HMSO £1.35 net

Forestry Commission Leaflet **80**

Forest Fire Fighting with Foam

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FRONT COVER. Gorse fire approaching foam barrier.

FOREST FIRE FIGHTING WITH FOAM

M J R Ingoldby and R O Smith

Introduction

The losses of forest crops due to fire over recent years amount to an average of 381 hectares per year, with heavier losses in drought years like 1976 when 480 hectares were lost. Recent research into fire fighting techniques has resulted in the introduction of new materials and modified equipment which greatly help the prospects for forest fire control. Alternative systems are discussed in this publication, and detailed recommendations are made on the most promising technique currently available.

Project objectives

At the outset of the research four objectives were defined:

a. To review fire fighting techniques appropriate to Forestry Commission requirements.

b. To assess existing equipment and determine the requirement for modified or alternative equipment.

c. To examine the potential role of fire retardants, "stickers", etc., in forest fire fighting.

d. To evaluate safety equipment available and its application to forest conditions.

Background

The need for such a project was recognised as a result of several factors. Firstly, the changing character of plantations, as post-war plantings move into established marketable crops, means that a different form of fire may be encountered. This is likely to be more difficult to control, to threaten potentially high capital losses, and to require different deployment of resources. Secondly, the reduction in availability of manpower for fighting forest fires has stressed the need for techniques to be used which will have a major impact on fire control using limited staff and equipment.

When many fire outbreaks occur at the same time, public fire services cannot always be guaranteed at forest fires. This means that the forest manager should have the ability to contain a fire outbreak even if outside assistance is delayed or not forthcoming.

Traditionally fire control has either been by means of beating – a labour intensive operation – or by application of water directly onto the fire. Water is usually available only in limited quantities and incurs high costs in transport to the fire site. Accordingly the need existed to improve the efficiency of water usage at the fire.

Water additive techniques

Of several options the choice of a water additive technique is most appropriate in making efficient use of water when dealing with forest fires. This may be achieved either by introducing fire inhibitors or by changing the physical characteristics of the water.

The operational requirements of such techniques are:

a. To contain the fire.

b. To permit effective barriers to be established in advance of the fire.

c. To allow men to stop an advancing fire safely and easily.

d. To be applicable to all forest vegetation.

e. To utilise simple low cost equipment based on existing systems.

f. To make economical use of water.

g. To permit treated boundaries to be easily identified.

Various techniques were examined:

a. *Viscous water*
This method involves "thickening" water by the addition of a viscosity agent such as sodium alginate. On application, viscous water will be retained at the point of contact as an effective barrier against fire. Loss from drainage or evaporation is minimal. Accordingly, water supplies can be used to maximum advantage. However, while of significant potential benefit, there are specific disadvantages in using this technique. The difficulty of mixing, operational inflexibility, and extended subsequent maintenance of the specialised equipment, limit its usefulness. Due to such constraints, viscous water would appear to have no role to play in forest fire control. This argument is strengthened by the ability of other media (e.g. foam) to produce the same advantages with none of the drawbacks.

b. *"Wet" water*
If water is "thinned" by the addition of a detergent which reduces surface tension, "wet" water is produced. This technique has long been established as aiding the penetration of water into organic soils or through dense matted vegetation. A wetting agent should not be added for actual fire fighting where it offers no advantage; but in damping down it facilitates the penetration of water to deep-seated hot spots.

c. *Chemicals*
Various chemical additives are available for fire inhibition or retardation. Most are an integral part of water bombing, and as such are used essentially in aerial techniques. An extremely costly and sophisticated operational structure with full ground based support is required, to incorporate specialised storage, mixing, and handling facilities. Accordingly, the use of chemical additives is unsuitable for the scale and requirements of fire control in British forests at the present time.

d. *Foam*
By introducing a foam concentrate into water and aerating the solution, using a branchpipe, water can be expanded into foam (see Appendix I – Definitions). Trials with different specifications of concentrate have indicated that the use of a fortified detergent-based compound is most suitable for forest conditions. Protein foam, which had been used in the past, was shown by field trials to have a short operational life. The early cost advantage of protein compared with fortified detergent has also been reversed, as improved formulation of the latter permits the induction rate to be reduced by 50 per cent.
Various expansion rates are available according to operational requirements.
Fortified detergent foam increases the efficiency, economy and versatility of water as a fire control medium by providing an insulating, reflective water blanket over the vegetation. The equipment required is of low cost and extremely straightforward.

It was for these reasons, that of all the currently available techniques, foam appeared to be the most suitable for forest fire fighting in this country.

Foam

Foam offers all the advantages of viscous water with some additional benefits:

a. It facilitates water economy by reducing evaporation and run-off and thus enables water to be more effectively deployed.
b. Being visible it saves waste of water by over-treating and enables areas where foam application (and hence protection) is breaking down to be quickly pin-pointed and reinforced.
c. Operationally it is versatile, with changes between untreated water, foam and "wet" water (in the case of detergent concentrate) being instantly possible.
d. It may be used over a wide range of fire situations and vegetation types with equal success and can be projected up to any height depending on equipment capacity, e.g. 20 metres using a 12 hp pump.

e. When properly used, it allows fire outbreaks to be controlled more easily with less resources.

f. It is non-toxic, non-abrasive, possesses long shelf life and requires minimal post-operative maintenance of the associated equipment. No special protective clothing is required during its use.

