SECTION 2 - USE OF WATER AND ADDITIVES

This section covers types of pumps, basic hydraulics, pump setups, hose lays, and tactical use of water and additives. This section is not intended to replace the Portable Pumps and Water Use, S-211 training course. Safety is a primary concern in any fireline job and will be discussed as it relates to water and additives.

Water is beneficial to firefighting because it cools through its heat absorbing capability. Flaming combustion occurs around 600 ^{o}F in woody fuels. By reducing the temperature of the air and the exposed surface of the fuels, combustion will be retarded or even stopped. This effect is best realized in fine fuels.

Second, water when properly applied can reduce the oxygen supply to the fire by smothering. A fine spray can saturate the air with water vapor, or a solid stream of water can block off the oxygen supply to the fire. If water is plentiful, you can literally drown a fire.

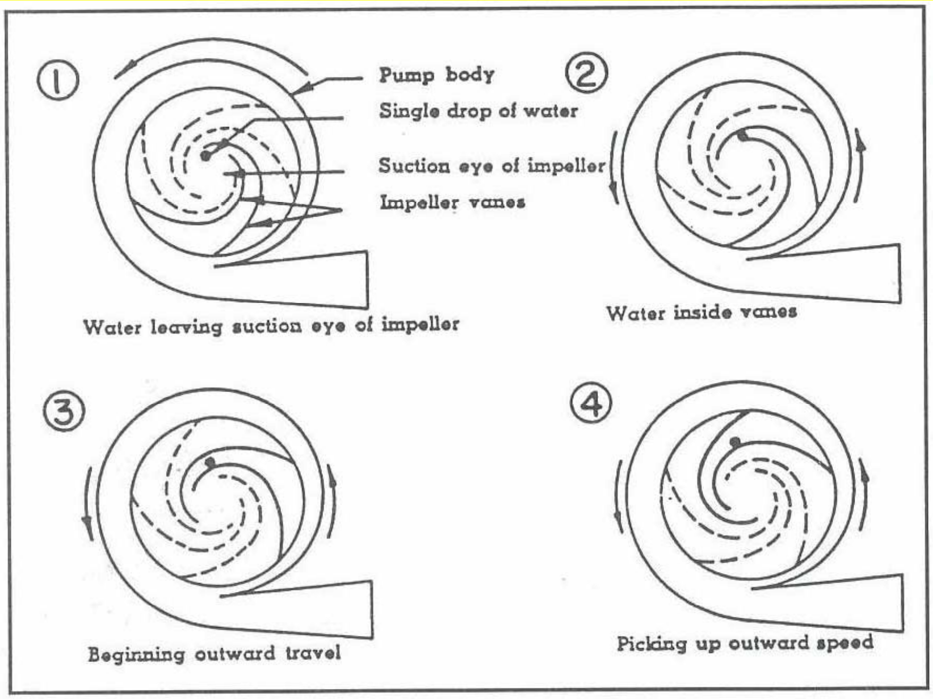
Third, water dampens fuels to make them less combustible. Wet fuels will not bum until liquid moisture has been driven out. It takes a great deal of heat energy to convert water in liquid form to water vapor.

Whether water is abundant or scarce on your fire, it can play an important role in the suppression of the fire. Its availability will certainly affect how well you manage its use.

TYPES OF PUMPS

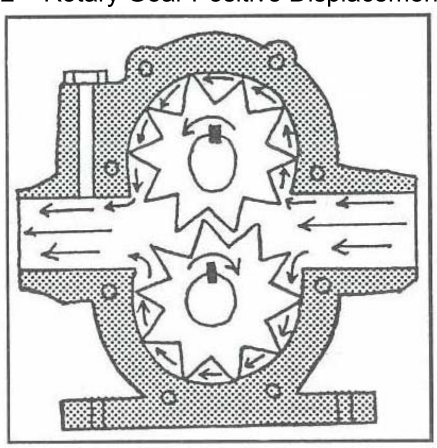
It's important to understand the differences between the two types of pumps available, their capabilities and limitations, and when to use each. There are two basic types of pumps--centrifugal and positive displacement. The centrifugal pump has a more or less open chamber that contains an impeller to move water (see Figure 1).

Figure 1 – Centrifugal Pump



The positive displacement pump uses gears or pistons to do the same job (see Figure 2).

Figure 2 – Rotary Gear Positive Displacement Pump



Although the results can be the same at the nozzle, you should realize there are advantages and disadvantages to using either type of pump.

Positive Displacement Pump Advantages:

- Does not usually require priming.
- Will draft water higher than a centrifugal pump - 15' to 20'.
- Does not require a foot valve on suction hose.

Positive Displacement Pump Disadvantages:

- Water must be free from sand and grit.
- Pump must be shut down when nozzle is off unless there is a pressure relief valve in line.
- Pumps cannot be started when there is head pressure on them, i.e., an uphill hose lay full of water.
- Almost always has to be returned to shop for maintenance or repairs.

Centrifugal Pump Advantages:

- Water does not need to be clean.
- Less maintenance cost. Can sometimes be repaired in the field.
- Nozzle can be shut off for a short period of time while pump is running.
- Pump can be started with head pressure.
- A pressure relief valve is not required, but is highly recommended.
- Pressure and volume can be changed by adjusting the speed of the pump motor.

Centrifugal Pump Disadvantages:

- Requires priming.
- Cannot draft water as high as a rotary pump.
- Should have a foot valve with the suction strainer.

Each type of pump is better adapted to certain jobs than the other. The high pressure positive displacement pump may be found on engines. They use shorter hose lines but have higher pressures at the nozzle. Centrifugal pumps are better adapted for moving large volumes of water where lower pressures can be tolerated. This is the practice on most wildland fires where hose lays are commonly used.

If a primed pump is not able to lift water, or its performance is poor, there are three things you should consider to improve its performance. Three ways to improve the pump's suction capabilities are:

1. Locate the pump at or near water level.

2. Decrease the length of the suction hose. This usually means placing the pump close to the water source.

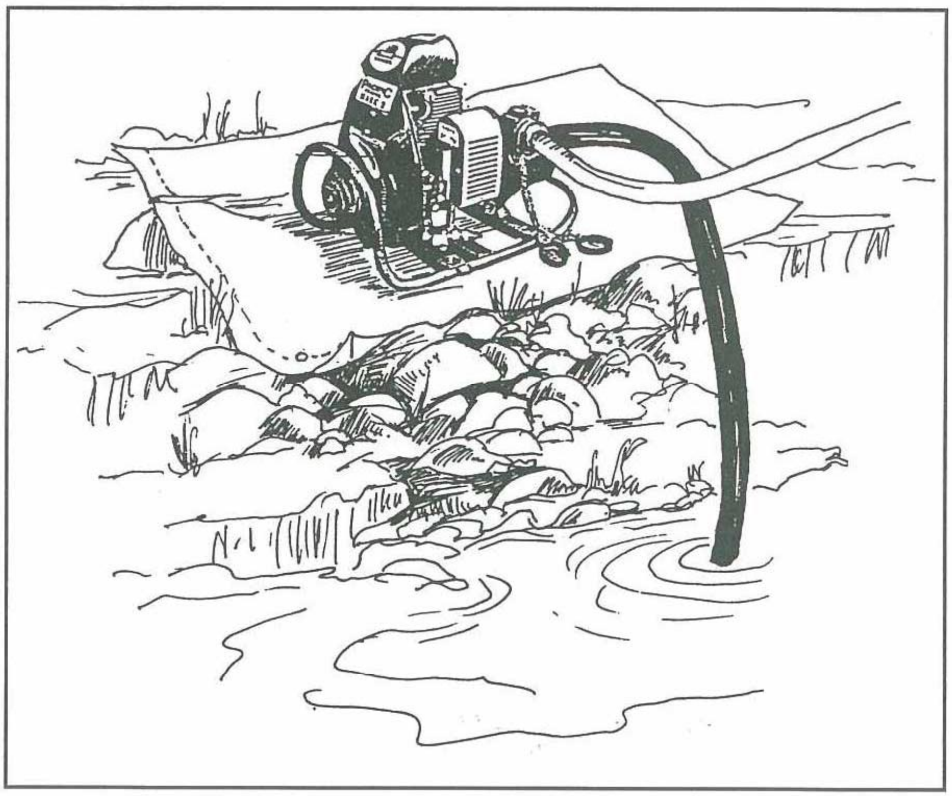
3. Tighten fittings.

HYDRAULICS

It's important to understand the hydraulic forces that influence the performance of pumps and hose lay systems. These forces are: suction or lift, head or back pressure, friction loss, and nozzle pressure.

The first force encountered in any pumping system is suction or lift at the input side of a pump. The maximum practical vertical lift capability from a water source to the pump is approximately 20 feet at sea level. Lift is reduced one foot for each 1,000 feet of rise in elevation above sea level. The more lift or suction required, the less efficient the pump will be on the discharge side. This is why a pump should be set up as close as possible to the water source to reduce the suction or lift (see Figure 3).

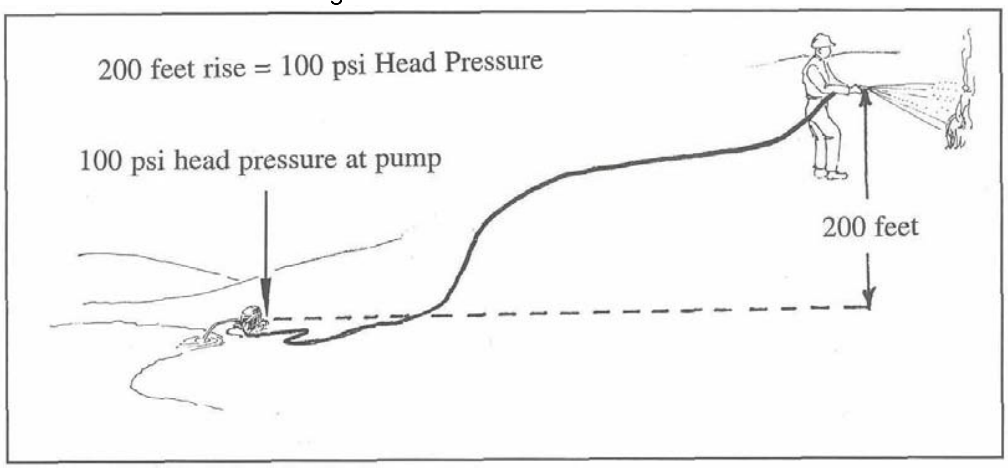
Figure 3 – Set Up Pump Close To Water Supply



The second hydraulic force is head (H) or back pressure. This is the pressure generated by the weight of water in a vertical column, such as the hose above or below a pump. When converted to pressure, it will equal approximately one pound per square inch (psi) for each two feet of vertical rise (see Figure 4). A hose line with a 200 foot vertical rise will exert 100 psi of head pressure. Without considering friction loss or nozzle pressure it will take a pump pressure of 100 psi to lift the water 200 feet in elevation. Head pressure is the primary force which prevents pumping water high vertical distances uphill.

