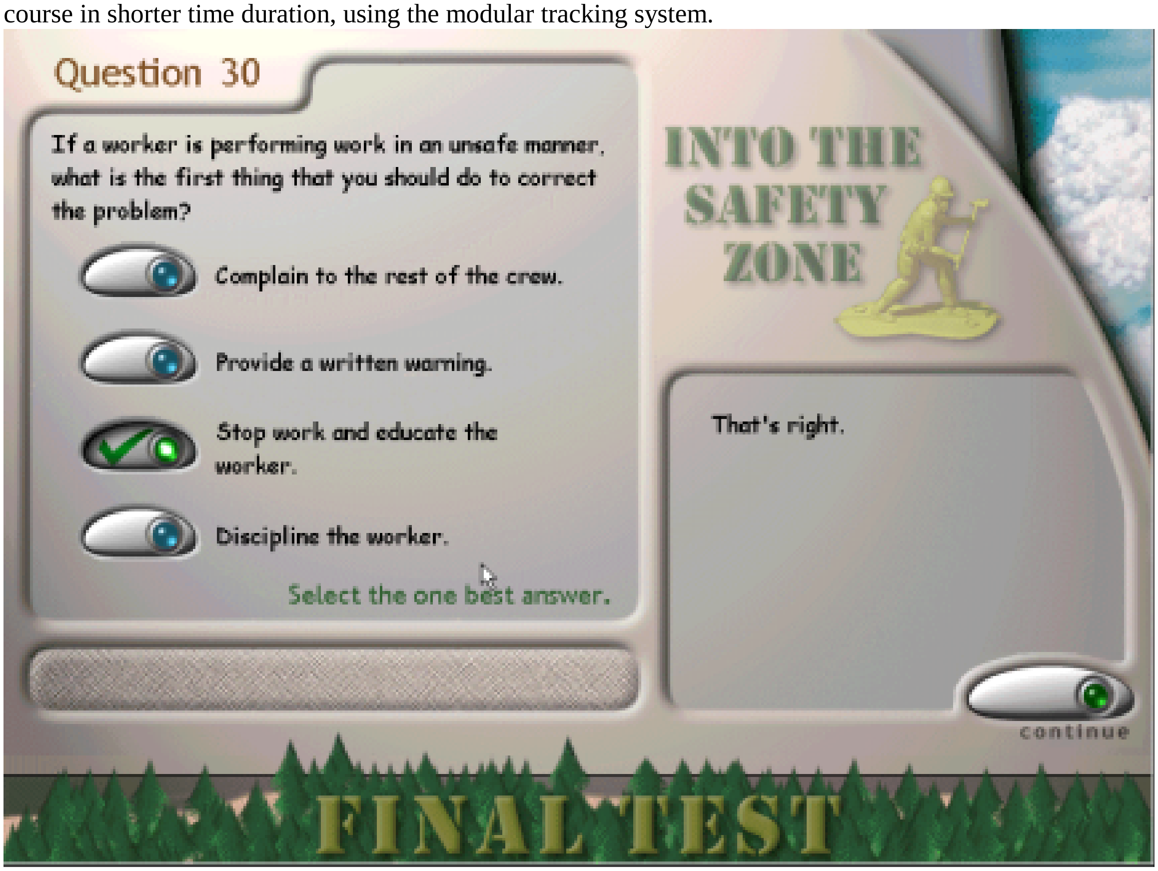


Figure 4. Sample window from the ***Wildland Fire – Safety on the Fireline*** CD-ROM illustrating a final test question.

What Are the System Requirements?

The course can be run on a stand-alone computer or over a network. All computers, workstations, local computers, etc. where a course will be run should have:

- ✓ Pentium 166 or better with Windows 95, 98, or NT.
- ✓ A minimum of 32 Mb RAM and 100 MB of free hard drive space (4 MB actually required for software).

- ✓ Color SVGA monitor set for 800 x 600, 16 bit color and 4 MB video memory.
- ✓ 16 bit sound card (SoundBlaster).
- ✓ A 16X or better CD-ROM and its driver(s) (on every workstation).
- ✓ Mouse.

Why Use Interactive Multimedia in Wildland Fire Safety Training?

Here are the perceived advantages of using interactive multimedia technologies in wildland fire training courses like ***Wildland Fire – Safety on the Fireline***:

Take it any time you want - by using computer based training (CBT), you can make use of low productivity time. All employees have periods of downtime. They have to wait for materials to arrive, or they finish the job an hour before the end of the day. Now, using CBT, you can turn lost time into productive time.

Take it anywhere you want - CBT can be delivered on computers at any location. There is no more traveling to a training center. Employees can even take these courses at home! Student's inputs, selections and performance can also be tracked for certification purposes.

Reduction in learning time - CBT is up to four times more efficient than traditional training methods. That means that a traditional two-day training course can be delivered in as little as four hours. Since the largest cost in providing training to your employees is their time away from the job, the savings can be enormous.

Educational consistency - a CBT course always provides the same content, day after day. When using multimedia training is consistent. There are no bad days for the instructor and the content does not vary from class to class. High quality expertise can be delivered to a large number of students

Refresher training - time required to take refresher training can be significantly reduced since the program provides learners with control over their own learning path and depth.

Job-aid component - because CBT can remain at the worksite, even certified employees can return to the course, select a small section from a course menu or index, and get the information they need to do a particular job. The courseware, in this way, does double duty as an on-line job aid.

Learner retention - complex theory is easy to teach. Knowledge is ensured through remedial feedback, practice and testing.

Quality training - Training your employees to do the job right reduces waste, increases productivity, and prevents incidents and accidents.

On the Future of Computer-based Wildland Fire Training

The computer has been gaining a steady foothold in the business of training in general over the last few years. In 1997, 80% of training was delivered by instructors (Trainsersoft Corp, 2000). It is expected that by the year 2001, over 50% of all training will be delivered by computers (Trainersoft Corp, 2000).

The Environmental Training Centre has been riding the wave of technological advancement in computer based training for many years now (Thorburn 1990) and is currently starting out to develop a fifth interactive multimedia training CD-ROM. Its content will address the subject of the Canadian Forest Fire Weather Index System, a major module of the Canadian Forest Fire Danger Rating System (Stocks *et al.* 1989).

Interactive multimedia technology is suited not only to wildland fire management training but has the potential for many applications in other sectors of forestry as well. This has been demonstrated in the past by work done by Christie Communications and Vicom on lumber grading, mill orientation, and stand tending to mention a few.

References

Alexander, M.E. 1998. A wildland fire behavior researcher's perspective of firefighter safety in Canada. In: Proceedings Canada/US Wildland Fire Safety Summit. International Association of Wildland Fire, Fairfield, Washington, p. 37.

Anon. 1997. Intermediate wildland fire behavior, S-290. Environmental Training Centre, Hinton, Alberta, and National Wildfire Coordinating Group, Boise, Idaho. National Fire Equipment System (NFES) 1592. CD-ROM. [to order see: http://www.blm.gov/fna/gbk/index.htm]

Anon. 1998. Principles of fire behavior. Evironmental Training Centre, Hinton, Alberta. CD-ROM. [to order see: http://www.ubcpress.ubc.ca]

Anon. 2000a. Wildland fire -- safety on the fireline. Evironmental Training Centre, Hinton, Alberta. CD-ROM. [to order see: http://www.ubcpress.ubc.ca]

Anon. 2000b. NWCG National Fire Equipment System catalogue part 2: publications. National Wildlfire Coordinating Group, Boise, Idaho. National Fire Equipment System (NFES) 3362. 114 pages.