The use of foam requires only the following simple precautions:

a. Avoid contamination of water courses because of amenity considerations.

b. Although non-toxic, prolonged contact between the skin and the concentrate should be avoided. To remove concentrate wash thoroughly with water.

c. Flushing of solution from plain steel or galvanised water tanks is required to prevent accelerated rusting.

Foam production

Foam is produced by adding a small quantity (normally 1.5 – 2.5 per cent) of concentrate to water and aerating it by pumping through a foam branchpipe. Most foam units are adaptations of conventional units which already have a water reservoir and a pump (Diagram 1). Additional equipment required for foam production consists of an inductor, which regulates the amount of concentrate introduced into the water delivery, and a foam branchpipe. It is the branchpipe specification which will determine the characteristics of the foam.

It is possible to dispense with the inductor unit and mix a predetermined solution in the water reservoir. However, this negates the system's operational flexibility and will be wasteful of concentrate should foam not be required.

Present systems offer various expansions, low (8 – 10× volume of water), medium (60 – 100× volume of water) and high (up to 1000× volume of water). High expansion foam having low water content soon breaks down and is not satisfactory for forest fires. Accordingly, consideration was restricted to low and medium expansion foam. These have shown themselves to be efficient control agents in various categories of fires. The equipment used requires only simple post-operational maintenance.

The choice will depend on the performance criteria required. Normally medium expansion foam is most suitable for ground traces and vegetation up to 2 – 3 metres high. Low expansion foam, having more mass and accordingly better projectability, is used for canopy applications.

Fire fighting with foam – techniques

With 30 wildfires and at least 10 test fires successfully controlled by foam techniques, a basic series of operational guidelines has been firmly established. While the deployment of foam must always be based on management requirements, certain fundamental aspects of foam application should be remembered.

The use of foam should be limited to the application of protective barriers – be they on the ground against encroaching surface vegetation fires (Front cover) or in the canopy to control oncoming crown fires. It should *not* be used for direct application onto fire where untreated water is preferable because of its superior penetration and cost efficiency.

Barriers should be continuous as even a break of a few millimetres may be quite sufficient to allow the fire to pass, and in most cases build up again having penetrated the barrier. Similarly, short strips of foam do not normally serve a useful purpose as fire will outflank them.

Ground barriers should be 0.6 to 1.0 metre wide whether applied by the pedestrian or from a vehicle (Plates 1 and 2). Canopy application should ideally be complete, and this is most efficiently achieved by projecting the foam to the top of the tree (Plate 3). So that the foam may have the greatest chance of controlling canopy fires advantage should be taken of any natural breaks in the vegetation. Initially foam application is made to the side of the break furthest from the fire.

