CHAPTER 9

Research Highlights

The General Rate–of–Flow and Grimwood Formulas

Now the authors want to present the most significant result of the research done in the United States and in Europe. This result is the proof that two Rate–of–Flow formulas are actually the same.

Keith Royer and Bill Nelson created the Iowa gallonage formula at the Fire Service Institute at Iowa State University in 1954. The formula is:

$$gal = \frac{Vol}{200}$$

In this equation "gal" equals the number of gallons of water (the right amount of water) needed to fill a confined space full of steam, "Vol" equals the volume of the confined space in cubic feet.

To convert the Iowa gallonage formula to a metric formula, we must start with the liter. The liter, like a gallon, is a measure of volume with one gallon equal to 3.785L. One liter equals on cubic decimeter, or one one–thousandth of a cubic meter. Since the volume of structures is usually expressed in cubic meters, we must transform liters to cubic meters. This is easy to do with the metric system.

The expansion ratio of liquid water to steam is 1,700/1 no matter what unit of measure is used. Therefore, one liter of water expands to 1,700L of steam. The liter formula is:

$$L = \frac{V}{1{,}700}$$

In this equation both L and V are in liters. To change the number V to cubic meters, it is necessary to divide the numerator and denominator of the fraction by 1,000.

$$L = \frac{V/1{,}000}{1{,}700/1{,}000}$$

V/1,000 may be rewritten as "Vol" in cubic meters. The denominator becomes 1.7.

$$L = \frac{Vol}{1.7}$$

In this equation "L" equals the number of liters, and "Vol" equals the volume in cubic meters. Since the Iowa formula assumes that 90% of liquid water is transformed to steam, we must do the same for the metric formula. Thus the denominator becomes 1.5, that is, 90% of 1.7. The equation is the general Rate–of–Flow formula in metric units.

Paul Grimwood's article[1] discusses his formula for minimum fire ground flow–rate requirements:

$$A \times 2 = Lpm$$

To transform Grimwood's formula into the General Rate–of–Flow formula, we add time to the formula and multiply by the liters per minute. There is a basic mathematical reason for this. The equation states, in essence, that a certain number of liters (A x 2) equals the same number of liters per minute. However, liters per minute is a rate of flow, and this equation is valid only if time equals 1min ((Lpm) x 1 = Lpm). This is the only time that will produce the same number of liters per minute on both sides of this equation. We don't want to be restricted to an attack time of 1min; we want an equation valid for any length of time. So making this change in Grimwood's formula gives

$$A \times 2 = \text{Lpm} \times t$$

This generalizes Grimwood's formula and makes it valid for any length of time.

To transform Grimwood's formula to volume, the area (*A*) must be multiplied by the ceiling height. Let's do this for ceiling heights of 8ft and 10ft (2.5m and 3m). Of course, if we multiply the numerator by 2.5 or 3, we must do the same for the denominator:

$$\frac{3 \times A \times 2}{3} = \text{Lpm} \times t \qquad \frac{2.5 \times A \times 2}{2.5} = \text{Lpm} \times t$$

Since 3 x A (or 2.5 x A) equals volume, we can change notation to get the following equations:

$$\frac{\text{Vol} \times 2}{3} = \text{Lpm} \times t \qquad \frac{\text{Vol} \times 2}{2.5} = \text{Lpm} \times t$$

Our final change is to simplify the fraction by eliminating the number in the numerator of each fraction. This is done by multiplying the numerator and denominator by 0.5:

$$\frac{\text{Vol}}{1.5} = \text{Lpm} \times t \qquad \frac{\text{Vol}}{1.25} = \text{Lpm} \times t$$

Note that the 10ft (3m) ceiling height gives an equation identical to the General Rate–of–Flow formula. The 8ft ceiling height (2.5m) is almost within 90% of the general formula.

What is the significance of this finding? First, these two formulas were created 36 years apart and in different countries. Second, both formulas are the result of careful research based upon scientific facts and principles. This convergence adds further proof to the validity of the General Rate–of–Flow formula. All of the research that has been done on fog nozzles has converged upon identically the same set of facts and principles. It is safe to say that the General Rate–of–Flow formula is the only valid formula the fire service will ever have to work with for confined fires.

Chief Lloyd Layman's Research

- Created the indirect method of fire attack using fog nozzles, the first alternative to the solid–stream attack from a smooth–bore nozzle.

- Created a theory of atmospheric displacement to explain how the indirect method worked.

- Successfully adapted the indirect method to fighting Class A structure fires.

- Demonstrated the indirect effect of a fog attack, whereby fire is controlled in adjacent areas remote from where the fog attack is made.