Butler, B.W., R.A. Bartlette, L.S. Bradshaw, J.D. Cohen, P.L. Andrews, T. Putnam and R.J. Mangan. 1998. Fire behavior associated with the 1994 South Canyon Fire on Storm King Mountain, Colorado. USDA Forest Service Research Paper RMRS-RP-9. 82 pages. [see also: http://www.fs.fed.us/rm/pubs/rmrs_rp9.html]

Hirsch, K.G. 1998. Canadian Forest Fire Behavior Prediction (FBP) System: interactive training and reference. Canadian Forest Service, Northern Forestry Centre, and Alberta Environmental Protection, Forest Protection Division, Edmonton, Alberta. CD-ROM. [to order see: http://www.ubcpress.ubc.ca]

Maclean, J.N. 1999. Fire on the mountain: the true story of the South Canyon Fire. William Morrow and Company, Inc., New York, New York. 275 pages.

Stocks, B.J., B.D. Lawson, M.E. Alexander, C.E. Van Wagner, R.S. McAlpine, T.J. Lynham and D.E. Dube. 1989. The Canadian Forest Fire Danger Rating System: an overview. Forestry Chronicle 65(6): 450-457.

Trainersoft Corp, 2000. Multimedia Authoring Program, Tutorial Introduction.

Thorburn, R.W. 1990. Videodisc/microcomputer technology in wildland fire training. In: The Art and Science of Fire Management (M.E. Alexander and G.F. Bisgrove, technical coordinators). Information Report NOR-X-309, Forestry Canada, Northern Forestry Centre, Edmonton, Alberta, p. 100-101.

Footnote

*The team members were R.W. Thorburn, who served as the project coordinator, M.E. Alexander, D. Campbell (Department of Environment & Resource Management, Prince Albert, Saskatchewan), and J. McLevin (Land & Forest Service, Lac La Biche, Alberta).

Analysis of Three Fatal Accidents Involving Portuguese Firefighters

D. Xavier Viegas
ADAI, Department of Mechanical Engineering, University of Coimbra
Polo II, Pinhal de Marrocos, 3030Coimbra, Portugal
Phone:+351.239.790732; Fax: +351.239.790771; email: xavier.viegas@dem.uc.pt

A. J. Matos Silva
ADAI, Center of Forest Fire Studies
Rua Pedro Hispano, 12, 3030Coimbra, Portugal
Phone:+351.239.708580; Fax: +351.239.708589; email: ajms@esoterica.pt

M. Gomes Cruz
ADAI, Department of Mechanical Engineering, University of Coimbra
Polo II, Pinhal de Marrocos, 3030Coimbra, Portugal
Phone:+351.239.708580; Fax: +351.239.708589; email: mgcruz@selway.umt.edu

Abstract. The circumstances under which three accidents involving fatalities due to fire entrapment in Portugal are described. Five fire fighters lost their lives in these accidents. A brief description of the environmental conditions and the fire behaviour situation is given. The standard factors affecting fire accidents are analysed for each case.

Keywords:
Fire safety
Fatal accidents
Fire entrapment

Introduction

One of the motivations for the research on forest fire behaviour is the improvement of the safety conditions of firefighters and other persons present near the fire front. A way to assess and to improve the existing knowledge on the subject consists on the study of past incidents.

In this article the authors describe and analyse three separate accidents in wildfires resulting in the death of five firefighters. Case 1 occurred in Tabuaço (10-7-1999) and resulted in the death of two firefighters; Case 2 occurred in Mação (16-6-2000) and resulted also in two deaths, one of the victims being the Commander of the fire brigade. Case 3 occurred in Alvão (24-6-2000) and caused one victim.

Methodology

The sites of the accidents were visited few days after their occurrence and several times afterwards. By courtesy of the Portuguese Air Force a helicopter flight was made over the Tabuaço area in order to obtain overview photos of the acident site.
In this research the authors obtained the support from the National Fire Brigade Service to inquire the personnel involved and to obtain the necessary paper information from the relevant agencies. The first visit to investigate Case 1 was made together with the Investigation Team of the Fire Brigade Service.
All the persons involved in the accident, including civilians were interviewed and the evidences left on the terrain or on the vehicles were thoroughly examined.
Meteorological data from nearby weather stations and weather reports were obtained from the Portuguese Institute of Meteorology. In the two last cases wind data from wind power stations that existed very close to the accident sites were also obtained.
In case 1 a written report was prepared and its preliminary version was presented and discussed with some relevant persons. Their comments and suggestions were considered in the preparation of the final version of this document (Viegas and Maricato, 1999) before it was released to a restricted number of personalities. A

short version of this report (Viegas and Maricato, 2000) was published in Wildfire. Reports on the other two cases are in the process of discussion with the relevant persons involved.

Accident Description and Analysis

Case 1 - Tabuaço Accident

The site of the accident (figure 1) was a valley 4km South of the town of Tabuaço with a North South orientation between two elevations with an altitude of around 940m each; the bottom of the valley has a positive inclination going towards North and therefore it forms a sort of a canyon or ridge near the area of the accident. The surrounding area has a very rough topography with ridges and valleys that contribute for poor general visibility conditions and to a turbulent and complex wind flow at the site in most conditions.

Figure 1 *– General view of the accident site taken from the top of the West side hill. The fire propagation was from the bottom to the top of the photography; the group was on the road at the centre of the image.*

Several fires that occurred in the region during the past years have destroyed the forest cover in the area, therefore only isolated plots of pinus pinaster surrounded by tall shrubs (*Citisus* spp) and herbaceous vegetation are found.

At the date of the accident very dry conditions existed in the region with dead fuel moistures in the range of 7-9%; FWI was around 30 and fire danger index for the area was rated as High or Very High.

When the fire started wind was relatively weak and blowing from NW but at around 16.00h there was a wind shift that began blowing from W and its velocity increased from 8 to 18Km/h at the meteo station of the Meteorological Institute situated near Viseu at a distance of 60 km from the place of the accident.

Table 1 – Persons Involved in Case 1 Incident

Ref.	*Name*	*Age*
A	A. A. Gonçalves	58
B	B. A. T. Santos	39
C	J. L. Longa	22
D	A. S. Rodrigues	42
E	A. M. Rodrigues	24
F	J. O. Caseiro	23
G	A. J. Morais	32

The identification of fire fighters involved in the incident is given in table 1.
At the time of the accident this group of fire fighters was placed between points P1 and P2 on a road that runs near the bottom of the valley with a fire truck with 5 m^3 of water (see figure 2). They were trying to suppress the fire that was coming towards them descending the West side of the valley. Due to the light wind conditions it seemed possible to develop this suppression successfully.

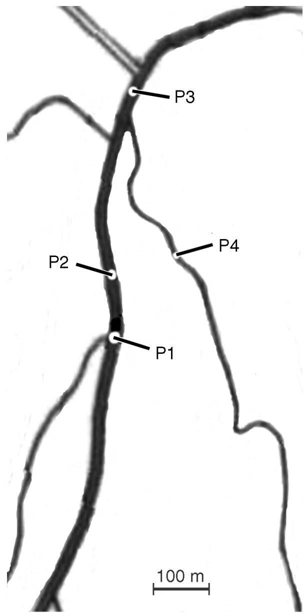


***Figure 2** – Schematic view of the incident area.*

At around 17.30h when wind velocity increased and the fireline intensity was such that the fire fighters decided to retire to a safer place. In this process the fire crossed the road some meters below the location of the group. The driver of the truck ***A*** got into it and drove from P1 in the North direction. After advancing some ten meters (P2) the cabin of the truck was engulfed by a huge flame from a torching tree. This flame crossed the road and ignited the vegetation on the East side of the road beside the truck. The driver left the truck and tried to escape to the unburned vegetation on the East slope above the road.
In the meantime ***F*** and ***G*** led by ***D*** took cover on the east side of the truck when it stopped, waiting for the complete passage of the fire. As soon as the fire intensity decreased they ran along the road towards point P3 which they reached unharmed.
C and ***E*** remained near the road going from one side to another to escape the heat and the smoke, trying to breath fresh air. ***A*** called his comrades and asked them to follow him but only ***B*** did so; the other two tried in vain to persuade them not to go in that direction.
A and ***B*** proceeded on their run through the shrub vegetation and managed to reach a secondary road which they probably thought that would provide them safety or at least a better way to escape to point P3. In spite of the difficulties and the circumstances they managed to walk the distance of around 140m and reach the road before the fire front. But once they reached the road they must have realised that the fire was all around them and they layed at the side of the road in the gutter (P4) to protect themselves from the fire. They must have been sufocated by the very hot gases surrounding them and killed by the heat from the surrounding flames. Their bodies were found embraced, the younger firefighter tried to protect his comrade with his body but to no avail.
In the meantime ***D*** decided to return to the incident area in order to recover his comrades and the truck. With the help of a civilian he managed to reach the vehicle and to drive it to a safer place. ***C*** and ***E*** heard the noise of the truck moving and ran after it managing to climb to its rear platform and got out of the smoke and heath. With the confusion and the lack of visibility ***D*** only realised the presence of his two comrades in the rear of the truck when he got out of it near P3.

