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Form F.D. 80B

FORESTS DEPARTMENT

PROTECTION, COMO Office,

To ....

JANUARY 26 1977
Western Australia

Reference—H.O. 229/75

Local F00 5/6e

SUBJECT: WATER USE - INCLUDING RELAY PUMPING

Attached please find an article on water use and relay pumping, which apart from general interest in water use at fires, should materially assist those divisions setting up or using relay pumping systems.

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AJA/VGH

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USE OF WATER

A. WATER-USE TECHNIQUES

Opinions respecting the value of water on fires vary widely. Some experienced firefighters will have little or nothing to do with it, reasoning that the only way to fight fire is to burn up all fuel inside the fireline, and that the manpower employed on pumps and hose can be put to better use elsewhere. Others rely heavily on water, on the assumption that it is the natural enemy of fire, and that it can control and extinguish any fire if sufficient numbers of pumps are used. As is usually the case, neither of these opinions is totally correct nor totally wrong.

As a general rule, there is a good use for water on every fire, providing it is used efficiently and with the proper use of manpower. The key words here are "efficiently" and "manpower". If water is not used effectively, then it and the manpower employed to pump it to the fireline have been wasted; if too much emphasis is placed upon water, the entire suppression effort will suffer because the manpower is not being used properly.

1. Extinguishing Small Fires

If water is available, the average small fire (depending upon density of fuel) can be completely extinguished. However, the warning must be repeated -- the fire must be swamped out, each piece of fuel must be worked over, and every hot spot must be thoroughly puddled. It is not an easy matter to extinguish a hectare or so of moderate fuel. It takes lots of water, lots of dirty work, and lots of determination. But, if it is done right, the fire is out. Reburns are usually the results of carelessness, failure to do the job properly in the first place, or failure to maintain patrols until the fire is definitely proven out.

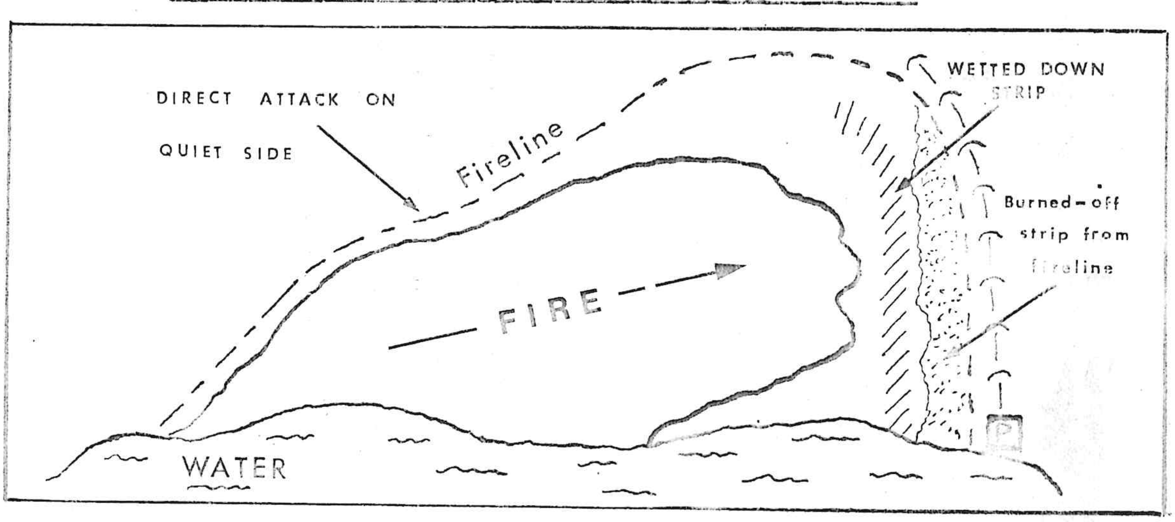
Remember that water knocks the fire down until it looks out. Avoid the false sense of security that comes once the burn is black and apparently lifeless. Maintain a patrol until the fire is proven lifeless.

2. Slowing Down an Advancing Fire

In moderate to heavy fuels, particularly if the fire is to be held on a down-wind or up-slope flank, the fire may advance too quickly for effective burning-off. In such circumstances fuels well inside the fireline may be wetted down to slow the advance of the main fire and to allow burning-off to proceed. The strip of fuel along the inner side should always be kept dry enough to get fires started, since a good clean burn close to the edge is vital.

