fire service information

fire service education
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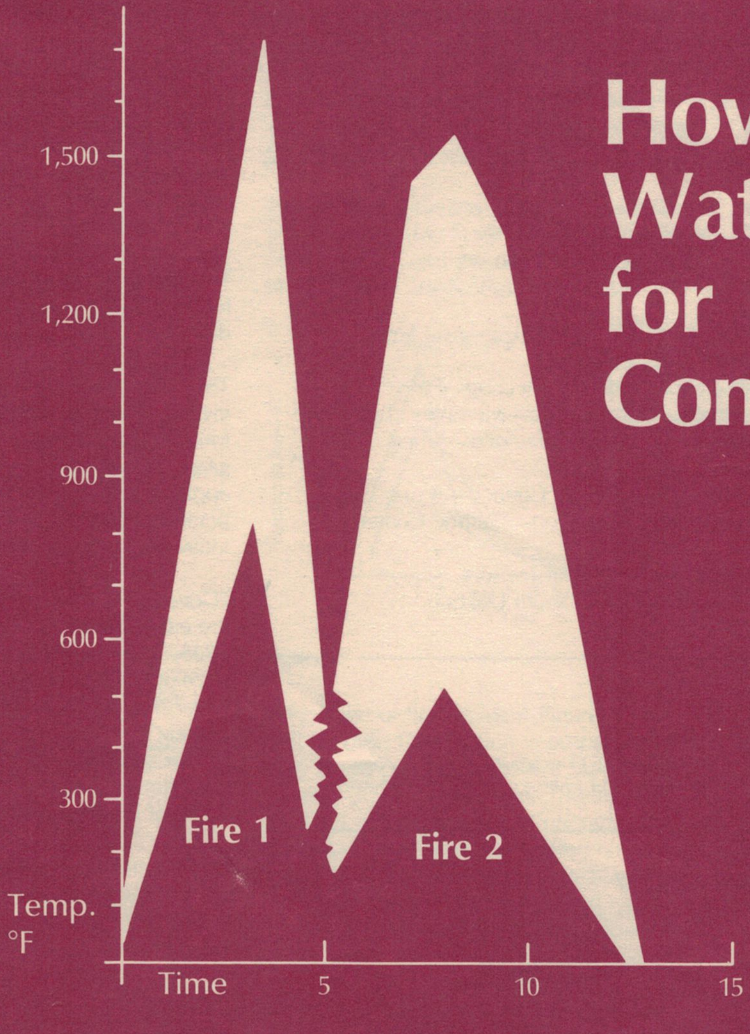

How Much Water Flow for Fire Control?

Water for Fire Fighting—How Much and How to Apply It!

by Keith Royer and Floyd W. Nelson

Editor's note: This month's feature article is reprinted from the August, 1959, issue of "Fire Engineering." Why, you may ask, are we reprinting information over twenty years old? The answer is twofold. First, the information is as valid today as in 1959. As a matter of fact, use of the rate-of-flow formula during these twenty years has continued to prove its value.

Second, we have learned more about how to use (and how not to use) this concept. We have learned that this is an excellent strategic planning tool. It has become the foundation block for Fire Protection planning—i.e.: application to master planning, manpower requirements and deployment, target hazard analysis, equipment requirements, code development, and much more.

However, it is not a tactical tool. That is, it should not be used to decide how to attack a fire after arriving at the scene. It is a planning tool you can apply now—before the incident. Read on and discover what the rate-of-flow formula can do for you.

Two important questions which seem uppermost in the minds of many firemen are: At a given fire how much water do we need and how should the water be used? Lacking even a suggested formula for determining flow rates for a specific fire, many fire officers have developed some method of their own for "guesstimating" the required flow. The big problem is that it is generally so vague that few officers can explain just how this is done. As a result there is no way to pass this information on to a new fireman who needs and wants this information. Hence he must wait until he has had enough actual experience to develop the means to answer this question to his own satisfaction.