The thickness of the barrier may be determined by local conditions and may, for

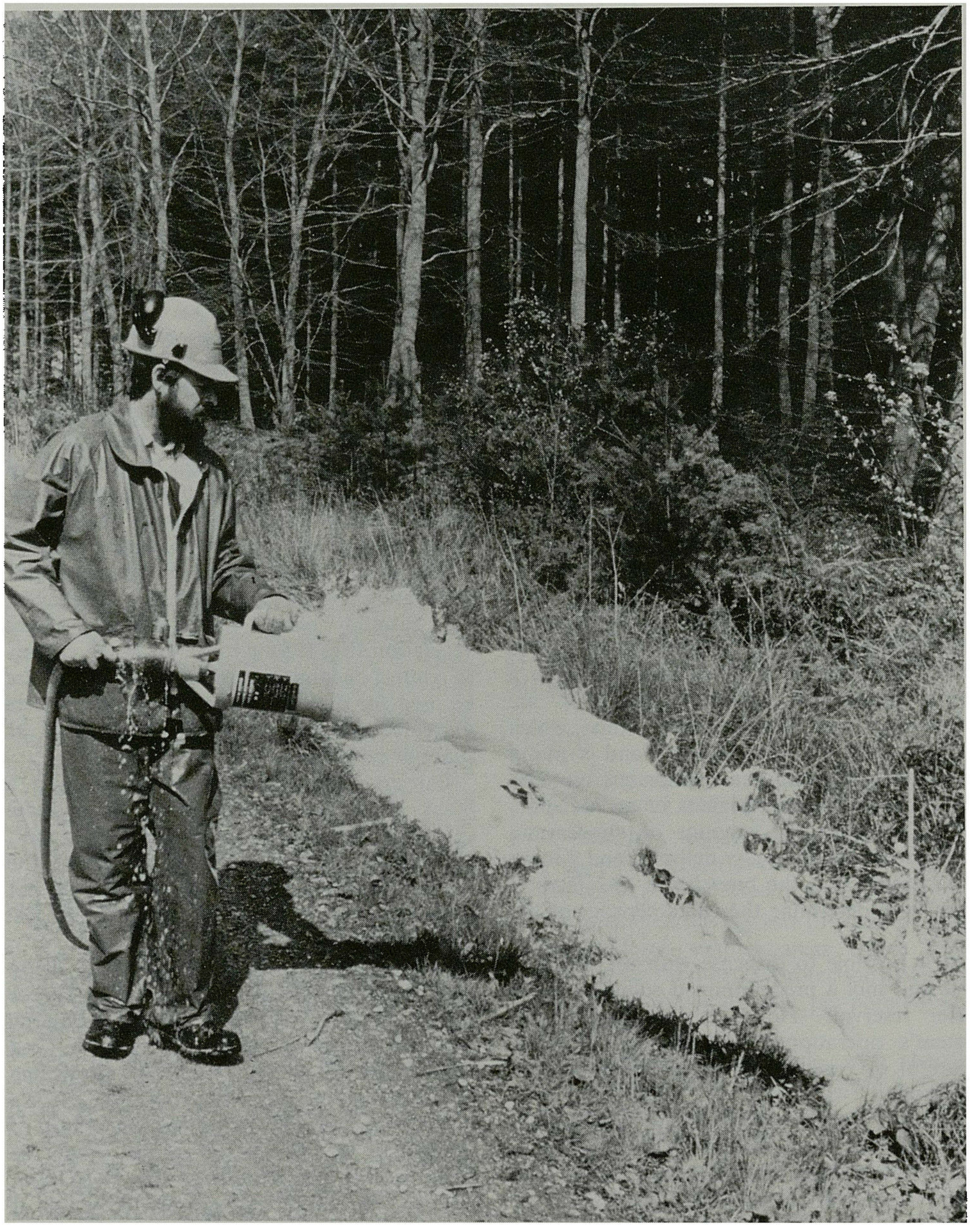


PLATE 1 Pedestrian application of medium expansion foam using 25 mm (1″) hose and Macron MX 50 branchpipe.

instance, be increased by treating both sides of the break if time permits. With the recommended equipment, vehicle-based delivery should be capable of laying up to 100 metres of barrier per minute for both types of application.

It is important that foam barriers should be applied not less than 5 minutes nor generally more than 60 minutes before the fire front hits them. After application a gradual process of leaching of solution starts from the body of the foam and this will penetrate through the vegetation and into the upper soil levels, creating a full barrier. Efficient penetration is aided by the detergent in the water reducing surface tension. If foam is laid too near the fire it may not have a chance to protect the lower vegetation and soil level, and the chances of a fire breakthrough under the foam are increased.

Foam quality will depend on various factors including pump pressure (foam quality may actually deteriorate with high pressures), water quality and concentrate induction rate. A true induction rate of 1.5 – 2.5 per cent is recommended. Trained operators will be able to obtain the quality of foam they require by adjusting pump pressure and induction rate, but for most applications a thick creamy foam is desirable. In trials using a 5 hp high pressure pump and 25 mm (1″) lay flat hose, good quality medium expansion foam has been generated over distances in excess of 150 metres on flat ground.

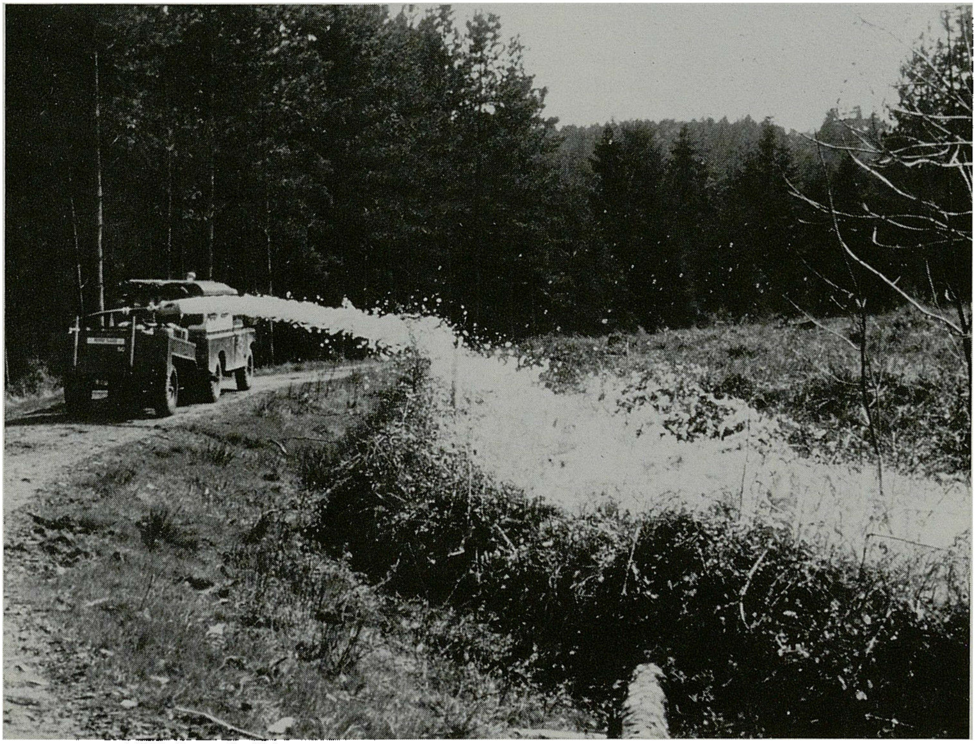


PLATE 2 Trailer laying medium expansion foam trace on ground vegetation.

PLATE 3 Canopy application using low expansion branchpipe and 64 mm (2½") hose.