Power-pumps are usually necessary, using a nozzle delivering a wide heavy spray that will be thrown well inside. A solid stream may be thrown farther in, but its effect is not as good as the heavy spray.

Figure 1 - Delaying the Fire with Water



3. Knocking Down Hot Spots

Heavy accumulations of fuel too close to the firebreak may cause trouble. Fires in such accumulations should be held in check and allowed to burn out slowly. The spray stream is normally the best choice with its fineness adjusted to suit the heat intensity. A solid stream will waste 75 per cent of the water, since most of it is forced right through the flames to the ground beneath. What is required is a blanket of droplets, with its smothering and cooling effect. The stream should be used judiciously to knock down flare-ups as they occur without putting the fire out. Remember, we want the accumulation burned out.

Accumulations of heavy fuels such as logs may need an occasional solid stream to force the water between them. At the same time, some fuels may have to be worked over and extinguished if there is a danger that they will burn long after the adjoining line is otherwise safe. If they are to be extinguished, they should be pulled apart as soon as possible and each log swamped.

4. Dousing Fire in Dry Stags and High Stumps

High stumps and stags burning close to the line are always dangerous. If the fire is high up the stag, pressure and a solid stream nozzle are required. If the whole stag is afire, it is usually advisable to start at the bottom and work up. Remember that the water pressure may actually throw sparks and live embers off instead of extinguishing them. If there is imminent danger of fire spread by embers from the top of the stag, hit the top as gently as possible, then slowly work downwards to cool the tree. Then return to the bottom and work upwards trying for total extinguishment.

Fire inside stags will require pressure to reach through checks or other openings in the bole. As it is often difficult to fell such stags, water in quantity is a most valuable aid.

Stags close to the line must be felled. Water may be used to keep fire from the base until this can be done.

High stumps, not as prevalent as formerly, may be dangerous if they occur close to the fireline. The fire will be in the bark or between the bark and the dead wood. To conserve water, open up or tear bark loose with a rake or axe, then play the water on the burning material inside.

5. Wetting Down Outside the Line

If the fireline runs through moderate to heavy fuels, there will be an accumulation of dry fuel on the outer side of the firebreak which may be ignited by radiated heat from the main fire, or by sparks thrown across by the wind. Water may be used to wet down the outside of the firebreak, using a wide fine spray. In this connection, where a power-pump is being used on the line for any reason there will be periods when water will not be required but the pump will remain operating. Make sure that beneficial use of this water is made by spraying it on the outer side of the fireline. It is good insurance to have the outside of the fireline wetted down wherever possible.

The same remarks apply where only packsprays are available. However, the obvious difference is in the volume of water available, necessitating strict conservation of water.

6. Constructing Firebreaks Hydraulically

Where fires are burning in light fuels on shallow soils, a firebreak can often be constructed hydraulically by using a jet stream from a power-pump. Working from about 0.3 metres away from the edge of the fire, play the stream on the soil in front of and perpendicular to the fire's edge. The shallow soil is torn up, moistened, cooled, and thrown back into the flames. At the same time if the nozzle is held low, the head of the stream will widen out into a heavy spray and effectually kill the fire's edge. Allow the inside of this strip to burn clean, to provide a connected, fuel-free gap around the fire. Follow up by putting a good hand-tool firebreak on the outer edge of the burned strip if a continuous mineral firebreak was not accomplished by the hydraulic hose operation.

7. Gravity Systems

Make it a point to ascertain whether there is a suitable water source from the hillside above a fire. This may be in the form of an existing dam, creek or storage tank.

A very small creek will provide a surprising volume of water at the nozzle. Workable pressures are available from standpipes in Nannup's Folly plantation on the lower reaches from the town water supply dam.

Remember that every metre drop in elevation will give approximately 10 kPa (1.5 p.s.i.) at the nozzle. Expressed more exactly, the field formula to use is :

Nozzle pressure kPa = Fall in metres x 10-friction loss.