Case 2 - Mação Accident

This accident occurred on the 16th. of June 2000 near a forest road running along a slope between two hills (figure 3), during a fire that was originated by the rekindling of a previous fire (P1 in figure 4) that was extinguished on the previous day. As there were no survivors or witnesses of the accident in this case, some of the events that are mentioned below are deductions made by the authors from the elements that were found, but are still open to question.

The fuel was shrubland under a mixture of young *pinus pinaster* and *eucalyptus globulus* cover.
Wind was blowing quite strongly from south-east and the noon temperature and relative humidity at a nearby weather station were respectivelly 33.2ºC and 25%. The FWI value was 58.8, which corresponded to very high danger in this region and it was increasing during three successive days.
The two persons killed in this accident were F. M Lopes (**A**), the Commander of the Fire Brigade of Mação and B. Santos (**B**), that was driving the command vehicle, a Nissan Patrol. This and two other vehicles - a tanker and a fire truck - with a total of nine fire fighters of the same fire brigade arrived at the fire scene at about 15.30h. The daughter of the Commander was among the fire crew.

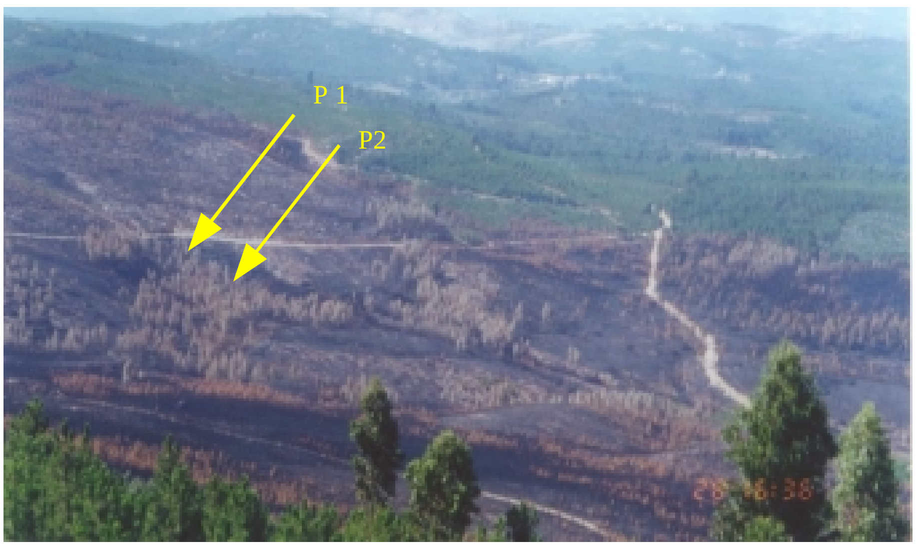


Figure 3 *– General view of the accident site of the Mação accident. The arrows indicate the places where the car went off the road and victim **A** was found (P1) and where victim **B** was found still alive (P2).*

Table 2 – Victims of the Case 2 Incident

Ref.	*Name*	*Age*
A	**Francisco M. Lopes**	43
B	**C. Bruno Almeida Santos**	22

Some minutes after their arrival at the fire site (P2) the fire truck was nearly entrapped by the fire but its crew managed to escape driving the vehicle into the area that had burned on the previous day (P3). The Commander went across the fire front to join this crew and to check their safety. At 16.30h they were able to leave the area and went to replenish the tank at a nearby pond, where the tanker was standing by (P4).
In the meantime other forces were coming to help the personnel on the terrain. The Commander decided to move to a pre-defined site (P5) to establish his command post and guide the oncoming forces. On their way to this site, at around 17.30h they had to go along the road passing by P5 and P6. The fire was spreading on the slope below this road but we assume that it was not very close to it in order to make the trip very dangerous. Due to the fire sections of the road were covered by smoke which impaired the driver’s visibility. It was found that the vehicle was running in the 2nd. gear indicating that the driver was going relatively slowly which is understandable given the circumstances. Near point P6 the driver turned too soon

and the vehicle went off the road. The car fell on its left side on a platform some six meters below the road level with the two men inside.

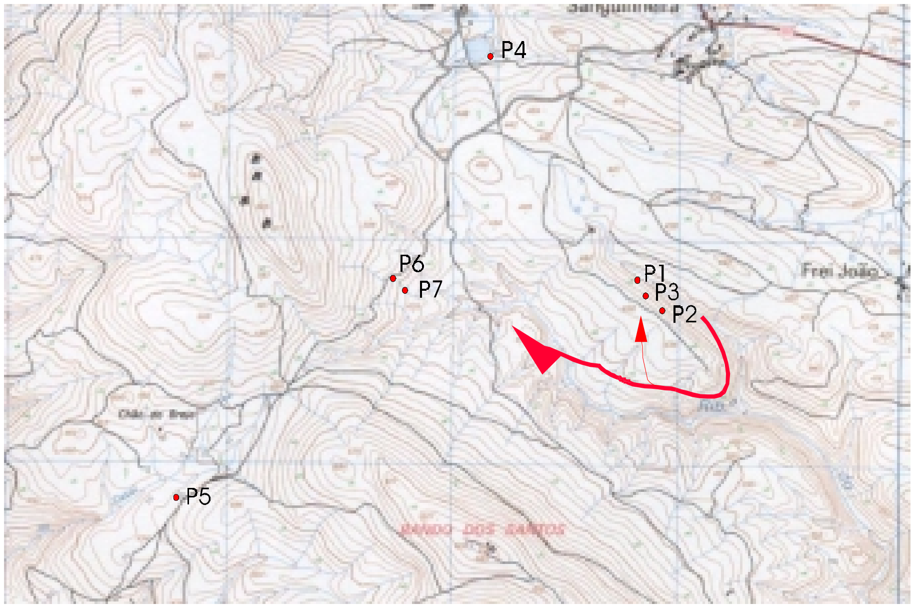


***Figure 4** – Schematic view of the accident site of Mação.The arrowed line indicates the direction of spread of the fire before the accident. North direction is towards the top of the figure. The distance between the gridlines is 1000m and the vertical distance between contour lines is equal to 10m.*

The Commander was injured in the accident and the driver must have helped him to get off the car. This effort must have taken some time and in the meantime the fire must have reached the vehicle burning both men and the car. Probably only then the driver, already with severe burns, left his Commander and ran for shelter downslope. The Commander's body was found near the vehicle and the driver was found severely burned but still alive some 40 m from the vehicle (P7). He was taken to the hospital but died on the next day. The vehicle was entirely destroyed by the fire.

Case 3 - Alvão Accident

This accident occurred on the 24th of June of 2000 in a very steep slope cut by several water lines forming very dangerous canyons (figure 5). The vegetation was a mature *pinus pinaster* stand with low to medium shrub cover below.
The temperature and relative humidity measured at noon at the nearby station of Vila Real was respectively 24.9 ºC and 38%. The FWI for the area that day was 23, which corresponded to High danger for this region. The value of FWI was increasing during the previous three days.
The fire was originated by a prescribed burn on slash at the road side (P1 in figure 6) made by local foresters on the 21st. of June after a short rainfall episode. On the 23rd. there was a rekindling of this burn that was extinguished on the same day. During the early hours of the 24th.
with a strong wind from north there was a second rekindlement that was attacked by the fire brigade of Mondim de Basto. Given the size of the fire help was requested from nearby fire stations.

