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At the end of this module, students will be able to:

- ✓ Discuss the **role of water** use on the fireline;
- ✓ Describe the basic **characteristics of water**;
- ✓ Summarize the characteristics of quality **water sources** (natural and artificial);
- ✓ Describe the process of **pumping water** including: where and how to set up, start, operate, and troubleshoot a variety of pump types;
- ✓ Identify main parts of a Mark III pump;
- ✓ Specify all types of fireline **hose, fittings and accessories**, and tell how they are used in hose lays;
- ✓ Describe the different types of **hose lays and water delivery systems** employed on fires;
- ✓ Explain the techniques of **using water** effectively and efficiently in both suppression and mop-up;
- ✓ Summarize the reasons for and use of **fire extinguishing agents**;
- ✓ Address water pressure requirements through the use of the basic **pumping equation**.

LEARNING OBJECTIVES - SKILLS

During the field exercise, students will be expected to demonstrate:

- ✓ How to set up, start, and **operate a variety of pumps**;
- ✓ How to set up a **standard hose lay**;
- ✓ How to set up a **multi-pump system**;
- ✓ Basic **troubleshooting** on the different pumps;
- ✓ The correct use of the different types of **hose, fittings, and accessories**;

LEARNING OBJECTIVES - KNOWLEDGE

- √ The skills of **stringing, changing, and rolling** hose;
- √ The proper use of **good working water pressure** through nozzle practices.

INTRODUCTION - THE ROLE OF WATER

Water is by far the most important and valuable tool in fire suppression. It cannot be taken for granted as there are times when it is scarce and expensive to deliver. The majority of the time a firefighter spends on the line will be using water either in suppression or mop-up activities. Water must be used properly Under All Circumstances.

LARGE FIRE (EXPANDED ATTACK)

Every situation, despite the variables, should produce the same result... constant water under great pressure! Herein lays the problem: pressure does not come easy. To achieve this requires thought, experience and, above all else, a commitment to be unsatisfied with mediocre pressure. Every nozzle person, whether there is one or ten, must be afforded the same luxury of bark peeling pressure. This initial effort ensures the quality, effective and efficient use of water. Your overall time to complete suppression will be considerably shorter with good water pressure. This is how we are measured!

SMALL FIRE (INITIAL ATTACK)

Initial attack crews look towards the same goal too: constant water under great pressure is always the best option, and it is very often attainable. However, certain variables on small fires make it very difficult or even unnecessary to provide this luxury. Many IA fires are small, require a short duration of attack, and are in remote locations far away from adequate water sources. As a result, needed water is often flown in via helicopter. This is a very expensive option thus only minimal amounts of water are transported. Proper techniques and skills must be employed to use this water efficiently.

CHARACTERISTICS OF WATER

Understanding all the properties of water is unnecessary for its application to firefighting. However, some **general knowledge** about water will aid in comprehending how it is used and why it is the most efficient firefighting tool.

WATER, which is composed of hydrogen and oxygen, is a most remarkable substance. It exists in each of the three states of matter: as a solid (ice), a liquid (water) or a gas (steam). The behavior of water and its characteristics are extraordinary when in its natural state.

WATER CANNOT BE COMPRESSED

In other words, it is not possible to squeeze water into a container which is smaller than the space it would occupy in its natural state. This same fact is true in terms of pumping equipment. We can therefore put water under pressure, move it long distances, and use this to our advantage.

WATER IS HEAVY

One litre of water weighs **one kilogram**. As a result of its natural properties (weight and incompressibility) water has come to be recognized as an extremely powerful force. This property makes moving water uphill challenging. It also makes it very dangerous to be below air tankers or helicopters bucketing. On the plus side, the weight of water allows us to use it as a hydraulic or to penetrate the ground.

ABSORBS / REDUCES HEAT

Water, which has a direct effect on the heat component of the fire triangle, also reduces the amount of oxygen available to maintain the fire.

Heat is reduced or eliminated when water is applied to the burn area, effectively cooling down the fuel. Furthermore, water partially affects the oxygen component of the fire triangle by diluting the amount of oxygen in the air and raising the relative humidity.

WATER SOURCES

Now that we have determined water to be the most valuable tool in fire suppression - the next step is to find it. Water sources can be plentiful and in close proximity. They can also be non-existent, which presents a challenge to firefighters. In either case, our goal is still to supply crews with constant water under high pressure whenever possible. There are several natural and artificial options. We will list them in order of preference and give an idea of the costs involved with each.

NATURAL WATER SOURCES

Large water bodies

Oceans, rivers and lakes, etc. fall into the category of inexhaustible water sources. No matter how hard you try, you cannot drain the Pacific Ocean, Columbia Lake, or the Fraser River. If any water source of this volume is close by, use it. It should even be considered over closer water sources that have the potential of running dry. The cost of using this water is merely the cost of the fuel to run the pumps. If you have to choose between two equally good sources, then always choose the one at a higher elevation as gravity will aid in creating the type of pressure you are looking for.

Smaller water bodies

These are generally suitable, but may require some work and attention. **Ponds, creeks and streams**, etc. may offer challenges based on volume, depth, cleanliness and lack of pooling. A firefighter must apply their abilities to ensure the water source will allow for unlimited pumping. For instance, shallow, murky water will potentially require some digging to be able to fully submerge the suction hose/foot valve. It also may require constant checking for clogging. Fast moving, shallow streams may need damming or careful reconnaissance to find areas with a sufficient pool. Fast moving water is also turbulent so there is risk that the suction hose will lose its prime if it takes in air. Glacier fed streams will rise and recede throughout the day. The cost of using this water is the cost of the fuel plus some diligent hours expanding the water source and periodically monitoring it.



Intermittent water bodies

These are water sources which that cannot be used consistently throughout the day no matter how hard you try. The water supply will just not keep up with your water demands. Examples of these are **small streams, large puddles, swamps and standing melt water**. All the same steps used for smaller bodies of water should be employed to maximize their capabilities. This may require crews to limit the number of nozzles being used and increase work done with hand tools. This makes mop-up slower and more labour intensive, but at no greater cost. If the work load is excessive it may be frustrating or fruitless to continue with this operation and other alternatives must be considered.

ARTIFICIAL (HUMAN-MADE) WATER SOURCES

The absence of water sources at many fire locations has led to the development of a number of different systems for providing water to the fireline.

Water Tenders

Water tenders and portable reservoirs are commonly used by wildland firefighters when water must be transported to the fireline and temporarily stored. Water is delivered to fires by a variety of water tenders ranging from pick-up trucks with slip-on tank units to large water carriers (tank trucks). Water tenders usually come fully outfitted with on and off loading pumping equipment, and can carry upwards of 5000 gallons of water. The limitations of this operation include **suitable road access** and **turn-around time**. Turn-around time is how long it takes the tender to return full to the off load site. To set this up properly, you must have enough portable reservoirs allowing for sufficient water storage while ensuring there is no down time between trips. If the turn-around time is still too long, you need more water tenders. If the truck is sitting and waiting to off load, you need more reservoirs. This is still a relatively cost-effective way of using water. Water tenders are relatively inexpensive in the overall big picture, and the costs can be made up in mop-up productivity.



Portable Reservoirs

As mentioned, to truck or move water to a designated area is only half the equation. We must have some way of storing it. The BCWS has two main types of reservoirs to use:

Relay Tanks - 'Pumpkins' or 'Bladders'

Pumpkins are self-supported, open-topped reservoirs that can be set up on any reasonably flat surface and filled with water by tank trucks, bucketing helicopters or pump systems. They range in size from 1500 gallons to 5000 gallons.



Porta-Tanks

Porta-tanks are square, 'swimming pool' style, reservoirs usually capable of holding up to 5000 gallons. The fabric liner is roped into the folding metal frame and filled with water by tank trucks, bucketing helicopters or pump systems. This system is very cumbersome and should only be used if there are no alternatives.

****** The key to success is making sure you have a flat surface to set these up. This may require the help of some heavy machinery, some hard work, and/or some ingenuity. If it is not flat, you will never fill these reservoirs close to their capacity.

Sumps

When the availability of portable reservoirs is scarce the alternative is to simply dig a big hole. This work is best suited for an excavator rather than a firefighter with a shovel. These can be built to suit volume needs and can be done in short order. It is wise to consider lining the hole with plastic to prevent leakage, silt filled water or sloughing. In special cases, holes can be blasted to facilitate water storage. Sump holes can be dug below the level of ground water and will fill overnight. The water in this case should only be considered useful for the short term, as once the sump empties it will take a long time to recover. The additional cost to this operation is approximately an hour of excavator time.



Stilwells - Helicopter Portable

Helicopter transportable reservoirs include **stilwell** bags which are filled with water and long-lined in to smaller initial attack fires by helicopter. The relatively small quantities of water they contain (60 gallons) are adequate for application by firefighters using backpack pumps and hand tools, or small fire pumps and econoflo hose. This water is expensive as helicopters cost a minimum of \$1000/hr. This method is advisable only in small fire situations where the duration of water needs is short.



Helicopter Bucketing into Relay Tanks

This is the process by which helicopters transport water with **bambi buckets** or **belly tanks** to desired locations and off load them into portable reservoirs. This is a last option as you can imagine how expensive this water is. Medium or heavy helicopters are almost always used; you may even need to use two or more to keep up with the demand. This can cost upwards of \$7500/hr. so you better make efficient use of every last drop!



Helicopter Bucketing

FIRE CREW TRAINING STANDARD



Helicopters will be used a lot in suppression by bucketing on fires during the initial attack stage, in areas without manpower, or areas too hot to safely deploy crews. There are times when crews will employ a bucket machine in the mop-up stage. They will expose hot spots by grubbing them up and allowing water to hit them directly when dropped from the air. This is the least efficient method and should only be used as a last resort.

PUMPING WATER

Now that we have found or created a water source - the next step is to deliver it to the fireline. BC fire crews need the ability to operate a variety of water pumps and understand their uses and capabilities when it comes to pressure, distance and elevation.

The complete water delivery system consists of all the equipment components involved in getting the water from its source (the pump) to the fireline (the nozzle). Therefore, when any fire pump is used it must be considered as only one component of the complete water delivery system. Other important components include hoses, fittings and accessories (e.g. **intake and discharge hoses, valves, adapters, couplings, nozzles, etc.**) that all interact with the pump to govern overall system performance.

CHOOSING A PUMP SITE

Upon arriving at a fire, the first task a pump operator is faced with is choosing a suitable area to set up the pump. **The first and paramount consideration is that the site must be free of overhead hazards and in a safe location.** Ideally, the pump should be located on level, solid ground close to and at the same level as the water source. Establishing the pump on this “ideal” site assures operators that the pump can be set up quickly, efficiently, and that relatively few problems will be experienced (e.g. suction lift is minimized and less strain is placed on pumping equipment).

Quite often the perfect pump site is not readily available or easily accessible. The pump operator may be forced to set up the pump in a small creek where the water supply is limited, or perhaps on a spongy or rocky shoreline. Sometimes the site is sandy, the terrain sloping, or characterized by negative obstacles to overcome. Pump operators are expected to use common sense and rely on their creativity under such circumstances.

Soft, Spongy shoreline

In a situation where the shoreline is soft and spongy the continuous vibration from a pump will cause the pump to gradually sink into the soft ground. In these scenarios, a pad should be constructed for the pump to sit on. The fuel tank should also be supported.



