

Contents

- 1 Introduction
- 1 Objectives
- 2 Methods
- 3 Results
- 7 Recommendations and conclusions
- 8 References
- 8 Acknowledgements

Assessing the need for footwear with protective toecaps for wildland fire operations in Alberta

Abstract

This study identified footwear appropriate for Alberta wildland firefighters and assessed the need for protective toecaps on their footwear. Hazard and risk of foot injuries were assessed, and recommendations are made.

Keywords

Firefighters, Wildfire, Safety, Footwear, Boots, Protective toecaps, Alberta.

Author

Ray Ault,
Wildland Fire Operations
Research Centre

Introduction

In the past 20 years, advances have been made in the design and manufacture of footwear in response to consumer demand for high performance, task specific footwear. The result is an array of lightweight, comfortable, durable, and functional products. When these new products are compared to protective footwear certified by the Canadian Standards Association (CSA), the results from a wildland firefighter perspective are disappointing. Changes in safety footwear have focused on developing electric shock resistant and static dissipative soles for the industrial market (Figure 1). These hazard conditions rarely occur in the wildland firefighter's work environment.

The wildland fire environment is severe and footwear must withstand contact with embers with temperatures up to 400°C,¹

exposure to corrosive substances, and frequent immersion in water. These boots must also provide ankle and foot support. Recognizable hazards include uneven terrain, slippery footing, obstacles and tripping hazards, and slips, twists, cuts and abrasions are common injuries.

The primary performance requirement of footwear meeting the CAN/CSA -Z195-M92 standard is a protective toecap: "3.1.1 All protective footwear covered by this standard shall provide toe protection and may provide sole, metatarsal, electric shock or other specific types of protection" (CSA 1992). In essence, toe protection is the only requirement and it is usually provided by a steel toecap. Firefighters believe impact and cut injuries to the toes are a minor hazard and question the appropriateness of safety toe footwear for general fireline tasks.

Objectives

This study identified footwear appropriate for Alberta wildland firefighters and assessed the need for CAN/CSA-Z195-M92 protective footwear on the fireline. To achieve these objectives, FERIC:

- Assessed hazard and risk.

Figure 1. Example of CSA-compliant leather boot used by firefighters.



¹ J. Beck, formerly of the Wildland Fire Operations Research Centre, field trials in Jasper, Alberta, temperature of burning forest fuels, summer 2001. Unpublished data.

- Identified appropriate footwear.
- Reviewed CSA footwear design and performance requirements.
- Examined issues related to safety-toe footwear on the fireline.
- Investigated future developments in footwear for wildland firefighters.

Methods

Hazard and risk

Appropriate personal protective equipment for an occupation is determined by conducting a job task analysis, a hazard assessment, and a risk analysis. This process was applied to wildland firefighters in Alberta to determine if toe protection is required for this occupation.

The job task analysis is a comprehensive listing of the significant work performed. The tasks identified for the Ontario Ministry of Natural Resources (OMNR 1996) are consistent with those of Alberta firefighters and therefore this listing was used.

Hazard assessment determines specific hazards associated with a specific task. Risk analysis determines the potential frequency of exposure to the hazard, accident probability, and severity of consequences.

Hazard assessment and risk analysis for fireline construction had been completed in 1999 by Fireline Safety Officers at the Environmental Training Centre in Hinton. These documents were used to identify the degree of risk for specific hazards. FERIC also contracted Safety Environment Assurance Leaders International (SEAL) of Calgary to perform a hazard analysis to determine potential firefighter foot injuries.

To identify the frequency of fireline injuries, annual Alberta Environmental Protection (AEP) accident summaries for 1996–2000 were reviewed, with the assistance of AEP, Sustainable Resource Development (SRD), Occupational Health and Safety. Each file was

reviewed to determine specific cause of the accident and the injury description. This information was summarized and compared to the risk analysis for footwear.

The foot injury data for Alberta—which requires firefighters to wear safety toe footwear—was compared to data from B.C.—which does not.