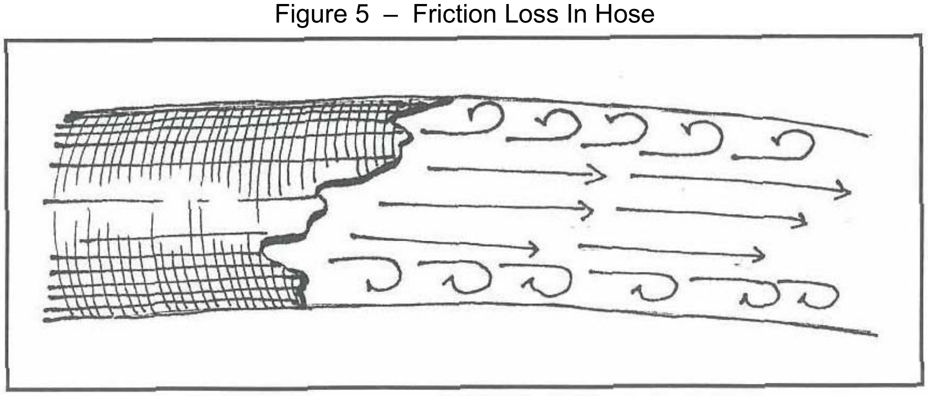
The reverse is also true for head pressure. One psi of pressure will be gained for each two feet loss in elevation. A hose line with a 200 foot vertical drop will gain 100 psi of pressure due to head pressure. Exercise caution when pumping downhill because more pressure can be obtained than a hose can withstand or there may be more nozzle pressure than a nozzle person can safely handle.

Figure 4 – Head or Back Pressure



The third hydraulic force affecting a hose lay system is friction loss (FL). Friction, anywhere in the system, will reduce pressure. The amount of friction and pressure loss due to the hose depends on the diameter of the hose, its length, its inside texture, and the loss through nozzles and other hose lay appliances. Lied hose has a layer of rubber inside the collapsible fabric exterior. Friction loss through lined hose is considerably less than through unlined hose. Figure 5 shows the eddy effect of water flowing through a hose. The water flowing on the outer edges is slowed down (friction loss) due to the loss of energy caused while rubbing against the lining of the hose.

Figure 5 – Friction Loss In Hose



A drop in pressure will occur when a fitting (appliance) is added to a hose lay. This pressure change is affected by the following variables: fitting size, fitting bends, design, condition, and flow rate. This friction loss should be added in hose lays when determining friction loss.

Add five psi pressure loss due to friction for each appliance (gated wye, Siamese, tee, water thief, etc.) used in the hose lay.

The fourth force to be considered is nozzle pressure (NP). Nozzle pressure depends on the pressure of water to the nozzle and the size of the orifice in the nozzle. A smaller orifice will reduce volume, but increase nozzle pressure. The length of a straight stream can be increased by using a smaller nozzle orifice. However, this gain in pressure always results in less volume in the water stream.

The effective nozzle pressure for firefighting purposes depends on the specific nozzle used. Each is designed for more efficient use at a certain pressure. However, nozzles can be divided into two categories for basic hydraulics and pump pressure determination for wildland firefighting.

1. Straight streams, effective working pressure 50 psi.

2. Fog nozzles, effective working pressure 100 psi.

The only exception is the "Forester" nozzle which has an effective working pressure of 50 psi.

Each of the four hydraulic forces has an effect on the delivery of water to the fireline, some positive, some negative. How can you be sure that your hose lay system will deliver water to the fireline and with enough nozzle pressure to be effective? Of course, one way is to set it up and try it out. A better way is to perform a few simple calculations which will tell you whether or not it will do the job before you set it up.

The standard hydraulic equation for determining pump pressure is as follows:

PP = NP + or - H + FL + A where:

PP = Pump pressure at the discharge side of the pump.

NP = Nozzle pressure which is the pressure delivered to the nozzle.

H = Head. Add (+) if pumping uphill and subtract (-) if pumping downhill.

FL = Friction loss. The smaller the hose the greater the friction loss and the larger the hose the lower the friction loss.

A = Number of appliances used in the hose lay such as in-line T's, gated Wye's, etc. Each appliance increases friction loss and decreases nozzle pressure by about five psi. DO NOT COUNT THE NOZZLES OR HOSE CONNECTIONS AS APPLIANCES.

A drawback of using this equation is you must: 1) know the nozzle bore size, 2) use a Nozzle Discharge and Friction Loss Calculator or some other method to determine hose flow rate in gallons per minute and 3) apply the determined flow rate to a table for different size and types of hose to determine friction loss per 100 foot section of hose.

Tables 1 through 4 display the necessary pump pressure to achieve 50 and 100 psi nozzle pressure for 1 and 1 1/2 inch hose. However, remember nozzle pressure will be reduced approximately five psi for each appliance used in the hose lay.

Table 1 – Pump Pressure for 50 psi Nozzle Pressure (1-inch hose)

Length Hose in feet	Nozzle Above Pump in feet	Tip size in Inchs 1/8	3/16	1/4	5/16	3/8
100	0	51	52	55	62	75
	100	94	95	98	105	118
300	0	52	56	65	86	121
	100	95	99	108	129	164
	200	139	143	152	173	208
500	0	53	60	75	110	167
	100	96	103	118	153	210
	200	140	147	162	197	254
	300	183	190	205	240	297
1000	0	56	70	110	170	282
	100	99	113	153	213	325
	200	143	157	197	257	369
	300	186	200	240	300	
	400	229	243	283	343	
	500	273	287	327	387	
	600	316	330	370		
Discharge (GPM)		3	7	12	19	28
PSI Loss/100 ft.		0.3	1.8	4.7	11.0	23.0

Table 2 – Pump Pressure for 50 psi Nozzle Pressure (1 1/2-inch hose)

Length Hose in feet	Nozzle Above Pump in feet	Tip Size in Inchs				
		1/8	3/16	1/4	5/16	3/8
100	0	51	51	51	52	53
	100	94	94	94	95	96
300	0	51	52	53	56	60
	100	94	95	96	99	103
	200	138	139	140	143	147
500	0	51	53	55	60	66
	100	94	96	98	103	109
	200	138	140	142	147	153
	300	181	183	185	190	196
1000	0	51	55	59	68	82
	200	138	142	146	155	169
	400	224	228	232	241	255
	600	311	315	319	328	342
2000	0	52	59	67	84	114
	200	139	146	155	171	201
	400	225	232	241	257	287
	600	312	319	328	344	374
	800	298	405			
3000	0	53	64	75	100	146
	200	140	151	162	187	283
	400	226	237	248	273	319
	600	313	324	335	360	
	700	356	367	378	403	
Discharge (GPM)		3	7	12	19	28
PSI Loss/100 ft.		< 0.1	< 0.1	0.1	1.5	3.1

Table 3 – Pump Pressure for 100 psi Nozzle Pressure (1-inch hose)

Length hose (ft.)	Nozzle above pump (ft.)	Tip orifice size (inch) 1/8	3/16	1/4	5/16	3/8	1/2
100	0	101	103	109	118	135	200
	100	141	146	152	161	178	243
200	0	101	106	118	136	170	300
	100	144	149	161	179	213	343
300	0	102	109	127	154	205	400
	100	145	152	170	197	248	443
	200	189	196	214	241	292	487
400	0	103	112	136	172	240	500
	100	146	155	179	215	283	543
	200	190	199	223	259	327	587
	300	233	242	266	302	370	630
500	0	103	115	145	190	275	600
	100	146	158	188	233	318	643
	200	190	202	232	277	362	687
	300	233	245	275	320	405	730
1,000	0	107	131	190	280	450	
	100	150	174	233	323	493	
	200	194	218	277	267	537	
	300	237	261	320	410	580	
	400	281	305	364	454	624	
	500	324	348	407	497	667	
	600	368	392	451	541	711	
Discharge (gpm)		4.7	10.5	18.7	28.7	42.1	74.7
Psi loss/100 ft.		0.7	3.1	9.0	18.0	35	100

Table 4 – Pump Pressure for 100 psi Nozzle Pressure (1 1/2-inch hose)

Length hose (ft.)	Nozzle above pump (ft.)	Tip orifice size (inch) 1/8	3/16	1/4	5/16	3/8	1/2
100	0	101	101	102	103	106	117
	100	144	144	145	146	149	160
200	0	101	102	103	107	112	134
	100	144	145	146	150	155	177
300	0	101	103	105	110	118	151
	100	144	144	148	153	161	194
	200	188	190	192	197	205	238
400	0	101	102	106	113	124	168
	100	144	145	149	156	167	211
	200	188	189	193	200	211	255
	300	231	232	236	243	254	298
500	0	101	103	108	117	130	185
	100	144	146	151	160	173	228
	200	188	190	195	204	217	272
	300	231	233	238	247	260	315
1,000	0	101	105	115	133	160	270
	100	144	148	158	176	203	313
	200	188	192	202	220	247	357
	300	231	235	245	263	290	400
	400	275	275	289	307	334	444
	500	318	322	332	350	317	487
	600	362	366	376	394	421	531
2,000	0	102	110	130	166	220	410
	100	145	153	173	209	263	433
	200	189	197	217	253	307	527
	300	232	240	260	296	350	570
	400	276	284	304	340	394	614
	500	319	327	347	383	437	657
	600	363	371	391	427	481	701
	700	406	414	434	470	524	744
	800	450	458	478	514	568	788
3,000	0	103	115	145	199	280	610
	100	143	158	188	242	323	653
	200	190	202	232	286	367	697
	300	233	245	275	329	410	740
	400	277	289	319	373	454	784
	500	320	332	362	416	497	827
	600	364	376	406	460	541	871
	700	407	419	449	503	584	
	800	451	463	493	547	628	
Discharge (gpm)		4.7	10.5	18.7	28.7	42.1	74.7
Psi loss/100 ft.		0.1	0.5	1.5	3.3	6.0	17

Caution---Pump pressures over 450 psi exceed the normal working pressure of Single Jacket, Cotton-Synthetic Lined Hose (USDA Forest Service Specification 5100-186).

Following is an example to determine pump pressure from the previous tables.

What pump pressure will be required to deliver a nozzle pressure of 50 psi using a 318-inch nozzle attached to 1000 feet of 1 1/2-inch lined hose? The rise in elevation is 200 feet. There are three in-line T's in the hose lay.

From Table 2-Pump Pressure for 50 psi Nozzle Pressure (1 1/2-inch hose), the pump pressure for the 1000 foot hose lay with a 200 foot rise in elevation using a 318-inch nozzle is 169 psi. Add 15 psi for the three in-line T's and the required pump pressure is 184 psi.

There may be times when some interpolation is needed to use the tables, but the main thing to remember is to use a little common sense with hydraulic calculations. Remember, the purpose of hydraulic calculations is to give you some idea if the proposed hose lay system will work. Table *5* gives the operating psi and maximum lift for some of the common pumps used in wildland firefighting.

