

Righting a Wrong

By John D. Wiseman

In 1966 Warren Y. Kimball, who was then Manager of the Fire Service Department of the NFPA, wrote two books published by the NFPA on FIRE ATTACK. In Chapter Six, of volume one, titled “Estimating Required Fire Flows”, on page 82 at the beginning of this Chapter he wrote two paragraphs starting with the following sentence.

“Theoretically, if water is applied in the form of fog with maximum efficiency, one gallon of water will generate 223 cubic feet of steam.”

Warren Kimball began this sentence with “theoretically” for a reason. In the next paragraph he says that “Such theoretical considerations seldom work out under actual fireground conditions.” This is a highly puzzling statement when one considers the scientific facts related to the expansion of liquid water to steam. The expansion of one gallon of liquid water to 223 cubic feet of steam occurs at a temperature of 212° F (100° C). The ignition temperatures of all fuels (300° F to 400° F) is well above the temperature needed to convert water to steam, and flame temperatures range on upward far above ignitions temperatures.

So what fire “condition” could possibly prevent the conversion to steam? Warren Kimball doesn’t say anything about this. Is there anything from his experience that supports the truth of this statement? Is there any scientific research? Warren Kimball gives us nothing to justify the truth of his statement.

Warren Kimball does say that

“It is seldom possible, using hose streams, to apply water evenly and efficiently over an extensive fire area without using considerably more water than might be necessary if the water distribution could be scientifically engineered as is the case with automatic sprinkler installations.”

What does “extensive fire area” mean? We are talking about a structure fire, so certainly this does not mean a one room, or even a two room fire. The example used by Warren Kimball in Chapter Six is a three story building of 150,000 cubic feet with a required fire flow estimated to be 4,500 gpm. This building would have to be located in a large metropolitan area so that at least nine pumper companies would be available to provide the needed fire flow.

A fire involving all or a major part of this building would qualify as an “extensive fire area”. However, large fires in larger buildings are not typical fire fighting encountered by most fire departments. The NFPA reports that 75% of all structure fires are in one or two family detached houses, and that almost the same percentage is confined to the room of origin using a single attack line. So we need to separate our analysis into two parts: first, confined structure

fires, and second, larger open structure fires. A confined structure fire is defined to be one in which the roof or ceiling is intact. A fire burning out a window or a door is still a confined fire. So let's not consider an extensive fire but structure fires confined to a single room, or maybe two. It makes a great deal of difference whether a structure fire is confined, or not. An open structure fire certainly takes more water to achieve extinguishment than would be required for a confined fire. Warren Kimball is right here. If a structure fire is open, than a factor of safety would be at least three, or four, times what is required for a confined structure fire.

Let's go back to 1966 when Warren Kimball's books were published. . The conversion from smooth bore nozzles began in the United States in 1950 with the speech delivered by Chief Lloyd Layman of the Parkersburg W.V. fire Department to the FDIC Conference held at Memphis TN. His speech, entitled "Little Drops of Water" was published by the NFPA. NFPA later published two books by Chief Layman. He is credited with introducing a new method for fire attack to the fire service, the Indirect Method with Atmospheric Displacement. Chief Layman recognized that the industrial type fog nozzles were not suitable, and that he had not solved the problem of how much water is needed in a fog attack.

An Exploratory Committee worked for a number of years arranging tests, producing videos that promoted the use of fog nozzles. Still little was known through the 1960s about the scientific foundation of the use of fog nozzles. Research begun at Iowa State University at the Fire Service Institute by Keith Royer and Bill Nelson continued for years and involved the burning of more than 75 structures. These two men discovered a number of scientific facts about fire behavior and fog tactics. The most notable is the Iowa Rate-of-Flow formula. That became widely known through two articles appearing in Fire Engineering magazine.

The second sentence on page 82 of Warren Kimball's book states, in essence, the Iowa Rate-of-Flow formula.

"And if water could be applied with 90 percent of its theoretical extinguishing capacity utilized,, one gallon of water per 100 cubic feet of fire area might generate sufficient steam to cool a fire within 30 seconds."

There is no doubt that these three numbers constitute the Iowa Rate-of -Flow formula Yet it is the professional responsibility of every author to clearly identify the source of every idea that is not his own. I will not speculate as to why Warren Kimball failed to do what is clearly his duty. There is no excuse for this failure.

The research of Royer and Nelson in no way can be characterized as theoretical. Their experiments (75) were conducted in a scientific way, and their data was analyzed very carefully. Their conclusions were based upon actual fireground conditions and always worked out consistently with the underlying theory.. Kimball's claim that "theoretical conditions seldom work out under fire ground conditions" is simply not true for this research. In other words, one gallon of water applied to any room fully involved in fire will always generate 227 cubic feet of steam without any exceptions.

The Iowa rate-of-flow formula was not stated by an equation, which lead everyone, including Warren Kimball, to misuse this formula. The ratio V/100 is valid only for a time of 30 seconds. Keith Royer used this ratio to determine whether a fire department could provide the needed fire flow (NFF) for structures in its district. In other words, is the fire department able to provide the NFF to control all structure fires in a time of 30 seconds? The equation should be written as follows:

$$\text{NFF}_{30\text{sec}} = \frac{\text{Vol}}{100}$$

This equation gives a NFF of 0.01 per cubic foot (1/100). Keith Royer recommended that this formula be used only to determine the ability of a fire department to handle structures in its district.

There was a second error that occurred in the use of the Iowa Rate-of-flow formula. Keith Royer said that his formula should be used only for the largest open area of a structure, not for the volume of the entire structure. Royer believed that a structure with many rooms would not become fully involved within ten minutes, the maximum response time for a fire departments.

Warren Kimball's final statement is:

A desirable factor of safety where extinguishment is to be chiefly by hose streams would appear to be at least three to one and in many cases a factor of four to one would be justified

Warren Kimball worked with data supplied by fire departments throughout the United States. His conclusion is right. For larger open fires in larger structures, the rate of flow must be increased by a factor of three or four to provide enough water to control such fires. A factor of four gives the following formula.

$$\text{NFF} \times t = 0.04 \times \text{Vol}$$

This formula should be used with larger open fires in larger structures.

The Royer-Nelson formula for confined structure fires follows:

$$\text{NFF} \times t = \frac{\text{Vol}}{200}$$

where the constant "200" is based upon two scientific facts.

1. One gallon (3.78 L) of water expands instantly at 212° F (100° C) to 227 cubic feet (6.424 L) of steam. This number is rounded down to 200 cubic feet (5.660 L) to allow for 90% conversion to steam at 212° F (100° C)
2. One gallon (3.,78 L) of water with a margin of safety absorbs all the heat produced by the oxygen in 200 cubic feet (5,660 L) of normal air.

This formula gives a rate-of-flow per cubic foot of 0.005 per cubic foot with using a fog nozzle. This means that the efficiency and effectiveness of a full fog attack upon a confined structure fire is far greater than that of smooth bore nozzles. Many people in the fire service do not realize the vast difference between the efficiency and effectiveness of these two types of nozzles.