Using the AEP Fire Information Resource System (FIRES) database, the payroll time for SRD firefighters was calculated and compared to foot injury data to establish the ratio of foot injuries per thousand work hours. This ratio is a useful measurement of risk.

Appropriate footwear

A description of footwear needs, based on wildland fire conditions in Alberta, was developed from fireline activities observed by FERIC researchers and discussions with firefighters. Boot manufacturers were provided with this summary, and were asked to identify boots that would best meet the fireline conditions observed.

FERIC conducted two surveys of Alberta firefighters to determine the CSA footwear worn, their purchasing habits, and the suitability of their footwear for the fireline. In the first survey, 94 firefighters were asked a series of questions, and the condition of each respondent's boot upper and outsole was examined. In the second survey, 25 Sector Boss trainees completed a written questionnaire similar to the first survey. The experience level of firefighters ranged from one to twenty-three seasons and averaged 6.5 seasons.

CSA footwear design and performance requirements

The design and performance requirements of CAN/CSA-Z195-M92 were compared to the primary hazards and work environment faced by Alberta firefighters to determine the suitability of the standard.

Forest Engineering Research Institute of Canada (FERIC)

Eastern Division and Head Office
580 boul. St-Jean
Pointe-Claire, QC, H9R 3J9

(514) 694-1140
(514) 694-4351
admin@mtl.feric.ca

Western Division
2601 East Mall
Vancouver, BC, V6T 1Z4

(604) 228-1555
(604) 228-0999
admin@vcr.feric.ca

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Safety toe footwear on the fireline

Other agencies involved in wildland firefighting, or with similar tasks in the forest environment, were asked about their footwear requirements, advances in boot technology, pertinent footwear standards, and medical issues involving footwear.

Future developments

Canadian and international organizations with an interest in wildland fire footwear were contacted to learn what advancements are on the horizon. Manufacturers selling composite toecaps were contacted and a field evaluation of moldable composite toecaps was conducted.

Results

Hazard and risk

The work performed by firefighters centers on locating, controlling, and suppressing fire in a forest environment. Hiking with tools, operating water delivery systems, removing forest fuels, and patrolling fireline are the primary tasks of firefighters. Alberta firefighters can be expected to work up to 14 h/day, for up to 19 consecutive days.

The hazard assessment and risk analysis of fireline construction, completed by Alberta Fireline Safety Officers, determined foot hazards include being struck or cut by a tool,

blisters, foam irritation, slips, trips, and falls. Only slips, trips, and falls were identified as being of significant risk of injury.

The SEAL analysis also determined that the primary hazards related to footwear are a consequence of slips, trips, and falls. Impact injuries to the toes were identified as a minor hazard.

The two hazard analyses are further supported by the SRD accident data for the period 1996–2000 (Table 1). The frequency and severity of impact injuries to the toe are minimal, with only 5 of the 689 reported injuries involving an impact to the foot (0.7%). These five injuries accounted for 47 of the 9205 days of lost work, a factor of only 0.5%.

Most wildland fire agencies in Canada require a CSA-compliant boot. B.C. is an exception where firefighters are required to wear substantial footwear, defined as “heavy work boots with 15–20 cm tops and composite soles.”² A comparison of foot injuries in B.C. (does not require safety toe) and Alberta (requires safety toe) indicates both have low incidence of impact injuries to the foot (Table 1). Impact injuries to the foot represents 0.6% of all injuries in B.C. fire operations and 0.5% of

² File 735-05 Protective Clothing, File note: Safety footwear for BCFS wildland fire fighting, November 19, 1999. Phil Taudin-Chabot, Training and Safety Team Leader, B.C. Ministry of Forests, Forest Protection Branch, Victoria, B.C.