Sandy, Gravel sites

On sandy sites and gravel beaches, a pack board will make the pump more stable. Another option is to use a log platform to prevent the pump from settling into the sand or gravel.

Sloping Terrain

There may be a situation where the only site to set up the pump is on sloping terrain. In this situation the pump operator will secure the equipment to prevent both pump and fuel can from sliding down the slope and into the water. The pump and the fuel container must be securely tied in place by using stakes or a tree.

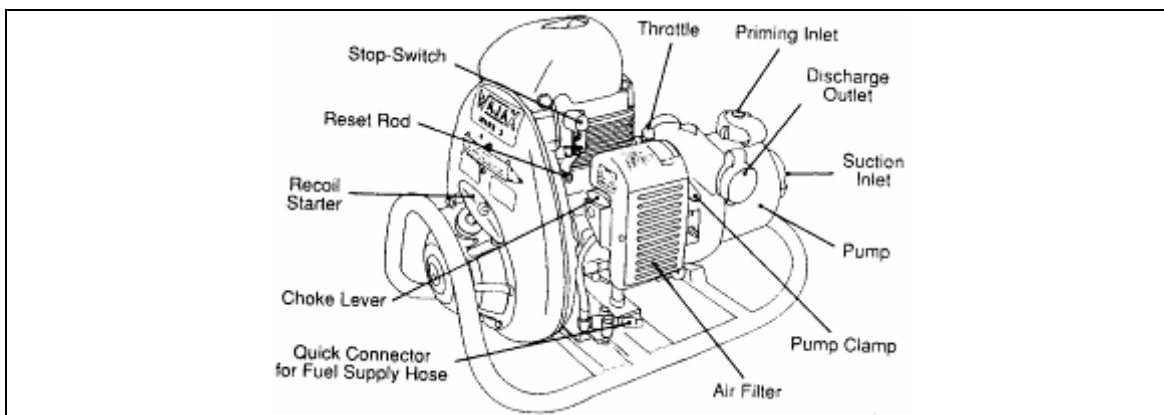
Wave Breaks

If a pump is set up on a shoreline with wave action that could wet the pump, then a simple break can be constructed. If rocks are not available, staked logs will offer a secure break. Also remember to anchor the foot valve below the surface of the water to prevent the waves from lifting it out of the water and sucking air.

SETTING UP THE PUMP

Once the pump operator has secured a suitable site - the pump can now be set up. For the purposes of this chapter we will use the Mark III pump as our example. A **Mark III complete** comes equipped with a pumping unit, a suction hose, fuel tank and a tool box. The tool box contains all the necessary tools, spare parts and accessories to keep a pump running (**see Appendix 2 for a list of contents**). This is the most commonly used pump in large scale water delivery. There are other pumps that will be addressed; however, an understanding of the Mark III is essential as it will be used often by all firefighters. Here is the step by step procedure to setting one up.

PARTS OF THE MARK III



Connect the Fuel Line

To prepare the pump for operation: remove the flexible fuel line from the pump tool box, check that it is clear and attach the appropriate end to the fuel tank. Next, open the fuel tank's supply valve by turning it counterclockwise and open the air vent on top of the fuel tank. Opening the air vent allows air pressure to push fuel through the fuel line. Finally, fasten the line to the quick connect adapter on the pump frame.



Connect the Suction Hose

Centrifugal pumps, like the Mark III, are incapable of creating a vacuum within the pump chamber. Suction is only created when the suction hose and pump chamber are completely filled with water. Therefore, **priming** is required with centrifugal pumps.

Keeping in mind the need to prime the Mark III, the pump operator will:

- Remove the foot valve and strainer assembly from the tool box and check the return spring found on the foot valve to make sure it is not damaged. A damaged or malfunctioning foot valve will cause the pump to lose prime;
- Thread the foot valve and strainer onto the male coupling of the hose intake and properly place it in the water source (completely submerged, free of debris and off the bottom);

- Fill the suction hose with water. This facilitates the subsequent priming process. (Only after the hose has been filled with water will the operator attach it to the pump); and
- Attach the female coupling of the intake hose to the pump intake opening. (Make certain all connections are air tight).

In some situations the water depth is more than adequate to submerge the foot valve, but water plants or decayed vegetation could clog the screen. This is not uncommon when pumping from a **boggy area, a lake, or a pond**. If the foot valve or screen is obstructed, then water flow to the pump is reduced or could be completely eliminated. Increased revving places undue strain on the pump - the unit will cut-out, or could be seriously damaged. There must also be a **minimum depth of 20 cm of water** so that air is not being drawn into the foot valve.

To prevent the foot valve screen from clogging, it is recommended that the operator:

- Lay rocks under the foot valve or place the foot valve on a submerged rock. The operator's goal is to keep the screen clear of debris.
- Drive a stake into the bottom of the pond, securing the foot valve to the stake, so that the screen rests off the bottom.
- Tie the foot valve to a floating log making sure the foot valve is still completely submerged.
- Use a bucket, container or the tool box to surround the foot valve and keep it free of debris.

Prime the Pump

The operator filled the suction hose with water and then attached it tightly to the pump inlet opening to facilitate priming. To complete the priming process, the operator will grasp the intake hose (at approximately the middle) and hand-pump the hose. **Hand pumping** basically involves pushing the foot valve and strainer vigorously up and down (in the water source). Remember to keep the foot valve completely submerged while priming the pump. This vigorous action activates (opens and closes) the foot valve. Water is forced into the intake on the down stroke (pushes the foot valve open) and retains it there on the up stroke (closes the foot valve). The operator continues this process filling both the intake hose and pump head with water, and stops only after some additional water is forced through the discharge outlet. Be careful not to hit the foot valve on a hard surface as this can jam it open or shut.

In the case where this operation is too difficult or the water too shallow; the pump operator can prime the pump by pouring water into the pump head through the primer valve until it is filled. This is a little more time consuming.

Connect the Discharge Hose

Once the suction hose and pump head are primed the pump operator will turn his/her attention to the discharge side of the pump. The discharge outlet has a quick connect coupling which allows for easy attachment of Wildfire Service hose.

* ensure the first length of hose is rated at the highest pressure as this is where the pump produces the greatest pounds per square inch (PSI) of pressure.

Start the Pump

Starting the engine is a four step process involving four basic controls (the choke shutter, the throttle lever, reset rod and the starter rope). The operator will:

- Close the choke shutter to the START position if the engine is cold. (The choke shutter control should be left open at the RUN position if the engine is warm);
- Move the throttle lever to the START/WARM-UP position;
- Make sure reset rod (over rev switch) is pushed in and;
- Place one foot on the carrying assembly and with one hand on the spark plug cover (to maintain balance), grasp the starter rope grip with the other hand. Pull until the engine fires. Switch the choke shutter to the RUN position and pull until the pump starts.

* Some Mark III's are equipped with an ON/OFF switch. Make sure it is switched to the ON position when starting.

**Should the starter rope break, be pulled out of the rewind mechanism, or the mechanism fail the Mark III's starter cover can easily be removed exposing a conventional slotted starter pulley that allows the operator to start the engine manually.

Once the Engine is Running

The operator will allow the engine reasonable time (~ 2 minutes) to warm-up by leaving the throttle in the WARM-UP position once the engine is running. Open the throttle slowly to the RUN position once the engine has warmed up.



Stopping the Engine

To stop the engine the operator will:

- gradually close the throttle reducing the engine to an idle before placing the throttle completely in the “stop” position; and
- depress the stop switch (only after the throttle is in the “stop” position).

Safety Note: The muffler on any pump will be hot after extended use. Be sure to avoid the hot muffler when handling the pump after it has been running.

TYPES OF PUMPS

Pump Classifications

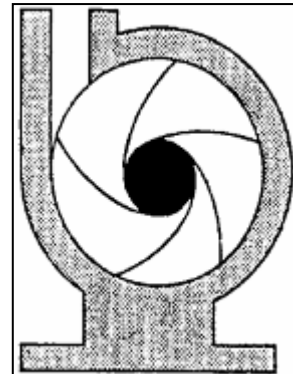
There are two pump classifications that wildland firefighters may encounter. They are:

- **Centrifugal pumps** - common and well-suited to wildland firefighting.
- **Positive displacement pumps** - rarely used.

The terms ‘centrifugal’ and ‘positive displacement’ describe the way the pump takes water into the pump chamber and discharges it.

Centrifugal Pumps

Centrifugal pumps have curved impellers that rotate inside the pump chamber. Water is drawn into the suction inlet and water pressure is increased as the water is thrown outwards (by means of centrifugal force) through the discharge outlet.



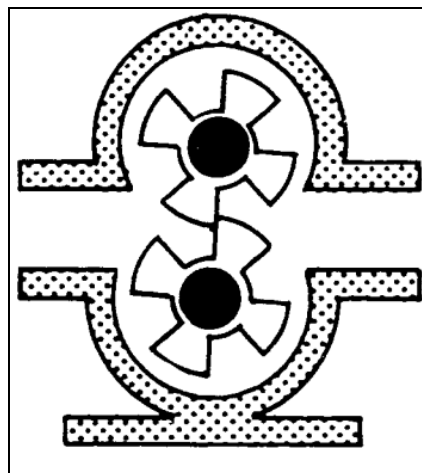
- **Advantages:**
 - Ability to pump from muddy water sources with minimal impeller damage.
 - Capable of pumping 'in-tandem.'
 - Pressure can be changed by adjusting RPM.
 - Fewer moving parts.
- **Disadvantages:**
 - Must be primed.
 - Requires back check valve between pump and head.
 - Requires foot valve on suction hose.

Positive Displacement Pumps

Positive displacement pumps (sometimes called rotary or gear pumps) are rarely used for direct wildland firefighting. Positive displacement pumps are usually vehicle-mounted and powered from the vehicle engine through a power take off (PTO). Positive

displacement pumps have different operating requirements than centrifugal pumps.

- **Advantages:**
 - Self-priming.
 - Better suction lift than centrifugal pumps.
- **Disadvantages:**
 - Subject to internal wear.
 - Fixed output performance.
 - May stall under heavy load.
 - Relief valve required.



Pump Engines

There are two types of pump engines commonly used to power portable fire pumps.

- The two-cycle engine.
- The more powerful four-stroke engine.

Two-Cycle Engines

Two-cycle engines require 'mixed-gas': the pump engine is fueled and lubricated by a gas/oil mixture. BCWS two-cycle pump engines use a 24:1 gas/oil mix ratio.

Firefighters should be sure that only properly mixed gas (tagged "24:1 MIXED GAS") is used to fuel two-cycle pump engines. If a two-cycle engine is operated without mixing oil in the gas, then it will seize. Yikes!

Four-Stroke Engines

Four-stroke engines require 'straight-gas': the pump engine is fueled with gas and a crankcase is filled with oil from a splash-sump or oil pump lubricator. Firefighters should be sure that only straight gas is used to fuel four-stroke pump engines and that the oil level is checked before starting as well as frequently during engine operation. Oil is critical to all engines. If the pump's crankcase is allowed to run completely dry, the engine will seize.

PORTABLE FIRE PUMPS

The following pages provide a brief summary of the technical specifications of the most common fire pumps used in British Columbia. These are the pumps you will be working with the majority of the time. You will be expected to know how to operate all of them.