***Figure 5** – View from the accident site of Alvão taken from road E1. The fire line was at the right hand side of the photo, spreading to the left. The water hose was extended along the centre of the figure. During the accident the fire spread from the bottom towards the top of the slope. The body of the victim was found near the fallen trunk on the centre left of the photo.*

The fire brigade from Celorico de Basto responded with a fire truck crewed by five men, including the Chief J. Avelino Pereira (47) and the R. M. Mesquita (23). They arrived at the fire scene at 10.00h and were ordered to suppress a flank fire between roads E1 and E2. They stopped the vehicle at P2 behind a light tanker that was already fighting the fire and were soon joined by two other vehicles. There were fourteen firefighters plus four civilians at the scene when the accident happened. There were no firefighters or other personnel in the road E2 at the bottom of the slope. When this crew arrived at the site the fire was advancing against the wind with flames less than one meter long and offering no major threat apparently.

A water line of around 200m was extended from the road E1 downslope in the direction of point P3. The personnel handling the hose were situated between P4 and P5. Rui Mesquita was placed at P4 and he was the nearest to the road. Chief Avelino was placed ahead of the hose team at P5 guiding the advance of the crew and watching the behaviour of the fire. The truck drivers remained on the road.
The crew managed to suppress the fireline for about two thirds of its length, but the last 50m were particularly difficult due to rocks and very steep slopes. At around 11.30h the fire had spread across the water line (P3) below the position of the entire crew and began to spread upslope along the canyon.

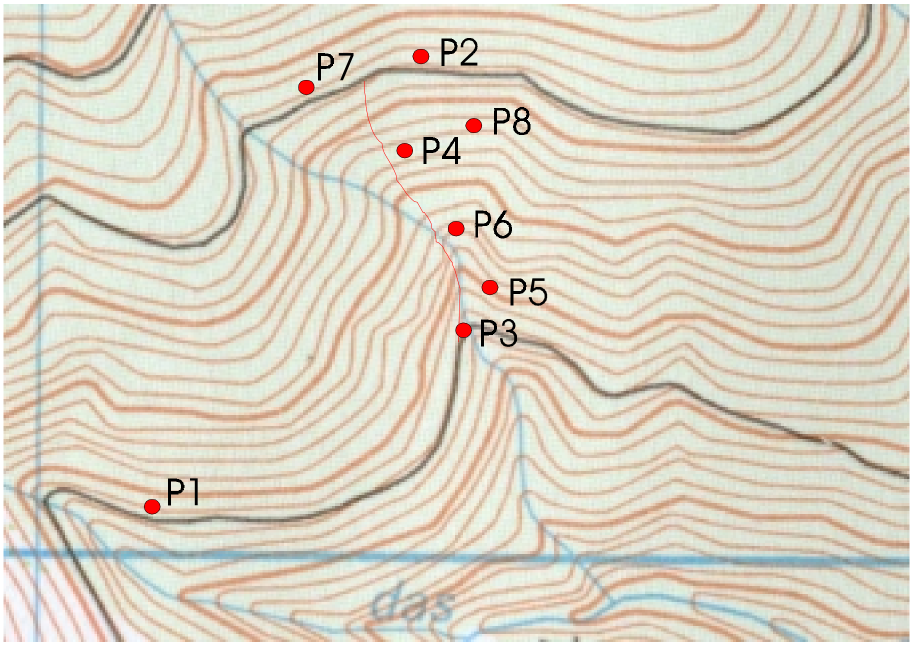


Figure 6 *– Schematic view of the accident site of Alvão. Road E1 is on the top of the figure and road E2 is on the bottom. North direction is towards the right side of the figure. The distance between the vertical gridline to the right border of the figure is equivalent to 1000m. The vertical distance between contour lines is equal to 10m.*

Chief Avelino gave the alarm and ordered everybody to get out of the water line and to move to the already burned area. He himself could not reach that area because he was on the other side of the canyon but he only fled after he knew that his order was followed by all men. This included the drivers with whom he had contact by radio. All the firefighters with the exception of Rui Mesquita ran across the recently suppressed line into the area that was already burned and went upslope to reach the road E1. The drivers managed to pull out their vehicles to safety advancing some 100m along road E1 to a location (P7) above the already burned area. The fire was spreading upslope very quickly and with very long flames. Witnesses refer that the flames were very close to the ground and had lengths of the order of ten meters. In spite of its intensity the fire did not spread as a crown fire in the accident area. This fact may be due to the relatively high moisture content of the needles that is estimated to be of around 140% and to the high crown base to the ground distance of the order of six meters.
When the alarm was given one of the civilians that had descended some meters to help with the hose ran away. He went upwards to the road and to the opposite side in relation of the remaining group. He did so in order to meet the other civilians that were on the road and knew well the place. Perhaps this fact induced R. Mesquita to follow the same path but having to run a much longer distance upslope with the flame front raging below him. Unfortunately he could not make it and was caught by the fire front and killed some 60m below the road (P8). One of his brothers was among the other crew members that were able to escape with minor burns on the face and on the hands due to contact with hot ground and burning material during the run.

Discussion and Conclusion

In all three cases described the fire fighters did not carry fire shelters. This is quite usual among Portuguese fire fighters in spite of the fact that many of them have this piece of protective equipment assigned for their personal use. The debate about the usefulness of the standard fire shelter in these cases may therefore seem academic. In the opinion of the authors in Case 1 the use of fire shelters could have saved the lives of the two fire fighters. In Case 2 it is doubtful if it could have saved both fire fighters given the particular circumstances of this accident. Possibly B. Santos could have used one and save his life when the fire reached the vehicle site, but it is very doubtful if he would make use of it under those circumstances. In

Case 3 the use of a fire shelter would not save the victim, given the large amount of ground fuel and the intensity of the fire.

Another relevant issue to address is the possibility of using the vehicles to survive the passage of the fire. In Case 1 it there are evidences that if the driver the other victim and eventually other members of the crew had remained inside the vehicle they could have supported the entrapment without great difficulty. The truck remained with its engine running during the entire accident and it was actually driven from it immediately afterwards as was said above. In Case 2 one may consider that if the car stayed on the road in its normal position it could have been a safe place to withstand the passage of the fire front, given the width of the road (6m) and the lack of vegetation on its banks. In Case 3 the vehicles could not survive and give shelter if they remained at the same place given the small width of the road (4m) and the intensity of the advancing fire.

Following the recommendations of Mangan (1995), we proceed to analyse the relevance of various factors on the outcome of each accident.

In Tables 3 and 4 the meaning of the abbreviations used is the following:

DNC	Did Not Contribute	SC	Significant Contribution
I	Influenced	NO	No Opinion

In table 4 we consider the compliance to the "18 watch-out rules" that are recommended by the USDA in each case (cf. Thomas and Saltgram, 1998).