Table 1. Comparison of foot injuries for Alberta (steel toes) and B.C. (non steel toes) wildland firefighters 1996–2000 ^a

	1996	1997	1998	1999	2000	Totals
Reported injuries, all causes						
Alberta	73	88	236	174	118	689
British Columbia	390	346	435	314	302	1787
Firefighter days lost, all causes						
Alberta	1 060	379	3 412	2 804	1 550	9 205
British Columbia	834	552	3 038	963	816	6 203
Impact injuries involving foot or toes						
Alberta	0	1	4	0	0	5
British Columbia	4	1	2	2	1	10
Days involving lost foot or toes						
Alberta	0	17	30	0	0	47
British Columbia	13	0	16	0	0	29

^a Lorraine Methot, Occupational Health & Accident Prevention, Human Resources Branch, B.C. Ministry of Forests, Victoria, B.C., personal communication by e-mail, July 19, 2001.

time loss due to injury. The infrequent incidence of impact injury to the foot in B.C. where firefighters do not wear safety toe boots suggests the benefit of this protection is low.

While impact injuries are few, 16% of all reported injuries in Alberta were caused by slips, trips, and falls, accounting for 25% of time loss due to injury (Table 2).

Slip, trip, and fall data for B.C. were not available for 1996–2000. However, B.C. Accident Prevention Branch data for 1989 and 1990 indicated slip accidents alone accounted for 18% of firefighter injury.³

The FIRES database for 1995–2000 showed that 5 836 023⁴ work hours were recorded in fireline occupations. Fourteen impact injuries to the foot occurred in the corresponding period, or 0.002 per thousand-work hours. This indicates that the risk of impact injury is minor.

Appropriate footwear

Manufacturers or their representatives⁵ were asked to identify footwear suited to the wildland fire environment. Rubber or rubber composites outsoles were recommended by all, with most suggesting an aggressive outdoor tread design. The outsole material influences its durability and manufacturers suggested some materials are better suited to the higher

temperatures and rough surfaces found on the fireline.

As indicated in the assessment of hazard and risk, slips, trips, and falls account for 16% of all reported injuries. The two surveys conducted by FERIC indicate sole design and composition may be a contributing factor in these accidents.

FERIC's surveys identified the CSA-compliant footwear worn on the fireline, and showed a wide range of manufacturers, sole design, and sole composition. In the first survey, 65% of firefighters wore leather footwear and 35% wore rubber-type water resistant footwear.

Twenty percent of the boots were considered a poor choice for the fireline due to outsole material or design. Some CSA-approved footwear was being used in an environment outside its design purpose (Figure 1). The design of the sole tread will influence the grip or traction of a boot for a particular surface condition. Seventeen percent of the boots used a Vibram trademark composite rubber sole with an aggressive lug design which manufacturers had identified as appropriate for the fireline (Figure 2).

Ninety-two percent of the boots on the fireline had less than four seasons of use (with 38% having one season or less, 34% having two seasons, and 30% having three seasons). Over 50% of the firefighters purchased their footwear from Marks Work Warehouse or its affiliate Work World. Five percent of those

Figure 2. Boot with a rubber composite sole and aggressive lug tread, suitable for use in forest conditions.



³ Lorraine Methot, Occupational Health & Accident Prevention, Human Resources Branch, B.C. Ministry of Forests, Victoria, B.C., personal communication by e-mail, July 19, 2001.

⁴ K. Brooks and B. Bereska, SRD, Edmonton, Alberta, personal communication, January 2002.

⁵ Edmonton Boot Show, Western Shoe Travellers Association, February 2, 2002.

Table 2. Slip, trip, and fall accidents for Alberta 1996–2000

	1996	1997	1998	1999	2000	Total
Lost days of work, all causes	1 060	379	3 412	2 804	1 550	9 205
Lost days of work, footwear	349	47	839	656	389	2 280
Reported injury, all causes	73	88	236	174	118	689
Reported injury, footwear	2	7	56	24	20	109

interviewed on the fireline wore borrowed footwear. There was a low incidence of excessive wear of the boot uppers, and some models showed a poor fit or minimal ankle support.

Rubber footwear was either water resistant chainsaw protection footwear or injection molded PVC boots. Fifty-seven percent of those wearing rubber footwear were using chainsaw protection footwear (Figure 3). Although twice the cost, firefighters told us that these boots are popular because they can be used for winter employment.

Chainsaw protection boots have several advantages compared to the injection-molded type. First, the outsoles are lugged for better traction. Many of the injection-molded boots have sole tread designs that offer poor traction in a forest environment. Second, the rubber material in the chainsaw boots has better flame-resistant characteristics. Finally, the chainsaw boots offer cut protection.