Wildfire Mark III

Applications:

- **High Pressure** / Medium Volume.
- Used primarily by Unit Crews in expanded attack and extensive mop-up operations.
- Ideal for multi pump water delivery systems.
- The **most common** fire pump on the fireline.



Performance:

- 10 hp - 2 cycle engine
- Fuel consumption: 1 gal/hour

- Fuel capacity: external tank
- **380 psi @ shut-off**
- 95 gpm @ free flow
- Weight: 55 lbs.

Mercedes Wick 375

Applications:

- **High pressure**/Medium Volume.
- Completely **interchangeable with Mark III** and its applications.

Performance:

- 10 hp - 2 cycle engine
- Fuel consumption: 1 gal/hour
- Fuel capacity: external tank
- **360 psi @ shut-off**
- 90 gpm @ free flow
- Weight: 53.5 lbs.



Wildfire Mark 26

Applications:

- Medium Pressure / Medium Volume.
- A "scaled down" version of the Mark III.
- More conservative with water in exchange for less pressure.
- Commonly used on **Initial Attack pump trucks**.

Performance:



- 5.0 hp - 2 cycle engine
- Fuel consumption: 0.6 gal/hour
- Fuel capacity: external tank
- **170 psi @ shut-off**
- 70 gpm @ free flow
- Weight: 38 lbs.

* The BCWS is trying to phase out the Mark 26 pumping unit; IA truck pumps are being replaced by the Honda Goliath.

Shindaiwa GP-25

Applications:

- **Low Pressure / Low Volume.**
- Used by IA crews when flying to fires due to weight restrictions.
- Best used for pumping out of **small water sources/stilwells.**
- Only used when water is needed for a short duration as pressure is extremely limited.
- Normally used with 5/8 " econoflo.
- Hose with smaller 1/ 8 " econoflo nozzles.



Performance:

- 1.3 hp - 2 cycle engine
- Fuel consumption: 1 litre/hour
- Fuel capacity: 1 litre integral tank
- **40 psi @ shut-off**
- 37 gpm @ free flow
- Weight: 13 lbs.
- Positive displacement

Shindaiwa GP-45

Applications:

- The same as the GP-25 with slightly greater capacity.

Performance:

- 2.3 hp - 2 cycle engine
- Fuel consumption: 1.4 litre/hour
- Fuel capacity: 1.5 litre (integral)
- **50 psi @ shut-off**
- 66 gpm @ free flow
- Weight: 17 lbs.



**** Both Shindaiwa pumps are out of production and are being replaced by the Honda WX-10.**

Honda WX-10

Applications:

- The same as the GP-25.
- **Replacing GP-25 as IA pump.**

Performance:

- 1.3 hp - **4-stroke** engine
- Fuel consumption: 1 litre/hour
- Fuel capacity: 0.55 litre integral
- **40 psi**
- 37 gpm
- Weight: 13.4 lbs.



C.E.T. Goliath

Applications:

- Medium Pressure / Medium Volume.
- Will replace Mark 26 as
IA truck pump.

Performance:

- 6.5 hp - **4-stroke** engine
- Fuel consumption: 1.5 litre/hour
- Fuel capacity: 5.7 litre integral
- **150 psi**
- 80 gpm
- Weight: 60 lbs.



Hand Tank Pumps

Applications:

- Small scale mop-up/patrol operations.
- Manually operated.
- Effective in light fuels.
- Easier to move water when only small quantities are needed in different places over a big area.
- Two styles – solid plastic/metal container or collapsible membrane.
- Commonly known as “piss can.”

Performance:

- 5 gallon tank
- PSI determined by strength of operator



- Fuel requirements: operator must stay well-nourished and hydrated

Limitations:

- Limited water supply
- Limited water supply for decreasing heat in medium to heavy fuels
- Limited nozzle penetration abilities

On occasion you will encounter other types of pumps. These pumps are for **specialized purposes** and are best avoided for normal water delivery operations. They should be used only when the standard pumps are unavailable.

They include:

- **Honda Volume Pumps**
 - Low Pressure / **High Volume**.
 - Good for loading water tenders or skidder tanks.
- **Wildfire BB4**
 - Very heavy (165lbs), with only marginal improvement in pressure (450 psi) over the Mk III.
 - Can be used on the road side but not in the bush.
- **Hale Fyr-Flote**
 - Designed to pump without a suction hose by floating on the surface of a water source.
 - Overcomes shallow water source issues; however, a Mark III can always be adapted and used more effectively in these situations.



GENERAL MAINTENANCE AND TROUBLESHOOTING

Occasionally a pump does not perform as expected, and determining the specific problem may be difficult. Engine failure is a result of deficiencies in one or a combination of three areas **AIR, FUEL, OR IGNITION**. The following steps and procedures are based on the Mark III, yet the same general principles can be applied to any fire pump.

Air

Suction Problems:

- The foot valve being temporarily lifted out of the water allowing **air** to be sucked into the line;
- The foot valve becoming clogged with weeds, or other debris, causing the pump to overwork and restricting the flow of water;
- A poor intake connection at the pump allowing air into the line. This connection must be air tight to maintain full prime;
- A faulty foot valve not allowing the suction hose to remain primed.

Solutions:

- When a pump loses its prime, it will begin to over rev. If the speed exceeds 6300 rpm, the over-rev switch self-activates and the engine stops. The over-rev reset rod must be returned to the IN position before re-starting;
- In all of these cases the course of action is to:
 - Ensure all connections and seals are tight and functional;
 - Keep foot valve clear of debris and completely submerged;
 - Re-prime suction hose and pump.



Air Filter Problems:

- Air filter becomes clogged during prolonged use or dusty conditions, restricting air to the carburetor. Lack of air seriously affects the performance of the pump.

Solution:

- Check and clean the air filter regularly



using soap and water, or fuel.

Fuel

It is quite possible that fuel is not reaching the cylinder. A quick and easy means of investigating this problem is to pour a small amount of fuel into the cylinder through the spark plug opening, replace the plug, and pull the starter rope. If the engine starts and stops, the pump operator has confirmed the cause of failure - lack of fuel. In this situation, the operator should check two specific areas, the **fuel line** and the **carburetor**.

Fuel Line Problems:

- Fuel tank is empty and the air vents are closed; a standard container of fuel will run for **4-5 hours on full throttle**;
- Poor fuel flow between the fuel tank and the end of the fuel supply line;
- Issues with fuel line on pump that runs up to the carburetor. This must be clear of air bubbles, cuts and leaks.

Solutions:

- Ensure tank is full and vents are open;
- Use a blunt tool to depress the ball valve recessed in the end of the quick-connect fitting and with the fitting held below the level of fuel in the tank. Ensure that fuel flows freely out of the fuel line;
- If any bubbles, cuts, or leaks, the lines should be replaced. If there is no replacement, electricians tape can temporarily solve the problem. As a last resort the fuel supply line can be cut and attached directly onto the carburetor fuel inlet.

Carburetor Problems:

A gummed up carburetor will inhibit engine starting and performance.

- Bad fuel mix
- Oil left behind in chamber
- Carburetor is loose

Solutions:

- Ensure pumps are run with a **24:1 gas:oil mix**.

THIS IS ABSOLUTELY ESSENTIAL!!! AS A PUMP OPERATOR YOU MUST BE CERTAIN THAT FUEL IS MIXED - IF IT IS NOT THEN A 2-CYCLE ENGINE WILL BE DESTROYED! MIXED FUEL WILL BE OILY TO THE TOUCH. MIX YOUR OWN GAS WHEN POSSIBLE.

- Run the pump dry at the end of each day - gas in the fuel mixture will eventually evaporate, but oil will not and will be left behind;
- Ensure carburetor is tight at the intake manifold. If the carburetor is loose, then air rather than fuel will be taken into the cylinder.

Faulty Fuel Pump:

If the fuel lines and carburetor are operable, the problem may be within the **fuel pump**. The Mark III is not rendered in-operative simply because of this problem.

Solutions:

- To overcome this problem the pump operator should position and secure the fuel supply tank above the pump. The fuel tank needs to be placed only slightly higher than the engine carburetor. This procedure allows gravity to ensure fuel continues to flow to the engine. Siphoning may be required to start initial fuel flow.

Ignition

Flooding:

- This results from over-choking or repeated attempts at starting the pump. Fuel continues to be pumped into the cylinder: resulting in a wet spark plug.

Solution:

- This is an ignition problem due to excess fuel in the cylinder. This fuel must be removed before the pump will start. To eliminate excess fuel:
 - disconnect the fuel line from the engine;
 - remove spark plug;
 - with the ignition cable still attached, place the electrode end of the plug over the spark plug opening in the top of the cylinder;
 - ground plug on head and ensure adequate spark -



replace if necessary;

- completely open both the choke and throttle;
- pull starter cord repeatedly until dry;
- clean and dry the spark plug;
- replace plug and fuel line, and re-try starting sequence.

****this may take several attempts - persevere before deeming *unserviceable (U/S)*.**

Spark Plug Problems:

When a pump quits or will not start examining the spark plug may identify the problem:

- The spark plug may be burned or have a carbon accumulation. Carbon accumulations can result when the engine overheats or if the spark plug has had many service hours.
- The spark plug gap may be closed or open to wide to create a spark.

Solution:

- Replace or re-gap spark plug.

**** If spark cannot be found with a new plug, other electrical problems exist beyond field repair and the pump will be deemed U/S.**

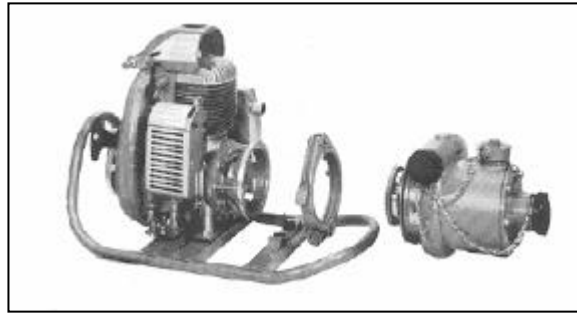
Other Possible Problems

Leaky Pump Head:

- At times, pumps can develop a leak between the pump head and the engine head. This reduces pump output and soaks the working area around the pump causing other problems. The pump should remain operational, but needs be attended to as soon as possible.

Solutions:

- Ensure pump head is greased regularly;
- Exchange pump head if available off of other U/S pump. Both the engine head and the pump head of the Mark III are interchangeable and can be simply and quickly connected and disconnected by means of the adjustable clamp assembly. If more than finger pressure is required to close the clamp and secure the engine/pump head, then they are not properly lined up with the clamp assembly.



Recoil Starter:

- At times the recoil starter cord will break, be pulled out or get jammed.

Solution:

- If the pull cord sticks in the out position, tapping on the recoil housing can activate the spring recoiling the cord.
- If the cord breaks, the Mark III's starter cover can be unbolted, exposing a conventional slotted starter pulley that allows the operator to start the engine manually. Ensure correct direction of pull, re-wrap cord manually and pull clockwise.
- The recoil starter can easily be exchanged with another one from another U/S pump.

Obviously there are many other things that can go wrong most of which are outside the scope of a firefighter's skill set. Unless you are a small engine mechanic it is best not to delve too deep into fixing pumps in the field. However, **developing your trouble shooting and repair skills will make you an invaluable member of any crew.** If the pump is not running on a Unit Crew, then potentially 20 people are no longer productive!

