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# IOWA RATE OF FLOW FORMULA FOR FIRE CONTROL

### BY KEITH ROYER

*It has been brought to my attention that the Royer/Nelson Rate of Flow Formula for fire control is being misunderstood and misused and that attempts have been made to alter it. I have read some of the interpretations and applications of the formula and believe that many do not understand the physical and chemical laws and principles on which the formula is based.*

The research and experiments from which the formula evolved were conducted in the `50s and `60s. We did not set out to find a formula; it evolved from the research we were doing related to uncontrolled fire behavior in structures.

When faced with a fire problem, one of the things we need to do first is identify the problem and its cause. Otherwise, our efforts to overcome the problem will be nothing more than trial-and-error methods until, of course, we come to a method that works (eliminates or controls the fire). If we do not, the fire will burn itself out.

#### FORMAL EVOLUTION

The formula evolved from research done in the `50s by Iowa State University. The objectives were to identify and define what happens in uncontrolled fires in structures and why fire behaves the way it does in these environments. Hence, the term "fire behavior in uncontrolled environments" came into being.

This was not the first research in this area. This type of work had been going on for many years in several other countries and institutions. When questions arose during our research, we found many of the answers in chemistry and physics books as well as in research papers prepared by many others before us.

After we gained a better understanding of what was happening in structure fires, and why they were happening, we started research on the application of water early in 1952. We closely coordinated with research groups in other countries. The British Fire Research Station was very helpful, as were researchers in Canada, Germany, Japan, and Australia.

In early 1953, a pattern of water used in all of Iowa State`s fire experiments began to evolve. By 1955, it was clear we had found a way to estimate water needs. From 1955 to 1959, hundreds of experiments were conducted to test the method for determining water needs for controlling fires in all sizes of structures. The results of the research conducted at Iowa State University from 1952 to 1959 first were published in Fire Engineering (August 1959) and, in that same year, in Iowa State University Bulletin #18, "Water for Fire Fighting--Rate of Flow Formula."

#### THE FORMULA

The Iowa Rate of Flow Formula is

## *Cubic Feet/100 = GPM*

This formula spells out the rate of flow needed to knock down (control) a fire in a single open area when that area is fully involved. (Note: Control is not extinguishment. It means you have control of the fire instead of the fire`s having control of you.)

This formula states that the cubic feet involved, divided by 100, equals the gallons per minute necessary to knock down a fire in an area if that flow is properly distributed over the entire area.

Points of access for distribution should be established before the fact. Doing this enables you to conduct a size-up and develop plans for using a direct, indirect, or combination attack to achieve the best distribution of water using fog or straight streams.

Note: This formula is designed for use for the largest single open area in a given building. It does not take into account any water that is to be flowed at the same time in other rooms in the building or water that might be used for exposures. It spells out only the amount of water necessary to knock down the fire in the largest single open area.

**The formula is based on and supported by the following:**

- the heat absorption capability of water,
- the heat production based on the volume of air in a given open area, and
- the steam generated and the amount required to displace air in a given area.

**MISAPPLICATIONS OF THE FORMULA**

Fuel loading of structures.

Two natural laws apply and control this:

- The only way to increase the heat-absorbing capability of any heat-absorbing material is to increase its surface area. Almost all fuels--solid or nonvolatile liquid--must be heated to their vaporization point before fuel in a state of readiness is available to burn and release its energy (heat). Some fuels will absorb heat very quickly and readily volatize; others will be slower.
- It has been determined that most burning fuels, regardless of their calorific value, will release 535 Btus of heat when combined with one cubic foot of pure oxygen. It is also a proven fact that flame production stops when the oxygen falls to 14 percent. Normal air has 21 percent oxygen. In normal air, seven percent oxygen is available for heat release regardless of how much or what type of fuel is involved. This means approximately 37 Btus of heat would be released for each cubic foot of normal air.

The result of this, then, is that we need to know and keep in mind: Oxygen (normal air) is what governs the rate of heat release, not the fuel load.

Many times, you will see heated, oxygen-starved fuel vapors traveling in the thermal column until they encounter an air supply, upon which they burst into flame (heat release), far removed from the main body of fire.

The formula has been misapplied in that rates of flow have been changed for different fuel loads. The formula should not be altered regardless of the fuel load or type. This does not apply to the application stage. There is a difference between planning and application. Planning tells you the rate of flow; application tell you the volume, which is governed by time. Example: With a 100-gpm rate-of-flow requirement, if control is achieved in 30 seconds, the volume used would be 50 gallons; if it took one minute, 100 gallons would be used.

Control of the main body of fire is your objective. The environment the fire is in many times controls the time the flow is needed. If everything were perfect or close, a 30-second application would achieve control. When the fire blacks out, shut the nozzle down. Overapplication can be damaging.

I realize application is getting into tactics, but this can be very important. Floyd "Bill" Nelson in Qualitative Fire Behavior put it so aptly:

"If a combination attack is made and the nozzle is not advanced to the proper location and properly manipulated, the fire will not black out. When the fire does black out and the nozzle is not shut down within a reasonable time, the area will be overcooled, and overhaul will be difficult. In multistoried situations, late shutdown may even lead to the loss of the building."

