# Fog For Fire

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TABLE OF CONTENTS

# INTRODUCTION

Man's best friend sometimes becomes his worst enemy. Fire is just such a friend or enemy, depending upon how man handles it. Fortunately, fire has an enemy that man has used for centuries to help keep fire under control. This enemy is water. Until recently not much thought was given to the form (stream, spray, or steam) in which water was applied to a fire. The main idea was to get as much water as soon as possible on the fire.

With the growth and development of the United States, fires have increased in number and seriousness of damage done. Science has developed many explosive and inflammable products which people use every day. At the same time, people are not very careful with fire and the way in which they handle it. The results are obvious. When one scans the accounts in daily papers, he reads of fire destroying anything from homes to extensive forests. Fire fighters were aware of the need for faster and more efficient fire extinguishing agents. This need was aggravated by World War II and the United States air development. Planes would crash and burn, and any still living occupants would perish while fire fighters squirted water and chemicals on the fire, desperately trying to extinguish the roaring inferno.

Something was needed and needed quickly. Tests were started, using all imaginable things as fire extinguishing agents. As a result of the tests, the value of fog as an extinguishing agent was established and proved.

The use of fog in fighting fire is not new. However, it has only

been since 1942 that fog has been developed as a fire fighting weapon. Fog is a spray -- the product of breaking down a solid stream of water into small droplets. This breaking down of a solid stream of water is accomplished through the use of pressure and a specially constructed nozzle. There are two classifications of fog: high pressure and low pressure. The amount of pressure used in developing the fog determines whether it will be high or low pressure fog. Both classes of fog act on a fire in practically the same manner; yet there is much disagreement as to the best class of fog to use. Unfortunately no tests have been run comparing low pressure and high pressure fog to definitely determine the advantages and disadvantages of each. The limited number of articles that have been published were written by men who had had experience with one of the aforementioned classes of fog. The authors of these articles are divided into two groups. One group is champion of the low pressure fog, while the second group is sure that the high pressure fog is the better.

Perhaps by understanding the principle of high and low pressure fog a clearer picture of fog for fire might be obtained by those who are interested. The author hopes that the reader will have a better understanding of the two classes of fog when he has finished this paper.

## HISTORY AND DEVELOPMENT OF FOG

Fog was first used, not for fighting fires, but to spray orchards and farm crops. There are instances on record where these same spray machines were used in fighting small grass fires on the farm. However, fog was not considered as an important weapon against fire until some years ago. As a matter of fact, Glenn Griswold, Battalion Chief of the

Los Angeles County Forestry Department, is credited with the invention of the "fog nozzle" and the technique of application over twenty years ago.(5) The high pressure fog equipment was originated by the John Bean Manufacturing Company, Division of Food Machinery Corporation of Lansing, Michigan, a number of years ago.(6) Even with this early development of fog and fog equipment, it was not an accepted method of combating fire until the armed forces adopted it during World War II.

The Air Corps needed something to combat gasoline, oil and crashed plane fires. The Navy needed something to fight fires aboard ships. Fog was their answer. The Navy established fire fighting schools where thousands of men were taught how to use fog on all types of fire under varying conditions. The Army Air Corps equipped many of their crash trucks with high pressure fog units. With this equipment, burning planes were rendered harmless in a matter of minutes or seconds. Rescue crews were protected by a blanket of fog, making possible speedy evacuation of crash victims.(2) According to Mr. Orell, a high pressure fog unit was used at Camp Adair on all kinds of fires -- brush, forest, grass, burning buildings, trucks, and on one oil fire. The fog unit proved very satisfactory, and Mr. Orell praised it highly.(3) The results of the use of fog on fires was so spectacular that municipal fire departments and some forest fire protection units wanted to try fog. It was not until after the war that equipment was available to such fire fighting units. As soon as possible, however, municipal fire departments acquired fog equipment. The results were amazing according to reports from various fire departments. Fires in buildings have been extinguished in a minimum of time with a minimum of water damage to the interior of such buildings.