FIRELINE HOSE

We expect a great deal from the BCWS fire hose. Fire hose must be able to withstand tremendous water pressure yet not restrict the flow of water. We want to be able to drag them through burning embers, yet we do not want the hose to burn. We pull them over sharp rocks, jagged stumps, around snags and deep into overgrown bush, but we do not want them to develop leaks. The hose used by the Wildfire Service is made of polyester, and orlon (synthetic)

materials which are light-weight, strong, and resistant to rot and mildew. They are easy to carry and handle, pliable enough to roll, but sufficiently firm to not lose their form.

BC WILDFIRE SERVICE HOSES

There are five main types of BCWS hose. They are the:

- **2" Suction Hose**
- **1½" Lined Hose / 1½" Lined Percolating Hose**
- **1½" Unlined Hose** (Weeping or Percolating)
- **1" Lined Hose** (Big Inch)
- **5/8" Econoflo Hose** (Shindaiwa)

2" Suction Hose

A 2" suction hose is used directly from the water source and is coupled to the intake opening of the pump. It is used nowhere else in the water delivery system. Designed to withstand external water pressure; the suction hose is reinforced against collapsing inward. In terms of centrifugal pumps, a foot valve is incorporated into the suction hose making it one complete operating unit.



1½" Lined Hose

The 1½" lined hose creates the least friction and is the best at withstanding pressure. For these reasons it is the most commonly used hose on the fireline. Lined hose is manufactured with a polyurethane inner lining. It does not sweat or weep and is therefore susceptible to heat on the fireline. It is not recommended for use inside the fire. Burning embers, sparks or simply dragging the hose through ash will damage it.



1½” Lined, Percolating Hose

Percolating hose is designed to weep slightly, yet continue to retain close to the same water delivery capabilities of lined hose. This weeping characteristic helps prevent hose from burning when dragged through hot ashes, and permits the hose to be used within the fire area for short durations.

1½” Unlined Hose

Unlined hose is the only type of hose recommended for use in the fire area. Its construction includes small spaces between the woven fibre to allow the hose to weep slightly. Although unlined hose is usually not susceptible to small embers or low radiated heat care should still be taken. It will not stand direct contact with extreme heat. This hose should never be used in the mainline because it has a negative effect on pressure.

1” Lined Hose

This smaller diameter hose can be very useful when working with mobile tankers when smaller volumes of water will adequately serve the suppression effort. It is fitted with 1½” couplings to make it easily interchangeable with standard 1½” hoses.



Hose Lengths and Couplings

Wildfire Service mainline hose is supplied in 100 foot lengths; however, some hose has undergone repair and therefore might be significantly shorter. This is important when changing hose as the replacement must be of sufficient length. The actual length is written on the hose near the coupling.



All hoses are fitted with quick connect couplings. The benefit of these instant couplings is that either end of the length of hose may be quickly and easily coupled. Each coupling is fitted with a rubber washer to ensure a tight seal.

5/8” Econoflo Hose

Econoflo is the smallest hose used by the Wildfire Service. It can be used with small Shindaiwa pumps or



in conjunction with water thieves off 1½" mainline. It is light weight, easy to maneuver, and can withstand high levels of pressure. Econoflo is conservative on water, making it the best choice for mop-up. Unlike all the other hose, econoflo comes in 50 foot lengths and has threaded garden hose-style couplings.

Stringing Hose

BCWS hose is pre-rolled for easy stringing. Cutting the twine, splitting the roll open, and pulling the coupling from the centre allows the hose to unravel easily without any twists.

There are **two main ways** to string out a hose lay:

1. **Move rolled hose as you progress and unroll one at a time.** This style is used in difficult terrain and/or where the hose is required to take many turns.
2. **Cache all rolled hose in one central location and string all together.** This style is faster in easier terrain and when long distances of hose are being laid in a straight line. By splitting all the rolls open and attaching the appropriate couplings a firefighter can begin pulling until it gets difficult. At this point another firefighter begins to pull, and so on, until the hose is strung. This allows each crew member to move unencumbered.

*When coupling hose together it is important to ensure rubber washers are in place; otherwise the hose lay will leak.

The placement of the hose lay is also very important. In a **fuel free/hand guard scenario**, the hose should be strung on the **non-fire** side of the hand guard so as to prevent it from burning. It should not be placed on the guard as erosive properties of leaking water will compromise your work.

In a **dozer line scenario** the hose should be strung on the inside edge of the guard. This is to maintain close proximity to the fires edge as dozer line can be upwards of 50 feet wide. This will save you one length of econoflo hose. In addition, this keeps the hose lay off the guard allowing heavy machinery to pass without threat of damage to the lines.

A delivery line must be set up in situations where the water source is not adjacent to the control line. These may vary in length from a few hundred feet to a few kilometres. A **hose path** should be constructed to facilitate ease of movement to and from the water source. A hose

path is a brushed trail free of obstruction that only needs to be a few feet wide. This trail can and may serve as your **access egress route or potentially your escape routes**.



CHANGING / REPAIRING HOSE

Inevitably, hose will begin to leak or blow completely. It is important to be able to change or repair hose quickly, efficiently, and without shutting down the pump. Upon discovering the hole in the hose; here are the steps to replacement:

- Find a serviceable replacement hose of suitable length;
- Obtain a **hose strangler** (tool used to clamp off fire hose);
- String good hose next to broken hose in preparation for changing;
- Strangle hose directly before the broken hose near (5 feet) the coupling;
- Quickly uncouple broken hose and replace with good hose;
- Un-strangle.

This should take a matter of seconds, and therefore the pump need not be shut off or turned down. The amount of down time with the water delivery system will be minimal.

If there is no replacement hose or the hole is very small, a **hose mender** (found in pump tool kit) can be used. This is an appropriately sized metal clasp which encircles the hose around the leak. When the hose is charged it applies firm pressure against the hole. The steps to applying one of these devices are essentially the same as changing a hose less uncoupling the broken hose. (Note: the broken hose must be without pressure to get the hose mender on).



ROLLING HOSE

When fire crews are finished with hose it needs to be rolled. This hose may or may not be re-used before leaving the fireline. In either case, it is imperative to be able to roll hose properly. The rolls must be tight, neat, and well tied for ease of transport and relaying on to other parts of the fire. The same standards apply if the rolls are being transported off the fire. Good rolls facilitate organized slinging and truck transportation of hose. They also make things easier for staff at the warehouse to inventory and clean. All U/S hose should be rolled to the same standard. There are no exceptions to rolling hose properly.

The Wildfire Service standard for hose rolling is the **melon roll** and in some cases the **figure 8**.

Melon Roll

The hose must first be laid out completely flat and drained of water. Next, make a solid structure 12 to 16 inches in length at one end of the hose by tightly folding the hose around itself starting with the coupling. This portion of the melon roll is called a 'Bone.' Begin rolling the hose end over end once this support is in place and give a slight twist each time to secure the end of the melon. Continue this procedure to the end of the hose leaving enough of a tail in the hose to tie the roll off. The knot will be demonstrated in the field.



Figure 8

The Figure 8 is primarily used when short hose lays have been established and the hoses are put right back on the truck. This is a quick means of demobilization. The same quality must still be applied. When done properly it will work as a satisfactory alternative to the melon roll. This roll may be demonstrated in the field or at your zone.



Rolling Econoflo is done like you would coil an extension cord. Each hose is rolled separately and tied securely so it does not become intertwined with other lengths. It is re-rolled in its original form once it has been returned to the warehouse.



Care and Maintenance

Depending on the circumstances, Wildfire Service hoses are subject to varying conditions of care, and it is often not possible to carry out preferred maintenance practice.

However, it is useful to understand what causes hose deterioration and why it is invaluable to establish a good maintenance and storage program once the hose has been returned from the fireline.

- **Abrasion:** External abrasion is the worst enemy of fire hose. The hose is particularly susceptible to damage when filled with water because it vibrates. Every effort should be made to prevent the hose from rubbing against stones, splintered wood, and other hard or sharp objects.
- **Mildew:** All hose today is chemically treated by the manufacturer to prevent mildew. But never assume the use of rot-resistant hose makes it any less important to exercise the same precautions that would be used in the case of untreated hose. Dirt is a natural breeding ground for rot and mildew.
- **Deterioration from Sunlight:** Hoses should not be left in the sun. Prolonged exposure causes organic fibers, some synthetic materials, and rubber to slowly deteriorate.
- **Cleaning and Storage:** To avoid problems, hoses should be unrolled, washed, hung to dry and re-rolled immediately after they are returned from the fire. A mild detergent soap should be used to wash the hose. Hose should be stored in an area that is dry and is well-ventilated to prevent mildew.



HOSE LINE FITTINGS AND ACCESSORIES

Hose line accessories and fire equipment fittings include a variety of pumping equipment such as couplings, valves (back check, 3 - way), nozzles, strainers and adapters. These are the key accessories necessary on the fireline, and are stored in Provincial, Fire Centre and Zone Warehouses.

Couplings

Couplings serve to connect the ends of two independent pieces of equipment (i.e.: the pump to the hose, two hoses, or the hose to a nozzle).

- **Fire Hose Coupling**

- Standard equipment affixed to all fire hoses;
- Used to connect two lengths of fire hose together;
- Usually called “quick connect” couplings.



- **Tandem Coupling**

- Used to connect two pumps in tandem;
- Connects the discharge hose of first pump to the suction inlet of the second pump.



- **Female Suction Hose Coupling**

- Used to connect the suction hose to the suction inlet.



• Male Suction Hose Coupling

- Used to connect suction hose to the foot valve.



Nozzles

The Wildfire Service stocks many nozzles; several of which are adjustable. These allow the firefighter to modify the manner in which water is being applied without changing the nozzle.

• Hansen nozzle

- A lightweight, incompact nozzle;
- The nozzle can be adjusted from the shut-off point to any one of three (or sometimes four) straight stream apertures;
- Combining any two of the three apertures converts water application to a spray;
- Connects to 1½" quick connect coupling.



• Foam nozzle

- Usually made of plastic and quite large in comparison to standard water nozzles;
- Foam nozzles incorporate a number of holes around their base which permit the foam/water mix to be



aerated.

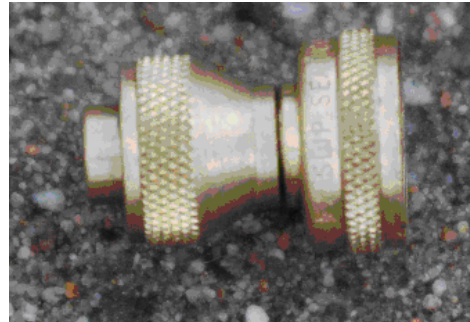
- **Fog nozzle**

- Used in applications when cooling down areas of intense heat;
- Usually used as a spray nozzle.



- **Econoflo Nozzle**

- Only nozzle used with econoflo hose;
- Threaded and adjustable stream;
- Can produce hydraulic stream or spray;
- Allows for effective water conservation;
- Every firefighter should keep one handy at all times.



Valves

The function of valves is as critical to the water delivery system as nozzles or couplings.

There are several types of valves stocked by the Wildfire Service and each is designed to perform a specific task.

- **Three - Way Valve**

- Used to split the discharge hose from one line into two separate discharge lines;
- There are both plastic and aluminum 3 - way valves.