After several years, and hundreds of experiments, a rate-of-flow formula has evolved which seems to be a practical answer to the first question. This is based on the following data:

1. Study of expansion ratios of water to steam indicates that 1 gallon of water will produce, with a margin of safety, 200 cubic feet of steam

2. Study of heat production in relation to oxygen also indicates that in the conversion of water to steam, 1 gallon of water will absorb, with a margin of safety, all of the heat that can be produced with the oxygen available in 200 cubic feet of normal air.

These two factors lead to the formula: Cubic area in feet divided by 200 equals the required gallonage of water for control of a specific area involved in fire.

Experiments have shown that this formula was sufficient as a rule of thumb for the required amount of water, but it still did not establish the necessary rate of flow.

Analysis of time temperature curves, prepared from test fires both in Iowa and by the National Exploratory Committee, indicate that results are best when rate of flow is sufficient to introduce the required amount of water into the area of involvement in 30 seconds.

This led to a rule-of-thumb rate-of-flow formula: GPM equals cubic area in feet divided by 100.

The cubic feet in the formula refers to a given cubic area involved in fire. The formula gives an ideal rate of flow for a given fire situation. Its successful application definitely requires pre-fire planning. The following quotation* is interesting at this point:

"Developing a formula for water flow for fire extinguishment is not new. As early as 1925, Engineer Stanzig in Vienna developed a procedure for determining water flow for given fire test situations. Stanzig's experiments and experiences were further substantiated by Chief Fossoult of Anderlecht, Belgium, and later by Chief Folke of Fredericksburg, Denmark.

"Elaborations of the Danish experiments have shown that a formula may be worked out for a minimum superior jet as a function of time. This formula holds only: (1) when the scene of the fire is not too large for the jet to control the entire area, and (2) if the fire is still principally in the combustion stage without large amounts of glowing coals or other hot substances.

NFPA Quarterly, April 1947, Vol. 40, No. 4, "Deductions from Research on the Use of Water," H. Adeler, Chemical Engineer, Danish Fire Protection Committee.

coming events 1982

February 20	Joint Council of Iowa Fire Service Organizations—Ames
March 6-7	National Fire Academy Courses—Ames
March 28	Iowa Firemen's Association Mid-Year Meeting—Perry
March 28-April 1	Fire Department Instructor's Conference—Memphis, Tennessee
May 4-7	Iowa Fire Department Instructor's Conference—Ames
June 15-18	58th Annual State Fire School—Ames
July 30	Iowa Fire Service Education Advisory Council—Ames
September 16-19	Iowa Firemen's Association Convention—Guthrie Center
September 25-26	Tri-State Fire School—Keokuk
October 2-3	International Society of Fire Service Instructors Mini Fall Conference—Sioux Falls, South Dakota

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"In other words, in the case of many fires reached in the early (ignition and combustion) stages, it is deduced from the plotted figures arrived at that $Q = t \div 100$.

"Q is the liters per minute per square meter of burning surface, and is in minutes. (The formula, with Q as U.S. gallons per minute per square foot would be roughly $Q = 5/4{,}000$.)

"In practice this means that ½ liter per minute per square meter (roughly ½ quart per square yard) of floor area will produce a fire stream superior to an ordinary fire. If there is already much heat at the scene of the fire, 5 liters per minute per square meter (roughly 1 gallon per square yard) will, as a rule, still be superior.

"The results of the Danish experiments conform to the views of Stanzig. The 'standard' jet or stream of 500 liters per minute (130 U.S. gallons) has thus proved to be rather large. In the majority of cases, 200 liters per minute per 100 square meters (about 50 U.S. gallons per minute per 1,000 square feet) would suffice. Often even half this amount would be sufficient."

While test fires are seldom lost, time temperature curves of experimental fires reveal many cases where trouble was encountered either in knockdown or overhaul. The following composite graphs were prepared from the study of many time-temperature curves of actual fires where the formula was tested.