Table 5 – Expected Output of Commonly Used Portable Pumps*

Pump Type	Operating psi	Maximum lift (ft)
Waterous (Floto Pump)	150	200
Gorman Rupp (621/2)	190	280
Mark 3	250	400

*All calculations were made using 1 1/2 inch hose and Forester Nozzle with 3/16" tip and a nozzle pressure of 50 psi.

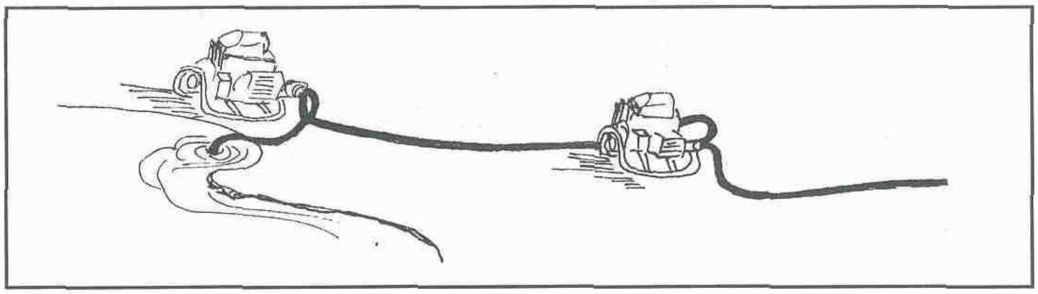
From the above example, 184 psi pump pressure is required to produce 50 psi nozzle pressure with a 318" tip attached to a 1,000 foot hose lay with a three inline T's and a 200 foot rise in elevation. From Table 5 both the Gorman Rupp and Mark 3 will produce enough psi to accomplish this setup.

SERIES, PARALLEL AND STAGED PUMPING

If a single pump is inadequate to supply enough pressure or volume of water, an alternative is to use a series, parallel, or staged pumping setup. This concept applies to all types of pumps. It is extremely useful and important that you understand the various effects of these methods.

With series pumping, two pumps are connected "in-line." Water is pumped by the first pump directly into the second pump. The hydraulic effect is to **increase pressure** (see Figure 6).

Figure 6 – Series Pumping



Pumps in series will almost **double the pressure.** The volume will be limited to that of the first pump. This assumes that both pumps have equal capabilities in term of pressure and volume. In field applications, the pressure will be slightly less due to hydraulics.

> Example: One Mark 3 pump will produce a flow of 12 gpm and 275 psi. By adding another Mark 3 pump in series, the combination will still only produce 12 gpm. However, the theoretical pressure will be 550 psi, while in field applications the pressure will be closer to 450 psi.

The Water Handling Equipment Guide, NFES No. 1275, available through the Publication Management System provides performance and output capabilities of many of the portable pumps used in wildland firefighting.

Series pumping can produce more pressure than the hose can withstand so be careful. It's a good idea to use one or two sections of lined hose at the beginning of a hose lay when setting up pumps in series.

Pumps with different capabilities may be connected in series. Usually, the pump with the highest capability is placed closest to the water source. Then the lower capability pump is placed "in-line." The limiting factor is the ability of the first pump to supply enough water to the second pump. The following situations illustrate this principle.

The first step in series pumping is planning the system. This should include:

1. Required water needs. This should be based on the desired nozzle pressure and volume needed at the application. In other words, you need to know how much water is needed in order to supply it.

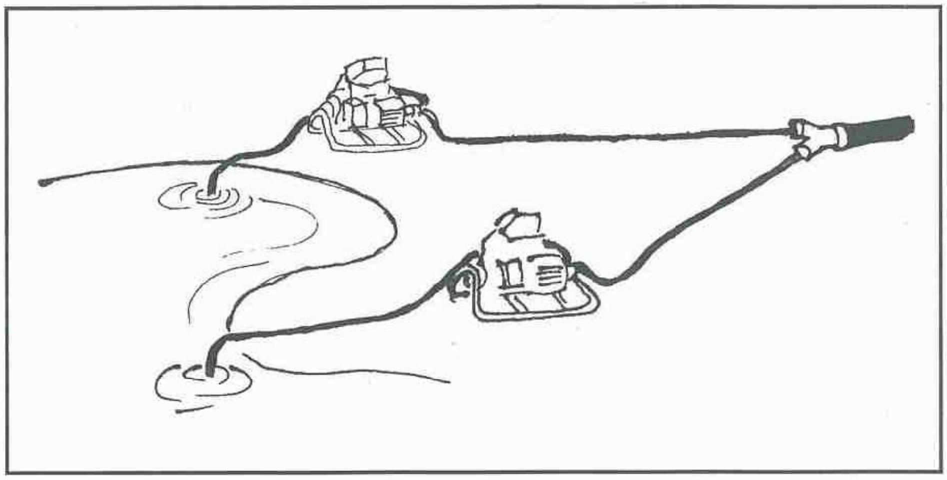
2. Location and type of water sources. The water source should have enough water to supply the users. The type refers to streams, ponds, portable tanks, etc.

3. Personnel requirements. Determine how many operators will be needed to ensure the pumps can be adequately monitored and operated. Establish communication procedures between the pump operators and the users.

4. Pump, hose, and fitting requirements. Determine how many pumps, hose, etc., will be needed to supply the desired volume and pressure at the end of the hose lay. In many field situations, the hose and fittings available will determine how the pumps are arranged. In some cases, it may not be possible to meet the water needs with the available equipment.

With parallel pumping two pumps are connected "side by side." Water flows from each independent pump into a single hose lay. The hydraulic effect is to nearly double water volume (see Figure 7). Ideally, pumps should have equal capabilities in terms of pressure and volume.

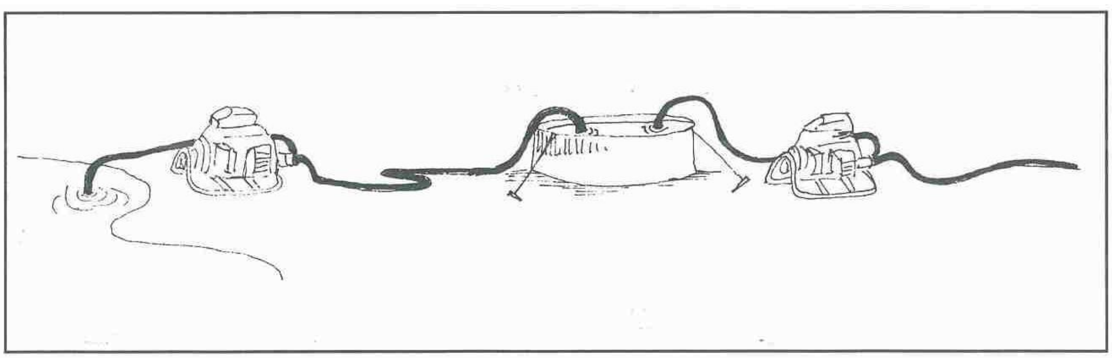
Figure 7 – Parallel Pumping



Pumps with unequal capabilities may be connected in parallel. However, pressure and volume will be limited by the capability of the smallest pump. In field applications, the actual volume produced will be less than double primarily due to friction loss.

With staged pumping the pumps are not directly connected, but are operated independently from each other (see Figure 8). The hydraulic effect is equal to the capability of each pump.

Figure 8 – Staged Pumping



Staged pumping moves water to a temporary storage reservoir which is then relayed by a second pump. The second pump can then supply the water directly to the fireline or supply another reservoir. An advantage of staged pumping over series is that the water supply is less likely to be interrupted if a pump must be shut down for repairs or servicing.

There is no limit to the number of times water can be relayed. Staged pumping is only limited by the capability of any of the pumps.

Pumps may also be connected in any combination of parallel or series to supply temporary reservoirs depending on the desired volume and pressure.

It is possible to have several combinations of series, parallel, and staged pumping arrangements all at the same time to supply water. It takes skill and knowledge to make the pump combinations effective. The more complex system that is designed, the more planning is needed to ensure the system will meet the fire's needs.

Remember: **KEEP IT SIMPLE.**

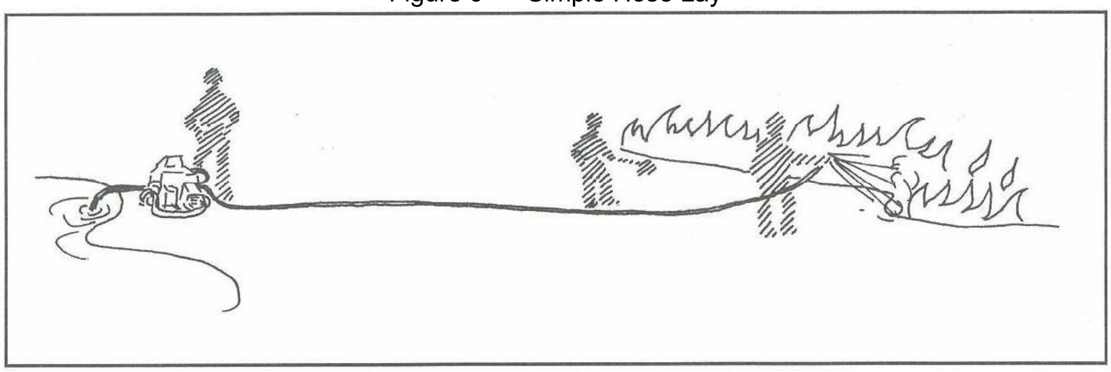
HOSE LAYS

Once the firefighter is familiar with how to set up, operate, and maintain a portable pump, they then must get the water to the fire in an efficient and safe manner. This is accomplished by flowing water through the hose, fittings, and nozzles. There are numerous ingenious methods for dispensing hose and fittings to accomplish this. Here we will discuss the types of hose lays, not the methods used to lay the hose out.

The two types of hose lays are simple and progressive. Both types of hose lay may use either 1 inch or 1 1/2inch hose of whatever type construction that is preferred.

Simple - one that comes straight off the pump and goes directly to the nozzle with no junctions in between.

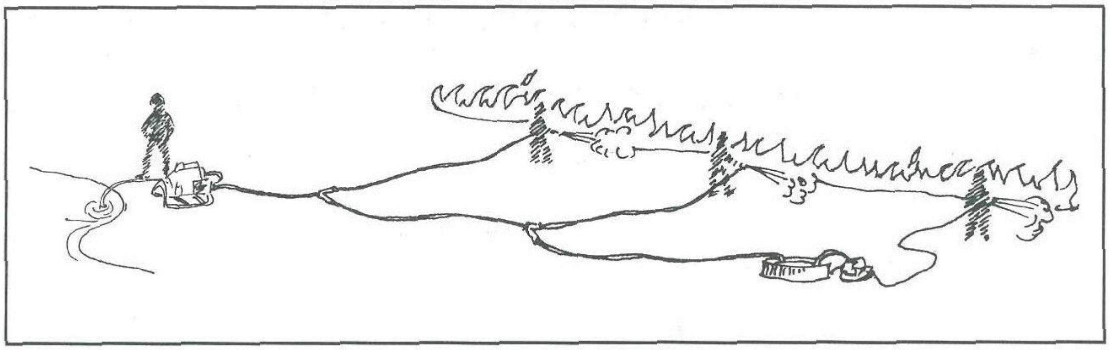
Figure 9 – Simple Hose Lay



A simple hose lay is easily installed and can vary in length as needed. This type of hose lay does not have a lot of friction loss due to additional fittings, which is an advantage. The key disadvantage of the simple hose lay is that the water flow must be stopped before it can be extended by adding a length of hose. There also are no provisions for safety should the fire flare up behind the nozzle operator. A simple hose lay is more difficult to use in mopup as you must either revise the installation process or pull large amounts of hose.