- **Back Check Valve**

- This valve prevents water from flowing backward through the pump (back pressure);
- The back check valve can be used anywhere in the hose lay to counter the negative effects of back pressure on the pump;
- It includes a release valve to relieve pressure.



- **Foot Valve**

- Combination equipment which incorporates both a foot valve and strainer into one piece of equipment;
- Used on the intake side of suction hose;
- Stops debris from entering pump;
- Spring mechanism prevents water from draining out of suction hose.



- **Water Thief**

- Used to attach econoflo to 1½" mainline;
- Made of both plastic and aluminum;
- Has a shut off valve.



- **Econo flo Three - Way Valve**



- Used to split econoflo hose from one line into two separate lines.

Metal Hose Patches

These can be used for quick and temporary repair of fire hose on the fire line. These are used in the event there is no hose nearby to replace the damaged line. These can also be used if there are damaged/blown couplings. **One method that is used is to stuff the end of one hose into the next coupling for approximately 2 to 2.5 metres (6.5 to 8 feet) and to then use two metal hose patches to secure the hose.** It may be necessary to turn the hose around to allow for maximum use of the surviving couplings. It is important to stuff the hose in the direction in which the water is being pumped.



Hose Strangler

The strangler enables a firefighter to instantly shut off water flow in charged fire hoses. These are extremely valuable for changing and adding hose as well as removing accessories. A strangler should be readily available when working with any type of hose lay.



THE PUMPING EQUATION

Starting a pump is the easy part of water delivery. The real challenge is in understanding pump capabilities when dealing with numerous variables in an ever-changing fire environment. The key variables to consider when constructing a water delivery system are **suction, elevation, friction** and **nozzle pressure** requirements.

SUCTION

Although not a direct input to the equation, suction is an important component to be considered when choosing an adequate pump site. **Static Suction Lift** is the vertical distance the water has to be lifted from the water source to the centre of the pump. Pump operators can minimize static suction lift by placing pumps **as close to the water source as is possible** and at the same level.

The two **primary inputs** of the pumping equation to calculate when estimating the capabilities of a pump and water delivery system are **Elevation (Head) and Friction**.

ELEVATION (HEAD)

Static Delivery Head describes the vertical height from the centre of the pump to the water delivery level (i.e. nozzle). **Total Static Head** is static delivery head as well as the elevation gain on the intake side of the pump to the water. **Total Head** includes static delivery and total static heads as well as the friction head created at the foot valve. Whew!!!

It is important to not get too concerned about the specifics of Head. The Pumping Equation is used as an **ESTIMATE** of pumping capabilities. When doing the calculation in the field; all you need to know is an elevation (head) gain **estimate from water source to nozzle** to complete the basic calculation. Do not sweat the particulars of the components of head described above, as their inputs will not significantly change the result.

The elevation rule of thumb is: **FOR EVERY FOOT OF ELEVATION, A ½ PSI IS LOST**. This **back pressure** is caused by the weight of water and the influence of atmospheric pressure (Remember? Water is heavy!).

In steep terrain, this is the number one obstacle when constructing an efficient water delivery system. For example, a hose line full of water with a static delivery head of 400 feet would create a back pressure of 200 psi at the pump end. If your pump's pressure capacity is below this, you will not move any water. Therefore, a 380 psi Mark III pump will work while a 170 psi Mark 26 would not (excluding all other factors).

FRICTION

We just learned that elevation gains provide the greatest pressure losses in a water delivery system; therefore, this will be the largest part of the pumping equation. However, there are also losses due to the turbulence created by the pressurized water stream contacting the inside of the hose. **Friction** is the result of one body of matter adhering to another.

Pumping operations measure friction by the amount of water pressure lost due to this force. **Friction Head** is the resistance set up by the motion of the water through the intake hose into the pump and on through the hose lay. Friction is influenced by:

- **Volume of water flowing through the hose.** The more water flowing, the more water in contact with the sides of the hose = the greater the pressure loss.
- **Size of the nozzle opening** (related to the volume of water). The larger the nozzles opening, the more water flowing through the hose = the greater the pressure loss.
- **Diameter of the hose.** The smaller the hose diameter, the more water forced to come in contact with the hose walls = the greater the pressure loss.
- **Type of hose lining.** The rougher the surface interior of the hose, the greater the turbulence in the water flow = a greater pressure loss. **Lined hose loses 2 psi/100 feet, while unlined hose loses 4 psi/100 feet.**
- **Number of in-line accessories.** Water delivery appliances placed in-line in the hose lay, such as a back check or gated 3-way valve, create turbulence. The greater the number of appliances = the greater the pressure loss.
- **Wet-water agents (fire foam)** decrease surface tension or friction and allow water to flow readily.

NOZZLE PRESSURE

Once all other factors have been accounted for, there must be a certain amount of pressure left over at each nozzle. **The rule of thumb is a minimum of 25 PSI per nozzle;** however, achieving something closer to **50 PSI** per nozzle will greatly increase productivity in suppression and mop-up operations.

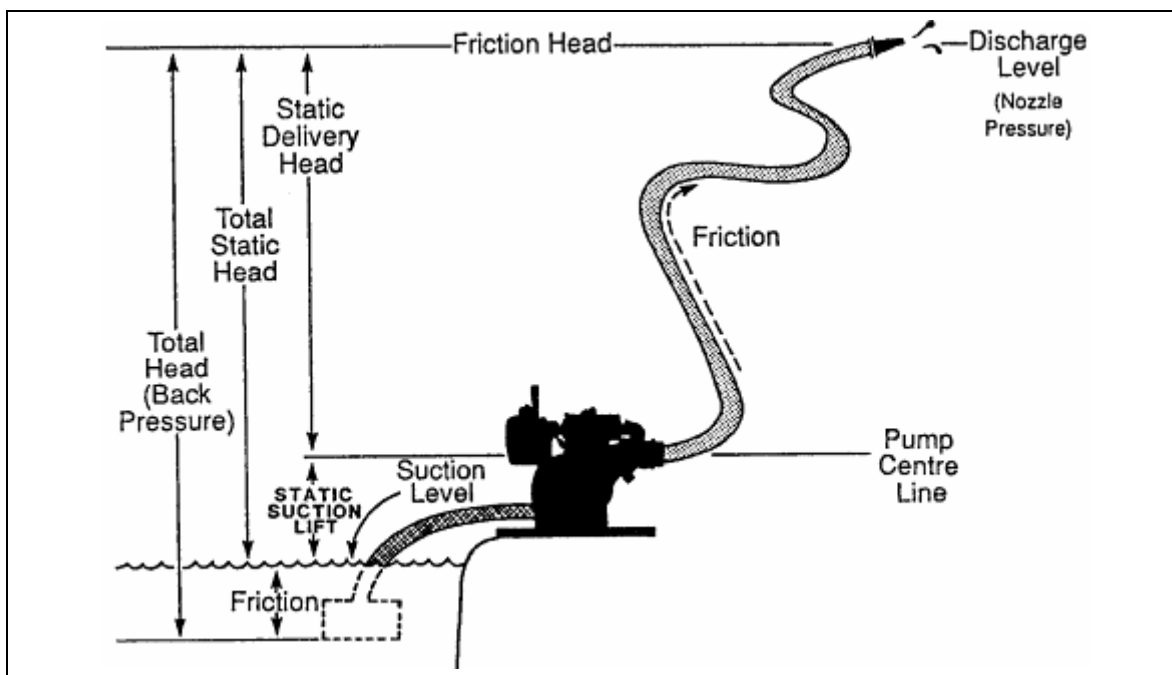
THE PUMPING EQUATION

Okay - now that we have all the components, let's put them into the equation. The purpose of the pumping equation is to help personnel quickly estimate what is required to produce the needed nozzle pressure in a particular fire situation given all the variables discussed above.

$$\text{Pump Pressure} = \text{Nozzle Pressure} + \text{Head (elevation gain)} + \text{Friction Loss}$$

OR

$$\text{Nozzle Pressure} = \text{Pump Pressure} - \text{Head (elevation gain)} - \text{Friction Loss}$$



SAMPLE SITUATIONAL PROBLEMS

Calculate the answers to the following examples using the **1/2 PSI** rule of thumb for head and assuming a **25 PSI** minimum effective nozzle pressure for firefighting. Refer to friction loss values in Appendix I at the back of this module.

Problem #1:

The elevation difference from the pump to the fire is 150 feet. The hose required to deliver water to the site is 1,000 feet of 1½" lined and 1,500 feet 1½" unlined. There is one back-check and two 3-ways in the line. The pump capacity is 200 PSI.

- a.) Will the pump deliver the desired minimum nozzle pressure of 25 PSI?
- b.) What would happen to your pressure if a larger nozzle opening were used?
Why?

Problem #2:

The elevation difference from pump to fire is 250 feet. Hose required to deliver water is 1,000 feet of 1 ½" lined and 1,500 feet of 1 ½" unlined. You will need one back check valve and one 3-way.

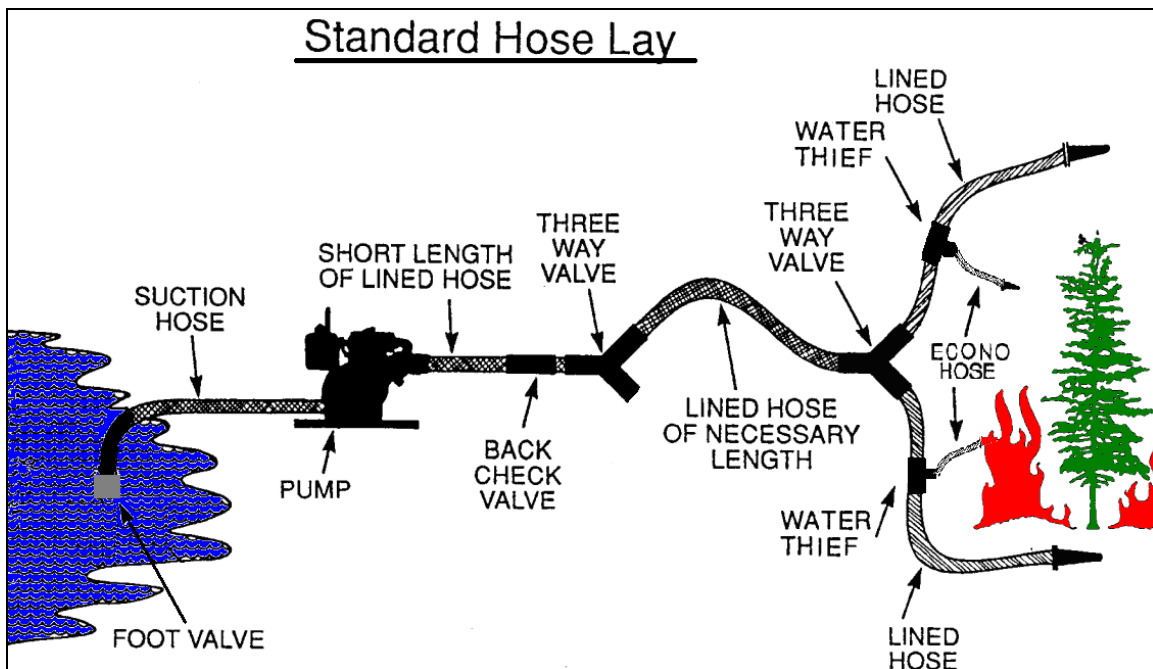
What capacity pump will be required to deliver a minimum effective nozzle pressure of 25 PSI?