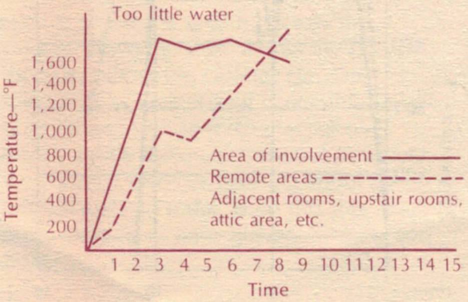

Figure 1

When the rate of flow is too small in relation to heat production and accumulation, there may be only a slight temporary reduction in temperatures in the fire area. Rate of heat production in remote areas may be increased. Figure 1 would also be typical of circumstances where the rate of flow was ideal but proper distribution was not made.

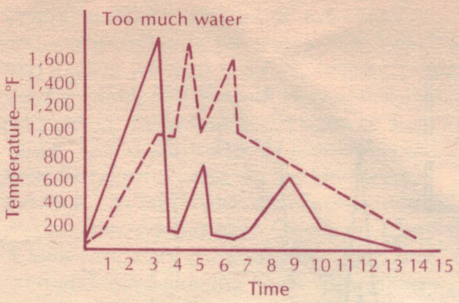

Figure 2

When the rate of flow is substantially greater than ideal, the temperature drop in the fire area will be very rapid, steam production will be limited, and heat production will increase in remote areas. Smoke from smoldering fuels will hang in the cool atmosphere of the area complicating overhaul, sometimes to the extent that spot fires will come back as illustrated by figure 2. This will also delay control of fires in remote areas especially if the only approach to these areas is through the area of first involvement.

The above conditions can also be created when rate of flow is ideal but application is continued beyond the point where the fire in the area of application blacks out.

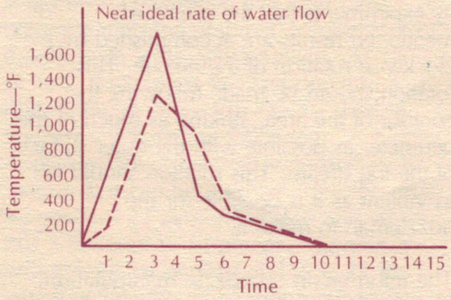

Figure 3

When rate of flow is ideal (figure 3), results will be best. Distribution is proper and the flow is stopped when the fire blacks out (usually 20 to 30 seconds). The area will be filled with steam and temperatures will continue to fall after application is stopped. Steam will flow into remote areas where heat or fire may have spread and temporarily suspend heat production in these areas. Temperatures in the area of involvement will be relatively high—200°F to 400°F at ceiling level—and smoke in the area will lift rapidly. Overhaul crews will be able to move in to extinguish spot fires in both the main area and the remote areas.

Examinations of figures 1, 2, and 3 indicate that results were less than ideal when the rate of flow was either above or below the ideal rate. This posed the additional question as to why excessive application of water would complicate fire control.

The only possible answer seemed to be that excessive application would limit steam production and that the smothering effect of the steam produced was a more important factor in fire control than heretofore considered. This led to setting up tests to determine the relative importance of steam production.

The time-temperature graph (figure 4) was recorded at Story City, August 1954. This was a residential-type structure. The fire involved the three rooms illustrated. All doors and windows were intact enabling close control of air flow to the fire. The fuel load was composed of light wooden crates and cardboard boxes and was somewhat heavier than would be encountered in the average residence.

The fire was ignited in rooms 1 and 3 simultaneously and spread into room 2. The front door was left open for the first 2 minutes as the men who had ignited the fire watched it build up from the doorway. The temporary leveling off of temperature rise between the second and third minute was a period during which the fire was apparently forced to set up new patterns of air flow when the front door was closed. When the available oxygen in the area was consumed at the end of 4 minutes, heat production slowed and temperatures dropped rapidly. During the next 12 minutes temperatures rose and fell as the fire breathed.

At the end of 17 minutes the front door was opened slowly to allow temperatures to build up in the area. At 19 minutes, application was made into room 1 in an attempt to determine if steam produced here would affect the fire in room 3. The application of water in this case was somewhat clumsy. The nozzle pattern was not adjustable to fit the area and the rate of flow was excessive. Results did show, however, that steam produced in one area would have a marked effect on a fire in another connected area.