Progressive - one that comes from a pump source to the fire which has a series of lateral junctions in place between the pump and lead nozzle.

Figure 10 – Progressive Hose Lay

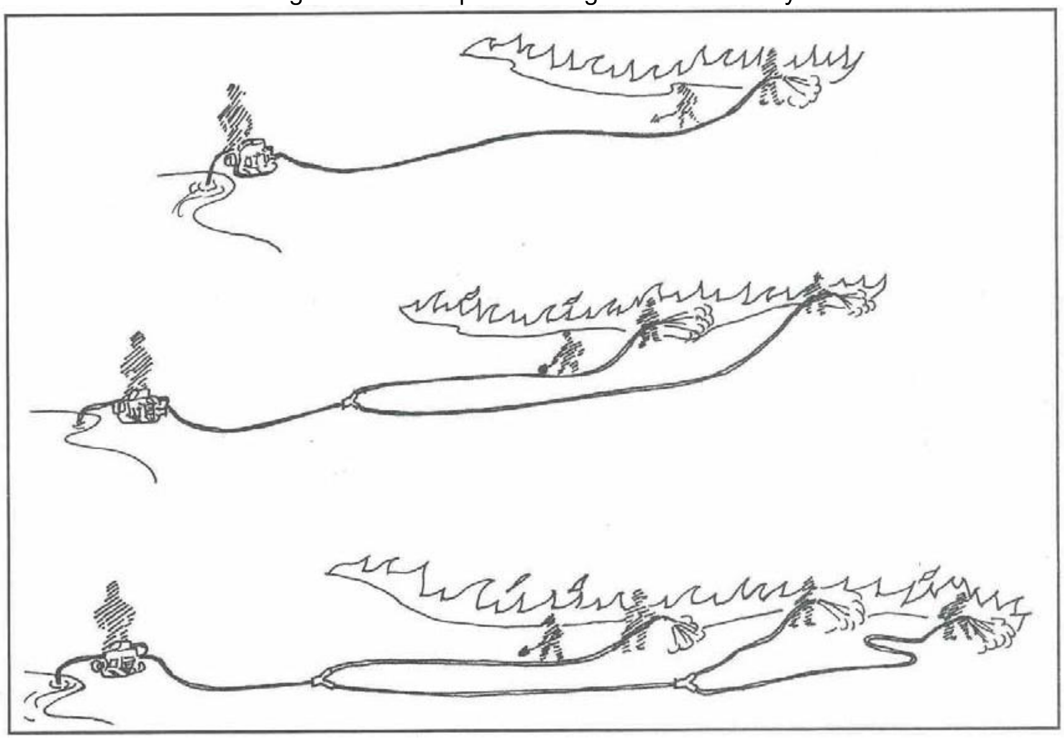


A progressive hose lay is one that incorporates a series of lateral lines off of a main trunk line. The progressive hose lay has several advantages over the simple hose lay in that it provides for a continuous attack on a fire without risking shutting down the hose lay to extend its reach. The progressive hose lay provides a security margin for the lead nozzle operator in that there is a charged or easily charged lateral line left behind should there be a flare up. It also can provide for multiple attack lines on spot fires across the control line. A progressive hose lay does create a higher friction loss in your hose lay due to the increased numbers of fittings (approximately five psi each). A progressive hose lay may be slower to install, but is inherently safer for direct attack and much more efficient in mopup.

To install a progressive hose lay (see Figure 11) a crew first stretches a trunk line of 1 1/2 inch hose from the pump to the fire as a simple hose lay. Once they reach the fire, they install a gated wye and proceed 100 to 150 feet with the trunk line to install another gated wye, which has a 1 1/2 inch to 1 inch reducer on one side (towards the fire) and attach 100 feet of 1 inch hose with the preferred nozzle. One person can then operate this nozzle to attack the fire as another person stretches the next section of the trunk line which is attached to the remaining side of the gated wye. Once the trunk line is stretched and the second lateral gated wye is in place the first nozzle operator then charges the trunk line and returns for more hose once the second lateral attack line is flowing water. This process is repeated until the fire is contained or the pump has reached its capacity.

A progressive hose lay is very efficient when mopup time arrives. A progressive hose lay from a Mark 3 pump can easily supply three to five nozzles depending on friction loss and required head pressure. This can efficiently keep a 20 person crew busy. A progressive hose lay provides numerous opportunities for lateral lines to speed up mopup and prevent having to move 1 1/2 inch trunk lines.

Figure 11 – Steps of a Progressive Hose Lay



Hose Lay Safety

Avoid using hardlines (or any other 1-inch lines) on extended hose lays. Friction loss is too great and there may be an inadequate volume of water to protect the nozzle operator and effectively extend the line as the fire progresses.

Combination nozzles providing a fog pattern will add an extra measure of safety, as long as adequate water is available at the nozzle.

Always provide communications between the nozzle operator and the pump operator and have an anchor point for the hose lay.

MOPUP

One effective use of water is for mopup. Where and how to use the available water supply is always a concern to fireline supervisors. Here are some priorities usually set during mopup:

1. Put out any spot fires outside the fireline.

2. Extinguish any hot spots immediately inside the fireline that could possibly threaten the line.

3. Put out hot spots further inside the burn, but adjacent to unburned islands of hazardous fuels.

4. Mop up all smokes inside the line for a reasonably safe distance.

5. Patrol and/or mop up the entire burn area until the fire is dead out.

6. On peat fires, peat nozzles or flooding using irrigation pumps are effective methods of mopup.

7. On deep burning ground fires, moderate to high volume sprinklers are effective methods of mopup.

Water can be used very sparingly but effectively when hand tools are used to expose burning fuels and mix soil with fire. Wetting agents and foam will greatly help water penetrate into fuels and hot spots.

Mopup is normally a slow, tedious job. Water does not necessarily reduce the amount of work required, but it can save you time. Some firefighters attempt to drown out fire, but find this usually doesn't work. Water does not readily penetrate deep organic layers and can actually insulate hot spots under the ground. These hot spots can come to the surface later.

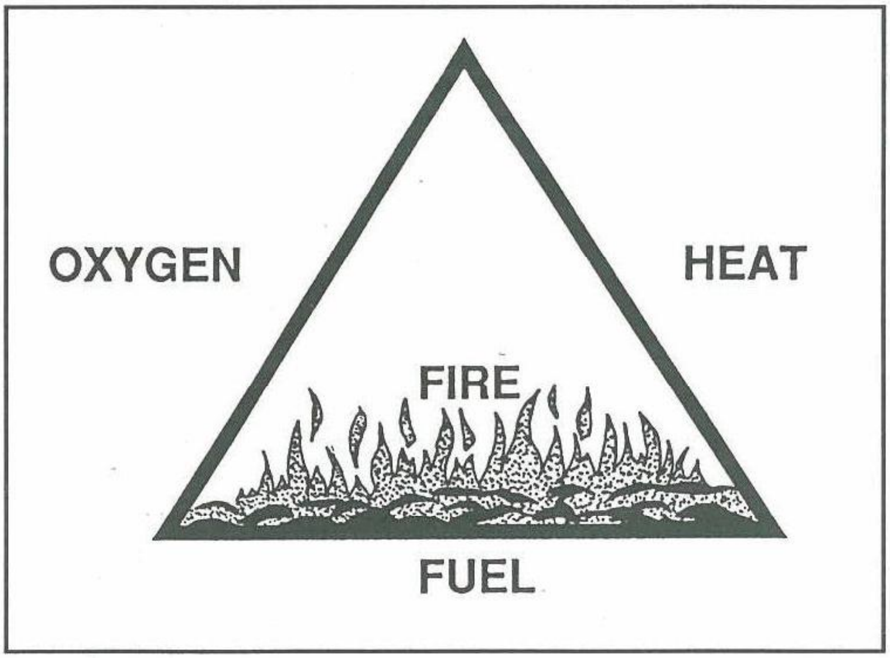
The most effective procedure is to break up and scatter burning fuels, then cool them down with water. Dig, scrape, and scatter-hard work, but necessary to insure that the fire is out and safe to leave.

High water volumes and pressures at the nozzle generally are not needed during mopup and often cause a hazard from steam and blowing debris and ash. Gloves and goggles should be worn when doing mopup with water. A few squirts from a backpack pump can easily cool down hot embers. Mopup kits which contain a series of garden hoses as laterals are excellent for mopping up large sections of fireline. Remember, a combination of water and hand tool work is a winning team for a speedy mopup.

TACTICAL USE OF WATER

From your fire behavior training, you have studied the fire triangle as a model for the process known as combustion.

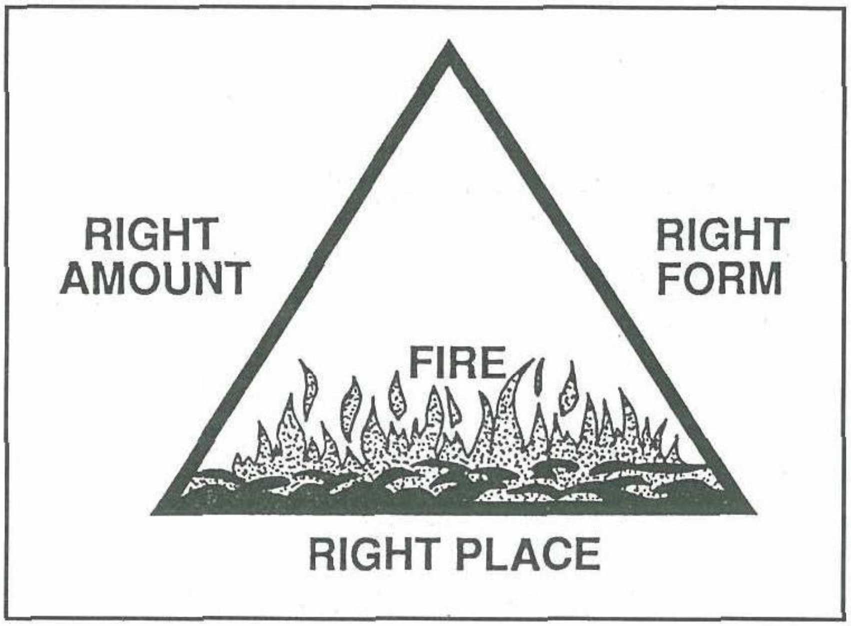
Figure 12 – Fire Triangle



The basic principle of fire suppression is to remove one or more of the three essential components of the fire triangle. This may be accomplished through the removal of the fuels; by reducing the temperature of the burning fuels below their ignition point, or by excluding oxygen. Equipment used to apply water carries out a dual function by excluding the amount of available oxygen and in reducing the temperature of the fuels.