Of the eight recorded cases of impact injuries to firefighters from a hand tool between 1994 and 2000, CSA rubber boots were specifically identified in half; the remaining cases did not identify the type of footwear.

The written questionnaire given to Sector Boss trainees indicated this group was willing to pay \$165 for footwear for the fireline. Thirty percent wear both leather and rubber boots for fireline duties. Surprisingly, 20% indicated they wear cotton socks, and another 36% wear a combination of cotton with either wool or synthetics while firefighting. Cotton socks are generally considered to cause blisters when damp.

CSA footwear design and performance requirements

The foundation of a standard is the design and performance requirements. The design requirements establish the physical characteristics of the product, and are based on the specific functions or the intended use. Performance requirements are published methods to test and rate the physical characteristics to a specified level. To be appropriate, design requirements must relate fundamentally to the intended application or task.

The CAN/CSA-Z195-M92 standard design and performance requirements reflect



Figure 3. Water resistant, natural rubber, chainsaw protective boots.

general industry needs and do not address the specific conditions firefighters face on the fireline. In essence the CSA standard only requires toe impact protection. As indicated in the risk analysis, impact injuries are a minor risk in wildfire operations. The CSA standard states that puncture resistance, metatarsal protection, electric shock resistant soles, and static dissipative properties may be included only when this protection is incorporated in footwear. However, these specific types of protection are not required, and are only provided if the manufacturers incorporate them in the boot.

A comparison of CAN/CSA-Z195-M92 and the National Fire Protection Association (NFPA) 1977 Standard on Protective Clothing and Equipment for Wildland Fire Fighting (NFPA 1998) is useful in identifying the design and performance requirements relevant to the hazards facing wildland firefighters. As the name implies, this NFPA standard reflects wildland firefighting operations and includes test methods for footwear including cut resistance, puncture resistance, corrosion resistance, conductive heat resistance, and abrasion and flame resistance. The NFPA standard also requires that manufacturers provide footwear in half sizes and three widths which improves fit.

Safety toe footwear on the fireline

Some firefighters believe the safety toe is uncomfortable and can be a source of blisters. Research identifying negative impacts of safety toe footwear could not be located. Organizations operating in wildland conditions, and not using safety toe footwear,

Note:

The hazards that the CSA standard addresses are generally faced by building trades and manufacturing workers and are not common hazards to the wildland firefighter.

were contacted but could not provide research documentation to support their policies. However, they did provide comments on the issue.

The USDA Forest Service (USFS) employed over 25 000 firefighters during the 2000 fire season. The organization does not require toe protection. Federal firefighters are required to wear footwear meeting the NFPA standard. According to George Jackson, a recognized authority on protective clothing and equipment in the U.S., the incidence of impact and cut injuries to the foot are infrequent on the fireline. The USFS does not specifically collect foot injury data, but the organization provides training on the choice, care, and maintenance

of boots, and on techniques for walking in the woods.

The Canadian Armed Forces generally do not wear safety toe footwear. Contacts with Department of National Defence (DND) to identify pertinent research studies on footwear highlighted some of the important

issues in selection of footwear for those travelling on foot in difficult terrain. Factors in footwear selection include comfort, biomechanics of the foot, and issues around job task. Toe protection is thought to reduce the marching performance of the soldier and is considered unnecessary.

As the worker tires, changing the center of balance can increase the potential for trip-caused injuries. As the tibialis fatigues, the natural response is to drop the toes, increasing stumbles.

For those firefighters who have difficulties in finding boots with a proper fit, discomfort

from the steel toe is a central issue. Minor irritations in foot comfort can compound over a period of days to affect individual safety and performance. Protective toecaps are manufactured of steel.⁶ For manufacturing efficiency, boot manufacturers will use one of two toecap widths (E and triple E) and a toecap of the same dimensions is used for multiple sizes. The # 10 toecap, for example, is used for size 9, 9.5, 10 and 10.5 boots. A study of the relationship between foot size and combat boot size in the Canadian Forces found most individuals fit boot width D, E or F (Dyck 2000). The D width boots account for 18.5% of the individuals, E width for 58% and F width for 22.5%. These military boot widths can not be directly compared to CSA work boots widths, and fit for width is further complicated by foot circumference. However it is reasonable to conclude that approximately 20% of a population will not find a boot with a good fit for toe width.

