Forestry Commission
231 Corstorphine Road
Edinburgh
EH12 7AT
www.forestry.gov.uk

Forest and Moorland Fire Suppression

TECHNICAL NOTE

BY IAN R MURGATROYD OF FOREST RESEARCH

SEPTEMBER 2002

SUMMARY

Fire fighting techniques, methods and equipment are evaluated and described. An assessment of fire characteristics in UK forest and moorland situations is included in the evaluation. The range of fire fighting techniques investigated includes the use of waterless, foam and water-based systems, helicopters and fire breaks, with recommendations on best practice. Health and safety in fire situations is discussed and covers personal protective equipment and the effects of heat stress, again with recommendations on best practice. As an aid to the standardisation of fire terminology the Australasian Fire Authorities Council Learning Manual was consulted and applied and the Australian fire danger classification system assessed, with the recommendation that it should be implemented in the UK.

This Technical Note is produced as a guide to the latest developments in wildfire fighting techniques and is the second in a series of three on forest fire control. The others are: *Planning controlled burning operations in forestry* and *Burning forest residues*.

INTRODUCTION

Fire fighting techniques continue to develop in the UK and throughout the world. This Technical Note collates current knowledge on new and existing techniques. The objective is to give guidance to forest and other land managers on appropriate equipment and techniques for the different types of fires which occur in the UK.

Within the European Union, the UK is classed as a low fire risk area. The UK has a relatively uniform annual rainfall pattern with no regular dry season. However, short droughts of 4 to 6 weeks often occur that can lead to catastrophic wildfires (Figure 1). Less research has been done in the UK into forest and moorland wildfire suppression than in countries such as Australia and America.

As explained in the Fire Characteristics section below, heather and *Molinia* fuels are classed as ‘fine fuels’. Dead material in these fuels dries out rapidly in all seasons. These fuels also have low fuel moisture contents when dormant in the winter/spring periods. Fires in these fuel types often develop sufficient intensities to be classed as ‘High’ or even ‘Very High’ in stronger wind conditions, using the Australian Fire Authorities Council rating system. It is imperative that individuals and organisations dealing with fire suppression and fire as a management tool are aware of the basic characteristics of fire and the mechanics of efficient fire suppression.

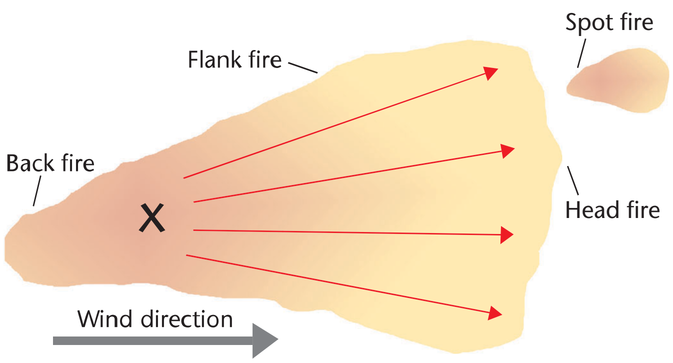
Figure 1 Heather wildfire

In the UK, whenever Fire Service personnel are in attendance at a forest or moorland fire they are the Statutory Authority. They are in charge of the incident with local staff under their direction and in a supporting role.

FIRE CHARACTERISTICS

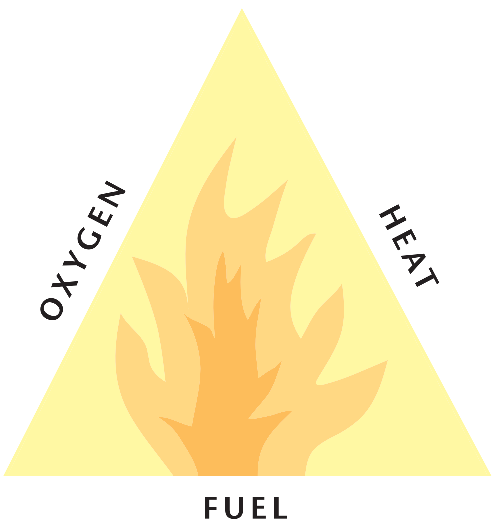
A simplified plan view of a fire is shown in Figure 2. The origin of the fire is shown at X. The head of the fire is the fastest moving part with the greatest intensity and the flanks are not as intense or fast moving. The back fire or back burn is the slowest moving part of the fire with the least intensity. Spot fires can develop in front of the head by blown embers igniting fuel.