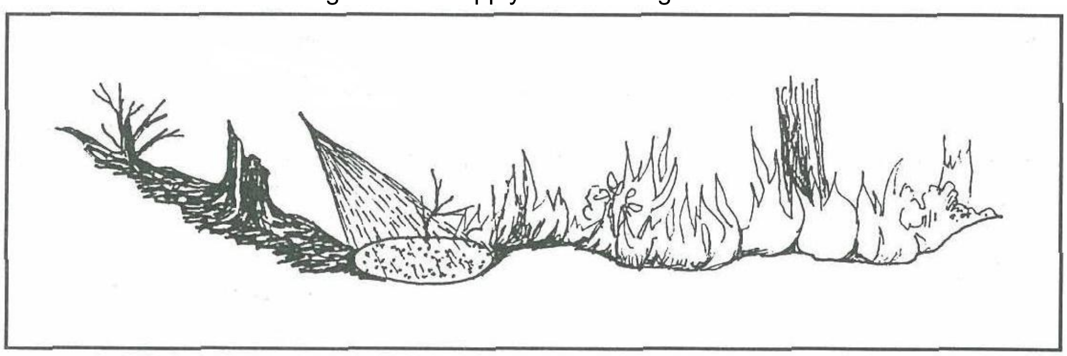
The water triangle (see Figure 13) serves as a useful model to explain how water, when applied in the **right amount, right form and right place** can increase your success in extinguishing flame and burning fuels.

Figure 13 – Water Triangle



First, lets look at how you can increase your effectiveness through the application of water in the **right place** on the fire.

Figure 14 – Apply Water at Right Place



If water is applied in the right place, the temperature of the burning fuel will be reduced below its kindling point. To accomplish this, the stream of water should be directed at the base of the flame, where the heating of the fuel and its conversion to a flammable vapor is taking place. The rapid lowering of fuel temperature effectively excludes the heat component of the fire triangle and flaming combustion is extinguished. This is particularly effective where flaming combustion involves fuels burning at or above the surface.

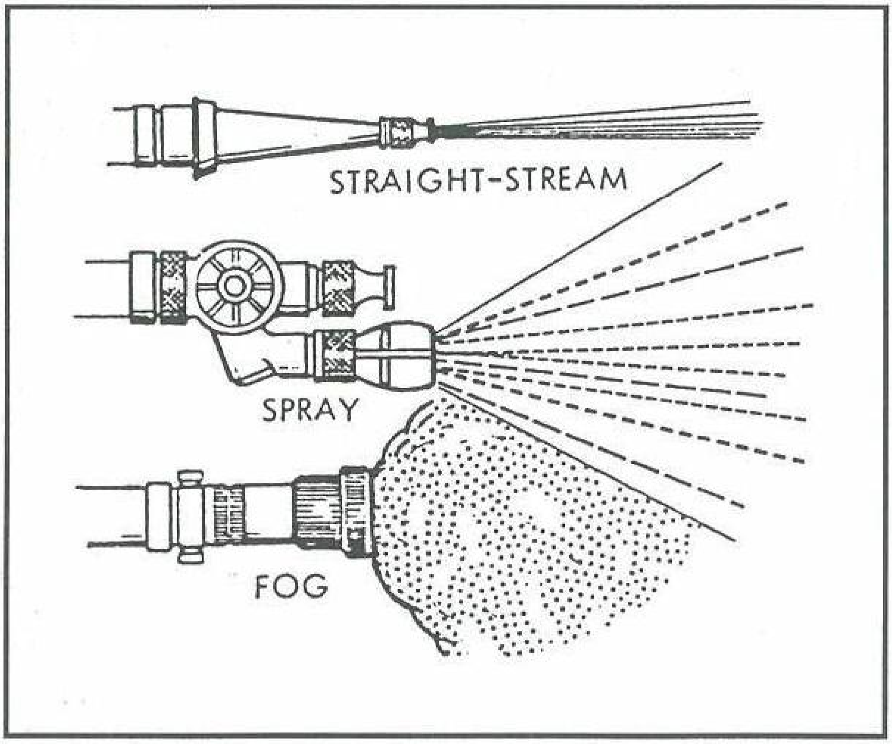
Where the fire is burning in the organic fuels below the surface, the same principle applies. You must get the water down to the source of the heat where combustion is taking place to be effective. Water applied elsewhere is a wasted effort.

This concept of right place applies to fires under all circumstances.

Water in the **right form,** is the next segment in the water triangle.

Nozzles allow you to form and direct a stream of water under pressure at the fire (see Figure 15). The nozzle and the skill of the operator at the point of application determine the degree of success which is achieved. Water can be highly effective or largely wasteful depending on which nozzle is selected and how it is used.

Figure 15 – Nozzle Types



While there is a large variety of nozzles to choose from, the types most often used for wildland fire applications can be broadly grouped as:

1. Plain: Plain screw on tips, either straight stream or spray pattern.
2. Select Tip Combination Shutoff: Multiple tip nozzle such as the "Forester" six-shooter.
3. Single Tip Shutoff: Straight stream or spray pattern with shutoff.
4. Twin Tip Combination Shutoff: Combination straight stream and fog pattern with shut off.
5. Adjustable Combination: Adjustable sequence from shut off to straight stream or spray pattern.

The various types of nozzles offer you the ability to make your selection based on rate of delivery (gallons per minute), pressure requirements and a variety of water patterns, from solid streams to spray patterns to a fine fog.

Combination nozzles that provide both straight stream and spray patterns are usually required in most wildland fire applications because of the need to vary the water stream to the conditions encountered along the fireline. To be effective with water, the nozzle operator must adjust water streams to the job at hand.

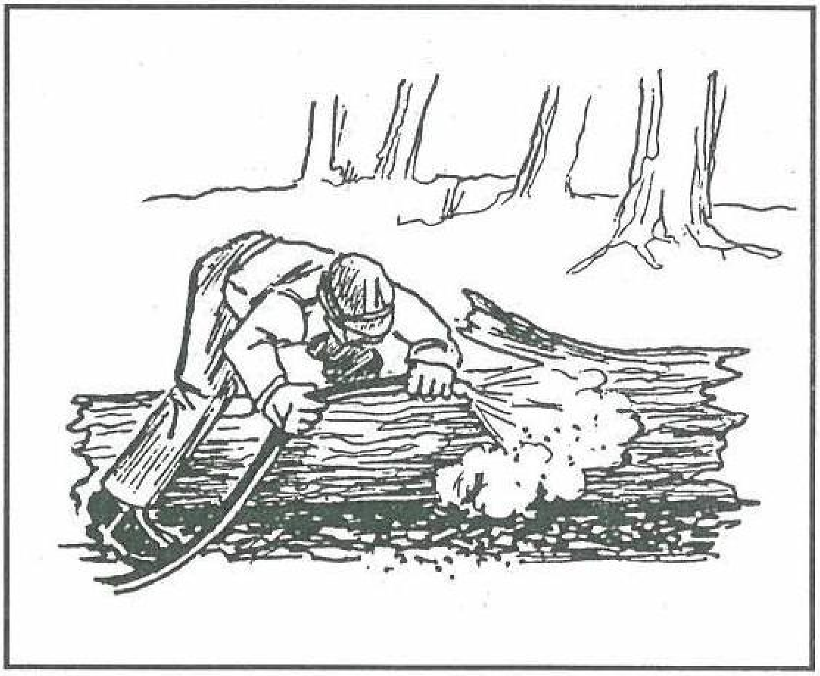
Solid water streams provided from the nozzles which flow water as a single straight stream are used where the ability to reach, or distance, is the key aspect in getting water onto the fire. Fire burning high up in a snag may require the additional reach which you can obtain from a straight stream. Where the fire is burning too intensely for the nozzle operator to work close to the fire's edge, the straight stream is used to cool the fire from a distance so that closer work can be performed later. In some situations where strong winds prevent you from directing spray patterns accurately, it may be necessary to switch to a straight stream to get the water into the right place. Straight streams can also be effective where penetration into matted grass, needles and duff is necessary.

While straight streams satisfy the requirement for reach and distance, they tend to use a higher volume of water than other methods. This is largely due to the delivery of water as a solid stream, which affects only a narrow piece of the fire area treated. These types of nozzles usually operate effectively at 50 p.s.i., though higher pressures may be needed when distance or surface penetration is needed.

Spray and fog patterns offer the nozzle operator more effective application of water because of the small droplet size. These types of patterns absorb more heat and treat a greater burning fuel surface area with a smaller volume of water. For these reasons, spray and fog patterns are used extensively for close work along the fireline and where protection from intense heat is needed for the nozzle operator.

The final component of the water triangle is water in the **right amount** (see Figure 16).

Figure 16 – Apply Water in Right Amount



When you think about the right amount of water, it is important to realize that a small amount of water is capable of extinguishing a lot of burning fuel. One of the ideas which is established early in your career as a firefighter, is that one volume of water is capable of extinguishing 300 volumes of burning fuel, if properly applied. Many nozzles are capable of producing a fine spray, which breaks the water stream into many droplets. Through the high heat absorbing capacity of water, many droplets can cool and extinguish many units of fire if applied to the right place and form.

In any given situation, the amount of water required to extinguish a fire will largely depend upon the fire intensity and the type of fuels burning. Generally, we can say that more fire intensity will take more water and less fire intensity will take less water.

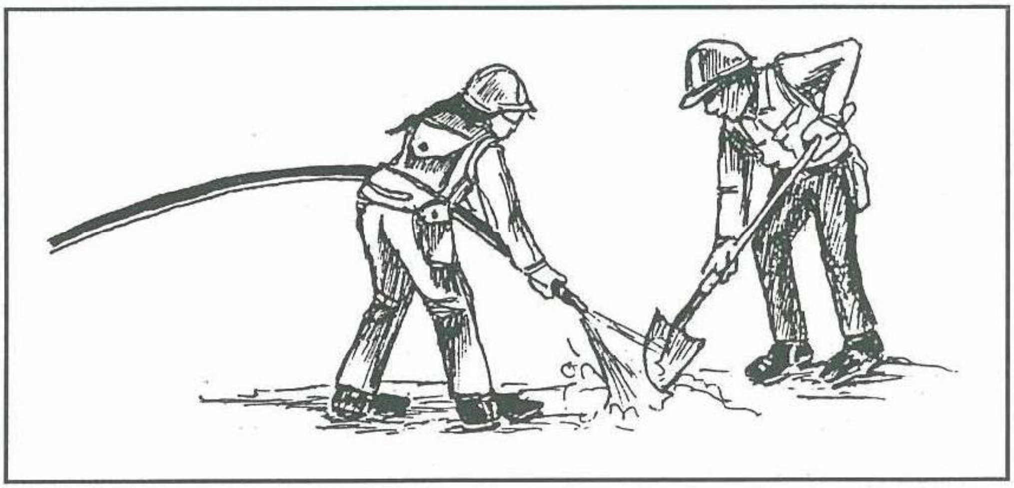
Water Conservation

Whenever possible, add a surfactant to your water supply. Surfactants have an advantage over plain water whenever complete wetting is needed. They will speed up the wetting of the ground fuels and less water will be wasted through runoff from the fuel surface. Surfactants used to produce foam work by holding the water on the surface of the fuel.