Table 3 – Relevance of Various Factors in each Incident

	Case 1	Case 2	Case 3
I - FIRE BEHAVIOUR			
Fuels	I	I	SC
Weather	SC	SC	I
Topography	SC	SC	SC
Predicted vs. Observed	NO	I	SC
II - ENVIRONMENTAL FACTORS			
Smoke	I	SC	SC
Temperature	I	I	I
Visibility	I	SC	SC
Slope	SC	SC	SC
Other			
III - INCIDENT MANAGEMENT			
Incident Objectives	I	SC	SC
Strategy	I	SC	SC
Tactics	SC	SC	SC
Safety Briefings/Major Concerns Addressed	NO	NO	I
Instructions Given	NO	NO	I
IV - CONTROL MECHANISMS			
Span of Control	I	DNC	SC
Communications	I	I	SC
Ongoing Evaluations	SC	SC	SC
"10 Standard Orders/18 Watch-out Situations"	SC	SC	SC
V - INVOLVED PERSONNEL PROFILES			
Training/Quals./Physical Fitness	DNC	DNC	I
Operational Period Length/Fatigue	DNC	DNC	DNC
Attitudes	SC	I	I
Leadership	NO	DNC	DNC
Experience Levels	DNC	DNC	DNC
VI - EQUIPMENT			
Availability	I	DNC	DNC
Performance/Non performance	DNC	DNC	DNC
Clothing and Equipment	DNC	DNC	DNC
Used for Intended Purpose?	NO	NO	NO

Table 4 **– Compliance with the "Watch-out Rules"**

		Case 1	Case 2	Case 3
1	Fire not scouted	DNC	I	SC
2	Unknown terrain	DNC	DNC	SC
3	Safety zone and escape routes not identified	SC	DNC	SC
4	Poor familiarity with meteo conditions	DNC	DNC	SC
5	Lack of information regarding tactics	SC	DNC	I
6	Instructions and orders unclear	DNC	DNC	I
7	Lack of communication inside the team	SC	I	SC
8	Building a fireline without a safe anchor point	I	DNC	SC
9	Building a fireline downhill with fire below	DNC	DNC	SC
10	Attempting a frontal assault on fire	SC	DNC	DNC
11	Unburned fuel between you and the fire	SC	I	SC
12	Cannot see the main fire, and cannot contact with anyone who can	SC	SC	SC
13	Working on a slope with the possibility of burning materials rolling downs and stsrting new ignitions.	DNC	DNC	I
14	Weather getting hotter and drier	I	I	I
15	Wind increases and/or changes	SC	I	I
16	Frequent spot fires across the fireline	DNC	DNC	DNC
17	Terrain and fuels make escape to safety zones difficult	SC	I	SC
18	Taking a nap near the fireline	DNC	DNC	DNC

A detailed discussion of each one of these factors is outside the scope of this report. If we wish to point out the most relevant factors in each case we can state the following:

Case 1 Change of wind direction and intensity

Case 2 Smoke and its effect on visibility

Case 3 Topography with steep slope and canyon effect on fire spread

To conclude the authors wish they should never had to write this report and hope not to have to make similar studies in the future.

Acknowledgements

The authors are indebted to the fire brigades of Tabuaço, Mação and Celorico de Basto for their support and cooperation during the research that was carried out under difficult phsycological conditions for all those involved. The support given by the National Fire Brigade Service through its national and regional delegates is also acknowledged. The meteorological data provided by the Meteorological Institute was of utmost importance in this study. Wind data provided by Enernova and Enervento is also acknowledged. This study is part of the research project INFLAME (Contract ENV4-98-0700) supported by the European Commission.

References

R. Mangan (1995) – Investigating Wildland Fire Entrapments – USDA, Missoula Montana, Technical Report TE02P16.

Thomas, T. e C. Saltgram – *Decision Making in Storm King Mountain* – Wildfire, Sep. 1998, Vol, 7, nº 9 pp 35-38.

Viegas, D. X. and L. Maricato (1999) – *Acidente de Tabuaço – 10 de Julho de 1999 – Relatório Preliminar*, (*in Portuguese*) - Edited by ADAI, Coimbra, July 1999, 35pp.

Viegas, D. X. and L. Maricato (2000) – *Two Firefighters Killed in a Wildfire in Northern Portugal* - Wildfire, Vol. 2, 2000.

Contact	Company	Phone	Fax	E-mail	Address	City	State	Zip	Country
Ackerman, Mark	University of Alberta				1 10012 112 St	Edmonton	AB	T5K 1L9	Canada
Alexander, Martie	Candian Forest Service		780-435-7359	malexand@nrcan.gc.ca	5320 - 122 Street	Edmonton	AB	T6H 3S5	Canada
Anderson, Leslie	Missoula Tech. & Developmental Center		406-329-3719	landerson@fs.fed.us	MTDC, Bldg # 1	Missoula	MT	59804	USA
Arcand, Bev	Alexander Forest Service		780-584-3885		Bag 1	Fort Assiniboine	AB	T0G 1A0	Canada
Arcand, Sheldon	Alexander Forest Service		780-584-3885		Bag 1	Fort Assiniboine	AB	T0G 1A0	Canada
Bachop, Steve	BC Forest Service		250-387-5625	steve.bachop@gems5.gov.bc.ca	2nd Floor, 2957 Jutland Road	Victoria	BC		Canada
Bailey, Brad	Alberta Enivironment Land and Forest Serv		780-623-2570	brad.bailey@gov.ab.ca	PO Box 450	Lac La Biche	AB	T0A 2C0	Canada
Baumann, Roddy K.	US Fish & Wildlife Service		503-231-2364	rbaumann@r1.fws.gov	911 NE 11th Avenue	Portland	OR	97232	USA
Beaver, Al	Yukon Forest Fire Center	867-667-3383	867-667-3355	beavera@inac.gc.ca	345-300 Main St	Whitehorse	YT	Y1A 2B5	Canada
Becker, Wayne C.	Alberta Enivironment Land and Forest Serv		780-891-3890	waynebecker@gov.ab.ca	PO Box 30	Wabasca	AB	T0G 2K0	Canada
Belanger, John	Alberta Land & Forest Service		780-427-0292	john.belanger@gov.ab.ca	9920 - 108 Street	Edmonton	AB	T5K 2M4	Canada
Bochon, Brent	Alberta Land & Forest Service	780-538-8071	780-538-1941	brent.bochon@gov.ab.ca	10811 - 84 Avenue	Grande Prairie	AB	T8V 3J2	Canada
Boyachuk, Greg	Alberta Enivironment Land and Forest Serv		780-623-2570	greg.boyachuck@gov.ab.ca	PO Box 450	Lac La Biche	AB	T0A 2C0	Canada
Brooks, Trinity	National Parks - Fire Management				Box 1348	Invermere	BC	V0A 124	Canada
Broyles, Paul	USDI-National Park Service		208-387-5250	Paul_Broyles@nps.gov	3833 S. Development Ave.	Boise	ID	83705	USA
Bruce, John	Alberta Environment Land and Forest Serv.		403-845-4750	wayne.crocker@gov.ab.ca	PO Box 1720 4919-51st Street	Rocky Mtn. House	AB	T0M 1T0	Canada
Buck, R. J.	Manitoba Fire Program			bbuck@gov.mb.ca	200 Saulteaux	Winnipeg	MB	R3J 3W3	Canada
Burgis, Doug	Tintina Forestry LTD		867-633-5392	burgisdj@internorth.com	207B Tlingit Street	Whitehorse	YK	T1A 2Z1	Canada
Burnstick, Joe	Alexander Forest Service		780-584-3885		Bag 1	Fort Assiniboine	AB	T0G 1A0	Canada
Bushy, Chuck	Montana Prescribed Fire Services Inc		406-259-7276	mpfs@mindspring.com	1333 Colton Blvd	Billings	MT	59102-2436	USA
Butler, Bret	USFS Fire Lab		406-329-4825	bbutler03@fs.fed.us	PO Box 8089	Missoula	MT	59807	USA
Campbell, Roy	Alberta Environment		780-532-3654	roy.campbell@gov.ab.ca	10811-84th Ave.	Grande Prairie	AB	T8V 3J2	Canada
Chamberlin, Paul	USFS - Region 1	406-329-4965	406-329-4955		Aerial Fire Depot 5765 W. Broadway	Missoula	MT	59808	USA
Cibart, Carl	Parks Canada		403-762-3240	carlcibart@pch.gc.ca	PO Box 2895	Banff	AB	T0L 0C0	Canada
Cirella, Sandro	Ontario Ministry fo Natural Resources	705-564-6017	705-564-6033		2621 Skead Road, Unit 14 A Postal Bag 500	Garson	ON	P3L 1W3	Canada
Cohen, Jack	USFS - Fire Lab		406-329-4825	jcohen@fs.fed.us	PO Box 8089	Missoula	MT	59807	USA
Courtreille, Norm	Alexander Forest Service		780-584-3885		Bag 1	Fort Assiniboine	AB	T0G 1A0	Canada
Cruz, Miguel	University of Coimbra		351-239-7085	mgcruz@selway.unt.edu	Apartado 1013	Coimbra		3030	PORTUGAL
Dakin, Gary	Alberta Environment Land and Forest Serv.		780-778-4659	gary.dakin@gov.ab.ca	5020-52nd Ave.	Whitecourt	AB	T7S 1N2	Canada
Dannenberg, Mike	Idaho Dept. of Lands	208-666-8646	208-769-1524		3780 Industrial Ave.	Coeur d'Alene	ID	83815	USA
Davis, Brent	Alberta Environment Land and Forest Serv.		403-297-3851	brent.davis@gov.ab.ca	PO Box 70028	Calgary	AB	T3B 5K3	Canada