WILDFIRE SERVICE HOSE LAYS

The next step in the water delivery process is to understand the different types of water delivery systems and hose lays the Wildfire Service employs. As stated earlier, each pumping situation will require some careful thought and variation to the text book answers. The systems that follow will act as building blocks to potentially more complicated scenarios in the field.

THE STANDARD HOSE LAY

The Standard Hose Lay is the most commonly used water delivery system on the fireline. All fire crew personnel are required to know this system. The Standard Hose Lay employs a single pump. When setting up this water delivery system; the standard layout described in the illustration is recommended and the accessories listed below are required:



- a short length of 1 ½" lined hose between the pump and the back check valve;
- a three-way valve;
- a main line 1 ½" lined hose from the first three-way valve to the second three-way valve at the fire's edge;
- branch lines of 1 ½" lined hose from this three-way valve surrounding the fire perimeter capped with nozzles;

- along branch lines are water thieves are placed as needed;
- econoflo hose and nozzles are attached to the water thieves.

Refer to the illustration provided on the previous page.

- The pump is located level and close to the water source.
- The short length of lined discharge hose is coupled to the pump because the pulsating action of the water being discharged from the pump creates the greatest pressure directly at the pump outlet. This is the most likely length of hose to fail and is much easier to replace when it is 10 feet rather than 100 feet. This 10 foot length is always made from the most durable type of lined hose.
- The back check valve is connected to the opposite end of the 10 foot hose. The function of this valve is to permit water to pass up the hose line (directional one-way flow), but not back into the pump. This protects the pump against back pressure. It must be placed in the right direction or water will not be able to flow into the hose lay.
- A three-way valve is then connected to the check valve. This device gives the pump operator the ability to bleed off or redirect water. This is helpful when changing lines. It should never be left open when the system is functioning as it is a tremendous drain on pressure. Three-way valves should be placed intermittently along any hose lay for these same reasons (every 400 to 1000 feet).
- The main line is constructed solely from 1 ½" lined hose. This hose has the least amount of pressure loss due to friction.
- A second three-way valve is then connected onto the mainline when it meets the fire edge. This allows water to be directed around the fire perimeter.
- The two branch lines should also be constructed with lined hose for the same reason as the mainline (least friction). They should be laid outside of the fire's edge. The only time unlined hose is necessary is when a branch line needs to be placed in a location where it is vulnerable to burning. Branch lines are capped with a **Hansen Nozzle** (it is possible to improvise when capping the hose lay (e.g. other nozzles, end caps, stranglers, etc. These are not nearly as versatile though).
- Water thieves are strategically placed along branch lines near priority areas first. If thieves are plentiful, it is wise to put them in at every coupling.
- Econoflo hose is used at each water thief to efficiently and effectively apply water directly to fire. It is very mobile, can generate excellent pressure, and allows for more nozzles to be open on one water delivery system.

**In more intense suppression situations the 1 ½" hose and nozzles will be used directly on the fire. This delivers greater pressure and volume at the end of the hose, but will render the rest of the hose lay virtually useless.

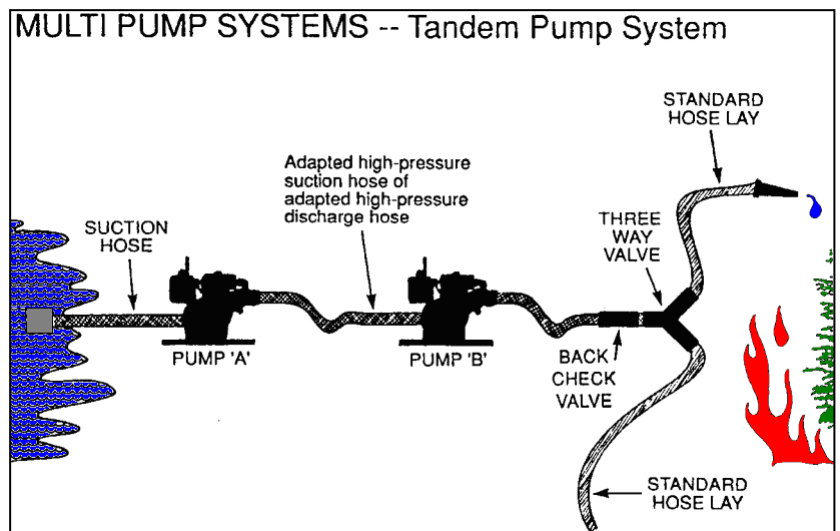
MULTI-PUMP SYSTEMS

Multi-pump Water Delivery Systems are used when a single pump is no longer able to maintain the required pressure needed to force water to a fire area beyond its pumping capacity. These systems incorporate additional pumps and equipment into the water delivery line. They are used in either **tandem** or **parallel** configuration. The overall purpose of Multi-pump Systems is to provide adequate pressure and volume under conditions where a single pump cannot overcome the effects of elevation gains and friction losses due to the length of the hose lay.

THE TANDEM PUMP SYSTEM

Tandem is not an unfamiliar term. It is used to describe two or more objects, or persons, situated one behind the other but working together.

In a Wildfire Service pumping operation, the term tandem describes two or more pumps (arranged one behind the other) pumping in conjunction.



Note how the pumps are coupled together. The discharge side of Pump A is connected by a length of good 1 ½" lined hose plus a **tandem adapter** (or by an adapted suction hose) to the suction side of Pump B. Pump tool kits come with all necessary equipment for this application.

The more powerful of the two pumps is placed closest to the water source for maximum output (this is determined by a warehouse tag with the pump's PSI rating). If the weaker pump is placed first and both pumps are run at maximum power, the second pump will run the first pump dry. This will collapse the hose between the two pumps and the second pump will then

over-rev and shut down. If both pumps are of equal power, then Pump B should be run at a slightly slower speed than Pump A.

Once the two pumps are coupled in tandem, with the more powerful unit closest to the water source, the Standard Hose Lay is set in place.

The second pump in a tandem system can be moved further away from the first pump as required. The amount of distance is dictated by pressure. There must be enough pressure to adequately supply the second pump. A tandem system can include many pumps depending on the distance and elevation gain.

A tandem system may also be employed when elevation and distance problems are not present. It is put in place to facilitate maintaining a high level of pressure while running a greater number of nozzles.

Advantages:

- Moves water greater distances while maintaining greater pressure;
- Can use as many pumps in series as needed;
- When pumps are close, the system can be operated by one person;
- Simplest to understand and install.

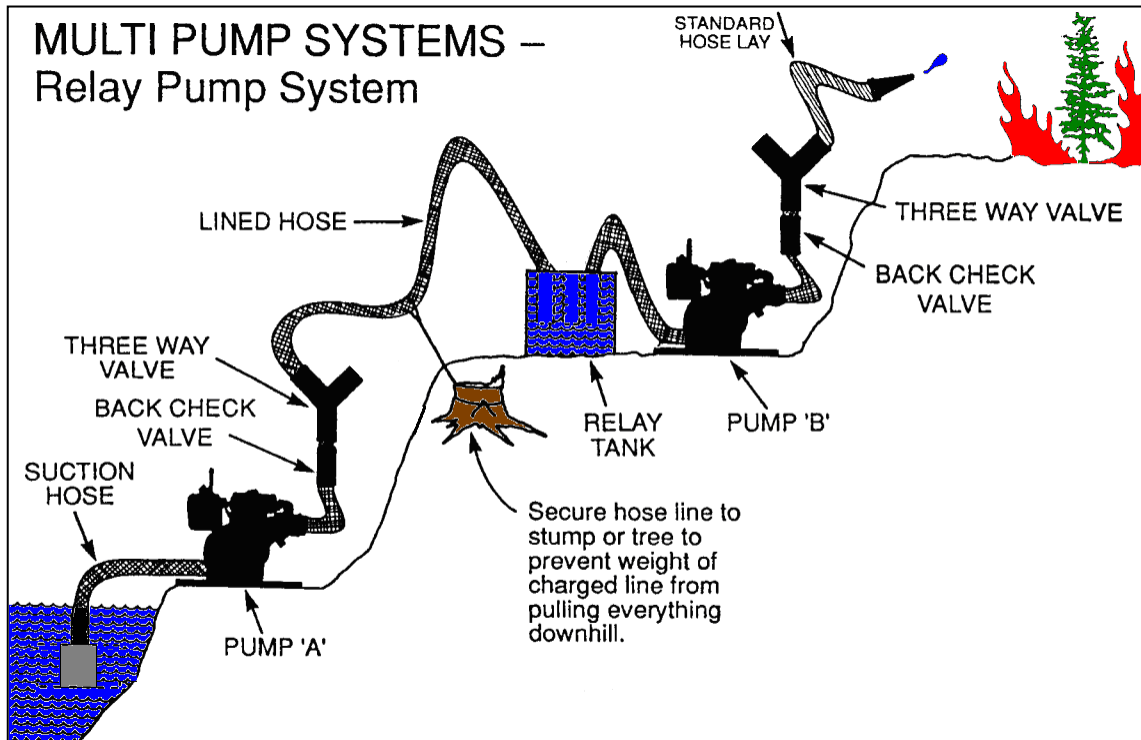
Disadvantages:

- If the first pump quits, or any other before the last, the whole system will fail;
- If not enough nozzles are in use, the increased pressure can blow hose;
- Cannot use hose between pumps for mop-up or suppression;
- As a tandem system becomes more elaborate (i.e.: more pumps, greater elevations), it requires greater attention by more personnel to keep it running properly.

THE RELAY PUMP SYSTEM

Similar to the Tandem System, the **Relay Pump System** also employs two pumps and places them one behind the other. The difference is this system incorporates some type of tank into the water delivery line. This **relay tank** is usually collapsible. It is placed between the two

pumps and serves as a reservoir in the relay of water from one pump to another. It is primarily used when pumping very long distances.



Pump A, which draws from the water source, discharges its output into the relay tank. Pump B, situated just below the maximum lifting capacity of Pump A, draws from the relay tank using the standard hose lay. Operators using the Relay Pump System must first allow the relay tank to fill with water before starting Pump B.

In situations where the pump is draining the tank faster than Pump A is filling it, Pump B must be shut down or turned down. To overcome this, it might be advised to install a tandem system in place of Pump A. The tandem system and the relay system are easily combined to suit your firefighting needs.

Advantages:

- No limit to how high and how far you can move water;
- Eliminates pressure strains on the hose lay;

- Feeder pump failure does not shut entire line down as water from the relay tank is still deliverable.