Some forest protection agencies have, since the war, adopted either high or low pressure fog for use on forest fires. Reports from such agencies favor fog especially for some kinds of jobs such as mop-up, but indicate that it is not so satisfactory on other jobs. As a matter of fact, fog is too new in the field of forest fire fighting to have yet proved its maximum value. With continued use and careful study of fog on fire, it will undoubtedly become the leading method in combating forest fires when and where water can be used.

## PROPERTIES OF WATER

To fully appreciate the significance of fog it is necessary to understand some of the properties of water. First, water absorbs heat. This fact is important in two ways: (1) The way in which water absorbs heat, which is through its outside skin. If a single water droplet could be isolated to watch what happens as it is brought in contact with heat, it would be observed that the outside of the droplet absorbs heat first, with the center of the droplet affected last; and (2) if sufficient heat is absorbed, the droplets are converted into steam. According to physics, it requires 1300 BTU's (British Thermal Units) to raise the temperature of one gallon of water from 50 degrees Fahrenheit to 212 degrees Fahrenheit. To convert the one gallon of water from 212 degrees Fahrenheit into steam requires 8,000 BTU's. Consequently, it requires approximately 9,300 BTU's to convert one gallon of water from 50 degrees Fahrenheit into steam. Second, steam plays an important part in the effectiveness of fog on fire. Again, physics shows that when water is converted into steam, it expands 1700 times its original cubic displacement.

## REQUIREMENT OF FIRE

Just by way of review, fire requires a combination of oxygen, heat, and fuel in order to sustain itself. For a fire to start, there must be fuel in the presence of oxygen and sufficient heat to raise the temperature of the fuel to its kindling point so that combustion will result. After the fire has started it creates its own heat to maintain itself. Oxygen is needed to combine with the burning fuel to sustain the fire. Air contains approximately 20.9 per cent oxygen. If the content of oxygen in the air is lowered to 15 per cent or less, combustion cannot continue; thus the fire is extinguished.(1) Not much can be said about fuel except that by removing the fuel, the fire is deprived of its sustenance. In other words, if any one of the three factors essential to fire is eliminated, the fire will be extinguished. With this background, it will be easy to understand why and how fog acts on a fire.

## HIGH PRESSURE FOG

### Equipment

High pressure fog is produced by forcing water through a specially constructed nozzle. A pressure of five hundred pounds to eight hundred pounds per square inch at the nozzle causes the water to break into a fine spray called fog. According to Orell, a high pressure fog machine produces approximately seven billion individual fog particles per gallon of water.(3)

As stated before, the Bean Manufacturing Company originated the high pressure fog pump. This high pressure pump is the reciprocating positive displacement type pump. The pump is powered by a gas engine. The pump and engine are mounted on a frame to make

a single unit. A machine with a capacity of twenty gallons of water per minute weighs approximately eight hundred pounds. High pressure fog machines are made with capacities of from four to sixty gallons of water per minute.

The forest fireman is apt to be more interested in the smaller fog units that can be mounted on "pickups" and still carry a substantial water supply without hindering the mobility of the "pickup". The greater the capacity of the machine, the greater the supply of water that is needed to keep the machine in operation for any length of time. Other equipment necessary to complete mobile fog unit include one hundred and fifty to two hundred feet of three-fourth inch high pressure hose, an adjustable fog gun, a reel on which to keep the hose, and, of course, suction hose equipment, strainers and adapters.

Besides the mounted type of fog unit, there is available a high pressure portable pump. It can be carried by two men the same as an Edwards or Pacific Marine. The pump will draft from any adequate source of water, and has a capacity of four gallons of water per minute. It will project a stream of fire-killing fog twenty-five feet or more.