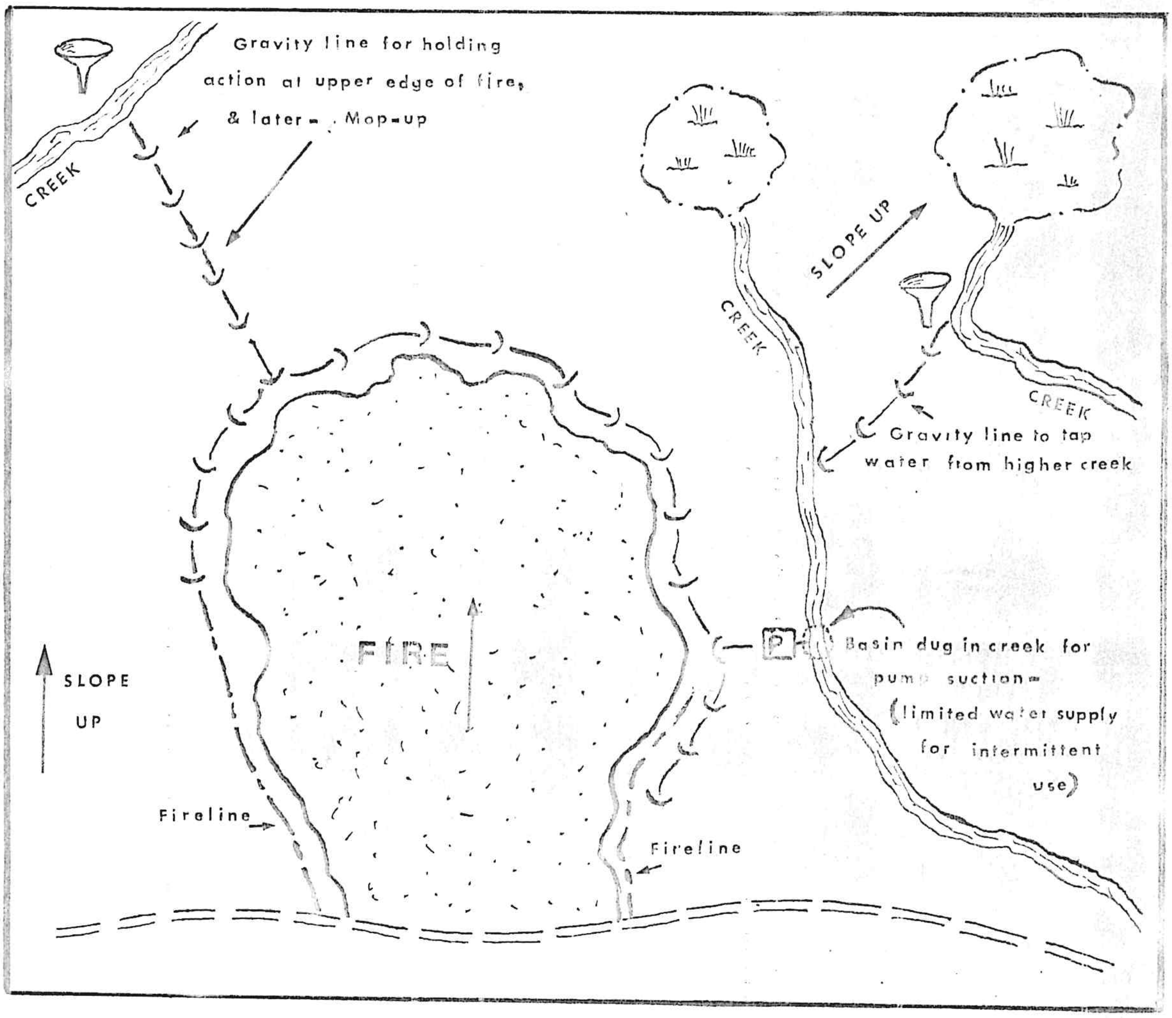
In setting up a gravity system, select an intake site at least 23 metres above the highest part of the fire. Tie the gravity funnel firmly in place, if possible under a short fall or in a location which will keep the funnel filled to a depth of 300 mm or so above the screen. A small creek may have to be dammed in order to get the desired depth for the funnel.

Couple the hose to the funnel and lead the first length or two downhill in the direction giving the greatest drop. If the water does not extend the hose, start from the funnel, pinching out the hose and leading the water downwards until it is flowing freely. It may be necessary to carry this process to the end of the second length, depending upon the slope. Once water is flowing freely, attach the hose to the required length, inserting three-way valves as desired to supply branch lines. The available water supply will determine the number of possible branch lines and nozzle sizes necessary. If the supply is minimal, only one branch and small nozzles may be necessary; if it is plentiful, several branches and larger nozzles may be possible.