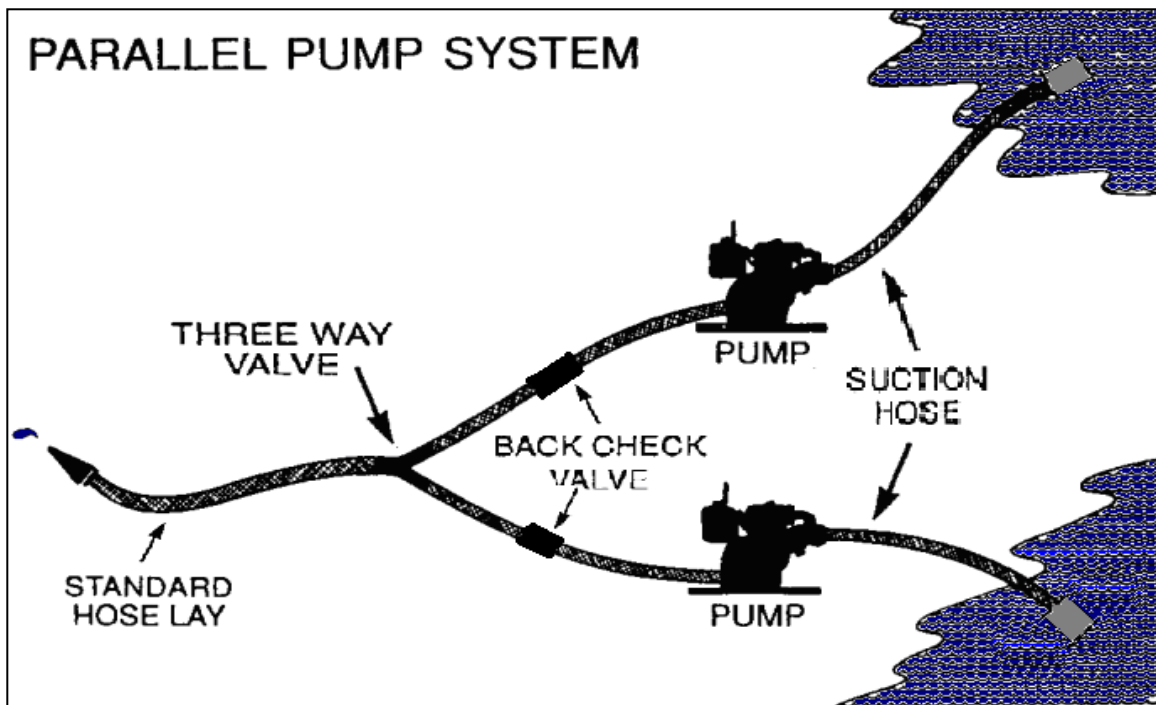
Disadvantages:

- Two or more pump operators;
- Terrain can make it difficult to find suitable relay tank sites;
- Potential down time due to filling relay tanks.

PARALLEL PUMP SYSTEM

A third multi-pump system, referred to as the **Parallel Pump System**, places two pumps parallel to one another rather than one behind the other. The purpose of this system is to utilize more than one water source when the sources are inadequate on their own.

Like any of the pumping systems, the Parallel System can be combined with other systems to suit water delivery requirements.



Advantages:

- Takes advantage of as many limited water sources as required;
- Moderate increases in pressure and greater increases in volume over long distances;
- Continuous water if one pump fails.

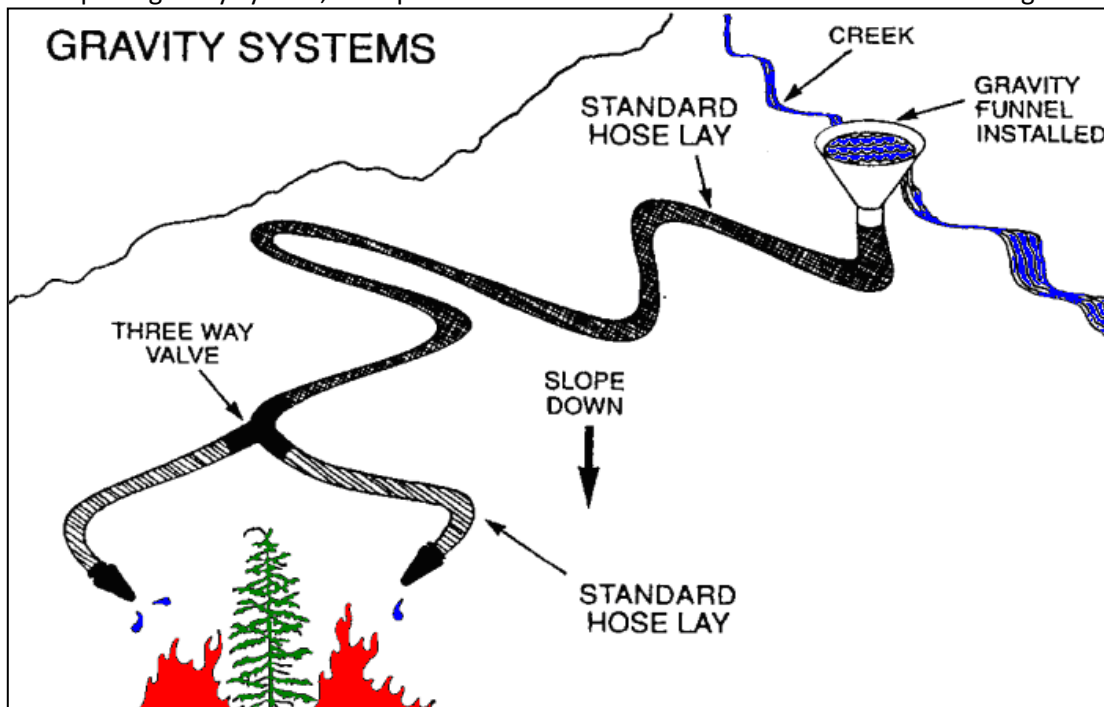
Disadvantages:

- The pressure increase is marginal;
- Multiple pump operators;
- If pumps are not exactly the same power, the lesser of the two will not move any water past the 3-way. The water between the pump and the 3-way can boil and the weaker pump will over heat and be damaged severely.

THE GRAVITY SYSTEM

The **Gravity System** is so called because it relies on gravity, not a mechanical pump, to move the water down-slope. It is understood that when water is being pumped up-slope the pump must overcome approximately 1/2 PSI of back pressure for each foot of elevation. The reverse is true: water pressure increases by the same rate when water moves down-slope.

To set up the gravity system, the operator will select an intake site above the fire. The greater



the elevation above the fire, the greater the pressure produced. A location where the funnel can be tied for greatest water collection is preferred. Next, the hose is coupled to the funnel, the steepest or longest drop on the hillside is chosen, and the standard hose lay is constructed.

Advantages:

- No pump or operator required;
- Limited maintenance;
- No fuel consumption;
- Takes advantage of slope to create pressure.

Disadvantages:

- Difficult to find ideal water source combined with suitable terrain;
- Gravity funnel screen gets clogged limiting water supply;
- Pressure is difficult to manage. It is often weak at the top of the fire, yet blowing hose at the bottom;
- Limited number of nozzles;
- Potential problems are greater than the effort required to install a pump.

SPRINKLER SYSTEM

Sprinkler systems can assist in fireline success and structure protection. You may be required to set up a system for either purpose. They are used on the fireline primarily for burning-off operations to wet down control lines before ignition. They are also used in place of nozzles once crews depart at the end of the day, or when conditions are too dangerous for firefighter to remain on scene. For structure protection, they are attached or placed adjacent to buildings to help protect them from advancing fire.

In order to maintain optimum pressure at each sprinkler head you will need a good water source and a **Mark III pump for every ten sprinklers**. There are two types of sprinklers. One fits directly into the 1½" mainline, and the other attaches to the end of a 5/8" econoflo hose. Ensure no dirt or other foreign particles get into the hose lay when connecting accessories to the line because it will plug up the sprinklers. Most sprinkler heads are aluminum so treat them gently when loading and unloading, and minimize rough impact while in transit.

USING WATER ON THE FIRELINE

Once the sprinkler system is set up it must be tested to ensure each sprinkler remains securely placed and all sprinklers are receiving enough pressure to be effective.

Sprinklers should be spread out to maximize coverage. In the case of structure protection, sprinklers will not necessarily be started right away; however, when the time comes there can be no failures with the system.

**** Sprinkler heads are water lubricated.** The worst thing that can be done to an impact style sprinkler is to apply a foreign lubricant (oil, WD-40, silicone, Teflon, pipe dope, etc.). These foreign lubricants might make the sprinkler work right away, but will actually cause the sprinkler to wear out faster because the lubricants attract dust and debris.

It is essential to use water to its maximum effect on the fireline. Fire personnel have come to recognize that different methods of applying water suit different fire situations through many years of firefighting experience. Conserving this valuable resource correctly and applying it to get maximum effect from available volume and pressure is critically important. There are essentially two ways of applying water to fire.

SOLID STREAM

Water is used to penetrate or burrow into the burn area. This is commonly known as **hydraulic**. This approach also allows for greater range of water application. A firefighter can reach areas potentially unsafe to stand or higher into the trees while still creating an effective stream.



FIRE CREW TRAINING STANDARD



DO NOT DUPLICATE

Solid Stream - Constructing a Hydraulic Fireline

When a fire is burning in light fuels, a fireline is often constructed very quickly using a jet stream of water. A firefighter applies the stream directly to the fire's edge and works quickly along the perimeter. The nozzle must be held as close to the fire edge as possible and pointed straight down in order to achieve maximum effectiveness. Water must be allowed to penetrate the duff layer as deep as possible to achieve success.

**** Hydraulic firelines are quick and temporary control solutions, and are always reinforced by firefighters. The firefighters are responsible for immediately constructing the standard fireline to mineral soil using hand tools.**

Solid Stream - Fire in Snags and Trees

One advantage of the solid stream is that long ranges can be obtained in situations where accessibility presents a problem. Fires in snags or trees threaten both the safety of the crew and effective control of the fireline. These fires are a serious problem and should be dealt with immediately.

If the entire snag is ablaze, use a solid stream of water at the very base of the stem first, and then work up the tree. A great deal of force is exerted by a solid jet of water. Sparks or embers could easily be knocked off the snag and thrown beyond the fireline. Be aware of this



potential hazard. To reach fires burning inside snags or trees use a solid stream of water to directly saturate the bole through checks or cracks. Interior burns can be difficult to reach; therefore, take advantage of all visible openings that can be accessed with a solid stream of water and thoroughly irrigate the area.

SPRAY STREAM

A spray stream is used when trying to cool down a large area. This approach limits the distance water can travel from the nozzle, and will not completely extinguish fire. However, this method can cover a lot more ground in shorter time and serves as the best way to eliminate intense heat from areas that have the potential to compromise control lines. The spray stream method is also used in burn off operations where fire crews are tasked with wetting down the green side of control lines before ignition.



Spray Method - Wetting Down Outside the Fireguard

A distinct improvement in fire extinguishing efficiency has been obtained by discharging water in the form of a spray. Combustion is more difficult to initiate and maintain when this extinguishing method is used. During burn off operations, or when fire intensity is high, accumulations of dry fuel on the outside of the fireguard could easily be ignited by radiant heat, sparks, and burning embers carried either by wind or convection. In such a situation, streams or jets of water should not be used. The amount of area needed to cover is greater than a solid stream can handle. This will also help in raising the **relative humidity (RH)** outside the control line making ignition in this area more difficult.



Spray Method - Puddling

When water is abundant the puddling of hotspots in mop-up operations will go a long way to ensure these areas are fully extinguished. A firefighter is simply applying enough water through the spray method to form a puddle of standing water on and around the hot area. This puddle will then continue to work to cool this spot well after the firefighter has moved on. If the fuel is not completely saturated, or carelessly doused, the little water that was applied will quickly evaporate. Although the fire may appear to be out, it is often smoldering deep within the duff.

