Fire Engineering

FIGHTING FIRE WITH WATER

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USING WATER WISELY

BY WILLIAM E. CLARK

Thousands of years ago, a caveman urinated on a small campfire and was surprised to see that it went out. Thus was born modern firefighting. Although we now use considerably stronger equipment, we still extinguish fires by squirting water at them.

This was not a controversial subject until 1863, when Dr. John Oyston of Little Falls, New York, obtained a patent on a spray nozzle and began to market it. Oyston, whose doctorate was in mechanical engineering, was eloquent in promoting his nozzle. He pointed out that when a water stream was broken into many tiny drops, the total surface exposed was much greater and therefore would absorb more heat. Furthermore, it would vaporize into steam quicker and thus absorb maximum heat. It was not long before fire chiefs were taking sides in the argument of fog vs. solid stream.

When researching the subject in 1956, I read some of these arguments in literature from the 1800s at the City of New York (NY) Fire Department library. The same arguments are being offered today.

In 1963, I found an Oyston nozzle in a museum and borrowed it. I had an adapter made to fit it on available 212-inch hose and gave the nozzle some tests. It was unique in design and superior in performance to modern fog nozzles, yet it enjoyed relatively short acceptance and was soon forgotten. From 1900 to 1937, fog nozzles were virtually unknown in American fire departments.

RESURGENCE OF FOG

The U.S. Navy was largely responsible for the resurgence of fog in the postwar years. During World War II, the Navy`s official nozzle was a combination spray and solid-stream device with two openings--one for fog, the other solid stream--that could be used alternately by moving the handle. The fog head could be quickly replaced by an applicator, a long pipe with another fog head. For the fuel oil fires in simulated engine rooms at Navy fire schools, these nozzles were quite effective. Nearly all the instructors were city firefighters who were enthusiastic about these nozzles when they returned from the Navy at the war`s end. At the same time, the nozzle manufacturer seized the opportunity to promote fog as the great cure-all for which the fire service had been waiting. Oyston`s theory was reintroduced, and fog was advocated not just for oil fires but for all kinds of fires.

Layman`s theory. During the war, the Coast Guard Fire School, commanded by Lloyd Layman, also used Navy nozzles. Layman made a discovery there that almost revolutionized American firefighting. It became known as the "indirect application of water fog." I had the privilege of being a friend of Layman`s and of having him explain his theory to me directly.

First, he told me that the discovery was accidental. They were using an old freighter for training sessions and started a fuel oil fire in the engine room. When they tried to enter, it was too hot; so they sought to cool it by sticking an applicator with a fog head into the skylight at the top of the engine room. The fog quickly turned to steam, which filled the entire engine room and smothered the fire.

When Layman returned to his peacetime job as fire chief of Parkersburg, West Virginia, he tried this method on structural fires and became so satisfied with it that he published a book about it. The method was quickly embraced by many fire departments throughout the country--especially those in smaller communities, some of which tried to use it as their only method.

The principle is very simple: Aim the fog stream through a window toward the ceiling. The water will expand about 1,700 times as it turns to steam, and the steam will smother the fire, even in places remote from the point of application.

Rules for success. Several rules must be met to obtain success, however. Layman told me the first three, namely:

1. The water must be in spray (fog) form.

2. The ceiling temperature at the site at which the water is applied must be at least 1,000°F.

3. Confinement of the steam within the building is essential to utilize the smothering effect, although cooling will extinguish the fire in the area where the water is applied.

Based on my own observations at several full-scale test fires, I offer two additional rules:

4. The effectiveness of steam smothering is in inverse proportion to the amount of ventilation. Even a small opening through which steam can escape will lower effectiveness considerably.

5. The effect of steam smothering is permanent on liquid fires but transitory on solid fuels because they hold heat longer and will reignite as the steam dissipates and is replaced by air. In one of our tests, the remote fire darkened by steam rising through a shaft was burning briskly again two minutes later.

Some will point out that the expanding steam can cause burns. There is ample evidence that this happens frequently to firefighters in the immediate fire area but not much to indicate that it happens to building occupants in remote areas. Some cases of skin burns have been reported. Theoretically, burns are likely because moist heat causes burns quicker than dry heat and at lower temperatures.

The 1970s and 1980s saw a notable trend among small departments to adopt the aggressive interior firefighting of their big city neighbors, and the indirect application of fog lost its popularity.