The most common injury caused by poor fit is blisters. The occurrence of blisters is most pronounced when working on uneven terrain. Lifesview Emergency Services documented first aid treatment related to foot problems at a fire near Blairmore, Alberta in 2000.⁷ Seventeen percent of all first aid visits related to the foot, with 40% of these injuries being blisters. This fire in rough terrain had almost 5 times the provincial average for reported foot injury. In another study, U.S. Marine Corps recruits participated in initial physical training in San Diego, California. Recruits with blisters were 50% more likely to experience an additional training related injury (Bush et al. 2000). Blisters are often

viewed as a minor irritant but they can lead to more serious injuries.

"It is well known that additional mass in the shoe has a large influence in energy expenditure due to the fact that the foot is constantly being accelerated and decelerated. Also, the additional mass in the toe region would require increased tibialis anterior activity and the tibialis anterior is not a large muscle so would be prone to fatigue." (Darren Stefanyshyn, Ph.D. Human Performance Laboratory, Faculty of Kinesiology at the University of Calgary, personal communication, 2002.)

⁶ Dave Sullivan, President, American Steel Toe Cap Company, personal communication, November 26, 2001.

⁷ Foot injury/illness survey, July 23–31, 2000, Gorge Fire P01-009-00.

Harold J. Nikipelo, Lifesview Emergency Services Ltd. Unpublished report to the SRD.

"Some trades in the army do require steel toed boots, typically where lifting and carrying heavy loads is concerned. But the numbers are few compared to the total. The dismounted infantry make up the majority of army personnel. They march. It has been found that steel toes move the center of gravity forward on the foot, and it doesn't take long before tibialis anterior fatigues. At that point, the toe is not lifted as high as the foot is swung forward, and stumbles occur. The added weight of the steel toes significantly reduces the foot's range of motion. The possible benefit of protecting the toes against impact is far outweighed by the detriment of too much weight positioned in the wrong place." (Walter Dyck of Defence and Civil Institute of Environmental Medicine, DND, personal communication, 2002.)

In August of 2000, Alberta and Ontario firefighters assisted fire control operations in Montana. One hundred Canadian firefighters worked alongside 60 U.S. firefighters. During a 19-day period, 56% of Canadian firefighters received treatment for blisters to the toe and 49% received treatment for blisters to the heel. None of the American firefighters reported toe blisters and 23% reported heel blisters, half of the incidence of injury to Canadian crews.

During the Montana deployment, Ontario fire staff issued an interim policy to allow firefighters to use NFPA footwear while in Montana. "The injuries to the tops of the feet are caused from steep terrain – the steel toe cutting into the top of the foot.... The injuries were evidence that if we did not do something, our Fire Rangers would have to return home. They would not be able to complete their assignment."⁸

Although inconclusive, indications are that the added impact and cut protection provided by the safety toe boot is offset by the increased discomfort and blisters caused by the steel toe.

Future developments

Internationally, the European Committee for Standardization⁹ is developing a new footwear standard for firefighters. The draft standard includes provision for a type-1-boot classification without toe protection. Australia and New Zealand, as members of subcommittee 14, are involved in this standard development as is a representative of the Canadian Interagency Forest Fire Centre (CIFFC). The CIFFC—Resource Management Working Group has identified appropriate protective footwear as a high priority.

In the future, the use of moldable composite materials instead of steel for toe protection promises to reduce the weight and heat conductivity of safety toes. FERIC sponsored a field evaluation of seven pairs of a composite-toe boot, and the results indicated they may overcome some of the difficulties found in steel toecaps. However, the manufacturer withdrew these boots from the market in the fall of 2001 after being unable to meet impact requirements in cold

weather. No composite toecaps are currently available in Canada.