On short drops of 45 to 60 metres the hose-line will be partially flattened except at the nozzle end. With good systems, however, having a plentiful water supply and long drops, it is possible to have too much pressure at the nozzle, even when several branch lines are in use. Excessive nozzle pressures may be reduced by - (a) using larger nozzles, (b) inserting a three-way valve in the line as a bleeder, or (c) by feeding the open end of the hose-line into a second gravity funnel located further down the hillside.

Once the system is operating, it is only necessary to keep the strainer in the funnel free from creek debris. As long as the water supply is flowing, the gravity system will carry water downhill to the fire with little supervision.

Figure 2 - Examples of Gravity Systems



8. General Remarks on Use of Water

One of the most important uses of water is in mopping-up and this subject will be covered later in the text.

There are no disadvantages in the use of water on a fire if it is properly used. Disadvantages and trouble occur only through misuse and over-confidence in its effect on larger fires. Some conclusions in its use can be summarized as follows:

1) Use water wherever available to assist in the control of the fire;
2) Use it as a secondary method; a support to the firebreak and not as a complete method of control in itself;
3) If water is available it can be put to good use on every fire. However, it should be used wisely and never at the expense of manpower that could be doing more vital work;
4) Water is consistently most valuable in the mop-up stage.

B. USE OF PUMPS AND HOSE

1. Pump Selection

In discussing pumps briefly we must emphasise the importance of selecting the proper unit for the job after considering portability, output, and available water supply. If the pump is to be carried in on foot, portability is obviously the key, regardless of the other two factors; on the other hand, if the pump can be driven in, the water supply available at the fire will be the determining factor. Pump selection for each fire must be made after considering these three main points and it becomes obvious that the most suitable pump for one fire may not necessarily be the best unit for another.

2. Setting Up the Pump

In the rush to get a pump operation started, the finer points of setting up are often overlooked. To avoid trouble, remember the following:

1) Set the pump on a solid, level bed - rock or gravel if possible;

2) Keep the pump as close to the water level as possible. Every extra metre of suction lift decreases the volume and pressure at the nozzle;

3) Make sure all couplings on the suction hose are tight. Air leaks may prevent suction of water. Popping air pockets at the nozzle are a sure sign of leakage on the suction side of the pump if it is continuous;

4) Remember that footvalves are essential on the suction hose on centrifugal pumps. Strainers are satisfactory on positive displacement pumps, but footvalves may be used;

5) Make sure the strainer or footvalve is covered by at least 100 mm of water. If the location of the water supply is sandy, gravelly or muddy, tie the intake end of the hose to a stake or log, place it in a pail, or rest it on flat rocks or wood. Tie it so that the footvalve stands vertically. Both these methods will help keep foreign materials out of the pump-end;

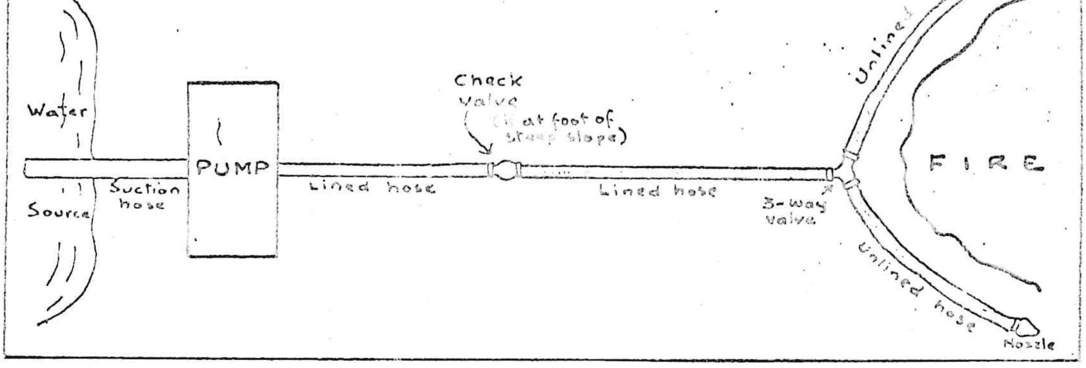
6) If the pump is water-cooled, lead the cooling water away from the pump setting so that the work area does not become mudded;

7) Do not set up in a position where falling trees or rolling material may endanger the pump operator. Remember that he will be able to hear little above the motor noise. Avoid setting the pump in depressions that allow the setting and accumulation of carbon monoxide fumes;

8) The suction hose will not stand heavy internal pressure. Always use a checkvalve on the discharge side of the pump to avoid rupturing the suction hose caused by back pressure from the weight of water in the discharge hose line.