Good communications should be established and maintained between the nozzle operator and the pump operator, by either radio or hand signals. The nozzle operator should always know how much water is available at the source, since this could make a difference in what type of action is taken on the fire. In turn, the nozzle operator should communicate whether the supply and delivery system is meeting the needs at the fire scene or not.

Personnel with hand tools should work closely with nozzle personnel. Mineral soil applied with skilled hand tool use can be effective to exclude oxygen, knock down flame and to cool burning embers leaving nozzle operators available to apply water where the greatest benefit can be attained. Where water is applied to extinguish flaming combustion and fuels are left in a glowing or smoldering state, have personnel with hand tools follow up by raking and mixing the treated fuels with mineral soil. The pulaski is an excellent tool for scraping and peeling heavy fuels, so that water can be applied directly to the source of heat. If a pump should fail, enough hand tools should be available to extinguish the fire with mineral soil.

Figure 17 – Handtools and Water



Know Your Equipment

A lot can be done to conserve water by knowing which fittings contribute to the effort, and assuring that they are used. There are four fittings which are commonly used to conserve water: low gallonage nozzles, the check and bleeder valve, the pressure relief valve and shut-offs. Let's take a look at each one of these to see how they contribute to the effort of water conservation.

First, by selecting the lowest gallon per minute nozzle(s) to safely do the job, you can, to a large extent, control the amount of water arriving at the fire. It doesn't make sense to select a 30 gallon per minute nozzle, when the same job can be safely accomplished by using a nozzle rated at 12 gallons per minute. Your knowledge of the gallon per minute rating of nozzles available to you is going to make a big difference in your contribution to water conservation.

The installation of the check and bleeder valve contributes to the water conservation effort by allowing the pump operator to circulate water back to its source while starting the pump against a head of water pressure. The check valve feature not only protects the pump from water flowing back against it when it is stopped, it also maintains the volume of water already in the hose lay system. This can be a substantial amount when you consider that each 100 foot length of 1 1/2 inch hose holds approximately 9 gallons of water and the same length of 1 inch hose holds about 4 gallons of water.

The main feature of the pressure relief valve is its sensitivity to pressure and its ability to relieve excessive pressure on the discharge side of the pump back to the water source. By presetting this valve to the desired working pressure, water under pressure which is not needed at the nozzle is then returned to the water source through a 1 inch hose at the valve. The ability to maintain constant pressure is an important feature for the protection of nozzle operators. Any sudden change in one line can cause a pressure surge on the other.

Shut-offs of various types represent the final water handling device used to conserve water. Hose clamps, in-line tees, gated valves and nozzles with shut-offs all allow you more control over maintaining water within the delivery system. By clamping off or shutting down gated valves, you can keep a broken hose from wasting water on cold ground. Nozzles with a shut-off allow you to move from one point of application to another, without wasting water where it isn't needed.

<u>Role Of The Nozzle Operator</u>

The nozzle and the skill of the operator at the point of application can determine the degree of success which is achieved. Water can be either highly effective or largely wasteful depending on which nozzle is selected and how it is used.

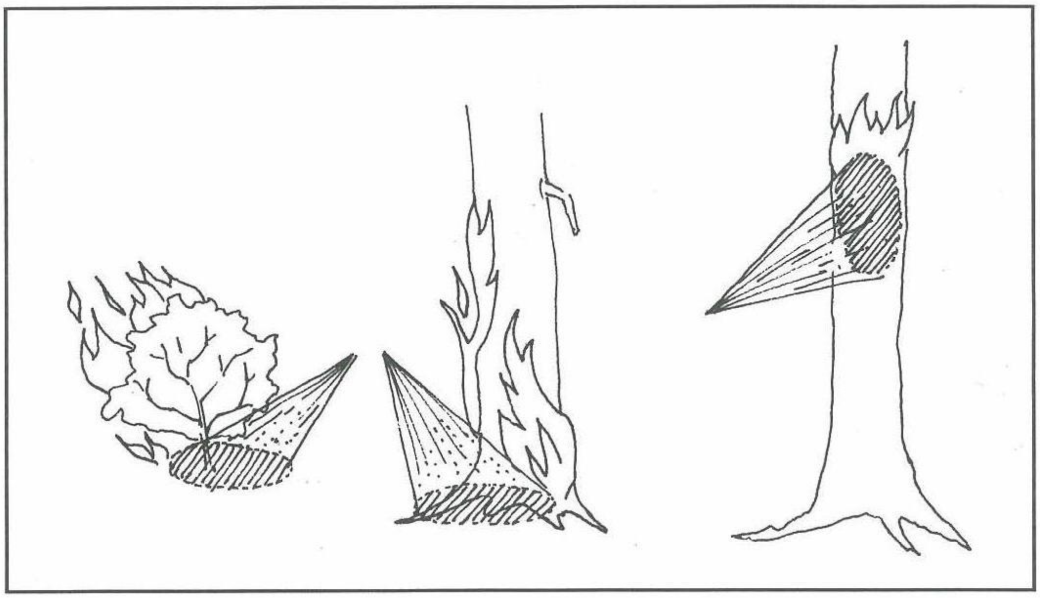
To be effective with a limited water supply, the nozzle operator must learn to master the use of the nozzle, the shut-off, the pressure and the method with which water is applied.

Nozzles vary in gallons per minute, pressure requirements and type of water streams produced. Your selection of the nozzle should be based on the lowest gallon per minute rating which will allow you to safely do the job. Whenever possible, select a nozzle which will offer you the versatility needed to do various tasks along the fireline without sacrificing high delivery rates or gallons per minute. Spending a few minutes with an experienced firefighter will get you started in the right direction.

Learn to adjust the nozzle pattern to match the water output to the fire intensity. As a general rule, we can say that more fire intensity will take more water and less fire intensity will take less water. Learn what types of fuel models and the fire intensity levels associated with them are attained during the average and worst conditions to help determine what works well.

Always apply water at the base of the burning flame.

Figure 18 – Apply Water at Base of Flame



Straight streams should only be used to:

Cool a hot fire, in order to get in closer.
Knock fire out of snags or Gee tops, where distance and reach are important.
Hit a dangerous hot spot ahead of you.

When it is necessary to use straight streams to cool a hot fire or hit a dangerous hot spot ahead of you, you can cool a greater volume of burning fuel by aiming your stream at the base of the hot spot and bouncing some of it off the ground in a fan shape.

Water can best be conserved by using spray and fog patterns to absorb more heat and cover a larger volume of burning fuel. Work the nozzle close to the fire whenever possible, you will have better accuracy and will achieve better penetration into fuels.

Learn the effects that pressure has on your nozzles. Some nozzles at high pressures deliver air and water on the fire which has the effect of fanning the flames at the edge of the application instead of knocking them down. Straight stream nozzles usually operate effectively at 50 p.s.i. Spray and fog patterns usually require more pressure to break the stream of water up into a fine spray or fog. They usually require 100 p.s.i., though many will continue to develop good patterns with less pressure. Aspirating nozzles usually require pressures of more than 100 p.s.i. to achieve the desired results of air induced foam. Your best opportunity here is to practice with various combinations of nozzle types and openings under different pressures.

While you may need the full potential of the system during the early stages of the fire, you can usually reduce operating pressures after the initial actions are completed and increase your water use time with lower discharge rates. As a general rule, flow rates are reduced to 314, when nozzle pressure is reduced from 100 p.s.i. to 50 p.s.i. With good communications, pressures can be increased or decreased to meet your needs.

Technique Of Applying Water

Learn to develop an on-again, off-again technique of application. This method is used in all fire situations and should serve as the basis for your application of water. An essential feature of this type of application is a quick acting shut-off.

On the fireline, direct a small amount of your stream at the base of the burning fuels and then shut off your nozzle and prepare to move on working parallel to the fire edge. Watch the line already treated, if the fuel re-kindles, apply additional water in a short burst. The fuels treated are then mixed by personnel with hand tools and water is applied if needed. When moving from one hot spot to another, shut off your water at the nozzle. Water should be applied intermittently on specific areas of fire to gain the most from your water supply.

This technique of on-again, off-again is continued all around the perimeter of the fire until it is out. By applying the water parallel along the fireline, you will cover more fireline area and be less likely to leave fire behind you. Water applied intermittently gives you a better chance of applying the least amount of water necessary to do the job.

It takes practice and experience to use just enough water to do the job and then shut off the nozzle, so that you can move on. Practice will save you water and increase your skill with this technique.

Tactical Methods Of Application

Four tactics commonly used in the application of water are: **hot spotting, deluge, containment and exposure protection.** As you look at each one of these tactics of application, you should pay particular attention to how water is applied and what the objectives are.

Hot Spotting

The tactic of hot spotting is usually associated with direct attack. It is often the initial step in initial attack with emphasis on first priorities. The rule here is to attack the point where the fire is most likely to escape. This means giving first attention to cooling down the head of the fire and any hot spots along the fire edge which threaten to ignite new fuels. The objective is to slow down or to stop the spread until adequate help arrives. Water is applied intermittently, moving from one hot spot to another making them temporarily safe.

Emphasis may be given to hitting hot spots ahead of the main fire, or to cutting the fire off from making runs through dangerous fuels such as young trees, heavy brush, logging slash, or grassy fuels leading into heavier fuels. Flare-ups are knocked down and hot spots are cooled to a safe condition. As you can see, the key to hot spotting is the continual size-up of the fire and staying as mobile as possible.

Deluge

With the deluge method, water is applied in sufficient volume for quick and complete extinguishment of the fire. The entire burning area is treated with water. The objective is to rapidly and completely extinguish the fire with little, if any, other help. This method is usually associated with small fires, since the availability of an adequate water supply is a key factor here. The decision to use this tactic is usually based on where an agency may be experiencing multiple fires over a relatively small geographical area, or where the fire danger and lack of additional resources necessitate it. In this respect, the fire is quickly drenched, allowing equipment to be available for reassignment to another fire. It is also used where good judgment shows that the fire can be kept from spreading to threatened high values in the path of the fire.