CSA released a new edition of Protective Footwear (Z195-02) in early 2002. In this standard, firefighters' footwear is identified as one of the tasks not specifically addressed.

Recommendations and conclusions

Alberta General Safety Regulations, Part 5 Personal Protective Equipment, Foot Protection 88 (1) reads as follows: "Where a danger of injury to a worker's foot exists or may exist, his employer shall ensure that the worker wears safety footwear that is appropriate to the nature of the hazard associated with the particular work process and is approved under the CSA Standard CAN/CSA-Z195-M92, Protective Footwear."

Under this regulation, if a danger of injury to a worker's foot is minor, the worker is not required to wear CAN/CSA-Z195-M92 footwear. Hazard assessment and risk analysis of fireline tasks performed by Alberta wildland firefighters indicate a minor danger of impact and cut injuries to the foot, therefore CSA-compliant footwear is not required.

Further, this study found the CAN/CSA-Z195-M92 standard design and performance requirements are unrelated to the conditions found in the wildland fire environment where slips, trips, and falls are the primary hazards. Research indicated boot fit for a number of firefighters can be compromised by the selection of steel toecaps. Proper fitting footwear is more important on the fireline than toe protection. Footwear appropriate for the fireline should be designed to provide traction in a forest environment, should allow the foot the fullest range of movement while providing stability for the ankle, and should be constructed of materials that are flame

⁸ Howard Dupuis, Fire Operations Program Officer, Ontario Ministry of Natural Resources, Sault Ste. Marie, Ontario, personal communication by e-mail, April 16, 2001.

⁹ European Committee for Standardization, CEN/Technical Committee 161, Working Groups 1-2. Brussels, Belgium.

resistant. Suitable footwear for the wildland environment can be found in both CSA-compliant and non-compliant footwear. This study recommends that the Alberta Forest Protection Division clarify its Wildfire and Aviation - Protective Clothing Policy FPD 4.2 to require footwear on the fireline to include the following:

- soles designed with an aggressive/lug tread pattern.
- soles manufactured of rubber or composite rubber compounds.
- boots of a minimum height of 20 cm (eight inches).

The policy should be specific in its requirements for both leather and water resistant boots. Leather boots must provide ankle support and a proper fit.

The use of water-resistant footwear on the fireline should include a requirement that only footwear manufactured of flame-resistant materials be allowed (Figure 3).

In the absence of a Canadian standard specifying minimum design, performance, testing, and certification requirements for wildland fire footwear, the Protection Division should provide its firefighters guidance in the selection of appropriate footwear.

The NFPA 1977 standard of a suitable leather boot should be considered for Alberta firefighters (Figure 4). This standard allows each agency to specify boot outsole requirements to reflect terrain features.

Manufacturers have indicated an interest in working with Alberta Protection Division in the design and production of footwear to meet the needs of wildland firefighters. This is an opportunity for the Protection Division to advance the development of high perform-

ance, fireline-specific footwear to minimize the overall number of fireline injuries.

References

- Bush, R.A.; Brodine, S.K.; Shaffer, R.A. 2000. The association of blisters with musculoskeletal injuries in male marine recruits. *Journal of American Podiatric Medical Association* 90(2): 194-198.
- Canadian Standards Association (CSA). 1992. CAN/CSA Z195-M92 Protective Footwear Occupational Health and Safety, A National Standard of Canada, Design requirements 3.1.1. Toronto, Ontario.
- Dyck, W. 2000. A study of the relationship between foot size and combat boot size in the Canadian Forces. Defence and Civil Institute of Environmental Medicine, Technical Report DCIEM TR2000-137. 18 pp.
- National Fire Protection Association (NFPA). 1998. NFPA 1977 standard on protective clothing and equipment for wildland fire fighting. Quincy, Maine.
- Ontario Ministry of Natural Resources (OMNR). 1996. Development of physical performance standards for OMNR initial attack forest fire fighters. Report prepared by Shaw Consulting. Volume 2: 105-131.

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Figure 4. The leather boot on the right meets the NFPA standard. Neither boot has a CSA-compliant steel toecap.