Study the standard hose lay illustrated below. It should be the basic lay for all water operations.

Figure 3 - A Standard Hose Lay



3. Factors Affecting Pressure and Volume

All pumping systems have one common goal - to deliver water to the nozzle in sufficient volume so that useful work may be done. Between the pump and the fire, however, other factors exert influence to determine whether a usable stream is delivered at the nozzle. These factors may be expressed in the pumping equation:

Nozzle Pressure = Pump Pressure - Static Head - Friction Loss.

(a) Nozzle Pressure

Nozzle pressure is the pressure remaining to force water through the nozzle after the pump pressure has overcome the effects of static head and friction loss. The minimum effective working pressure is usually considered to be 170 kPa for general-purpose firefighting.

(b) Pump Pressure

All Forest service pumps should be tested to determine the maximum operating pump pressure of each unit. The last pressure test for each pump should be kept in a log book in the pump box.

(c) Static Head

The head or back pressure exerted at the pump by the weight of water in the hose increases by 9.785 kPa per metre of elevation above the pump (or .433 p.s.i. for each foot of elevation.) This is commonly rounded off to 10 kPa and the rule of thumb to remember here for field calculations is that every metre of elevation between the pump and nozzle requires 10 kPa pressure developed at the pump to get water to the nozzle.

For gravity lines, this can be modified so that the nozzle pressure in kPa = Fall in metres x 10 - Friction Loss.

(d) Friction Loss

As water is forced through a hose-line, turbulence is created by the friction of the water against the interior surfaces of the hose. Additional pump pressure is required to overcome this effect, which increases with water flow, with reduction of hose diameter, and with the roughness of the interior hose surfaces. This loss is increased unnecessarily by bends and twists in the hose line. Therefore, all lays should be as straight as possible. At our minimum working nozzle pressure of 170 kPa (25 p.s.i.) approximate friction losses per 30 metres (100 ft.) length of various types of hose, using different nozzle sizes, are given by the following table:-

Figure 4 - Friction Loss by Nozzle Size and Hose Type

FRICTION LOSS PER 30 METRES (100 FT)	(1) #6 mm($\frac{1}{4}$")	(2) #8 mm(5/16")	(3) #10 mm($\frac{3}{8}$")	(4) #13 mm($\frac{1}{2}$")
38 mm (1$\frac{1}{2}$") Lined Hose	3 kPa (.5 p.s.i.)	6 kPa (.1 p.s.i.)	12 kPa (2 p.s.i.)	30 kPa (5 p.s.i.)
38 mm (1$\frac{1}{2}$") Percolating Hose.	6 kPa	12 kPa	24 kPa	60 kPa

NOTE: 1 p.s.i. = 6.89 kPa.

If we have to lift water to a particular spot there are specific things we must know before we can be certain that a pump will work (deliver water from the nozzle with at least 170 kPa (25 p.s.i.):

(1) The vertical height the water must be lifted (estimate);

(2) How long the hose line will be (estimate);

(3) The type of hose to be used and its friction loss (known and from Friction Loss Table);

(4) The maximum pressure that the pump can deliver (see pump log book).

Typical field calculations that must be done are illustrated as follows:

Example 1

Elevation = 46 metres (150 ft.), hose line required = 610 metres (2,000 ft.), 38 mm ($1\frac{1}{2}$") unlined hose available, maximum pressure of the pump=1 275 kPa (185 p.s.i.)

As we are trying to solve the pumping equation:

Nozzle Pressure = Pump Pressure - Static Head - Friction Loss and, as we know the nozzle pressure must be at least 170 kPa (25 p.s.i.) to be effective, it is a matter of solving the right hand side of the equation to ensure that it is greater than 170 kPa (25 p.s.i.)