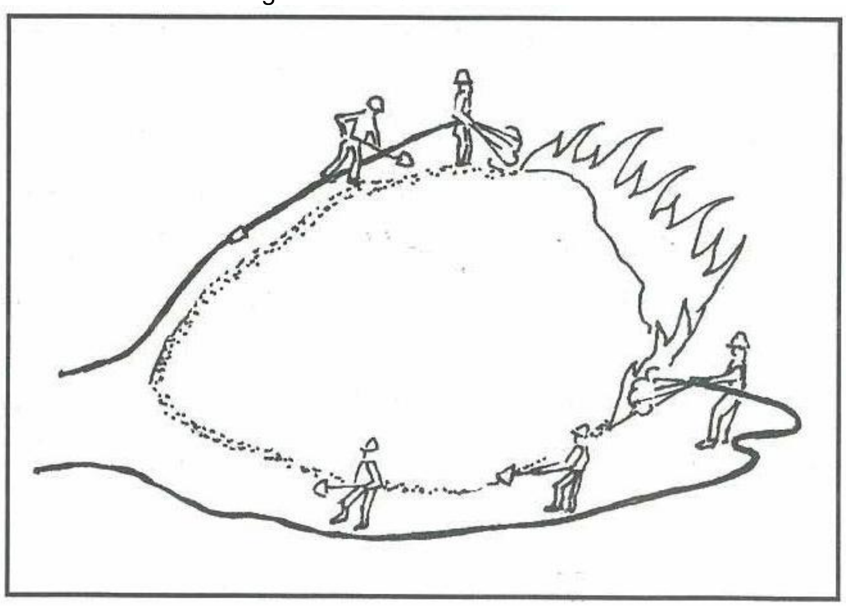
Your experience and good judgment is the key to the use of this tactic. You should know how much water you have and how much fire you can extinguish; what pressures and discharge rates are necessary to extinguish the fire. The application of foam is very compatible with the tactic of deluge, due to its ability to effectively knock down flaming combustion and form a blanket over the fire which acts **as** a vapor barrier. The potential to use less water is very strong since fuels are coated and less water is wasted from running off the surface of the treated area.

As with hot spotting, work should always begin where the fire is most likely to escape. If you run out of water, follow up with hand tools working as close to your original plan as possible.

Containment

The containment method is a progressive, stop the spread of the fire strategy. Tactically, water may be applied in as large a volume as necessary to knock the fire down and stop its spread. This method is often used where it is not possible to perform work at the head of fire. Instead, application is started at the rear of the fire where the control action can be safely anchored to a road or a natural barrier. From here, water is applied and progressive hose lays are continued down either flank, or both flanks as close to the fire **as** possible until the fire is completely surrounded. The objective here is the containment of the fire, rather than the complete extinguishment, fuels within the fire perimeter are allowed to bum out or mopup progresses when containment is achieved.

Figure 19 – Containment Tactic

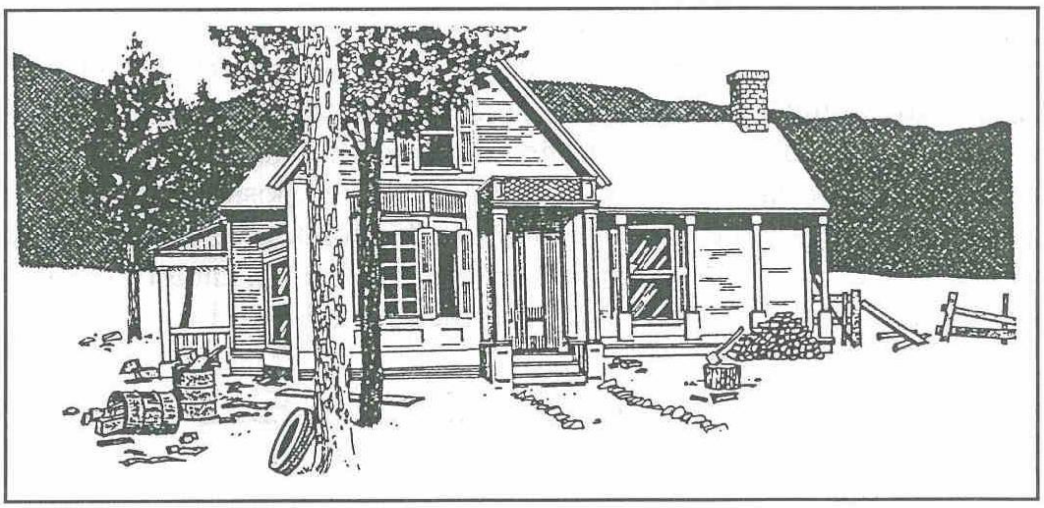


Flanking fires with this method of suppression, especially those spreading in one direction, is a common practice for several good reasons. The rate of the fire spread and fireline intensity on the flanks is often less than at the head of the fire, allowing personnel to work closer to the fire's edge and to make better progress than would be otherwise possible. Narrower firelines are required to contain the spread of the fire. Firelines can be safely anchored to natural barriers and it is generally easier to plan for and provide escape routes. And it may be the only safe area in which to work a direct attack.

<u>Exposure Protection</u>

The tactic of exposure protection involves using water to cool fuels or property ahead of, or adjacent to, the fire. The objective is the protection of values and exposures which are threatened by the fire.

Figure 20 – Exposure Protection



This method is used where priority is given to keeping fire out of high hazard fuel areas, away from high value property and away from public danger areas. The application here may be indirect or direct depending on whether fuels are being protected in advance of the fire or wetted as the fire directly threatens them.

With this method, water is used to protect fuels and exposures by forming a *C)* protective barrier against ignition, or by cooling and wetting the fuels in advance of the fire's spread. By raising the fuel moisture content of fuels they become less susceptible to ignition. The activities to achieve this tend to vary widely depending on the amount of water available and type of fuel protected. Where a large volume of water is available, the tactic may involve a hose lay incorporating sprinkler heads to protect a line during holding operations for burning out or backfiring or the fuels may be coated with foam to provide a barrier against radiant heat. In other situations, where water is less available, the application of water may not occur until the threat is more immediate and direct, as during holding operations for burnout and backfiring.

SURFACTANTS (WETTING AGENTS)

Surfactants are also called wetting agents. Surfactants reduce the surface tension of water which improves its wetting, penetrating, and spreading ability. Water treated with a surfactant will allow it to spread out over the fuel rather than run off.

Surfactants also change the physical properties of water. This change allows the water to bond to the carbon (charred fuels, ash etc.) which increases the penetration and ability to absorb heat.

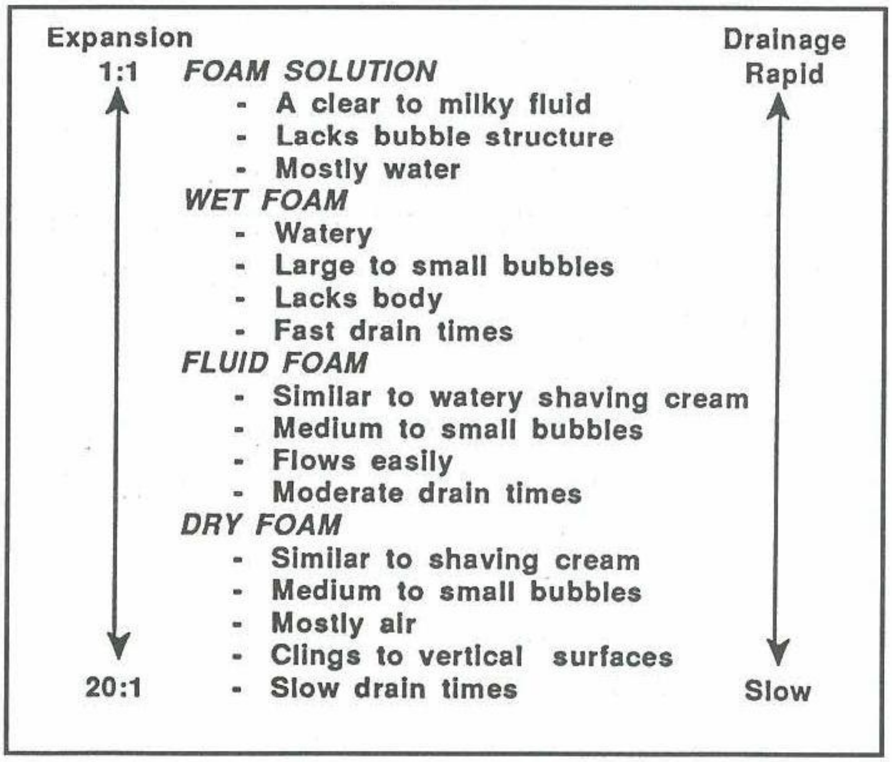
Surface tension reduction will make the fog nozzle droplets up to three times smaller. As the water droplet size is decreased, there is more surface area to absorb heat. This is not readily visible, but its effectiveness is there.

Surfactants are effective in reducing time to extinguish fires in high hazard fuel areas, high value property areas, and public danger areas. Surfactants may reduce the potential for fire escape or rekindle in these areas.

CLASS A FOAM

Foams used in wildland firefighting today are mechanical foams, so-called because they are produced by agitating a foam concentrate mixed with water and air and are available from several commercial vendors. Class A foams have been divided into four types to describe the varied consistencies that can be generated for low expansion foams (see Figure 21). Foam type is important to understand how the foam will perform. A foam with a fast drain time and a 5: 1 expansion ratio performs differently than a foam with a slow drain time and a 15:l ratio.

Figure 21 – Types of Class A Foam



Expansion is the increase in volume of a solution resulting from the introduction of air. It is a characteristic of the specific foam concentrate being used, the mix ratio of the solution, the age of the concentrate, and the method of producing the foam. Different generators such as Compressed Air Foam Systems (CAFS) or aspirating nozzles produce foams having different expansion factors using the same foam solution.

A 10 to 1 (10:l) expansion of a one percent solution creates a foam that is 90 percent air, 9.9 percent water, and only 0.1 percent foam concentrate. The net result is a foam that is much lighter than water given the same volume.

Expansion ratios are divided into three classes related to how much foam is generated:

Low expansion foam	expands up to 20 times (1 : 1 to 20: 1)
Medium expansion foam	expands 21 - 200 times (21:l to 200:l)
High expansion foam	expands 201 -1000 times (201: 1 to 1,000: 1)

The stability of the bubble mass is measured by the rate at which the foam releases the solution from within its bubble structure. This process, known **as** drainage, is a measure of the foam's effective life. The use of cold water tends to decrease the rate of drainage, while the use of hard or saline water produces a much faster draining foam.

Drain time indicates how quickly the foam releases the foam solution from the bubble mass. Once the solution is released it becomes available for wetting of fuels or it may run off the fuel. Foams with short drain times provide solution for rapid wetting. Foams with long drain times hold solution in an insulating layer for relatively long periods of time prior to releasing it.

Consequently, a wet foam is a low expansion foam type with few and varied bubbles and rapid drain t h e which is used for rapid penetration and fire extinguishment.

A fluid foam is a low expansion foam type with some bubble structure and moderate drain time exhibiting properties of both wet and dry foam types which is used for extinguishment, protection, and mopup.

A dry foam is a low expansion foam type with stable bubble structure and slow drain time which is used primarily for resource and property protection.

<u>Personal Safety And Protection</u>

Foam concentrates are similar to common household detergents and shampoos. Fire suppressant foam concentrate, diluted for use in fire fighting is more than 99 percent water. The remaining one percent contains surfactants (wetting agents), foaming agents, corrosion inhibitors, and dispersants.