Figure 2 Fire description



Fire is a chemical reaction that requires a combination of fuel, oxygen and heat. This is known as the fire triangle (Figure 3). Fire suppression requires the removal or reduction of one or more of these elements: see *Planning controlled burning operations in forestry* (Murgatroyd, 2002).

Figure 3 Fire triangle



Fuel description and characteristics

Fuel in forest moorland conditions usually consists of above ground vegetation (dead or living) and sometimes the organic layers in soil. The different characteristics of fuel affect combustion. Heather and *Molinia* are fine stemmed, aerated and arranged in close proximity, and have all the suitable characteristics for a combustible fuel. Heather and *Molinia* fuels are generally less than 6 mm in diameter and are classed as fine fuels. They can dry more readily and combust quickly compared to larger diameter fuels such as stemwood in brash mats. With greater quantities of fuel more intense fires can generally be expected. However, intense fires can develop in *Molinia*, where a relatively light fuel load can be burnt quickly.

Fire intensity and fire danger rating

Fire intensity can be expressed in kilowatt (kW) per linear metre. The intensity of test fires has been calculated using an Australian formula and can be related to flame height. Fire intensity will change as conditions change. For example, an increase in heather height (fuel load) coupled with an increase in wind speed will significantly increase fire intensity. A doubling of available fuel can quadruple fire intensity.

Fire line intensities that relate to heather growing phases based on flame height in Australian conditions are shown in Table 1. Flame height is measured perpendicular to the ground and flame length is the distance along the angled length of the flame, which is usually greater than the height. Suppression systems at given intensities are also linked to the Australian Fire Danger Rating classification.

To predict the fire danger rating of any given potential fire site, the probable rate of spread (ROS), fire line intensity, access and extent of fire fronts have to be known in advance. To calculate the fire line intensity, the fuel load, which can be directly linked to vegetation height in heather, needs to be known. Further work is needed to establish a consistent method of forecasting fuel loads across vegetation types. With this information it would be possible to determine which suppression systems are the most suitable and previously gathered data could be used to estimate the time required for fire suppression.

For large fires it would be possible to estimate how far the fire will travel and if suppression is possible with current resources at the time of the fire. However, although this is a good, structured approach, it can be thwarted by lack of available data/site information and changing conditions at the fire front. This information could be used as a basis for justifying helicopter call out, which is often seen as an expensive option in the short term. It could also be used to plan the creation of fire breaks and calculate lost ground.

Table 1 Fire line intensities related to fire danger rating and suppression techniques

Fire Danger Suppression Rating Conditions (Australian)	Flame height (m)	Intensity (kW/m)	Probable heather conditions	Suppression techniques
Low	<0.5	0–50	Young/sparse	Fires generally self-extinguish.
Moderate	0.5–1.5	50–500	Young/good cover Degenerate/limited cover	Direct attack with beaters, water-based systems.
High	1.5–3.0	500–2 000	Growing Mature Degenerate/limited cover	Direct attack strenuous, especially with beaters. Use water systems such as fogging with beaters. Helicopter water bombing. Consider indirect attack at upper limits (2000 kW).
Very high	3.0–10.0	2 000–4 000	Mature phase	Runaway heather fires: direct attack by helicopter water bombing. Flanking and indirect attack, i.e. fire breaks, recommended.
Extreme	>10	>4 000 can exceed 60 000	Not found in UK	Control efforts probably ineffective. Defensive strategy recommended.

FIRE DEVELOPMENT

As previously described, heather and *Molinia* have all the suitable characteristics for a combustible fuel. Exposed to heat in sufficiently dry conditions, fire will start and under some conditions in *Molinia* this can reach high intensities within one minute.

With a given fuel load, fuel moisture content (FMC), slope and wind speed will affect fire intensity. Fire intensities will increase with reductions in FMC and as wind speed and slopes increase. Pre-heating of fuels by wind directed smoke and flames will dry fuels in advance of the fire front; this will increase ROS in the initial stages and when a fire ascends a slope. ROS can be expected to double or quadruple on steeper slopes. Great care is required when fighting fires on slopes.