Overhaul was purposely delayed to see how long the steam blanket would hold. The graph shows the steam held for only about 1 minute and the fire in room 3 came back rapidly.

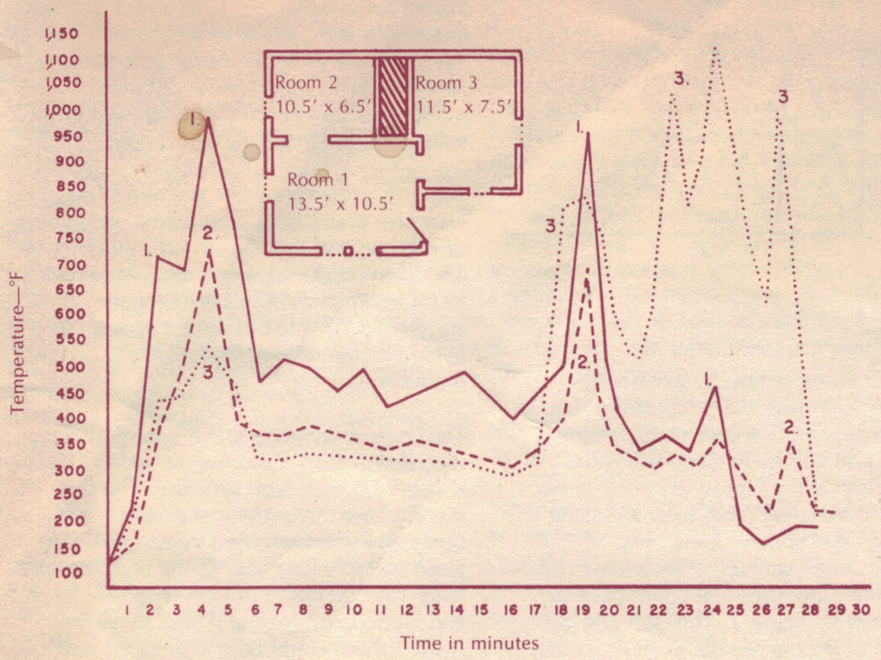

Figure 4

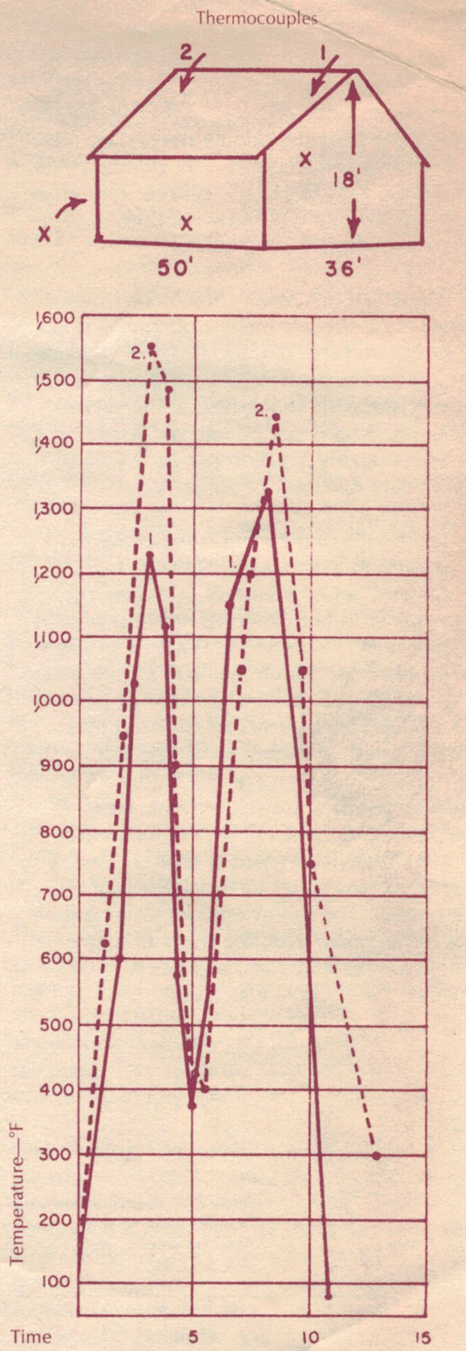

Figure 5. Wilton Junction 8/28/58—test fire in barn. Temperature 90—humidity 85—wind none. Water flow three 100 gpm fog streams from points x. Nozzles were allowed to flow for about 20 seconds at the 3-minute point on the first fire and at the 7-minute point for the second knockdown.