Fog Absorbs Heat

High pressure fog affects and is effected by fire in several ways. As stated before, fog leaves the nozzle at the rate of seven billion individual fog particles per gallon of water. Each droplet absorbs heat through its surface as it comes in contact with the fire. Compare the surface area of seven billion fog droplets per gallon of water with the surface area of a gallon of water applied to a fire in a solid stream. Figures are not available so that an accurate comparison can be made. Nevertheless it is obvious that the fog will

have many times the surface area per gallon of water than the solid stream of water. With the great surface area through which to absorb heat, a gallon of water in the form of fog is capable of absorbing the maximum amount of heat from the fire, thus reducing the rapidity of combustion and spread of the fire.

Smothering Action

As the fog particles reach a temperature of 212 degrees Fahrenheit, they are converted into steam which increases the original cubic displacement of the droplet seventeen hundred times. Multiply two hundred and thirty-one cubic inches (the cubic volume of a gallon of water) by seventeen hundred. The answer is 392,700 cubic inches of steam from one gallon of water. The sudden development of steam expanding to such a great volume disperses the air to the extent that there is not sufficient oxygen to support the fire. The steam makes a blanket over the fire which continues to deprive the fire of oxygen, thus smothering it. The combination of the absorption of heat and smothering effect of steam act instantaneously. This is fatal to the fire. If the efficiency of the fog on the fire is at a maximum, then a minimum of time is required to extinguish the fire and with a minimum amount of water.

The size of the water droplet is important. The smaller the particles, the quicker they absorb the heat and turn into steam. This action is so rapid that the entire drop of water is converted into steam. This develops the maximum utilization and efficiency of the drop. It has been said that the fog particles could be too small and that natural fog, while aiding to some extent in controlling a fire, cannot be depended upon to put it out or even prevent its spread.(1) There is

only one thing wrong with the above thought. Fog in its natural state is not concentrated on one spot of a fire as is pressure fog. It is easy to understand, however, that the smaller the water particles are, the more difficult it will be to keep them concentrated over a fire so that the maximum benefit might be derived from them. The idea is to get the most out of each fog droplet in absorbing heat from the fire and the conversion into steam of the entire droplet.

Compare the action of fog on fire with the action of a solid stream of water. As stated previously, the surface area of a gallon of water applied in the form of a solid stream is much less than the surface area of the same volume of water in the form of fog. For that reason, the water in the solid stream does not absorb nearly as much heat from the fire as it should to get the maximum use of it. Also, there is not nearly the maximum volume of steam produced, thus the lack of the smothering affect of the steam. Since only a small amount of the gallon of water is converted into steam, the rest of the water simply drowns out the fire in the small restricted area in which it is applied. This is a waste of water.

The author observed a demonstration of fog. Six truck loads of dry scrap lumber were dumped on the ground side by side, and each pile was about three feet deep. Gasoline and oil were used to get the fire going. After allowing the fire to get a good start, fog was used to control it. The pump truck was equipped with 225 gallon tank of water, a high pressure fog machine with a capacity of twenty gallons of water per minute, and two hundred feet of high pressure hose with an adjustable fog gun. The nozzle man worked on the fire for sixteen minutes, and had used approximately 180 gallons of water

out of the tank. At that point it was decided to let the scrap material continue to burn. However, the fire was so nearly out that the remaining forty-five gallons of water in the tank would have been more than enough to completely extinguish the fire. Unfortunately there was not a similar test using a solid stream of water so that the time element could be compared with that of fog. The fact remains that much more than 180 gallons of water would have been poured on the fire before it would have reached the point of control reached by the fog. Therefore, the amount of water used in the solid stream over the amount of water used in fog is wasted. It is important to get the maximum use out of water especially where water is scarce and has to be hauled.

Blows Out Fire

High pressure fog has the effect of blowing out the fire much the same as one blows out a match -- by actually separating the flame from the fuel. This blowing effect is caused by the high velocity of the fog when it leaves the fog gun.

Wetting the Fuel

When the fire has been cooled to the point at which steam is no longer formed, the fog particles then reach the fuel, thus dampening it and reducing the possibility of combustion re-occurring.