There are three types of fire in forest and moor/heathland conditions:

- **Surface fires** Surface fires burn fuels at or near ground level. This is the most common type of fire.
- **Ground fires** In dry conditions surface fires can burn organic soil layers and develop into ground fires. These can be difficult to detect and extinguish.
- **Crown fires** Surface fires can ascend into the tree canopy and develop into crown fires, which can move very quickly and become extremely intense. Ladder fuels, that is vegetation that links ground vegetation to tree branches, can increase the probability of crown fires. Sustained crown fires are rare in UK conditions.

The main techniques for removing the different components of fire, for prevention or to achieve suppression, are shown in Table 2.

FIRE SUPPRESSION TECHNIQUES

Terminology

The following Australian terminology (Australasian Fire Authorities Council, 1996) is used to describe fire suppression methods. It is recommended that this terminology is adopted in the UK.

- **Direct attack** The fire front is attacked directly with suppression techniques (water and beater based). Direct attack can be subdivided into flanking attack and head direct attack.
  - **Flanking attack is the most commonly used method of wildfire suppression on heather and grass at all intensities.** The fire flanks are extinguished from the

Table 2 Fire component removal and fire suppression

Fire component	Removal technique	Fire size type applicability
Fuel	Remove fuel by **prescribed burning. Bare earth** traces can be created by using machinery. Exceptionally fuel has been moved by forwarders or by bulldozing.	These indirect suppression techniques can be suitable for small and larger intensity fires, if the fire break is wide enough. In heather and grass, fire break widths of 5 m may be sufficient in some conditions. Fire break widths of 10 m will improve fire suppression success rates.
	Cut vegetation traces in heather (**herbicide** application in ***Molinia***) can alter fuel characteristics to disrupt combustion for a limited period of time in some conditions.	Trace widths up to 15 m may be required depending on expected flame length. Vegetation should be removed to improve fire break effectiveness.
Heat	Heat can be reduced by **applying water**. Fine water droplets (fogging) are more efficient for heat removal than jet streams of water.	Fire suppression by standard water jet stream is a common technique and can be used on all forest/ moorland fire types.
	Fuels can be effectively soaked by low and medium expansion **foam streams** and '**wet water**'. Adding **foam concentrate** to water, reduces water surface tension, which improves water penetration into the fuel.	Fogging systems are effective for most heather and grass fires. Fogging systems are less suitable for intense brash fires in strong wind conditions.
	Scrapers separate fuel from heat.	Low expansion foam streams are very effective in suppressing higher intensity fires in brash.
Oxygen	Oxygen supply can be interrupted by using **beaters**, **heaping earth** and by using direct (low expansion) and indirect **foam** (medium expansion foam traces) suppression systems.	Direct attack beater suppression systems are less suitable for more intense fires. Beaters can be used to improve fogging system water efficiency in more fire intense conditions.
		Foam systems can be used effectively in the right conditions to interrupt oxygen supply.

windward side with the fire being extinguished from the rear, round the flanks and pinched out at the head. The back fire should be extinguished from the windward side.

– Head direct attack is used in low or medium intensity fires when the head of the fire is directly attacked from the front. The use of this technique should be considered carefully when suppressing a fast moving *Molinia* fire.

- **Parallel attack** This method is not used very often in the UK. In parallel attack a fire break is created along the flanks and around the head of the fire.

- **Indirect attack** This method is used to control more intense fires and/or where access is difficult or dangerous. A fire break is identified or created in advance of the fire and may take one of several forms: excavated bare earth, burnt or cut vegetation, any of which can be augmented by foam traces.

General technique

The most common fire suppression tactic used is the flanking attack where suppression starts from the back fire along the windward side of the flanks, progressing to the head fire as conditions allow. To ensure the safety of the fire fighter the back fire should always be extinguished first, to avoid possible re-spread of the fire. In some conditions experienced fire fighters may decide to back burn from a secure fire break to reduce nearby fuel loads.

In the event of a fire it is essential that a clear working system is identified, agreed and understood and that it includes a clear command and control structure with good communications. The working system may have to be changed if conditions alter, e.g. wind shifts at the head fire.

TRIALS

Techincal Development Branch carried out suppression trials in winter 1998 and spring 1999, using waterless and water suppression techniques. Heather burning trials were in northeast Scotland in partnership with Michael Bruce of Glen Tanar Estate; *Molinia* burning trials were in a Forest Enterprise Forest District in southwest Scotland.