Fire fighting with foam – experience

Foam barriers may be laid as a primary defence. This is particularly likely when manpower is in short supply and conventional control is ruled out. However, with foam, even a few men can hold a fire front several hundred metres long by limiting their energies to attacking only possible breakthroughs. The supervisor must be prepared to create the line at least 5 minutes ahead of the fire front and sacrifice the vegetation in between.

Foam can be used as a back-up to normal fire fighting. A foam barrier may then be laid as a secondary line of defence while attempts are made to hold the fire by conventional fire fighting techniques. If this is unsuccessful the men fall back and hold the fire from behind the foam line.

Experience to date indicates that a ground foam barrier properly laid will be at least 95 per cent successful. Where breakthroughs do occur these can be quickly and effectively eliminated by beaters or water.

When a fire front hits a foam barrier there is a change in smoke colour. The blue coloured smoke from forest vegetation will change to cream as the foam reacts. In most cases this sign heralds the control of the fire and the progressive dieback of the flames. If cream coloured smoke is excessive and prolonged this is indicative of a breakthrough and supportive measures must be initiated.

Foam barriers are normally laid at 90° to the fire's downwind advance, in which case the fire should contact the barrier simultaneously along most of its length. Under such conditions detection of any breakthrough may be screened by smoke, and total control delayed.

Where local experience indicates that close supervision of the barrier is desirable, foam should be laid in a pattern which progressively reduces the width of the fire front. Observation and supportive measures can then be undertaken through relatively clear air.

Once the fire is controlled, damping down may start. This can be undertaken by conventional water application or by the use of "wet" water (mixture with 0.5 per cent foam concentrate) which will aid penetration. This may be particularly important on peat soils or in dense grass vegetation. Application is by means of live reel, lay flat hose with a water nozzle, or knapsack spray.

Maintenance after a fire is limited to flushing equipment with untreated water, and restocking the fire fighting unit for the next call out.

Base machines

Foam equipment may be mounted on any suitable water carrying unit and as such requires no specialised base vehicle. Foam is an additional, rather than an alternative, technique to plain water application. Thus it is clear that only the capability of water carrying units need be considered as foam may be produced wherever water equipment can gain access. Normally the cost per unit volume of water delivered is minimised in bulk carriers. The overriding objective is to move as large a volume of water as possible onto the fire site in the shortest practicable time.

The mechanics of water delivery and application to a forest location will therefore vary for different areas and forest structure. For example, if the forest is flat, with a good road network and easily accessible by public roads, the base vehicle can travel quickly and terrain capability is not significant. Conversely, in remote or mountainous areas, fast road speed may be sacrificed in favour of improved terrain capability permitting good penetration into the forest. These three factors, water payload, speed and terrain crossing must be tailored to suit specific local requirements.

The ideal vehicle for foam application in most situations is a purpose-built tender, especially as these may be obtained second-hand at a reasonable price. Equipped with all wheel drive, their terrain capability is relatively good. Water volumes of 2700 litres (600 gallons) or more offer maximum operational flexibility and there is not usually a critical payload problem with the weight of pump and other equipment. The only drawbacks are the difficulty in staffing a rota as Heavy Goods Vehicle licenced drivers are required, and the difficulties of maintenance with older equipment.

A good second choice is a trailer unit properly designed and equipped for the role (Plate 4). Pulled behind a Land Rover good road speeds can be achieved, but there are limitations regarding terrain capability. Water carried is normally 700 – 900 litres (150 – 200 gallons), but the weight of the unit including pump, water, etc., approaches the smaller Land Rover's safe towing limit. The trailer is self-contained and may be pulled by any suitable vehicle. (Trailer specification, see Appendix II).

A trailer unit designed for pulling by a forest tractor cannot achieve adequate road speed due to the limitations of the tractor itself. It cannot be considered as fire fighting equipment – normally having a role at the damping down phase only.

Flat-bed lorries, forwarders and other cross-country vehicles equipped with appropriate tank capacity warrant consideration in specific areas according to local requirements.

Helicopters are already being used for transporting men and equipment for conventional fire fighting. While it appears possible that foam could be applied from helicopters, the commitment in terms of resources is such that considerable further investment and research is required before this technique would be generally available.

Installation and training

While foam is a simple technique in principle, as with any new system, it warrants proper introduction and training at all staff levels if its fullest potential is to be exploited. Skilled operators are necessary to provide the versatility required in dealing with varying fire conditions. Because of the benefits of comprehensive knowledge and experience it is recommended that specialised crews are trained.

Operator training normally requires a course which should be held at the forest location and so can be orientated towards any special problems which may be encountered locally.

Experience in live fire is essential and must be provided during such training (or immediately after it). It is suggested that advantage be taken of controlled burning to permit the crews and supervisors to gain confidence under non-critical conditions. Alternatively, safe practice areas where "artificial forests" of tops and brushwood can be used for training must be provided.

In addition to operator training, it is important that all staff who may become involved in fire fighting have an appreciation of foam technique. This is essential if foam is to be properly used. The basic philosophy of fire fighting with foam is different from that of conventional methods and it is important that this is understood by all staff.

System description

The specification illustrated in Diagram 1 has been developed as the most effective low cost system for UK forest fire control. Major components (Table 1) have been obtained from the suppliers listed in Appendix III. The range of equipment and services offered by each of the suppliers varies. Full details of the facilities available should be obtained from each supplier in order to achieve the most cost effective system.