Therefore, Static Head 46 metres elevation x 10 kPa = 460 kPa
Friction Loss using 3# nozzle (20 lengths x 24 kPa) = 480 kPa
Total Losses = 940 kPa
Pump pressure (Log book) = 1 275 kPa

Therefore, nozzle pressure = pump pressure - Total Losses
= 1 275 kPa - 940 kPa
= 335 kPa

The system will work using 1 # , 2# and 3# nozzles but not with 4# nozzles. (See figure 4 and check the calculation).

Example 2

Consider the same pump and hose lay, but the lift is 91 metres (300 ft.).

Static Head 91 metres x 10 kPa = 910 kPa
Friction Losses using 3# nozzle (20 x 24) = 480 kPa
Total Losses = 1 390 kPa

As the total losses are greater than the pump pressure of 1 275 kPa the system will not work.

Similarly, by using a 2# nozzle the

Static Head 91 x 10 = 910 kPa
Friction Loss using 2# nozzle (20 x 12) = 240 kPa
Total Losses = 1 150 kPa

The nozzle pressure = Pump pressure - Total losses
= 1 275 kPa - 1 150 kPa
= 125 kPa

The system will deliver water but at less than the minimum effective pressure of 170 kPa.

However, by using 1# nozzle the

Static Head	910
Friction Loss using 1# nozzle (20 x 6)	120 kPa
Total Losses	1 030 kPa

The nozzle pressure = Pump pressure - Total Losses
= 1 275 kPa - 1 030 kPa
= 240 kPa which is ample pressure for effective fire fighting even though the volume of water delivered will be less.

4. Proper Use of Nozzles

At the nozzle itself, the manner in which water is delivered and used is extremely important. After laying the hose, setting up the pump and providing the necessary manpower, it is only good sense to use the water effectively once it is delivered to the nozzle. In fact, it can be said that the nozzle man is the key man on any pump operation. He should have a good working knowledge of fire behaviour, fuel arrangement, and the effective application of water.

The proper choice of nozzle depends upon the job to be done. For digging out fire from among stumps, roots or piles of heavy debris, or for reaching fire high in burning snags, a solid stream is required to provide both penetration and distance. For cooling down hot spots along the firebreak, or for wetting down behind the line, a broken spray-like stream is desirable.

For any given pumping system, the larger nozzles permit the greatest volume of delivery, usually in a solid stream and often at a sacrifice of pressure. Smaller nozzles restrict the flow, but break up and widen the stream into a spray of heavy droplets because of the increased pressure. The choice of nozzle size will therefore depend upon the job at hand. Normally, one of the four tips will be found suitable. With adjustable nozzles, the stream may be varied from a spray to a solid stream by turning the body of the nozzle to adjust the orifice using the same principle as the common garden nozzle.

5. Types and Use of Discharge Hose

There are three types of discharge hose in current stock. Each has its proper use:

(a) The 38 mm (1½") percolating hose - should always be used on the fireline, because its weeping properties protect it from hot ashes, embers, etc., as it is dragged through burned areas. Complete with couplings, it weighs about 6 kg per 30 metres dry. Its major disadvantage is its high friction loss, which increases rapidly as the water flow is increased.

(b) The 38 mm (1½") lined hose - weighs about 7 kg per 30 metres and should be used in the standard hose-lay from the pump to the three-way valve near the fire. Able to withstand greater pressures, and having about one-third the friction loss of the unlined variety, it is the logical choice for efficient delivery of water to the fireline. Since the nylon jacket remains dry in use, however, it is very susceptible to heat damage, and should not be used on the fireline. Heat also separates the lining from the jacket, and once the hose has been exposed to heat, it is impossible to determine the extent of the damage. Usually the entire length must be discarded in the interests of reliability for future use.

(c) 38 mm P.V.C. Heliflat. This hose supplied in 100 metre coils and will roll flat similar to canvas hose, but has a low friction loss due to its smooth bore. It will be supplied to relay pumping units for trial purposes.

This hose, due to the materials used, only requires draining of water and can be rolled back on hose reel ready for use again, not requiring drying, as with canvas hose.