DeGrosky, Michael	Consultant, IAWF Board Member	307-734-8616	307-734-8617	mdegrosk@wyoming.com	P.O. Box 7941	Jackson	WY	83002	USA
Dixon, Jeff	Parks Canada		780-992-2951	jeff_dixon@pch.gc.ca	RR 1, Site 4	Fort Saskatchewan	AB	T8L 2N7	Canada
Drapeau , Leo	Alberta Land and Forest Service			leo.drapeau@gov.ab.ca	9920 - 108 Street	Edmonton	AB	T5K 2M4	Canada
Driscoll, Dennis	Alberta Land & Forest Service		780-427-0292	dennis.driscoll@gov.ab.ca	9920 - 108 Street	Edmonton	AB	T5K 2M4	Canada
Dubina, Mike	Alberta Land and Forest Service		780-427-6807	mike.dubina@gov.ab.ca	9920-108 Street	Edmonton	Ab	T5K 2M4	Canada
Dupuis, Howard	Ministry of Natural Resources	705-945-5774	705-945-5785	howard.dupuis@mnr.gov.on.ca	124 Panorama Drive	Sault Ste. Marie	ON	P6A6V5	Canada
Emery, Chuck	Environmental Training Centre		780-865-8266	chuck.emery@gov.ab.ca	1176 Switzer Drive	Hinton	AB	T7V 1V3	Canada
Esnouf, Greg	Country Fire Authority, Victoria, Australia		613-9262-8397	g.esnouf@cfa.vic.gov.au	P.O. Box 701	Mt. Waverly	Victoria		AUSTRALIA
Fenby, Barrie	Alberta Land & Forest Service		780-427-0292		9920 - 108 Street	Edmonton	AB	T5K 2M4	Canada
Finn, Dave	Alberta Environment Land and Forest Serv.		780-542-7917	dave.finn@gov.ab.ca	PO Box 6090	Drayton Valley	AB	T7A 1S3	Canada
Finstad, Petter	Alberta Environment Land and Forest Serv.		780-790-1600	petter.finstad@gov.ab.ca	168 Airport Road	Fort McMurray	AB	T9H 4P1	Canada
Fleming, Vince	Alberta Land & Forest Service		780-427-0292		9920 - 108 Street	Edmonton	AB	T5K 2M4	Canada
Frederick, Kurt	Alberta Land & Forest Service		780-427-0292		9920 - 108 Street	Edmonton	AB	T5K 2M4	Canada
Freedman, Mark	Alberta Land & Forest Service				9920 - 108 Street	Edmonton	AB	T5K 2M4	Canada
Freehill, Kevin	Alberta Environment Land and Forest Serv.		780-826-5401	kevin.freehill@gov.ab.ca	Bag 900	High Level	AB	T0H 1Z0	Canada
Gamache, Marc	Alberta Environment Land and Forest Serv.		403-297-8865	marc.gamache@gov.ab.ca	PO Box 70028	Calgary	AB	T3B 5K3	Canada
Graham, Gordon H.	Alberta Land & Forest Service		780-422-4251	gordon.graham@gov.ab.ca	2816 - 37C Avenue	Edmonton	AB	T6T 1M3	Canada
Gravel, Mike	GNWT, RWED		867-777-2604	mike_gravel@gov.nt.ca	Bag Service #1	Inuvik	NT	X0E 0T0	Canada
Haggerty, Peter	NAIT Forestry	780-865-6950	780-865-8371	firebug@telusplanet.net	RM 134 - 1176 Switzer Drive	Hinton	AB	T7V 2B6	Canada
Hamilton, Scott	Yukon Forest Fire Center	867-667-3309	867-667-3355	hamilton@inac.gc.ca	345 - 300 Main Street	Whitehorse	YT	Y1A 2B5	Canada
Handel, Mark	Millar Western Forest Products		780-778-4631	mhandel@millarwestern.com	5004 - 52nd Street	Whitecourt	AB	T7S 1N2	Canada
Heap, Murray	Parks Canada		780-992-2951	murray_heap@pch.gc.ca	RR1, Site 4	Fort Saskatchewan	AB	T8L 2N7	Canada
Henricks, Jeff	Alberta Enivronment		780-532-3654	jeff.henricks@gov.ab.ca	10811-84th Ave.	Grande Prairie	AB	T8V 2J2	Canada
Herman, Howard	Environmental Training Centre		780-865-8266	howard.herman@gov.ab.ca	1176 Switzer Drive	Hinton	AB	T7V 1V3	Canada
Hirsch, Kelvin	Canadian Forest Service				5320 122nd Street	Edmonton	AB	T6H 3S5	Canada
Hollstedt, Bob	Ontario Ministry of Natural Resources		807-937-6060	bob.hollstedt@mnr.gov.on.ca	Box 850	Dryden	ON	P8N 2Z5	Canada
Houle, Rod	Alberta Enivironment Land and Forest Serv		780-790-1600	rod.houle@gov.ab.ca	168 Airport Road	Fort McMurray	AB	T9H 4P1	Canada
Kehr, Morgan	Alberta Land and Forest Service		780-712-4483	morgan.kehr@gov.ab.ca	#203-111-54 st	Edson	AB	T7E 1T2	Canada
Krayetski, Brent	Fire Management & Forest Protection		306-953-3447		PO Box 3003 - Highway #2 North	Prince Albert	SK	S6V 6G1	Canada
Kubian, Rick	Parks Canada		403-292-4404	rick.kubian@pch.gc.ca	Room 550 220 4 Avenue S.E.	Calgary	AB	T2G 4X3	Canada
Kurtz, Eric J.	MT DNRC: Fire & Aviation		406-842-4242	ekurtz@state.mt.us	2705 Spurgin Road, Bldg. C	Missoula	MT	59804	USA
Lacombe, Gerry	Alberta Environment		780-524-4316	gery.lacombe@gov.ab.ca	PO Box 899	Valleyview	AB	T0H 3N0	Canada
Lesiuk, William	Alberta Environment Land and Forest Serv		780-523-5757	william.lesiuk@gov.ab.ca	PO Box 149	High Prairie	AB	T0G 1E0	Canada