The types of pumps which may be used for foam production are many and various. Component specifications (Table 1) relate to the most suitable 5 hp pump for this operation. When larger capacity pumps are used, correctly sized heavier duty components may be required.

Where it is necessary to operate remote from the unit lay flat hose is required. 25 mm (1″) hose is recommended because of its low purchase price, light weight and economy in water requirement.

The major disadvantages of such small diameter hose, retrieval and storage, can be overcome by use of a reel hose retrieval system.

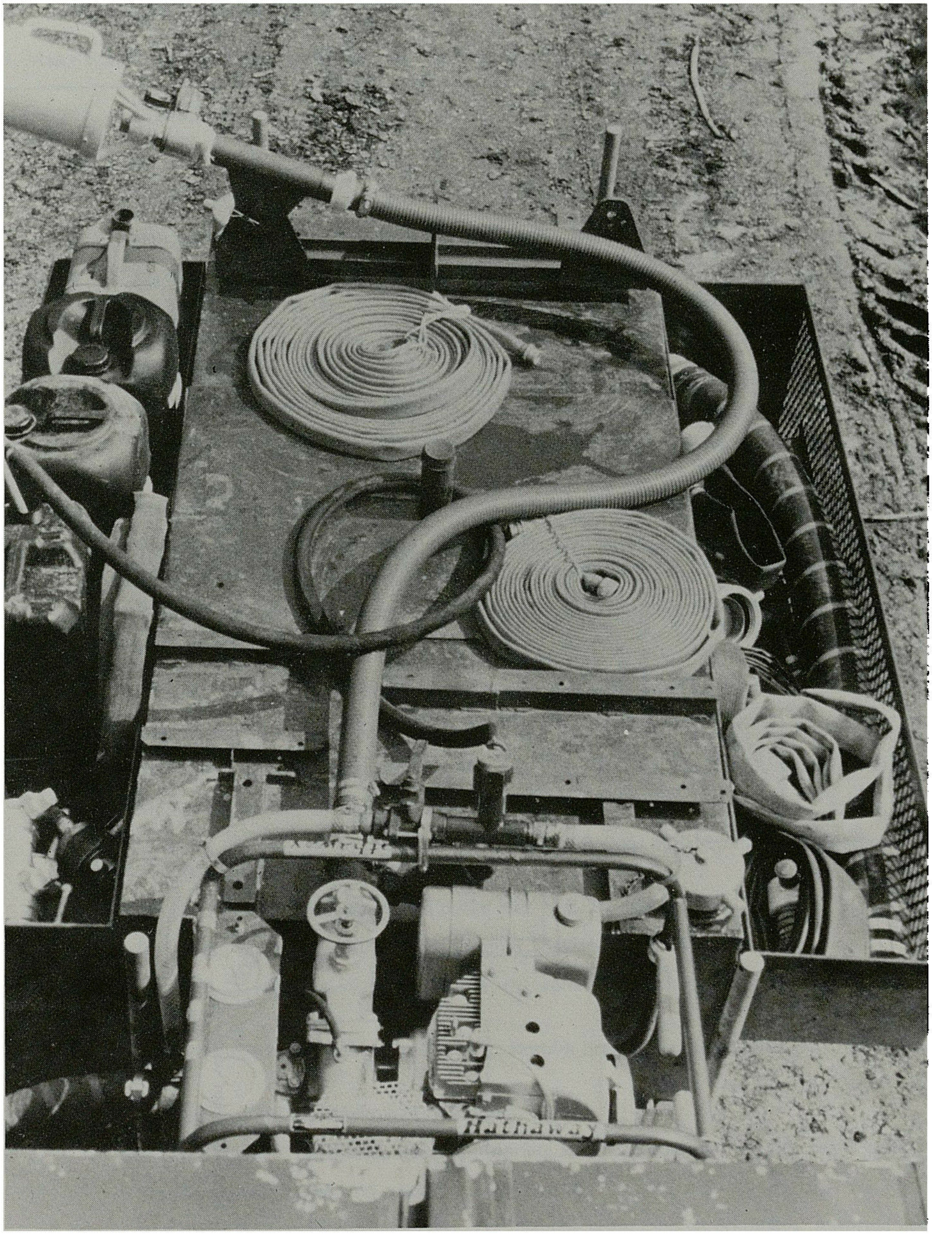


PLATE 4 Plan view of foam trailer (fitted with a large capacity pump for trial purposes). Designed by the Work Study Branch of the Forestry Commission.