Approved fire suppressant foam concentrates have all been tested and meet specific minimum requirements with regard to mammalian toxicity.

Foam concentrates are strong detergents. They can be extremely drying and exposure to the skin may cause mild to severe chapping. This can be alleviated with the application of a hand creme or lotion to the exposed skin areas.

All of the currently approved foam concentrates are mildly to severely irritating to the eyes. Anyone involved with or working in the vicinity of foam concentrates should use protective splash goggles. Rubbing the eyes or face may result in injury to the eyes if hands have become contaminated with the concentrate during handling.

All containers of foam concentrate or solutions, including backpack pumps and engine tanks, should be labeled to alert personnel that they do not contain plain water, and that the contents **must not** be used for drinking purposes. If a foam concentrate is ingested, the individual should seek medical attention as soon as possible.

All personnel must follow the manufacture's recommendations as found on the product label and product material safety data sheet. To eliminate possible health problems from prolonged exposure to the skin and eye the following precautions should be taken:

1. When handling concentrates, goggles, waterproof gloves (rubber or plastic), and disposable coveralls should be worn. Leather boots should not be worn at the mixing site, since foam concentrate rapidly penetrates leather, resulting in wet, soapy feet.

2. Clothing soaked with foam concentrate should be removed and thoroughly rinsed with water.

3. Eyes splashed with foam concentrate or a foam solution should be flushed as soon as possible with large amounts of clean water for at least 15 minutes.

4. If skin contact occurs, wash off with water and remove contaminated clothing.

5. A non-allergenic lotion/hand cream should be used to avoid raw chapping of skin.

6. Inhalation of foam vapors can be irritating to the upper respiratory tract and should be avoided.

Slipperiness is a major hazard at storage areas and unloading and mixing sites. Because foam concentrates and solutions contribute to slippery conditions, all spills **must** be cleaned up immediately.

Spills of foam concentrate can be covered with sand or absorbent material and then removed with a shovel. Do not apply water directly to a spill area. Foaming and possible contamination to the surrounding area may result.

Spills **must not** be flushed into drainage ditches or storm drains. Do **not** flush equipment near domestic or natural water supplies, creeks, rivers, or other bodies of water. If a large spill occurs or concentrate enters a water supply contact your local authorities immediately. Be prepared to provide them with the appropriate manufacturer's information.

Care should be taken during planning that personnel applying foam from the ground are able to stand in untreated areas **as** they proceed. Stepping onto a foam blanket which conceals objects or holes can be dangerous.

Foam Application Techniques

In general, enough foam is required to provide adequate water to the fuels. An important feature of foam is that the applicator can see when enough has been applied because it is visible and stays where it is applied.

No matter what hardware is used to produce foam, it must be flushed with water after use to prevent corrosion and clogging of fluid passageways.

Direct Attack

Apply foam to the base of the flame. On wide hotspots secure the edge and work toward the center. While attacking the edge, direct some of the foam stream onto immediately adjacent unburned fuels.

For pump and roll (running) attack from engines, apply as you would a water stream, long enough to ensure extinguishment. This will not take as long as with water. Leave a foam blanket over the hot fuels to smother and continue to wet the fuel.

Foam's ability to wet and cool fuels long after the applicator has left the area is a key to effective foam use. Greater efficiency results as the applicator moves on to a new area because the foam will continue to work where applied.

Indirect Attack

Apply foam as a wet line adjacent to a backfire or burn out, immediately ahead of the ignitors. The foam line should be at least two and a half times as wide as the flame lengths. Coat all sides of the fuel whenever possible. Apply foam at close range, as water would be applied, for penetration into ground and surface fuels. Then apply foam softly to the aerial fuels by lofting onto brush, tree trunks, and canopies to add an insulating barrier.

Medium and high expansion aspirating nozzles are effective for foam line construction during bum out and backfiring. Medium expansion foam can be applied in light fuels by pump and roll in single or double lines. Burnout between two parallel foam lines to create a fuel break. High expansion foam flows downhill nicely, creating foam lines from which to ignite without laying an extended hose lay.

Mopup

If foam was used in the attack, this may enable mopup to start earlier. Use of foam in mopup soon after the flaming phase is over helps prevent fires from becoming deep seated in the ground, requiring time-consuming mopup. This also eliminates residual smoke, reduces reburn potential and soil erosion. Begin applying foam on the edge of the bum and work in, concentrating on hot spots. Direct attack any flames. Apply foam as you would a water stream into burning material for best penetration. Before leaving the area, check for steam rising from the foam. Steam plumes indicate pockets of heat which need more attention.

A wet foam or fluid foam put on charred material early in mopup does the work of a conventional fog tip nozzle and a person with a hand tool. It quickly penetrates the fuel and the ground where it lays, and serves as a blanket to separate oxygen from any remaining smoldering fuel. This works extremely well on pitchy and punky material, duff and litter. For deep-seated fires in stumps, landings, and log decks a foam solution (see Figure 21-Types of Class A Foam) is the best type of foam to use. Application technique is no different than with water, but the foam is more efficient.

Medium expansion foam applied rapidly is an effective way to mop up a wide area of flame and smoldering surface heat. The foam blanket created smothers the fire, eliminates smoke, and does the work of many by slowly releasing foam solution onto hot fuels. Residual heat pockets requiring more attention will show themselves by releasing steam through the foam blanket.

Fire Proofing and Barrier Protection

The ability of foam to penetrate dead and live fuels quickly, to form an insulating blanket, and to cling to vertical and horizontal surfaces is very useful for fire proofing and barrier protection; whether the fuel is stands of timber, areas of brush and grass, wildlife trees, snags, fuel jackpots, endangered plants, or log decks. Barrier protection is achieved with less water, less application time, and with fewer people than conventional methods.

The rate of foam application for barrier protection depends on air temperature, relative humidity, and fuel loading and moisture content. Foam is a relatively short-term treatment, longer than water, but shorter than retardant. It is most effective when applied immediately prior to ignition. Regardless of the conditions, compressed air foam remains longer than nozzle aspirated foam. Under moderate conditions where foam is expected to remain for more than a few hours, application time may be well before ignition time, but monitoring the foam blanket is a must.

The characteristics of foam important to barrier protection are its wetting ability and its durability. The foam must break down to wet the fuels and remain stable to maintain a protective barrier. Use the foam types (see Figure 21-Types of Class A Foam) as a guide for barrier protection.

Dry foam	Very slow wetting, strong blanket
Fluid foam	Good for wetting and blanketing
Wet foam	Weak blanket, rapid wetting

Apply the foam directly from a short distance at high pressure, as water might be applied, for penetration of foam mass to ground and surface fuels. For fireline application, most work can be accomplished right from the line. The width of the foam line depends on fuel and fire behavior factors. In Western Oregon Model 13 slash, 20 to 40-foot wide foam lines were used successfully. Apply foam to all sides of the fuel when possible. Apply foam to ladder fuels and crown fuels above the foam line. Apply as long as it is necessary to coat all fuels with the desired amount of foam.

Structure Protection

The ability of foam to adhere and stay in place over time to vertical, sloped, upside-down and slippery surfaces is the key to structure protection. Apply foam to outside walls, eaves, roofs, columns, or other threatened surfaces. Loft foam from a distance sufficient to avoid breakdown of the foam's insulative blanket. Durability of the foam blanket is consistent with weather and fire behavior. In general, CAFS foam lasts for one hour in hot weather, nozzle aspirated foam for 30 minutes.

Additional Material On Foam

The following material on foam is available from the Publication Management System (PMS) at the National Interagency Fire Center Warehouse.

Publications

Foam vs. Fire. Primer. 1992. (NFES 2270)
This nine page publication covers the basics of using class A foams and discusses their adaptability to present application equipment. First in a series of three "Foam vs. Fire" publications.

Foam vs. Fire. Class A Foam for Wildland Fires. 1993. (NFES 2246)
This 30 page publication explains how to get the most firefighting punch from water by converting water to class A foam. Discusses how and why foam works. Explains drain time, expansion ratio, foam type, proportioning, aspirating nozzles, and compressed air foam systems. Also discusses application for direct attack, indirect attack, mopup, structure protection, and safety considerations. Second in a series of three "Foam vs. Fire" publications.

Videotapes

Introduction to Class A Foam. 1989. (NFES 2073)
First of a videotape series dealing with foam use. This video is a brief introduction to class A foam technology covering foam chemistry, foam generating equipment, and examples of foam application (13 minutes).

The Properties of Foam. 1993. (NFES 2219)
Second in a videotape series about class A foam. This video explains how class A foam enhances the abilities of water to extinguish fire and to prevent fuel ignition. Basic foam concepts including drain time, expansion and foam types are explained (15 minutes).

Class A Foam Proportioners. 1992, (NFES 2245)
Third in a videotape series about class A foam. Explains how common foam proportioning devices which add a measured amount of foam concentrate to a known volume of water, work. Advantages and disadvantages are presented (24 minutes).

Aspirating Nozzles, 1992. NFES 2272
Fourth in a videotape series about class A foam. Explains how aspirating nozzles make foam, the difference between low and medium expansion nozzles, and appropriate uses for each nozzle (11 minutes).

Compressed Air Foam Systems, 1993, (NFES 21611
Fifth in a videotape series about class A foam. Describes equipment, including water pumps, air compressors, drive mechanisms, and nozzles used to generate compressed air foam. Presents general guidelines for simple and reliable foam production. Explains procedures for safe operation. Compares compressed air foam to air aspirated foam. Presents advantages and disadvantages of the system (20 minutes).

National Wildfire Coordinating Group Publication

Foam Applications For Wildland & Urban Fire Management, Sponsored by USDA, USDI, and National Association of State Foresters in cooperation with Canadian Forest Service. For a free copy contact:

Program Leader, Fire Management
USDA Forest Service
Technology and Development Center
444 East Bonita Avenue
San Dimas, CA 91773-3198
(909) 599-1267; FAX (909) 592-2309
DG, SDTDC:W07A

RETARDANTS

Retardants reduce the flammability of treated fuels.

Long-term retardants are commonly used in fire suppression and prescribed burning. They are more effective on heavy fuels than water, and remain effective longer (until washed off). However, the cost of long term retardant is much higher.

Short-term retardants are more effective on light fuels and are less expensive; but they lose their effectiveness when they dry out.

Retardants can be purchased in clear or colored types. Clear may be preferred in visually sensitive areas. Colored retardants are more effective to work with because treated areas are easily identified, making line location and construction more effective.

Fire retardants generally are not used much during mopup. Water is less expensive and less messy for crews to work with.

Usually, helicopter bucket drops are employed when a water source is close and abundant. It would not be a good delivery system in the case of either a limited water supply or a long turnaround time.

Delivery of water and retardant by aircraft will be covered in detail in Section 5, Tactical Air Operations.

FIREGELS

These are new additives, which like foam, expand water and adhere well to roofs, wood, and vegetation.