In all heather fires (apart from a heather wildfire) the back fire, flanks and the fire head were suppressed. In the *Molinia* test fires only the back fire and flanks were suppressed because the head fires moved very quickly and were confined by fire breaks. In some test conditions, greater fire intensities were experienced with small fuel loads with a fast ROS, compared to fires with large fuel loads with a slow ROS. Data from the test fires indicated that the dry tonnes per hectare generally increased with heather height.

WATERLESS SUPPRESSION

A range of direct attack waterless fire techniques was evaluated which included three commonly used but distinct beater designs (Figure 4):

- Short handled (*c.* 1.9 m to 2.2 m) with belt head.
- Long handled (*c.* 2.8 m) with wire mesh head.
- Long handled (*c.* 2.8 m) with flat metal plate, often with additional chains attached.

Evaluations identified that in *Molinia* grass fires the conveyor belt head is best. Mesh heads were not suitable as flaming grass could become entangled in the mesh and help to spread the fire. A longer handle, which reduces operator exposure to radiant heat, would be an advantage although this would make transport more difficult. Sectional handles can overcome this difficulty.

In heather fires, long handled wire mesh beaters have been used by private estates for many years and were found to be most effective. This type of beater is good for fire suppression because:

- With a 2.8 m long handle the operator is at a greater distance from the heat source.
- Mesh heads are more durable than conveyor belts during fire suppression.
- Mesh heads can be used to rake and scrub muirburn vegetation.

Figure 4 Belt and wire mesh beaters

A 'Cawdor Estate' long handled design (Murgatroyd, 2001) with a partial tin insert was also judged to have an effective smothering and raking action in heather.

An aluminium grain shovel is often used as a fire scrubber. A fabricated version of this has been developed by Glen Tanar Estate in collaboration with D. Chapman, a local blacksmith and engineer. The scrubber is designed to be used with minimum effort and is therefore best suited to prolonged operations. It was judged to be most effective in shorter heather.

WATER SUPPRESSION

Two water-based systems were tested: high pressure portable pumps and very high pressure (low volume) pumps. In both systems water can be used in the following ways.

Jet stream

This is an unbroken stream of water from a nozzle normally directed onto the seat of the fire and moved across all burning material to achieve maximum cooling.

Conventional high pressure pumps with appropriate branches and nozzles are normally used to form jet patterns.

The advantages and disadvantage of a jet are outlined in Table 3.

Table 3 Jet stream use: advantages and disadvantage

Advantages	Disadvantage
• has a longer reach • has good penetration and can be used to dig into soil to expose hot spots • least affected by wind • less affected by radiant heat • can be used to cut into peat and vegetation tussocks (especially with pencil nozzles) to expose hotspots for damping down; very high pressure systems are very effective in this role	• large quantities of water may be used in an inefficient manner, especially with older branchpipe/nozzle combinations, with no control options

Spray pattern

Water is broken down into smaller droplet sizes by a spray nozzle or a variable control branch. Conventional small water pumps with appropriate branches and nozzles can be used to form spray patterns.

The advantages and disadvantages of a spray pattern compared to a jet stream are outlined in Table 4.

Table 4 Spray pattern use: advantages and disadvantages

Advantages	Disadvantages
• provides a water curtain for fire-fighter protection • accelerates the rate at which water is converted to steam, removing more heat from the surrounding fire • covers a large area and therefore more economical in its use of water	• has a shorter reach • will not effectively cool hot spots or objects unless it is applied directly onto them • has less penetration capability

Fog pattern

A fog pattern is a very fine spray of water droplets which increases the rate at which heat is removed from the fire by creating steam (Figure 5). This pattern is commonly produced by the very high pressure pumps which tend to be vehicle washing pumps modified for heather, grass and forest fire fighting.

Figure 5 Fog pattern

The advantages and disadvantages of a fog pattern are shown in Table 5.

The combined use of a fogging system and a team of beater operators was found to be the most efficient fire suppression method in both *Molinia* and heather fires. The fogging system was used to knock down and extinguish most of the fire front with beater support 5 m to 10 m apart to extinguish any remaining fire and subsequent flare ups. This method is the most economical in the use of water.

A fire fogging unit using 30 litres of water per minute (twice the current rate of 14 litres per minute) has recently been introduced and may be a viable alternative to foam in intense brash fires.