Diagram 1

Equipment layout – round the pump induction

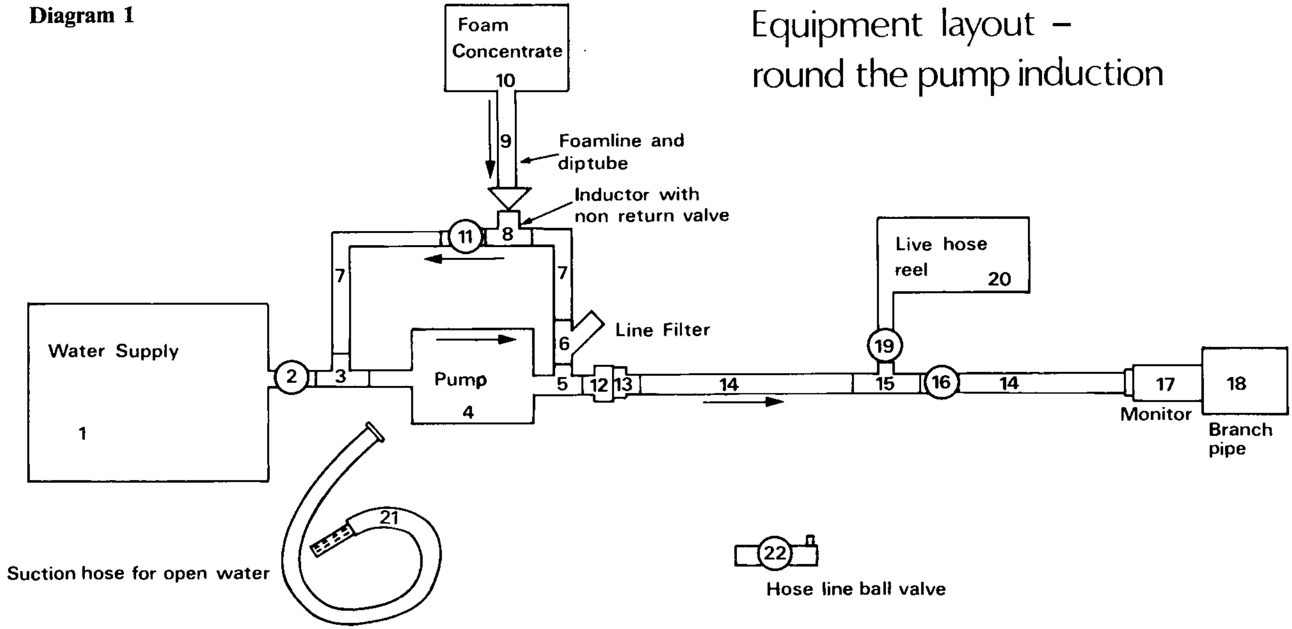


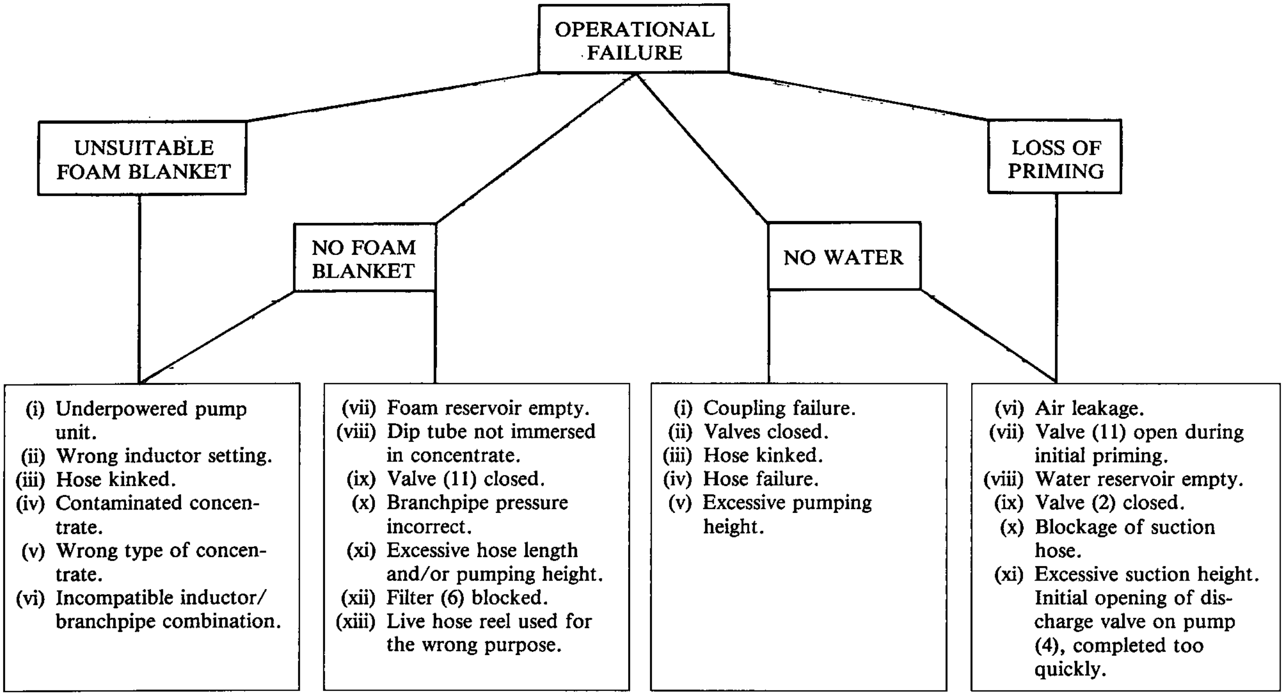
Table 1 Description of component parts

N.B. Many suppliers of components still specify Imperial measurement, therefore this is included below.