6. Laying Hose

The following hose system should be used as the STANDARD LAY (see Figure 3):

(1) One length of good 38 mm ($1\frac{1}{2}$") lined discharge hose from pump to three-way valve. The three-way is necessary as a bleeder line on steep slopes, but may be dispensed with otherwise;

(2) Check-valve just ahead of three-way valve (for moderate to steep slopes);

(3) 38 mm ($1\frac{1}{2}$") lined discharge hose from check-valve to a second three-way valve near the fire;

(4) Branch lines of 19 mm or unlined 38 mm hose to nozzles.

Always use the best hose near the pump, where the pressure is greatest, and the poorer lengths towards the nozzle, particularly on slopes.

Lay the main line by the most direct route, to reduce line length and friction loss. On steep slopes, however, lay a few shallow curves, around trees or heavy brush if possible, and tie the line at intervals to trees, etc., to prevent it from sliding downhill as it fills with water. A length of 38 mm hose weighs over 40 kg when full of water, more than enough to pull the entire line downhill unless measures are taken to prevent it.

Avoid dragging hose wherever possible. Abrasion from rock, gravel, trees, or other harsh surfaces will ruin hose quickly by weakening exterior fibres and causing pinhole leaks. For the same reason, avoid hose lays over sharp rocks because of wear from vibration.

Assign a hose line patrol to check the completed line for sharp kinks, leaky couplings or rubber gaskets, hose clamps, and strong cord for tying the line to trees, etc., when needed. A good emergency mender for a hole in the hose is a piece of twine. Knots are tied in the centre and the knot placed over the hose. The twine is then tied tightly to the hose (while filled). The twine will tighten as it becomes water-soaked and a reasonably good patch will result.

7. Tandem and Relay Pump Systems

Where it is necessary to force water to an elevation beyond the capacity of a single pump, one of three methods of using a second pump may be used. Each method has its advantages and disadvantages:

(a) The Short-Coupled Tandem Pump System (See Figure 5)

In this system the discharge side of the first pump is connected by either an adapted high pressure suction hose (or a length of good 38 mm ($1\frac{1}{2}$") lined discharge hose plus adaptor) to the suction side of the second pump. It should be evident from the above that proper adapters and hose will have to be preplanned and available, otherwise the system cannot be put together in the field.

The first pump "A" may be either a positive displacement or a centrifugal type; the second "B" should preferably, but not necessarily, be centrifugal to allow the water from pump "A" to pass through its pump head while pump "B" is being started. What is important, however, is that the capacity of the second pump should be less or equal to, but never greater than, the capacity of the first pump. The standard hose lay extends from pump "B" to the fire.

Pump "A" is started first, then "B", and both are operated at low throttle until the hose-line is filled and the back-pressure builds up. At full throttle, the effective pump pressure on the discharge side of pump "B" will be the sum of the individual operating pressures for the two pumps.

ADVANTAGES

(1) One experienced man can operate both pumps;

(2) Only hose need be carried up the hill.

DISADVANTAGES

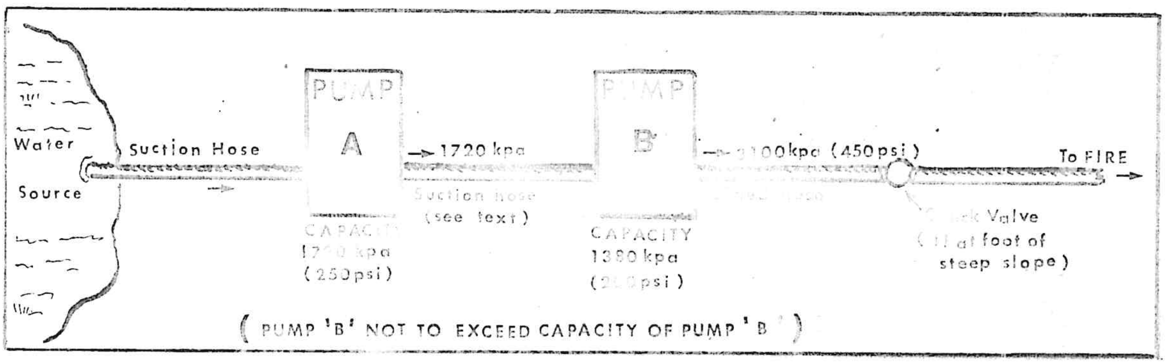
(1) Only high-quality lined hose will withstand the pressure near the pump;

(2) Hose adapters between the pumps are necessary;

(3) Pump heads on some models are not designed for such pressures, and may spring leaks;

(4) A break in the hose near the pump could endanger the operator.