Table 5 Fog pattern use: advantages and disadvantages

Advantages	Disadvantages
• maximises the effective use of water for heather and grass fires (and some brash fires) • uses small diameter (10 mm/3/8″), light and easy to handle hoses • can be ATC based • covers a larger surface area than water spray • absorbs heat rapidly • enhances the rate at which water is converted to steam, removing more heat from the surrounding fire than a spray pattern	• has a short reach • affected by wind • unsuitable for very high intensity fires such as heaped brash fires • may expose operators to high heat levels in intense fires • fogging pumps cannot be used to transfer water, therefore small water pumps are needed

There is some evidence that the addition of small quantities of foam detergent or other surfactants to create 'wet water' will improve the penetration of water, water efficiency and the duration of the fogging system's cooling effect.

Equipment for use with water-based systems

Hose

Small diameter 'flat lay' fire hose that complies with BS6391 Type 3, which is strong and has some degree of burn resistance, has been used successfully for forest and moorland fire fighting. The efficient handling of hose on site is essential for effective fire suppression. The use of lower quality hoses with couplings secured by 'jubilee' type clips should be avoided. Angus Duraline (25 mm/1″) hose, ordered with factory fitted couplings which are secured by metal ties with a canvas protection sleeve, is recommended. This sleeve helps to reduce internal hose chafing on metal couplings.

Small pumps

The Godiva GP250 and Davey fire fighting pumps tested had a similar performance to the Honda WH20XK1D pressure pump. The high performance Davey pump was effective for water spray and low and medium expansion foam. Honda pumps for water transfer and Davey pumps for front line fire suppression were found to be a good combination. Common couplings allow all pumps within the system to be compatible.

Knapsacks

Knapsacks can be used to suppress some grass fire types but are generally best used for damping down duties. There are purpose built fire fighting knapsacks such as the Canadian Flexpak. Where herbicide type knapsacks are to be used for fire fighting duties they should be clearly marked 'Fire' and used for fire fighting duties only. They have low water usage rates and are suitable for *Molinia* and heather damping down.

Foam

In forest and moorland fire suppression synthetic foam concentrate is used to form medium expansion foam traces. Foam concentrate can be supplied in different strengths and is mixed at different rates with water to form a foam solution. This solution is aerated by mechanical action through a branchpipe to form a foam stream, which can be used to create a foam trace (at medium expansion), or applied to the fire front in direct attack (at low expansion – see Figure 6). Foam systems use considerable quantities of water.

Figure 6 Direct attack of brash fire with low expansion foam

Expansion rates are divided into three classes:

Low expansion	1:1	to	20:1
Medium expansion	21:1	to	200:1
High expansion	201:1	to	1000:1

The foam stream is directed to the fire base to reduce stream fluid loss from updraughts and the hottest part of the flames. The perimeter of the fire front is suppressed and made safe and then the interior is extinguished. When attacking the fire front some of the foam stream should be directed to unburnt vegetation so that potential fuel is wetted. The visible nature of foam streams should reduce over-application. Hot spots can be smothered with foam.

Indirect attack by the creation of foam trace fire breaks or using foam traces to widen existing fire breaks such as tracks and treated vegetation (cut or herbicide) is the most widely known application of foam. Foam traces can also be used as a line to back burn from or burn to, creating wider burnt vegetation fire breaks. This application is seldom used in the UK but is likely to be the most realistic use of foam traces in wildfire suppression. Unless large quantities of water are available on site, foam is likely to be more effective to reinforce other barriers.

Foam concentrate can be used in damping down operations (0.5 litre per 100 litres water) to improve the efficient use of water. Wet water can be applied by:

- hose and branch with conventional pumps
- hose and branch with high pressure pumps
- purpose built knapsacks
- helicopter bucket.

Branchpipes should have on/off ball valves and be fitted with 63 mm (2.5″) instantaneous couplings. Branch effectiveness is dependent upon mixing rates and hose and pump performance in the conditions encountered.

In practice, the choice for forest fire fighting is between synthetic detergent (SD) and standard protein (SP) foam. Some manufacturers distinguish between standard and super SD, which requires less concentrate to make foam. Super SD concentrates were specified for helicopter fire suppression.

As foam is considered to be a pollutant, water supplies must not be contaminated.