****Any time crews are in mop-up mode, there should always be hand tools working in conjunction with each nozzle.**



USING WATER - THE SUPPRESSION STAGE

The use of water in suppression is very important. Crews will need to be efficient in its application to cover the most ground and contain fires quickly. This need is greatest at the IA level in order to maintain our targeted success rate (92 %). Shrewd judgment is needed by firefighters to make assessments on water supply vs. water needs in order to employ the most effective use of the water. Larger scale operations will take more time and thought to ensure water is used effectively and containment is achieved as quickly and safely as possible.

USING WATER - THE MOP-UP STAGE

Fire crews in expanded attack situations will spend the majority of their deployment mopping up. This task can be monumental as fire size increases and burning conditions remain high. At the IA level, the mop-up of smaller fires is just as important. The mop-up skills are the same, but on a smaller scale. Whether the objective is putting a fire 100 % out or making a 50 foot cold perimeter; crews **MUST be thorough** and not move on until these goals are met.

Small Scale Mop-up - IA

The hard and fast rule of IA mop-up is **100 % of all heat removed**. There is no excuse for crews leaving a fire without being able to guarantee all hot spots are out. This does not mean crews can spend extended amounts of time reaching this goal; they must make the best use of their resources to complete the process. Water must be applied efficiently especially when it is scarce. Hand tools are a must and an extensive **cold trailing** of the fire must be completed before departure.

Large Scale Mop-up - Expanded Attack

Project fires range in size, and therefore so do mop-up operations. Unit Crews will find themselves at the end of a nozzle or on a hand tool for long stretches. Regardless of the scale, crews are expected to obtain the same goals when given mop-up objectives. Generally, large fires will call for a certain amount of the perimeter to be mopped up unless the fire is in a sensitive or interface area (In this case 100 % may be required). Crews in this type of operations must also make the best use of their resources. Water must be applied in the most effective and, generally, the most conservative and cost-effective manner. If crews can cut their time on the fireline down by being diligent in this regard, they can cut suppression costs dramatically and be ready for re-deployment to other targets.

A common request of mop-up crews is called a **black line**. The term black line refers to the color of ash. It is grey when it is dry and turns black when it is wet. This is generally 10 feet or greater. Black lines are considered areas directly adjacent to control lines free of any hotspots. They serve to reinforce fire guards by increasing the width of area between potentially active fire and the unburned fuel. It must be understood that creating a black line does not require crews to hit every square inch ground with water to achieve their objectives. In the interest of being productive, areas which are clearly devoid of heat only need a quick once over to ensure there is no heat hiding before moving on to higher priority areas.



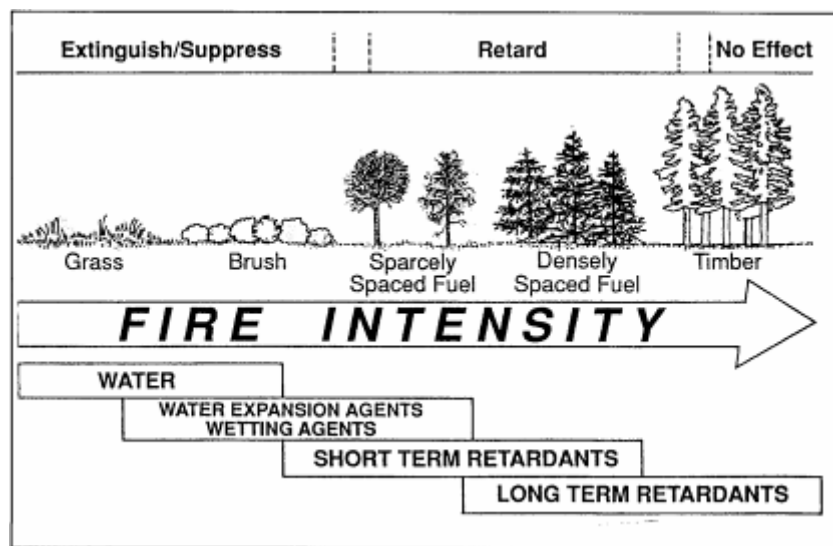
Crews will always cold trail their area before moving on, and make sure all hose is removed from within the fire before leaving the line each day. All extra hose should be rolled neatly on the main line. Keep your nozzle with you as your objectives may change from day to day.

It must be emphasized that **mop-up is not a sedentary task**. It requires firefighters to be active in carrying out their objectives. **Hand tools** must be employed to grub out hot spots before

water is applied. Water must be applied under good pressure and directly to hot areas. Nozzles must be pointed straight down and in close proximity to the target. This approach will alleviate some of the monotony of mop-up, and the work will get done considerably faster. It is not the amount of water used that has the greatest impact on the fire; it is the manner in which it is applied.

FIRE EXTINGUISHING AGENTS

Water has been historically relied upon to fight fire because of its accessibility. Therefore, it has traditionally come to be regarded as the most practical and accessible firefighting tool. However, water is not always readily available, and transporting it can be difficult, time-consuming and extremely costly. As fire intensities increase, water can become less effective and the need for other suppression agents may arise. In this case, the Wildfire Service may introduce the use of **foam** and **fire retardants**. It must be noted that fires can reach intensities on which no fire extinguishing agent will have any effect.



FIRE FOAM

Foams are designed for use on fires of porous fuels. They extinguish fire by increasing the wetting and cooling capabilities of water. In forest fuels, the effectiveness of water as a fire suppressant is increased approximately 300 % when firefighting foam concentrate is added to the water supply. Currently, the most common and widely used suppressant is Class A foam. Class A foams are essentially high density soaps.



Foam solution and the foam created by agitating that foam solution will increase the fire suppressing effectiveness of water in a number of ways:

- **Foam Solution Makes Water “Wetter”**
 - Pure water has strong molecular bonds and forms droplets. The surface of these droplets resists rupture (high surface tension). Surface tension prevents water from effectively penetrating into fuels.
 - A wetting agent added to the water will weaken this molecular bond creating a surface tension 60 % less than straight water.
 - Reduced surface tension also increases the surface area of water available for heat absorption. These qualities of foam solution are also effective in breaking down the water repelling waxy cuticle layer found on tree surfaces.
- **Foam Causes Water to "Stick" to Fuels**
 - Water adheres poorly to forest fuels. Up to 95 % of the water applied to a fire is ineffective unless the fuel surface is very rough and porous because it ricochets or runs off of the fuels and into the ground.
 - Foam solution, when agitated, forms a foam which is viscous; it will not drain off, but will flow gradually. Foam can be made to cling to vertical or underside surfaces of fuels or structures.
 - The bubble structure of foam contains water in the bubble walls; as the bubbles break down over the heat of the burning fuels the water flows onto the fuels wetting and absorbing heat.
- **Foam Reduces Heat**
 - The foam blanket is a reflective, insulating barrier for the fuels it is applied to. This layer reflects radiant heat.
- **Foam Cuts Oxygen Supply**
 - The foam bubbles flow onto and enclose the fuels and isolate them from oxygen. Air in the bubbles has a very high relative humidity (it contains water vapor and therefore less oxygen).
 - Water vapor (steam) is produced as the water in the foam extinguishes the fire. The foam blanket holds this water vapor in contact with the fuels, which speeds up the extinguishing process.

Making Foam

Production of foam is easily accomplished using a few accessories engineered for use with standard water delivery systems. Two basic methods are used to mix foam concentrate with water and produce a foam solution:

- **Hand Mixing**
 - Hand mixing is simply pouring concentrated foam into a portable water source (e.g. relay tank).
 - This method, also called **batching**, is convenient for conventional water pumping systems because no additional accessories are needed.
 - The simplicity of this method also makes it the most wasteful. The concentrate is wasted when exact mixing ratios are not followed.

- **Eduction (Induction)**
 - The term eduction describes the process of drawing and mixing two liquids.
 - Perhaps the simplest method of adding concentrate stored separately is by eduction with an in-line tee.
 - Systems using this method are able to draw directly from the standard concentrate container thus making this method especially useful when foam is generated from a natural water source.
 - The system is equipped with a **regulating valve** to correctly dispense the flow of both water and concentrate.

A specialized foam nozzle can be used to further increase the effect of foam; however, if one is not available, regular nozzles will suffice. It is important to use the appropriate ratio of foam to water to be effective but not wasteful.

Safe Working Practices for Foam Use

Foam concentrate is severely irritating to the eyes and moderately irritating to the skin. Prolonged or repeated use may produce skin irritation and inhalation of its mists may irritate the lining of the nose and throat. These precautions should be taken:

- Eye protection must be worn when handling foam concentrate. A quantity of fresh water for immediate flushing of eyes should be available at the mixing site should accidental contact occur.
- Spills of foam concentrate on clothing will require that the clothing be removed and the affected area washed off.
- The use of gloves is recommended when handling the concentrate. Exposed skin should be washed as soon as possible.

Environmental Considerations

Foam concentrate is highly biodegradable when placed in the natural environment; more than 85 % reverts to carbon dioxide within 28 days.

- Avoid use of foams in environmentally sensitive areas such as watersheds, hatchery drainages, or near water intakes. If foam concentrate enters the water supply, harmful effects to aquatic life in the immediate vicinity are likely.
- Take all precautions to prevent concentrate spills near the water source.
- Use foam education systems that allow foam concentrate jugs to be placed away from water source.
- Always use a back check valve below the point where foam is being introduced into the water delivery system.
- Before shutting down the pump at the end of the day, firefighters should turn off the metering device and allow time for the system to flush itself of concentrate (20 minutes). Failure to do this can allow foam concentrate to seep back through the suction hose and into the water supply. Un-flushed pump heads are prone to corrosion.

Fire Retardant

A **fire retardant** is any substance that, by physical or chemical action, reduces the flammability of combustible materials. Fire retardants are classified into two types: long-term and short-term.

Long-Term Fire Retardants utilize flame-inhibiting chemicals such as phosphates (liquid or dry fertilizers) and sulphates (dry salt fertilizers). Burning is slowed or stopped due mostly to

chemical reactions between the fuel and the retardant. Long-term retardants are normally **applied to fuels ahead of the moving flame front**, and remain effective even after the water in them has evaporated. Application of long term fire retardants is accomplished using air tankers or helicopter bucketing.

Short-Term Fire Retardants include water-modifying chemicals such as wet-water, thick water, gels, gums, clays and foams. Fire suppressants are **applied directly onto the burning fuel** by air attack.

Firefighters will seldom be working directly with retardants unless they are involved in small scale mixing operations for helicopter bucketing. Most contact with retardant will be after tankers have applied it to the fire. This will be discussed in greater detail in the air tanker presentation.



APPENDIX 1

Factors that influence pressure in a water delivery system:

- **Elevation:**
 - ½ PSI per foot of elevation
 - Example: 200 vertical feet requires 100 PSI

- **Friction due to Hose**
 - 2 PSI per 100 foot length of 1½" Rubber Lined Hose
 - 4 PSI per 100 foot length of 1½" Unlined Hose
 - Example: 3000 feet of Lined hose requires 60 PSI

- **Friction due to Appliances**
 - Three-way valve 2 PSI
 - Water thief 2 PSI
 - Back check valve 4 PSI
 - Example: 1 back check, 4 three-ways and 6 water thieves would have a combined pressure loss of 24 PSI