Figure 5 - A Short-Coupled Tandem Pump System



(b) The Long-Coupled Tandem Pump System

In this system the upper pump is situated up the hillside just below the maximum lifting capacity of the lower pump, whose output is fed directly into the suction side of the upper pump. However, this system is not recommended and either the short-coupled tandem system (previously mentioned) or the relay pump system should be used.

(c) The Relay Pump System (See Figure 6)

This operates in the same manner as the long-coupled tandem except that the open discharge from pump "A" is delivered into a relay tank drum, canvas tank, or a sumphole (lined with canvas or polyethylene). Pump "B" operates normally from the tank, the bleed-off valve should be opened to the extent required to maintain an adequate tank level. It is important to remember that a canvas pump cover should accompany each pump so that it can be utilized as the relay tank.

ADVANTAGES

(1) No excessive pressures are produced, relieving strain on hose and pump castings;

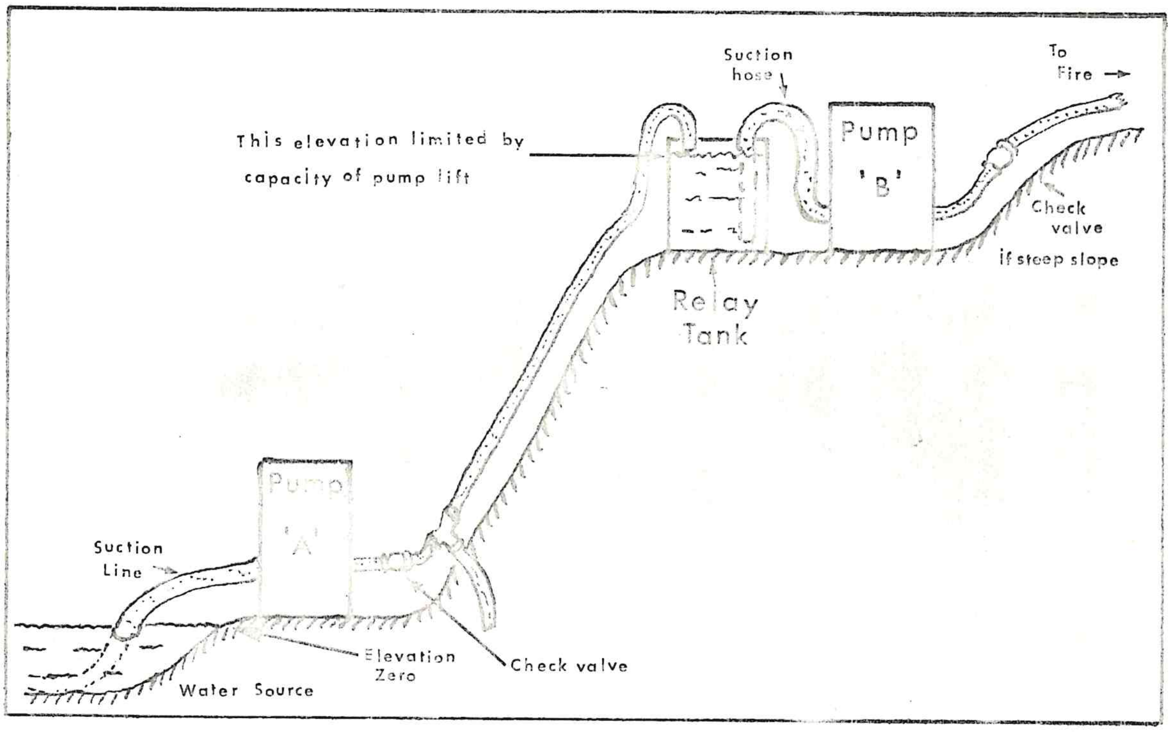
(2) Normal hose lays are used.

DISADVANTAGES

(1) Two pump operators are required;

(2) Pump, fuel, tools and relay tank must be carried uphill to the second pump site.

Figure 6 - A Relay Pump System



In all multiple pump systems, failure of any one pump renders the entire system inoperative and it is therefore always good sense to have a spare unit on hand. In fact, even with a single pump set-up, a second unit, if available, should be taken to the pump setting and kept there as a standby.

S.F.C.F.