Application of Ideal Rate of Flow

It was noted in experiments in 1953 that almost all motion of flame, smoke, and visible air currents were in the same direction. Specific experiments were set up to determine what effect various nozzle movements had on this apparent natural phenomenon. The direction of motion was to the right, or clockwise, as it was observed from the base.

After many experiments, the following was observed. When rotating the nozzle in a clockwise manner (1) most of the heated gases and smoke were driven away from the nozzleman; (2) any flame close to the nozzleman was driven away from him; (3) the steam formed by the application had a particularly violent rolling action; (4) the fire knockdown, by many timed experiments, was faster and the efficiency of the water was increased.

By rotating the nozzle in a counter-clockwise manner (1) a greater portion of the heated gases and steam were drawn toward the nozzleman; (2) any flame close to the nozzleman was drawn back toward him; (3) the steam formed by the application was very inactive and moved in a lazy fashion; (4) the fire knockdown was not particularly fast and efficiency of the water used was reduced.

Several attempts have been made by qualified people to explain this phenomenon which occurs with the clockwise rotation of the nozzle into highly heated areas. At this writing no satisfactory answer or explanation has been provided. However, there are strong indications that it involves natural forces which are at work on the molecule. It is known and proven by experiments that the previously mentioned results are accomplished by the clockwise rotation of the nozzle. This rotation should be made following the contour of the area, striking as much of the perimeter as possible with the outer surface of the fog stream. This rotation should be as violent as it is possible for the nozzleman to make it.

The information on nozzle manipulation, like rate of water flow, is not new. Chief Officer F. Folke, Fredericksburg, Denmark, in his paper "Experiments in Fire Extinguishment"* stated:

"Experiments as early as 1930, also, uncovered the importance of nozzle manipulation. Stanzig concluded a high nozzle pressure was still considered important—9 to 12 atmospheres (130 to 175 pounds). This was to obtain good distribution of the water from the ricochet effects. Good distribution was aimed at by very energetic movement of the nozzle pipes. Stanzig said, 'The nozzle pipe movement must be just as violent as bayonet fishing.'

**NFPA Quarterly*, Oct., 1937, Vol. 3, No. 2.

Herb Cohen "You Can Negotiate Anything"

"Following this principle, in Vienna it was customary to run out a few light hose lines quickly and after a few minutes the fire would be knocked down in most cases. As a result of this research on water flow and application, building codes and fire fighting equipment in Vienna were redesigned to conform to the findings of these experiments:

1. Laws enforced to subdivide buildings, particularly those of dangerous occupancy, into fire areas or compartments not exceeding 500 square meters (about 5,000 square feet).

2. In order to assure speedy turnout, many small stations were scattered all over the city. The engines were small and light. The cars had a water tank of 560 liters (150 U.S. gallons), could pump 250 to 350 liters per minute (60 to 90 U.S. gallons per minute) at 25 to 20 atmospheres (375 to 300 psi) through 400 meters (1,300 feet) of 2-inch standard hose

3. Each squad was equipped to master fires of 250 square meters (2,700 square feet). To buildings where fire areas were greater additional squads would be sent."

The proper distribution of water fog on the initial application is very important and the nozzleman must understand what he is trying to accomplish. The fog pattern is adjusted so it will just reach across the area involved. The nozzle is placed inside the area and rotated—following the contour of the area—striking as much of the perimeter of the area as possible with the outer surface of the fog stream. Across the ceiling, down the side, across the floor, up the side, across the ceiling, etc. This rotation is as violent as it is possible for the nozzleman to make it. In placing the nozzle inside the area, it should be inside the window or other opening about an arm's length. In order to do this the nozzleman must have gloves, helmet, and protective coat.