Fog nozzles. Back in the 1940s, we heard of "high-velocity" and "low-velocity" fog nozzles. The terms were never very apt, are no longer in general use, and should not be confused with "high-pressure" fog--something quite different, which was popular in the 1950s but fell into disuse because of its limitations. Firefighters with long memories will be surprised to hear that this fad of the 1950s is now being advocated in England and even in some parts of America.

Once again, the theory was sound but fell down in practice. If finely divided water absorbs more heat, then the finer it is, the better; and this can be accomplished by using extremely high nozzle pressure. However, the 600-psi nozzle pressure restricted hose diameter and flow, and 30 gpm will not extinguish much fire no matter how finely it is divided. Furthermore, the high-pressure stream entrained a tremendous amount of air that would accelerate the fire in areas ahead of the spray.

Thirty gpm will not extinguish a fire that requires 50 gpm, and 50 gpm will not put out a fire that needs 60 gpm, and so on. Probably the most important rule in firefighting is that every fire requires a given amount of gpm no matter what the pressure is and regardless of whether the water is in the form of fog, straight stream, or solid stream.

CRITICAL RATE OF FLOW

The minimum flow required to extinguish a fire is called the "critical rate of flow," a term sometimes wrongly defined as "the flow needed to absorb the heat as fast as it is generated."

This is wrong because much of the heat is absorbed by nearby materials, and much escapes outside by radiation and convection, leaving only a portion to be absorbed by the water. The most accurate definition is "the water flow needed to reduce the temperature of the burning material to where it no longer emits the flammable gases which are the fuel."

It is not sufficiently understood that the mechanism by which water extinguishes fire from most solid fuel sources is by removing the fuel through cooling the fuel source. How then do we determine the amount of flow needed?

Royer-Nelson theory. In August 1958, Keith Royer told me that he and his associate Bill Nelson at Iowa State University had developed a formula that answered that question. It was so simple that I laughed when I heard it and expressed my skepticism; but after I had tried it at test fires of various kinds and sizes, I became a believer.

These tests showed the formula worked whether the building was closed tight or well-ventilated and whether fog or solid stream was used. Also, the formula was well above the critical rate, allowing a comfortable margin of safety regardless of whether the fire area was small or large. One of our tests showed a fire with a fuel load of 50,000 pounds of lumber in a room of 82,000 cubic feet could be knocked down with a flow of 750 gpm in 26 seconds.

Attempts have been made to modify or replace the Iowa formula, but it should be left alone. One such attempt is the ill-founded formula of the National Fire Academy, based on the guesses of a group of students, which apparently has never been tested.

Many firefighters will ask why we should bother with formulas. Most of our fires are of the room-and-contents type and can be extinguished with any kind of nozzle and hose; even a garden hose can do the job. This is very true. The formula is for the other 10 percent of fires.

The formula can be valuable in several ways. It can assist in prefire planning by showing the flow that may be needed. And, as shown in Firefighting Principles and Practices, it can be extrapolated to give the needed numbers of pumpers and firefighters.

It is also a valuable tool on the fireground. If a fire continues to burn in the presence of the fire department, the rate of flow is not sufficient or the water is not coming in contact with the burning material. If the formula shows the water flow is adequate, the problem obviously is being caused by the other factor.

Just as there was a strong move toward the use of fog nozzles in the 1950s, there is a strong move toward solid streams in the 1990s. The trend involves heavy-stream devices as well as handlines. A survey in one state shows that more than 75 percent of its departments are using solid-stream (smooth-bore) nozzles on their initial attack lines. Many cities have switched to them on deluge guns, deck pipes, and aerial pipes.

The question arises: Why does the cycle appear to be going full turn again? Oyston`s and Layman`s methods were based on sound scientific theory, so why is there a difference between conceptual and perceptual knowledge regarding water application? There is a scientific reason and tests to prove it. This will be discussed in a future issue of Fire Engineering.

Of course, a fire can be extinguished without water--by high-voltage electric fields and sound waves, for example. The fire service, however, has long ignored these methods. Meanwhile, remember you must "put the wet stuff on the red stuff" in the right amount and in proper fashion. n

WILLIAM E. CLARK has had a long and distinguished fire service career and has long been an advocate of firefighter safety. He spent 20 years in the City of New York (NY) Fire Department, where he rose to the rank of battalion chief. He also has served as an industrial fire chief. Clark founded the International Society of Fire Service Instructors and was its president. He has served as chairman of the National Fire Protection Association committee on protective equipment and chairman of the International Association of Fire Chiefs training and education committee. He is the author of Firefighting Principles and Practices, published by Fire Engineering Books.