- Initiated the change from solid–stream nozzles to fog nozzles in this country in his "Little Drops of Water" speech in Memphis (1950).

- Presented an exposition of the theory and practice of fighting fires with water fog in his book, *Attacking and Extinguishing Interior Fires* (1955).

- Completely analyzed the eight tactical operations used in fighting fires in Tactics (1953).

Iowa State University Research Keith Royer and Floyd W. (Bill) Nelson

- Created the gallonage formula, the source of the Iowa Rate–of–Flow formula. The gallonage formula answers the question, "How much water is needed for control of a confined fire?"

- Stated the fundamental principle of fire control that depends upon using the right amount of water.

- Discovered that using too much water causes thermal imbalance problems that disrupt an effective fog attack.

- Confirmed that using too little water has little effect upon a fire.

- Created the most complete and accurate analysis of uncontrolled fire behavior in a structure.

- Stated the fundamental tactical principle that chooses the best method of attack for a given purpose and a given type of fire.

- Participated in creating the constant flow fog nozzle and the elevated master stream nozzles and aerial equipment to combat large fires.

- Derived sound conclusions from the scientific method of systems analysis that established a solid foundation for the safe and effective use of fog nozzles.

US Naval Research Laboratory

- Quantified the conditions required to produce the maximum compartment fire temperatures with natural ventilation.

- Defined two thermal conditions necessary and sufficient for flashover to occur: heat flux to the floor and upper layer temperature.

- Established the optimum application rate for boundary cooling together with the best ways to distribute water for horizontal and vertical cooling.

- Demonstrated the safety and effectiveness of 3–D gas cooling pulse tactics.

- Proved the superiority of 3–D gas cooling pulse tactics versus the straight–stream attack in providing a safe entry to a compartment when an initial direct attack is impossible to make.

- Demonstrated that a direct attack with a straight stream from a fog nozzle and a solid stream from a smooth–bore nozzle are equally effective.

- Established the importance of maintaining thermal balance when using fog nozzles.

- Demonstrated the weaknesses of protective clothing—especially gloves—that limit how long firefighters can remain in a hostile environment.

European Research

- Created 3–D gas cooling pulse tactics to enable firefighters to enter a burning compartment safely.
- Through the pulse tactic, eliminated the twin dangers of flashover and backdraft.
- Proved that the pulse tactic actually contracted the fire gases and steam in a compartment, preserving thermal balance.
- Conducted extensive research on all aspects of fog attack, including a comparison of various tactics, water droplet size, and fog patterns.
- Through research, confirmed the superiority of 3–D gas cooling tactics.
- Established the superiority of the automatic nozzle with slide shut–off valve.
- Created a flow rate formula that is identical to the General Rate–of–Flow formula.

Research Summary

All of the research on fog nozzles converges on the following set of facts and principles:

- The proper use of fog nozzles requires a balanced fire attack, that is, balancing the heat–releasing power of a fire with the heat–absorbing power of water (steam).
- Doing this requires using the right amount of water applied using the near–ideal rate of flow.
- A fog nozzle must be capable of varying the flow; for room–size fires the ideal rate of flow ranges from 30gpm to 60gpm (113Lpm to 227Lpm).
- Using the right amount of water results in a net contraction of fire gases and steam and the restoration of thermal balance.

- Thermal imbalance problems (*i.e.*, pushing a fire) are caused by using too much water.

- A straight stream from a fog nozzle, a narrow fog pattern (30°), and a wide angle pattern (60°) are useful in various fog attacks.

- No one method of fog attack is useful for all purposes and all types of fires.

- A fog nozzle is far superior to a smooth–bore nozzle in its ability to vary the flow and distribute water evenly throughout the fire area.

- All of this research leads to the final conclusion that a fog nozzle can be used safely and effectively provided it is used properly.

Summary

It is easy to see now why this book was written. Fifty years of research, completed in more than ten countries, all leads to the same set of conclusions:

- Fog nozzles can be used safely and effectively. In fact, these are the only nozzles that can handle certain types of fires.

- Proper use of fog nozzles can preserve thermal balance and provide safe entry for firefighters into the fire area.

- The formulas created in the English and metric systems are identical. Thus, there is only one valid formula to determine the needed fire flow for a fog attack.

- The direct attack, the combination attack, and the 3–D gas cooling pulse tactic are all useful for fire attack. No one method of attack can handle every fire situation.

Notes

[1]Paul Grimwood, "Compartmental & Structural Firefighting: Water Flow Requirements – International Research" (www.firetactics.com, 1999).