Diagram 1 Reference	*Component*
1	Water supply – any suitable vessel of about 900 litres (200 gallons) minimum capacity.
2	Ball valve fitted with 2″ Female inlet, 2″ Male outlet.
Connecting 2 and 3	Suction hose of appropriate length with one 2″ Whitworth Female coupling.
3	Modified suction connector with 2″ Whitworth Male inlet, 2″ Whitworth Female outlet, 1″ BSP Male foam inlet.
4	Pump – Hathaway Mk V (5 hp).
5	Modified delivery outlet with 1″ Female instantaneous coupling and 1″ BSP Male foam line outlet.
6	Line filter with 1″ BSP Female inlet and outlet, mesh size no larger than 5 mm (0.2″).
7	Standard 25 mm (1″) bore solid wall rubber hose. Two lengths as short as possible, the first with 1″ BSP Male inlet and Female outlet, the second with 1″ BSP Female inlet and outlet.
8	Variable Round-the-Pump inductor, flow control and non-return valve.
9	Piercer pick-up tube.
10	Fortified detergent foam concentrate in manufacturer's drum or reservoir.
11	Ball valve with 1″ BSP Female inlet, 1″ BSP Male outlet.
12	Instantaneous coupling adaptor 25 mm (1″) Male inlet, 64 mm (2½″) Female outlet.
13	Male half coupling 64 mm (2½″) instantaneous with a 2″ hose tail.
14	Semi-rigid plastic hoses 2″ bore, one with 2″ BSP Female outlet connector, the second with 2″ BSP Female inlet and outlet connectors.
15	'T' piece, 2″ BSP Male inlet and outlet and 1″ BSP Male outlet.
16	Ball valve, 2″ BSP Female inlet connector, 2″ BSP Male outlet connector.
17	Monitor, 2″ BSP Male inlet and outlet, the outlet fitted with 64 mm (2½″) instantaneous coupling.
18	Branchpipe, medium exapansion. Low expansion branchpipe with pumps of 10 hp or more only.
19	Ball valve, 1″ BSP Female inlet and outlet.
20	Hose reel with 1″ BSP Male inlet, appropriate length of hose and suitable outlet nozzle.
21	Standard suction hose and strainer for the pump.
22	Ball valve, 2½″ Male instantaneous, 2½″ Female instantaneous couplings. Assorted heavy duty clamps to fit each hose end coupling.

Table 2 Problem Identification

It is assumed that a suitable operational pump is used within the correct recommended system



Machine operating instructions

The equipment can be used to discharge foam (both from a vehicle and under pedestrian control), low surface tension water (i.e. "wet" water), and untreated water, from either an on-board reservoir or an open water supply. Operating sequences for each of these applications appear below. Possible causes of operational failure are listed in Table 2.

It is assumed that there is an adequate supply of fuel, water and concentrate available, and that the pump, of a suitable type, is serviceable and has been primed with water. Ball valve (11) must be shut during pump priming.

Foam generation – vehicle mounted operations

This is the primary role of the equipment.

Water is drawn from the on-board supply via suction hose and a modified suction hose coupling (3) into the pump (4).

From the pump the flow is divided by the pressure side coupling (5). A proportion of the water passes through the line filter (6) into the Round-the-Pump hose line (7) and thence to the inductor (8). The action of the water passing through the inductor causes foam concentrate to flow from its reservoir (10) down the foam hose line (9) and into the inductor via a non-return valve.

The flow of concentrate is controlled by a valve which has six different settings. The 2 per cent setting is selected initially. The solution is pumped through the ball valve (11) and down the Round-the-Pump line to the suction hose coupling (3). It then mixes with the water coming from the supply (1) passes through the pump and down the main semi-rigid hose line (14). Progressing through the 'T' piece (15), open ball valve (16), and monitor (17), it arrives in the branchpipe (18) at which point the foam bubbles are created. The monitor which holds the branchpipe can be adjusted both vertically and horizontally.

Foam generation – pedestrian operations

The pumping sequence and foam induction is precisely the same as for the vehicle mounted operation.

The adaptor (12), which is 25 mm (1″) or 38 mm (1½″) male instantaneous to 64 mm (2½″) female instantaneous, is removed and one or more lengths of hose are connected to the pump outlet. The adaptor (12) is fitted to the other end of the hose and the ball valve (22) and the branchpipe (18) are coupled to it in turn.

The hose is run out to the work area and the pump operated. When the ball valve (22) is closed for more than 10 seconds the valve (11) must be closed to prevent excessive build-up of concentrate.

As the working length of hose increases the flow rate decreases because of loss of pressure due to friction. The foam induction rate must be reduced to maintain the correct mixture.

Low surface tension ("wet") water

Pumping sequence as before.

The inductor control (8) is set to a low rate of mixture, i.e. 0.5 per cent concentrate.

For application through lay flat hose, all settings are as for the previous section.

The foam branchpipe is replaced by a water nozzle or fog gun.

The most usual method of applying "wet" water is through the hose reel (20). To use the hose reel the ball valve (19) must be open and valve (16) must be closed. It is possible to use both the hose reel (20) and the lay flat hose via the monitor (17) simultaneously, in which case valve (16) must be open.

Water

Pumping sequence as before up to position (5).

The ball valve (11) is closed to shut down the Round-the-Pump circuit.

Either or both the ball valves (16) and (19) are open as required and a water nozzle is used in place of the foam branchpipe. The hose reel may be fitted with one of the many different types of nozzle.