Focstop

Focstop powder is mixed with water to form a viscous fire suppressant. It reduces the surface tension of water, which improves fuel wetting and damping down operations, and can be used with conventional pumps, fire knapsacks and helicopter fire suppression buckets. Focstop and foam were found to have similar fire suppression rates but foam was less susceptible to incorrect mixing and was highly visible. Low expansion foam systems, with the greater reach, are to be preferred in suppressing intense fires.

HELICOPTER FIRE FIGHTING

Helicopters can be used to:

- Reconnoitre fire sites to plan suppression. Over-flying of larger fire sites can be useful for planning operations and safe deployment of personnel.

- Water bomb fire fronts. In recent years it has been reported that the most common role of helicopters on fire sites has been water bombing. They may also be used to support ground teams by supplying water to tankers (with a helicopter funnel) and flexi-dams.

- Extinguish hot spots during damping down operations once fire front suppression has been achieved.

- Transport water to ground based fire suppression.

- Transport equipment and personnel over difficult terrain.

Helicopters should be hired, where possible, with the operator supplying the bucket, fuel and personnel. The advantages of hiring contractors supplying their own buckets are:

- Health and safety issues are more clearly defined.

- Supply of efficiently operating equipment is defined.

- There is no requirement to maintain own equipment.

- There is no mismatch of own equipment with the helicopter.

Periodic training is essential to ensure that helicopters are used safely, efficiently and cost effectively. Training will help potential customers to make the most of this resource. Available water sources should be *c.* 0.9 m to 1.1 m deep, 2.5 m to 3.0 m wide with very little water current and accessible for helicopter use. Managers should identify suitable water supplies on site maps and mark 3.0 km radius circles around these supplies, or around the edges of larger areas of water. Where significant potential fire areas are not within efficient helicopter range, water supplies that can be pumped into Flexi-dams (with suitable access) should be identified. These water supplies should have a minimum flow rate of at least 300 litres per minute and be accessible for helicopter Flexi-dam operation.

Buckets The two types of bucket commonly used in the UK are the Bambi and the Big Dipper.

Flexi-dams Flexi-dams are used where water sources are too far away from the fire site or where water sources close to the fire site are not suitable for helicopter access and/or bucket use. Flexi-dams are constructed from heavy duty flexible PVC coated fabric and are self-supporting when filled with water. Models of 12 000 litre capacity with a large access diameter (easier for pilot) are most suitable for protracted fire suppression operations.

FIRE BREAKS

Fire breaks can be natural, man made or both. Vulnerable plantations may need to have a network of fire breaks so that fires can be contained in small areas. These may be created using tractor mounted chain swipes or ploughs as preventive measures.

During fires, fire breaks can be used for individual fire suppression where intensities are high and access difficult. Fire breaks can be created by using any of the following techniques/equipment:

- Herbicide – requires advance planning.
- Excavators and bulldozers.
- Cut vegetation – swipe.
- Foam – short duration.
- Burning the vegetation.

Experience has shown that to be effective a fire break is required to be at least 2.5 times flame height (expected flame length). This is normally 6 m to 10 m wide to be reliable under all conditions.

HEALTH AND SAFETY

Personal safety is paramount. Considerations such as safeguarding property should be of secondary concern. A clear command structure and good communications will assure the safety of personnel and equipment. Mobile phones or personal radios can give effective communication particularly where vehicles cannot reach fires, and the issue of torches is important for night-time fire fighting.

Personal protective equipment

Protection against falling objects should be worn in woodland fire suppression and when using helicopters. Helicopters can carry a range of underslung loads and the load or objects such as stones and sticks may be dislodged during transportation. Forestry helmets must be secured with a chinstrap and worn with ear defenders when required by the Risk Assessment. A Risk Assessment should be undertaken to assess if helmets are required for open land/hill prescribed burning or fire suppression. The assessment should take account of possible equipment use, fire spread into woodlands and helicopter use. The following safety clothing and skin protection products are recommended:

- Full length face shields (helmet or carrier mounted) provide excellent protection against radiant heat to the face and neck.

- Flame retardant clothing such as Proban-treated cotton overalls are the most suitable for fire fighting (conclusions from Australian research).

- Eye protection should be worn when using water-based systems especially high pressure fogging systems.

- Filtering face-piece respirators are advised for difficult working conditions with high levels of dust and ash.

- Safety boots or safety wellingtons with good ankle support and grip should be worn during fire suppression and be waterproof when using foam concentrate.