Where to Use High Pressure Fog

There are limits as to where fog can be used in fighting forest fires. Since it is necessary that all high pressure fog machines (except the portable units) be mounted on some mobile conveyance, topography and the lack of forest access roads are probably the most important limiting factors in their use. This can best be shown by studying the topography and road development of a fire patrol

organization such as Linn County Fire Patrol. The county can be divided into the following zones: (1) The agricultural zone in the valley; (2) the timber fringe where agriculture is combined with small forested areas; (3) the foothill zone where there is more timber and less farming; (4) the mountain area that has been cut over and is being cut over at the present time; and (5) the forested mountain area that hasn't as yet felt the sting of the logger's axe.

Linn County Fire Patrol has a high pressure fog unit with a two hundred and twenty-five gallon water tank mounted on a Dodge power-wagon. The problem is to see where in the county the power-wagon and fog can be used.

The agricultural zone will not be considered as it is outside the association boundary.

The forest fringe zone is largely on the valley floor with small wooded hills scattered throughout. In this area there is an excellent network of roads that are kept in good condition. Most of the wooded hills have some sort of road that was used at one time in getting out timber. All such roads can be easily traveled by the power-wagon. Seldom is a fire so far from a road that the power-wagon cannot get near enough to it to use fog in this fringe area.

The foothill zone is more of a problem. The topography begins to get rough and the roads are not as well developed as in the fringe zone. Fires occur that are too far from the road to enable the use of any pump truck unless a bulldozer is handy to break a short road to the fire for the truck. This is seldom done unless the fire becomes too difficult to handle.

The mountain area that has been cut and is being cut presents

the greatest problem in getting water where it is needed, when it is needed. Due to the truck logging method used in the Douglas-fir region, the cut over areas have a network of roads. These roads wind up the side of a mountain or follow along the ridge tops, leaving deep canyons and vast areas between roads. To make matters worse, the logging roads deteriorate very rapidly when they are no longer being used and maintained for logging. Such roads become impassable in a short time. It is evident that a fog unit with two hundred feet of hose is restricted to a very small area along the usable roads. This is a serious limitation in the use of tank trucks, for in the cut over areas there is a great amount of slash that becomes very flashy and hazardous during the fire season. It is important that the initial attack be fast and effective. A delay in action on a small fire could easily spell disaster for someone.

In the uncut mountainous area there are no roads, so fog is automatically out of the picture as far as fires in this area are concerned.

The question may be raised, "Why does Linn County Fire Patrol have a high pressure fog unit?" The answer is simple. Linn County Fire Patrol wants and needs equipment and fire fighting techniques that are fast and efficient. The power-wagon is to enable the fire fighters to go wherever it is possible to put the machine when necessary. The high pressure fog machine will get the greatest amount of good out of every gallon of water used, and make the two hundred and twenty-five gallons of water hauled extinguish a maximum area of fire. This is important because of the continual increase of slash and cut over land not only in the mountain area but also in the foothill and fringe zone.

Because of the high hazard during the summer months, it is most important to be able to catch all fires in such areas in their incipient stage. With the high pressure fog, one tank of water may be sufficient to extinguish a fire, while several tanks of water might be necessary when the solid stream is used. There is also the added danger of the fire getting away while the tank truck is going after more water when the solid stream technique is employed.

To use water in any form on any fire when possible is just good sense, but the fire fighter should take advantage of his opportunities, and use water in such a way as to attain the maximum benefit of it.

The heavy fog equipment that has to be mounted on a vehicle has its limiting factors; but the portable high pressure fog unit is restricted only by the absence of water and the distance the fire is from water, if the water supply is not large enough to use a relay pumping system. However, it would be very impractical to carry a high pressure pump with a capacity of four gallons per minute any place where there was sufficient water supply to accommodate the conventional pumps. For that reason it is difficult to see the value of a portable high pressure pump for use on a forest fire.