Light, Roger	Alberta Environment Land and Forest Serv.		780-926-5432	roger.light@gov.ab.ca	Bag 900 High Level	High Level	AB	T0H 1Z0	Canada
Lunn, James	Alberta Enivironment Land and Forest Serv		780-849-3299	jim.lunn@gov.ab.ca	PO Box 390	Slave Lake	AB	T0G 2A0	Canada
MacDonald, Dean	Parks Canada		867-872-3313	Dean_MacDonald@pch.gc.ca	Box 750	Fort Smith	NT	X0E 1E0	Canada
MacGregor, Bruce	Alberta Land & Forest Service		780-623-2570	bruce.macgregor@gov.ab.ca	Box 450	Lac La Biche	AB	T0A 2C0	Canada
Macmichael, Paul	New South Wales Rural Fire Service		248219833	paul.macmichael@bushfire.nsw.gov.au	Box 701	Goulburn	NSW	2580	Australia
Madden, Gene	Florida Division of Forestry		850-488-0863	maddeng@doacs.state.fl.us	3125 Conner Blvd.	Tallahassee	FL	32399-1650	USA
Mangan, Dick	USFS - MTDC		406-728-2097	KONA@BIGSKY.NET	11400 Kona Ranch Road	Missoula	MT	59804	USA
Manning, Todd	BRANTA Forestry and Tree Assessment		250-478-7855	tmanning@islandnet.com	5148 - Williamhead Road	Victoria	BC	V9C 4H5	Canada
Matlashewski, Steve	BC Forest Service		250-565-6672	steve.matlashewski@gem6.gov.bc.ca	1011 - 4th Ave.	Prince George	BC	V2L 3H9	Canada
McDonald, Kent	Alberta Environment Land and Forest Serv.		780-778-4659	kent.mcdonald@gov.ab.ca	5020-52nd Ave.	Whitecourt	AB	T7S 1N2	Canada
McDonald, Lark	Mission Centered Solutions, Inc.	303-646-3720	303-646-3720	lmcdonald@mcsolutions.com	PO Box 462102	Aurora	CO	80107-2102	USA
McGuinty, Chris	Alberta Environment Land and Forest Serv.		780-624-7192	chris.mcguinty@env.gov.ab	PO Box 5266	Peace River	AB	T8S 1R9	Canada
McGuire, John	US ARMY	253-967-5337	253-967-9937	mcguirej@lewis.army.mil	Public Works, AF2H-PWE (McGuire), PO Box 339500 ms 17	Fort Lewis	WA	98433-9500	USA
McLevin, John	Alberta Enivironment Land and Forest Serv		780-623-2570	john.mclevin@gov.ab.ca	PO Box 450	Lac Lac Biche	AB	T0A 2C0	Canada
Meek, Kelly	Alberta Environment Land and Forest Serv.		780-427-0292		9920 - 108 Street	Edmonton	AB	T5K 2M4	Canada
Miller, Dale	Fire Management & Forest Protection		306-953-3447		PO Box 3003 - Highway #2 North	Prince Albert	SK	S6V 6G1	Canada
Milne, Shawn	Alberta Land and Forest Service		780-778-4659	shawn.milne@gov.ab.ca	5020-52 Ave.	Whitecourt	AB	T7S-1N2	Canada
Munson, Steve	USFS			smunson@camasnet.com	Box 174	Elk City	IDAHO	83525	USA
Nichol, Doug	Alberta Environment Land and Forest Serv.	1-403-562-7143			11901-19 Ave.	Blairmore	AB	T0K 0E0	Canada
Nimco, Wes	Alberta Environment Land and Forest Serv.		780-675-8165	wesnimco@gov.ab.ca	4901-50 st.	Athabasca	AB	T9S 1E2	Canada
Niven, Shirley	University of Alberta			sniven@telusplanet.net	#1 10012 112 St	Edmonton	AB	T5K 1L9	Canada
Okray, Randy	Campbell County Fire Department		307-686-2222	randyo@vcn.com	200 Rohan Avenue	Gillette	WY	82716-3541	USA
Olsson, Ray	Alberta Land and Forest Service		780-712-4483	ray.olsson@gov.ab.ca	#203- 111-54 st.	Edson	AB	T7E 1T2	Canada
Otway, Steve	Parks Canada		780-992-2951	steve_otway@pch.gc.ca	RR 1, Site 4	Fort Saskatchewan	AB	T8L 2N7	Canada
Palmer, Stan	BLM - NIFC		208-387-5798		3833 Development	Boise	ID	83705	USA
Parsloe, Richard	Parks Canada		780-852-6135	richard_parsloe@pch.gc.ca	c/o Jasper National Park Box 10	Jasper	AB	T0E 1E0	Canada
Pichota, Ed	Alberta Environment Land and Forest Serv.		403-845-2645	gerald.sambrooke@gov.ab.ca	PO Box 1720 4919-51st Street	Rocky Mtn. House	AB	T0M 1T0	Canada
Porter, Ken	Alexander Forest Service		780-584-3885		Bag 1	Fort Assiniboine	AB	T0G 1A0	Canada
Regan, Gerald J	SK Environment Resources	306-235-1800	306-235-4511		Box 100	Buffalo Narrows	SK	S0M 0J0	Canada
Rivard, Paul	GNWT - RWED		867-587-3507	paul_rivard@gov.nt.ca	PO Box 130	Norman Wells	NWT	X0E 0V0	Canada
Robert, Phil	Environmental Training Centre		780-865-8266	phil.robert@gov.ab.ca	1176 Switzer Drive	Hinton	AB	T7V 1V3	Canada
Rodseth, Pat	Alberta Environment	780-623-4133	780-623-2126	pat.rodseth@gov.ab.ca	Box 450	Lac La Biche	AB	T0A 2C0	Canada
Ross, Chris	Advanced Safety Management		780-466-6719	info@advanced-safety.net	8850 60th Ave	Edmonton	AB	T6G 6A6	Canada