During 30 years of leading, directing, or backing up nozzlemen, the author has often issued the following advice: ___ ___ ___, SHUT IT OFF (the publisher would not allow the foregoing blanks to be filled with the proper words. Needless to say, they are not terms of endearment).

Using the cubic volume of the total structure. This is another common misapplication of the formula. Only the largest single open area of the structure should be used. As stated before, this does not take into account other water that may be needed for other parts of the structure or for exposures. The old axiom applies, "The best exposure protection is control of the main body of fire."

We were trying to fill the area with steam and smother the fire. This is a misunderstanding of the formula`s use in a tactical sense. This method can work if we fought fires only in closed compartments. The Navy and Coast Guard did a lot of work and experiments on this approach during World War II. That is where Lloyd Layman`s "Little Drops of Water" came from.

Do not underestimate the role of steam. The reference material illustrates that when water is applied in partially enclosed areas where temperatures are 1,000 degrees or above at atmospheric pressures, water converting to steam will expand more than two times the normal expansion ratio at 212°F (that is, will expand more than 2 ¥ 1,700 times its original volume). This steam can play a large role in cooling remote areas or multistoried buildings.

**A VALUABLE TOOL**

Once it was accepted as a valid tool, the formula has proved to be useful in many ways, including the following:

In the middle 1950s when the formula evolved, it became apparent a constant-flow nozzle was needed. Akron Brass designed this nozzle and introduced it to the fire service.

When we applied the formula to larger structures (bowling alleys, supermarkets, and the like), the need for a large-volume highly mobile water delivery system was created. Akron Brass came up with the remote-control ladder nozzle. Snorkel Fire Equipment started work on an elevated platform large water delivery system and, ultimately, the Squirt.

The formula provides for a systems approach to resource determination. When applied to a structure (before the fire), we could determine resource requirements (water, hoselines, and nozzles; manpower; pumps; and so on). If the resources available did not come close to matching the resources needed, there was "trouble in River City."

Note: Time is a negative factor. If the resource needs cannot be met and applied within 10 minutes after ignition, the fire can reach its maximum potential or the peak of its damage curve.

The formula provides for a systems approach to determining loss probability, based on the rate of flow formula and the assumption that a fire has started in this environment.

In analyzing the largest single open area of this structure--and based on all of the natural laws applied, which was the foundation of our knowledge of fire behavior--we looked at and evaluated the building fire potential, the contents fire potential, and the reduction factors (factors that either enhance or reduce your chances of being able to manage the situation).

Using this system and the system for determining resources can tell us whether fire control in this structure is manageable or unmanageable.

If it is unmanageable, the only option is loss of the building.

These structures or conditions are not designed, built, or put together by fire departments; but when the fire occurs, the fire department--regardless of its size, its knowledge base, or resources--is called on to cope with the fire problem.

At times, it may be necessary for a fire department to use the formula (tool) to assess the relative probability of loss of a structure to a fire and communicate that probability factor to others. Such information may be important for the following:

- an insurance engineer evaluating a risk,
- a fire chief wishing to assess target hazards,
- a training officer seeking to identify important buildings requiring prefire planning,
- an industrial fire protection specialist communicating recommendations to management,
- a fire marshal reviewing fire protection needs for specific buildings, or
- an architect assessing the value of various fire protection features.

Note: Many insurance engineers were taught to use the systems approaches to determining resources and loss probability in the `60s and `70s, which they used to assess risks for their underwriters when determining insurability. Most companies would not insure bowling alleys, supermarkets, and other structures with large open areas unless they were sprinklered.

I am not attempting to cover all the values of the Rate of Flow Formula. It is only an attempt to show that it is a valid tool that can be applied to many fire problems. A good analogy here might be the clock. We do not need to understand all of the natural laws, mechanical principles, and everything that goes into it to make it do what it does. We have come to rely on it as a valued tool to give us the time of day or night. Think of all the things you plan or do based on your reliance on this valid tool.

Remember also: "When you ignore or violate a natural law or proven principle, it will always give you a negative result." n

**Suggested Reading**

Books:

1. "Water for Firefighting," Fire Engineering, Aug. 1959.

2. "Water for Firefighting--Rate of Flow Formula," Iowa State University Bulletin #18, 1959.

3. Nelson, Floyd W. Qualitative Fire Behavior, International Society of Fire Service Instructors, Ashland, Mass., 1991, Isbn 0-929662-10-5.

Films:

1. The Nozzleman, Iowa State University (ISU), 1959.

2. Coordinated Fire Attack, ISU, 1961.

3. Closed Containers and Fire, ISU, 1976.

All should be available from the Fire Service Institute, Iowa State University, Ames, Iowa 50011; (515) 294-6817.

KEITH ROYER began his distinguished 43-year fire service career as a firefighter with the Wichita (KS) Fire Department in 1946. Three years later, he was one of the founding members of a statewide firefighter training program offered through the University of Kansas. In 1951, he joined the faculty of Iowa State University, where he was to become director of fire service education, college of engineering. It was there that Royer accomplished his most important work in firefighter education and fire science development. He retired from Iowa State University in 1988.