Something should be said about fog and the intensity of a fire. A fire of great intensity will be more efficiently controlled if a greater amount of fog is used on it. In other words, a high pressure fog pump with a capacity of four gallons of water per minute should not be expected to control a fire of great intensity as efficiently as a pump with a capacity of forty gallons of water per minute. The reverse is also true. Nothing is gained by pumping forty gallons of water per minute on a fire that a four gallon per minute pump will handle. A

reasonable amount of fog (four gallons per minute is not reasonable) is effective on any fire regardless of its intensity. However, there are cases where a solid stream applying a great volume of water to the fire would be quicker than fog. In this case a good water supply is essential.

## LOW PRESSURE FOG

### Equipment

Low pressure fog is so named because of the low pressure required to produce it. A specially constructed nozzle is used with the low pressure which results in a fine spray. According to Everts these nozzles operate at a nozzle pressure of one-hundred to one hundred and fifty pounds per square inch, and they (the nozzles) can be used in conjunction with portable pumps, tank trucks and gravity hose lines in steep country.(1) This makes matters quite simple for forest fire protection agencies as they already have on hand the conventional portable pump and hose to go with it. Many fire organizations also have tank trucks to facilitate quick initial action on fires. For such fire organizations to convert to low pressure fog, it would require the purchase of some low pressure fog nozzles to replace the standard solid stream type nozzles. This is convenient in that a change of nozzles gives the operator a choice of fog or a solid stream -- whichever he desires or needs.

### Fog Absorbs Heat

The fog droplets of low pressure fog absorb heat of a fire the same as the high pressure fog droplets do. Then what is the difference between a high pressure and a log pressure fog droplet? The difference is the size of the fog particles. Everts states that there are approxi-

mately twenty-three million fog particles per gallon of water in low pressure fog.[1] This means that the size of the droplets for low pressure fog is much larger than that of the high pressure droplets. There are approximately three hundred times as many high pressure fog droplets as low pressure droplets per gallon of water; which means that there is a larger total surface area for the high pressure fog than for the low pressure fog per gallon of water. In other words, the low pressure fog will not absorb as much heat nor as fast per gallon of water as does high pressure fog. Therefore, the effect of low pressure fog on a fire will be less rapid and the maximum efficiency of the water used will not be obtained.

Smothering Action

Because of the large size of low pressure fog droplets, they do not absorb enough heat to cause the entire droplet to be converted to steam instantaneously. The entire fog particle will probably be converted into steam in time, but it is the instant conversion of the water into steam that is important. The slower conversion of water into steam does not make as dense a blanket of fog over the fire. Again, the maximum efficiency of the water particles is not reached, and the smothering effect of the fire is less.

Wetting the Fuel

Since the low pressure fog particles are larger than the high pressure fog particles, they are heavier and will carry farther and will penetrate deeper into a fire. The fog particles that are not converted into steam will reach the fuel and wet it down. This helps extinguish the fire but the process is slower than when the fog particles are completely converted into steam.

Where To Use Low Pressure Fog

It has been pointed out that fog nozzles can be used on portable pump and tank trucks. For that reason low pressure fog can be used wherever the solid stream could be used. The tank trucks, of course, are limited by topography and roads as is the case of high pressure fog mobile units. The fog can be used on any kind of fire that the fire fighter might be called upon to fight.

The operator should understand the importance of fog and know when to use it. If speedy action on a fire is needed, use fog. If water is limited and has to be hauled in a tank truck, again use fog for the conservation of water. On the other hand, if quick action isn't necessary and there is an unlimited source of water, it is all right to choose either fog or solid stream.

## NOZZLES AND SPRAY PATTERNS

The manufacturers of high pressure fog equipment produce a special fog gun. This gun can be easily adjusted from a wide close-up pattern to a long reach fog stream by turning an adjustment on the barrel of the gun. The gun is equipped with a trigger shut-off so that fog can be turned on or off as the operator desires, and without disturbing the adjustment. There is a trigger latch to eliminate constant gripping when necessary. The wide close-up spray pattern looses its velocity within a few feet upon leaving the nozzle. It does not afford much protection to the nozzle man because the pattern is not more than twenty-four to thirty inches across. When the fog gun is adjusted to the long reach position, the fog is extended out a distance of sixty to seventy-five feet. The fog is very coarse

and is never as fine as the wide close-up pattern. The long reach stream is effective in cooling down a fire so that the nozzle man can get close enough to use the close-up pattern. This gun is for use on forest fires and grass fires. There are other nozzles being used by municipal fire departments that have varying pattern forms. Most high pressure fog nozzles have moving parts in the nozzle that break up the water as it is forced through the mechanism.