APPENDIX I: DEFINITIONS

Specialised terminology is incorporated in this publication, the keywords are explained below.

Inductor:
A control mechanism which allows a regulated quantity of foam concentrate to be introduced into the main hose line. Two types are commonly in use: (i) in-line inductor, where the unit is fitted directly into the water delivery line from the pump and operates only when the water is flowing; and (ii) Round-the-Pump inductor where a small quantity of water is bled from the pressure side of the pump, through a by-pass circuit to the inductor, and is returned to the suction side of the pump. Foam is inducted continuously as long as the ball valve (11)* is open, regardless of delivery through the main hose line.

Branchpipe:
A specialised nozzle in which air and foam solution are mixed to produce foam bubbles. Different expansion rates of foam are produced according to the type of branchpipe used.

Monitor:
A device permitting the branchpipe to be held firmly on the mobile unit providing vertical and horizontal adjustment to cater for the requirements of the application.

Foam:
There are three states of foam, these are:

(a) Foam concentrate as supplied by the manufacturer, referred to as *concentrate.*

(b) Foam solution, i.e. concentrate mixed with water from the reservoir, referred to as *solution.*

(c) Foam bubbles – a mixture of concentrate water and air as delivered by the branchpipe, referred to as *foam.*

* See Diagram 1.

APPENDIX II: FOAM/WATER FIRE FIGHTING TRAILER SPECIFICATION

(This specification excludes associated equipment such as pumps, hoses, etc.)

Tank Unit:

Dimensions
1930 mm long × 846 mm wide × 700 mm high (80 × 33.3 × 27.5 inches)

Nominal capacity
1035 litres (230 gallons)

Construction
All welded mild steel sheet 3 mm thick.

Baffles
One longitudinal in the centre and three transverse equally spaced. Mild steel sheet 1.5 mm thick, all welded. Sump at bottom front and with 1″ BSP plug for draining. Finish – Galvanised.

Tank fittings:
Two angle irons welded to the top of the tank for attachments. Three lifting eyes welded to tank, two at the front and one at the rear.
Two 2″ BSP male outlets, one on either side near the front.
One 2″ BSP female cap to be provided.
One filling aperture with anti-splash tube fitted to tank top at the rear, offset to near side.
Waterproofed hinged lid with "Tee" clamp.
Fixing plates for side panniers welded to tank sides.
Mounting brackets, tank to chassis, four on each side.

Panniers:
Fabricated from mild steel sheet 2 mm thick.
Expanmet edging stitch welded to top edges.
Front compartments to have hinged covers with locks.
Foam carrier capable of carrying four square or six rectangular 25 litre containers.
Drain holes to be provided.
Panniers to be attached to tank sides by set screws.

Chassis:
Fabricated from mild steel channel 100 × 50 mm (4 × 2 inches).
Plate provided on "A" frame for Hathaway Mk V pump, quick release attachment plate to be 6 mm (0.25 inch) thick.
Adjustable jockey wheel attached to "A" frame.
Two breakaway chains to be welded to "A" frame.
Adjustable prop stands attached to four corners.
Handle attached to "A" frame to assist manoeuvring of trailer when disconnected from towing vehicle.

Coupling:
A 50 mm ball type coupling with overrun brake actuator, parking brake operating lever and reverse brake lock.
Load rating 2036 kg (4480 lbs).

Suspension:
Avonride independent.
Load rating 2000 kg (4400 lbs).

Brakes:
Internal expanding.
Drum diameter 279.4 mm (11 inches).
Brake shoe width 63.5 mm (2.5 inches).
Wheel centres 1340 mm (52.75 inches).

Wheels and Tyres:
Wheels – Land Rover 5-stud fixing.
Tyres – Size 750 × 16, 6-ply rating.
Tread – On/off road pattern.

Lighting:
Lights and reflectors to comply with current lighting regulations.
7-pin plug and wiring to couple to towing vehicle.
Parking socket for 7-pin plug when disconnected from towing vehicle.

APPENDIX III: LIST OF EQUIPMENT MANUFACTURERS/SUPPLIERS

Angus Fire Armour Limited
UK Sales Division
Southgate
White Lund Trading Estate
Morecambe
LA3 3PB
Tel: (0524) 35881

Chubb Fire Security Limited
Pyrene House
Sunbury-on-Thames
Middlesex
TW16 7AR
Tel: (093 27) 85588

G.L. Developments (Bridgend) Limited
North Road
Bridgend Industrial Estate
Bridgend
Glamorgan
CF31 3TP
Tel: (0656) 2591

L. Hathaway Limited
Gobowen
Shropshire
SY11 3JB
Tel: (0691) 50541

Macron Fire Protection Limited
64 Edison Road
Rabans Lane
Aylesbury
Buckinghamshire
HP19 3TE
Tel: (0296) 32991

Enquiries relating to this publication should be addressed to the Publications Officer, Forestry Commission Research Station, Alice Holt Lodge, Wrecclesham, Farnham, Surrey, GU10 4LH.

Printed in England for Her Majesty's Stationery Office
by Hobbs the Printers of Southampton
(1575) Dd718472 C40 10/82 G387

First published 1982

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ODC 432.331:(410)

ISBN 0 11 710232 6

Leaflet 80: Forest Fire Fighting with Foam

HMSO