The purpose of rotating the nozzle is to obtain steam production over as much of the area as quickly as possible. When the water strikes any of the heated material in the room momentarily, it creates a steam blanket. If nozzle rotation is rapid enough, this steam blanket will hold until the nozzle has a chance to get around to that spot again. If the rotation is too slow, this steam blanket will not hold and the fire which has been knocked down will build up before the nozzle passes its way again.

In addition to the amount of water flow and manipulation of the nozzle, air flow into a given fire area is an important consideration. The amount of heat that is released by burning different types of fuels varies. This characteristic of fuel is referred to as its calorific value. In the Fire Service the fuels can be divided into two general classes with average calorific values: Class A fuels—ordinary combustibles—fuels that burn and leave glowing coals. This group has an average calorific value of 8,000 Btu's per pound. Class B fuels burn primarily on or above the surface and leave no glowing coals. For this group we use an average calorific value of 16,000 Btu's per pound.

The above figures are not of too much value to the fireman in thinking of fire extinguishment. They provide a means of figuring the amount of heat there will be if the contents of a building are entirely burned, and are of interest to people who design buildings to withstand fire.

The fireman is more interested in the amount of heat that is being produced when he makes his attack and the fact that the oxygen supply to a fire does more to set limits on heat production than the amount of fuel available.

It has been determined that with most common fuels the union of 1 cubic foot of oxygen with a fuel will produce 535 Btu's of heat. If we break this fact down to a rule-of-thumb figure that can be used by firemen, we have the following: Approximately 7 percent of normal air is oxygen that can be used by a fire. Normal air contains 21 percent oxygen and when this is lowered to 14 percent, burning is arrested. Seven percent of 535 is 37 Btu's, which is the amount of heat that can be produced by consuming the available oxygen. One gallon of water can absorb 9,330 Btu's of heat. If we divide 9,330 by 37, we find that 1 gallon of water should absorb all the heat that 252 cubic feet of ordinary air will produce. As a rule-of-thumb it can then be said that 1 gallon of water will absorb all the heat that 200 cubic feet of air can produce.

The above would be true if no air were allowed to enter or leave a given fire area. However, it must be remembered that as air flows into a fire area, heated gases and products of combustion must escape from that fire area. This coupled with the heat loss by conduction through the walls will mean that the total amount of heat in the area will remain fairly constant and very close to an estimate that can be arrived at by using the above figures. This will remain true on a varying scale up to the time that large amounts of red hot carbonaceous material accumulate in the fire area.

When a fire is partially ventilated it is difficult to judge the degree of ventilation. A rule-of-thumb formula needs to be developed for estimating the degree of ventilation on any given fire. This would be especially helpful in making comparisons of fire tests and experiments. It should be noted that the United Kingdom, through its Fire Research Station, is currently conducting experiments and tests in this area.

Films Available

Two films related to this month's lead article are available. The films are "The Nozzleman" and "Coordinated Fire Attack." These films demonstrate the practicality of using the rate-of-flow formula as a strategic planning device.

The films are available for rent from Media Resources Center, Iowa State University. The catalog number of "The Nozzleman" is S48651 and the rental price is $13.20. The catalog number of "Coordinated Fire Attack" is S58652 and the rental price is $14.60. For additional information regarding rental, call the Media Resources Center at (515) 294-1540.

Films may also be purchased through Film Communicators, Inc., 11136 Weddington, N. Hollywood, Calif. 91601. Their toll free business number is 800-423-2400.

"Water for Fire Fighting" Bulletin Available

Iowa State University Bulletin #18, "Water For Fire Fighting—Rate-of-Flow Formula," is available for purchase. This informative booklet explains the basis and application of the rate-of-flow formula as discussed in our lead article. Correct application of water and the associated concept of thermal balance are also explained. This information is a must for anyone wishing to understand and apply the rate-of-flow formula as a strategic planning tool. Order yours today ($1.00, postage and tax included) from:

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