Roth, Jim	Storm King Mountain Technologies		323-665-2201	j_roth@stromkingmtn.com	2311 W. Silver Lake Drive	Los Angles	CA	90039	USA
Ruby, Brent	University of Montana		406-243-6252	ruby@selway.umt.edu	Dept of HHP McGill Hall	Missoula	MT	59812	USA
Sayers, Terry	Alberta Environment Land and Forest Serv.		780-790-1600	terry.sayers@gov.ab.ca	168 Airport Road	Fort McMurray	AB	T9H 4P1	Canada
Schafer, Greg	SERM	306-425-4449	306-425-4625		P.O. Box 5000	LaRonge	SK	S0J IL0	Canada
Schmidt, Lance	RWED	867-873-7184	867-873-6230	lance_schmidt@gov.nt.ca	Box 2668	Yellowknife	NT	X1A 2P9	Canada
Schmitte, Bernie	Alberta Environment Land and Forest Serv.		780-697-3517	bernie.schmitte@gov.ab.ca	PO Box 39	Fort Chipewyan	AB	T0P 1B0	Canada
Scobie, Ferenc	Alberta Enivironment Land and Forest Serv		780-623-2570	ferenc.scobie@gov.ab.ca	PO Box 450	Lac La Biche	AB	T0A 2C0	Canada
Shepherd, Landon	Parks Canada		780-852-6175	landon_shepard@pch.gc.ca	Box 10	Jasper	AB	T0E 1E0	Canada
Skrecek, Milan	Alberta Environment Land and Forest Serv.		780-427-0292		9920 - 108 Street	Edmonton	AB	T5K 2M4	Canada
Smith, Dave	Parks Canada		780-852-2169	dave_smith@pch.gc.ca	Box 10	Jasper	AB	T0E 1E0	Canada
Smith, Doug	Alberta Environment Land and Forest Serv.		780-836-3666	doug_smith@gov.ab.ca	PO Box 749	Manning	AB	T0H 2M0	Canada
Smith, Evert	Alberta Environment Land and Forest Serv.		780-778-4659	evert.smith@gov.ab.ca	5020-52nd Ave.	Whitecourt	AB	T7S 1N2	Canada
Sorenson, Sten	SERM		306-662-4348	sten.sorenson.erm@govmail.gov.sk.ca	Box 850	Maple Creek	SK	S0N 1N0	Canada
Spencer, Owen	Alberta Environment		780-524-4316	owen.spencer@gov.ab.ca	PO Box 899	Valleyview	AB	T0H 3N0	Canada
Spila, Quentin	Alberta Environment Land and forest Serv				168 Airport Road	Fort McMurray			
St. John, Paul	Environmental Training Centre		780-865-8266	paul.stjohn@gov.ab.ca	1176 Switzer Drive	Hinton	AB	T7V 1V3	Canada
Steistol, Paul	Alberta Enivironment Land and Forest Serv		780-790-1600	paul.steiestol@gov.ab.ca	168 Airport Road	Fort McMurray	AB	T9H 4P1	Canada
Stewart, Louise	University of Alberta		780-449-1906	lis1@ualberta.ca	11347-70st	Edmonton	AB	T5B 1T3	Canada
Stewart, Tracey	Alberta Environment Land and Forest Serv.		780-926-5403	tracey.stewart@gov.ab.ca	Bag 900	High Level	AB	T0H 1Z0	Canada
Suenram, Bruce	Fire Logistics, Inc.	406-449-9761	406-449-9768	bsuenram@firelogistics.com	Fire Logistics, Inc., PO Box 2164	Montanat City	MT		USA
Taylor, David	Alberta LFS		780-865-7911	davidtaylor@env.gov.ab.ca	Box 6613	Hinton	AB	6613	Canada
Templeton, Mike	Alberta Environment Land and Forest Serv.	403-721-3965	403-721-3930	michael.templeton@gov.ab.ca	PO Box 23	Nordegg	AB	T0M 2H0	Canada
Thomas, Dale	Alberta Environment Land and Forest Serv	1-780-849-3299	780-849-3299	dale.thomas@gov.ab.ca	PO Box 390	Slave Lake	AB	T0G 2A0	Canada
Thompson, Rob	Alberta Environment Land and Forest Serv.		780-675-8165	ron.thompson@gov.ab.ca	4901-50 st	Athabasca	AB	T9S 1E2	Canada
Thorburn, Rob	Environmental Training Centre		780-865-8266	rob.thorburn@gov.ab.ca	Team Leader 1176 Switzer Drive	Hinton	AB	T7V 1V3	Canada
Topolnicki, Kevin	Alberta Enivironment Land and Forest Serv		780-790-1600	kevin.topolnicki@gov.ab.ca	168 Airport Road	Fort McMurray	AB	T9H 4P1	Canada
Viegas, Domingos x.	Adai-Univ. Coimbra		+351-239-780771	xavier.viegas@dem.uc.ot	Dept. Mechanical Eng. Polo II	Polo II - 3030 Coimbra-Portugal			PORTUGAL
Walkinshaw, Stew	Montane Forest Mgt.		403-678-9475	montane@telusplanet.net	#10 Eagle Landing	Canmore	AB	T1W 2Y2	Canada
Warren, Larry	Alberta Land and Forest Service		780-712-4483	larry.warren@gov.ab.ca	#203-111-54 st	Edson	AB	T7E 1T2	Canada
Watkins, Gord	Parks Canada		403-762-1427	gord_watkins@pch.gc.ca	Box 1625	Banff	AB	T0L 0C0	Canada
Woodcock, Doug	Fire Management & Forest Protection		306-953-3447		PO Box 3003 - Highway #2 North	Prince Albert	SK	S6V 6G1	Canada
York, Dennis	Alberta Land and Forest Service		780-778-4659	dennis.york@gov.ab.ca	5020-52 Ave. Whitecourt	Whitecourt	AB	T7S 1N2	Canada
Zwerzinsk, Shawn	Alberta Land & Forest Service	780-538-8080	780-538-1941	shawn.zwerzinski@gov.ab.ca	10811 - 84 Avenue	Grande Prairie	AB	T8V 2J2	Canada

VENDORS

NAME	ADDRESS	PHONE	FAX
Air Tractor E. Scott Smith	Box 485, Olney, TX, USA 76374	940-564-5616	940-564-5612
Bombardier Aerospace Byran MacCormick	Box 6087, Station Centre-ville, Montreal, Quebec, Canada, H3C 3G9	514-855-7638	514-855-7604
Economy Carriers Gerry Stephenson Wayne Percy	10502 - 17 St, Edmonton, AB T6P 1P4	780-417-1531	780-467-2171
Fire Facilities Inc	PO Box 834, Antioch,Illinois 60002, USA		262-862-6980
Fulford Consulting Doug Fulford	7 Millers Road, Sherwood Park, AB, Canada T8A 0T2	780-464-4610	780-417-0405
Global Star Canada Derek Graham	6563 - 54St NW, Calgary, AB, Canada	403-247-8888	403-247-2266
Mercedes Textiles Ltd. Norm Lee Gordon Ramsey	16633 Nymus Blvd. Kirkland Quebec, Canada H9H 4R9	514-697-0817	514-696-5297
Northern Titan Wade Smith	14811 - 134, Edmonton, AB, Canada T5L 4V5	1-800-661-9641	780-455-7569
PDL Mobility Troy Mutch Cam Knight	2420 42 Ave, NE Calgary, AB, Canada T2E 7E6	403-291-5400	403-291-5505
Prof Canada Tom Legale Dennis Holm	5817 - 97 St Edmonton, AB, Canada	780-496-7763	780-438-0289
Rapid Fire and Rescue Inc. Kent Ross Troy O'Connor	Box 246, Red Deer, AB, Canada T4N 5E8	403-341-3000	
Telus Mobility	3030 - 2nd Ave, Calgary, AB, Canada T2A 5N7	403-530-1623	403-272-4877

Travers Steve Leskiw	9647 - 45 Ave, Edmonton, AB, Canada	780-437-5665	
Tri-Data Mike DeGrosky	1000 Wilson Boulevard, Arlington, Virginia, USA	703-351-8300	703-351-8383
NAME	**ADDRESS**	**PHONE**	**FAX**
Velcon Canada Tom Bailey Bill Mononen	3304 Parsons Road, Edmonton, AB, Canada T6N 1B5	780-430-0808	780-413-0341
What on Earth Roy Wagner	104 - 11504 107 Street, Edmonton, AB, Canada T5S 1J7	780-455-5757	780-486-1306
Wildfire Dave Rolheiser	17550 - 105 Ave, Edmonton, AB, Canada	780-484-3705	780-484-5115

International Association of Wildland Fire

If you are currently not a member then we invite you to join. If you already are a member then consider renewing your membership now! Membership benefits include the following:

Individual membership will cost $52, and benefits will include:

- Free Subscription to Wildfire Magazine (Nonmembers Price Is $52)
- Reduced subscription rate to the International Journal of Wildland Fire (Members $100, Nonmembers $150, Institution/Library $250)
- Member Discounts on Conference Registration

Student Membership will cost only $25, and benefits will include:

- Free Subscription to Wildfire Magazine (Nonmembers Price Is $52)
- Wildfire Magazine **AND** the International Journal of Wildland Fire, $100

**The maximum duration that an individual can register as a Student Member is five years.

Organization memberships. IAWF is happy to customize memberships for organizations. We negotiate the price based on the number of authorized users and number of sites. Organizational Membership benefits include:

- Individual and General Membership Benefits for "Authorized Users" - You Pick How Many!
- Free Announcement of Your Organization's Meetings in our publications

Please renew my membership. All prices are in U.S. dollars.

____ Individual Membership $52

____ Individual Membership plus the International Journal of Wildland Fire $152

____ Student Membership $25

____ Student Membership plus the International Journal of Wildland Fire $100

____ The International Journal of Wildland Fire for Nonmembers $150)

____ Please contact me about an Organization Membership

Payment

☐ I have enclosed a check made out to the International Association of Wildland Fire

☐ I want to charge it to my Visa or MasterCard credit card.

Credit Card Number: | | | | | | | | | | | | | | | | |

Expiration Date: | | | / | | | Signature:____________________________________

☐ I have enclosed a donation to the IAWF in the amount of ___________________________

Name:____

Organization: ____

Street Address: ____

City, State, Country, zip or postal code: ___________________________________

Telephone:_________________________________FAX:_________________________

e-mail address: ____

Fill out form above and return to:

Membership Department
International Association of Wildland Fire
P.O. Box 2156
Montana City, MT 59634 USA