- Stout, flexible leather gloves will be suitable for most fire suppression activities. Gloves offer protection against abrasion, cuts, impact and embers. Waterproof neoprene (30 cm long) gloves should be worn when handling and using systems with foam concentrate, as it is a powerful degreaser and skin contact must be avoided. Clothes should be checked periodically with an ungloved hand to ensure that they are not getting too hot.

- Moisturiser creams and lip salves should be used to prevent the skin from becoming dry in hot fire conditions. Operators handling foam concentrate will be more susceptible to skin drying. Sunblock should be applied to exposed skin on the neck and face.

Heat stress

Fire suppression is a strenuous activity which often takes place in difficult conditions, and can cause heat stress leading to heat exhaustion and possibly heat stroke. Managers should ensure that fire fighters are aware of heat-induced illnesses and know how to treat the symptoms and call for help when necessary. Ample water supplies should be accessible to fire fighting teams. Personal water supplies should be supplied, with first aid equipment.

The symptoms of heat stress are weakness, dizziness and nausea. Where a fire fighter is removed from the fire front and given water, rest and shade, recovery will usually take place quite quickly. If heat stress is not recognised, the more serious forms of heat-induced illness, heat exhaustion and finally heat stroke can develop. Medical treatment is required for these heat-induced illnesses and the patient should be given water and kept cool.

Studies indicate that fire fighters may fail to replace body fluids even when they have drunk sufficient to quench their thirst. The fluid replacement taken in may be only half of what is actually required. Plenty of water should be drunk as soon as sweating occurs, before fire suppression starts and more than is felt necessary. The recommended amount is 1 litre of cool (not chilled) plain (sugar free) water per hour. Carbohydrate foods such as bread, pasta and cakes are recommended. Managers should ensure that teams have sufficient suitable food and water on site during prolonged fire suppression.

Fire plans and incident control teams should include provision for relief teams from identified sources. These sources should be notified as soon as it is thought that a fire will burn for a prolonged period. Fire fighting teams and managers should be changed (where possible) to ensure adequate rest, which is important for continued efficient and safe operation.

CONCLUSIONS AND RECOMMENDATIONS

- Fire suppression requires the removal or reduction of fuel, oxygen or heat from a fire front. Wind, slopes and fuel are the most important factors affecting fire behaviour.

- The Australian terminology and fire danger rating system which takes into account flame height and fuel load can be related to UK conditions and should be adopted in the UK.

- A consistent method of forecasting fuel loads across vegetation types needs to be established as an aid to predicting fire danger and estimating best fire fighting methods.

- Good communications are essential, using mobile phones or personal radios. Torches should be issued when fighting fires at night.

- For waterless suppression use long handled beaters with mesh heads for heather fires and conveyor belt heads for Molinia fires.

- For water and foam suppression the following techniques and equipment are recommended:

  – jet stream using a high pressure pump with appropriate branches and nozzles;

  – spray pattern using a small water pump with appropriate branches and nozzles;

  – fog pattern using a very high pressure pump and light, easy to handle hoses;

  – foam stream or trace using synthetic foam concentrate and aerated by mechanical action through a branchpipe;

  – damping down using purpose built knapsacks.

- Use hired helicopters for reconnoitering, transportation and water bombing.

- Fire breaks can be created using different techniques and equipment but to be effective they must be 6–10 m wide.

- The following health and safety precautions and protection are recommended:

  – drinking water to avoid the onset of heat stress;

  – forestry helmets secured with chinstrap and worn with ear defenders when required by risk assessment;

  – full length face shields to protect face and neck;

  – eye protection during fogging and filtering face-piece respirators when working with dust and ash;

- wearing proban-treated cotton overalls, safety boots or wellingtons and flexible leather or waterproof gloves;

- protecting skin by using moisturiser cream, lip salve and sunblock.

ACKNOWLEDGEMENTS

I would like to thank the staff of Glen Tanar Estate and Forest Enterprise South Scotland for their assistance during this project.

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Enquiries relating to this publication should be addressed to:

Forest Research
Technical Development Branch
Ae Village
Dumfries
DG1 1QB

Tel: 01387 860264
Fax: 01387 860386

E-mail: tdb.ae@forestry.gsi.gov.uk

ISSN 1470-6792
ISBN 0-85538-571-5

FCTN003/PPD(KMA)/ALLNDR-1.5K/SEP02