There are also many low pressure fog nozzles, each having a definite spray pattern. The patterns vary from a circular spread of twenty-six feet in diameter down to patterns that are only a few inches in diameter. The greater the diameter of the pattern, the shorter the distance that the fog will reach out from the nozzle. The advantage of the large diameter of the fog pattern is that it gives protection to the nozzle man from the heat and allows him to get closer to the fire.

The nozzle operator can direct the fog, or for that matter, any stream of water on to a fire with greater ease and effectiveness at a close range than at a distance of seventy-five to a hundred feet from the fire. Adjustable nozzles for low pressure fog have been tried but without much success. They are complicated mechanisms and the operators are not schooled in the technique of effectively operating them. Operators are inclined to use one or two different adjustments that they like even though other adjustments are more effective. Low pressure fog can be created by any one of several methods or a combination of them. The popular method is to impinge several small jets or streams utilizing the force of the streams to partially oppose each other. The bucking action breaks the form of the streams and produces

the fog. Low pressure fog can be projected under control, a distance of approximately twenty-five feet from the nozzle. This is the main reason for the necessity of protection to the operator to enable him to get close enough to the fire to use fog. The greatest effectiveness in fog application for general service in forest fire suppression seems to be a circular form, solid pattern fog of uniform density throughout the pattern. Low pressure fog nozzles are made for a capacity ranging from two and one-half gallons to fifty-four gallons of water per minute.

The spray patterns of both types of fog are more effective when applied at the point of maximum temperature instead of directly on the fuel base. A light passing of the fog over the flame of a grass fire immediately extinguished the flame, according to the Forest Fire Protection Notes.(4)

## LOW PRESSURE VERSUS HIGH PRESSURE FOG

There is some doubt as to whether high pressure fog is better than low pressure fog. Extensive studies will have to be made to definitely determine the value of one above the other. Probably low pressure fog will become more widely used by forest fire fighters than high pressure fog. The simplicity of converting to low pressure fog is a marked advantage. The cost of installing high pressure fog is many times greater than the cost of installing low pressure. This is another advantage of low pressure fog.

High pressure fog for mop-up is excellent. The velocity, when the fog gun is adjusted correctly, gives a tearing force. The duff and ground can be torn up; charred material can be knocked off logs.

Low pressure fog does not have the force as does a solid stream at the same pressure or as high pressure fog. For that reason low pressure fog is not as effective in mop-up work as far as extinguishing fire that is in the ground is concerned, but will work all right on material above the ground.

Both types of fog are excellent for dispersing smoke fumes and poisonous gases. This aids the operator.

Fog of either type is excellent for supporting back-fires. Orell, in his article on high pressure fog, says that in light duff, fern or grass it is possible to set back-fire against the wind without having a trail constructed and that the operation will be safe. The fog machine makes it possible to set back-fires more rapidly which is essential for effective control of the fire.(3) There is no apparent reason why low pressure fog would not work in the same way on back-firing, except that more water would be used for the same distance that is covered by high pressure fog.

Since high pressure fog has a negligible conductivity, it is safe to use on high voltage electrical fires. Such fires may occur where high voltage power lines run through the forests.

## CONCLUSION

Fog for forest fires is in its infancy. Much will have to be done before all the advantages and disadvantages will be worked out and fully understood. It is imperative that efficient methods of fire control be developed because of the increased fire danger. This augmented danger has been brought about by the great accumulation of slash in the Douglas-fir region. At present, fog seems to be the answer, and it will probably be only a matter of a few years before fog will be fully developed. Fog had its place in the war, and it will undoubtedly find a place in forest protection, in combating the forests' greatest enemy -- fire.

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