The Iowa-Grimwood formula: rate of flow formula for confined fires - Firefighting Technology

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The most impressive fact about the research on fog nozzles that has been done during the past 50 years in more than 10 countries is the convergence of all this research upon the same conclusions. These conclusions, the author concludes, establish without any doubt that fog nozzles can be used safely and effectively to fight confined structure fires, as well as other types of fires

A very interesting result of the research on fog nozzles is the proof that two rate of-flow formulas created in two different countries 36 years apart are actually the same formula. One formula uses the English system of measurement while the other formula uses the metric system. So, it is not immediately obvious that the two formulas are actually the same.

The switch from using smooth bore nozzles to the use of fog nozzles began in the US after a speech delivered by Chief Lloyd Layman of the Parkersburg W V Fire Department to the Fire Department Instructor's Conference (FDIC) in Memphis, TN, USA, in 1950. chief Layman had conducted the first research on the use of fog nozzles at the US Coast Guard Fire School, Ft. McHenry, Baltimore, MD, USA, during World War II.

The first formula was created in 1954 by two men, Keith Royer (Director) and Bill Nelson (Chief Instructor), at the Fire Service Institute of Iowa State University at Ames, Iowa, USA. At that time very little was known about fire behaviour or water behaviour in structure tires. Most of the information avail able was from combustion engineering. So they began their own research, systematically analysing actual structure fires.

Then they turned their attention to a second basic question: how much water is needed to control a tire with fog nozzles? They answered this question by creating the following formula.

Gal = Vol 200

In this equation, Gal = the number of gallons of water, Vol = the volume of a confined space in cubic feet, and 200 = a constant determined by two scientific facts

The first fact is that one gallon of liquid water converts to a gas (steam) at 212[degrees]F at a ratio of 1:1.700. That is, one cubic foot of liquid water expands to 1,700 cubic feet of steam. Since one cubic foot of water contains 7,48 gal, one gallon of water produces

1.700/7,48 = 227,

Or 227 cubic feet of steam. Thus one gallon of water converts to enough steam to fill a 227 [ft.sup.3] confined space. This number is rounded down to 200 to allow for 90 per cent rate of conversion to steam in actual firefighting.

The second fact is that one cubic foot of pure oxygen combined with ordinary fuels produces 538 btus of heat. Since air contains 21 per cent of oxygen by volume, and flame production stops when the oxygen level reaches 15 per cent, therefore

21% - 14% = 7%.

Thus only this amount of oxygen, seven per cent of air, is available for flaming com bustion. Multiplying seven per cent by the number of British thermal units produced by one cubic foot of oxygen gives

x 0.07 = 37 btu

This is the number of British thermal units produced by one cubic foot of air. The number of Btus produced by 200 cubic feet of air is

37 X 200 = 7.400 btu

To raise the temperature of one gallon of water from 62[degrees]F to 212[degrees]F requires 1.250btu (1 gal weighs 8.34 lb x 150 = 1.250). To vaporise one gallon of water at 212[degrees]F requires 8.090 btu (8.34 X 970.3 = 8.090) If one gallon of water is applied to a fire at 62[degrees]F, then this gallon absorbs 9.340 btu. Since 7,400 < 9.340, the conclusion is that one gallon of water can absorb all the heat produced by 200 cubic feet of air Notice the margin of safety, almost 2,000 btus.

It is quite remarkable that both scientific facts converge on the same constant, 200. This provides a solid foundation for the validity for the Iowa gallonage formula.

To convert the gallonage formula to a metric formula, we must start with the litre. The litre, like the gallon, is a measure of volume with one gallon equalling 3,785L Since the volume of structures is usually expressed in cubic meters, we must transform litres to cubic meters This is easy to do in the metric system.

One litre equals one cubic decimetre, or one one-thousandth of a cubic metre.

1.000L = 1[m.sup.3]

The expansion ratio of liquid water to steam is 1:1.700 no matter what unit of measure is used. Therefore one litre of water expands to 1.700 litres of steam.

L = V/1.700

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

L = V/1.000

1.700/1.000

'V/1.000' may be rewritten as 'Vol' in cubic meters Since the Iowa formula assumes a 90 per cent conversion rate of water to steam, we must do the same for the metric formula.

L = Vol

1,5

This is the Iowa gallonage formula in metric units.

Paul Grimwood has done extensive research on the flow rates used by various European fire departments. In his book, Fog Attack, he summarised his work by stating that the flow rate of 0,5Lpm/[m.sup.3] is close to the average used by firefighters in fighting actual structure fires. In a recent article he presented a formula that he characterised as a minimum rate of flow formula

Lpm = A X 2

In this equation Lpm is the rate-of-flow, and 'A' is the floor area of the confined space in [m.sup.2].

This equation differs from the Iowa gallonage formula in two respects First, it is a rate-of-flow formula, not a gallonage formula. Second, ii involves area of the confined space, not the volume.

What we must do is change the Iowa gallonage formula to a rate-of-flow formula. Any rate-of-flow formula must have time as a factor.

RoF X t = Gal (or L)

A rate-of-flow formula without time as a factor is valid for a time of one minute only.

RoF X 1 = Gal (or L)

For example, a RoF of 100 Lpm equals 100L only for a time of one minute. For all other times the equation is false (not equal) So making this change for the Iowa gallon age formula gives:

Lpm X t = Vol

1,5

Doing the same for Grimwood's formula gives the following equation

Lpm X t =A X 2

There is one final change. The Grimwood formula must be changed to volume. This is done by multiplying the area (A) by ceiling height. Let us do this for 2.5m and 3.0m (8ft and 10ft). Of course if we multiply the numerator of a fraction by a number, we must do the same to the denominator.

Lpm X t = 3 X A X 2

Lpm X t = 2,5 X A X 2

2,5

Since 3 X A (of 2,5 X A) equals volume, we may change notation to get the following equations

Lpm X t = Vol. X 2

Lpm X t = Vol. X 2

2,5

Our final change is to simplify the numerator of each fraction by multiplying the numerator and denominator by 0,5.

Lpm X t = Vol.

Lpm X t = Vol.

1,5

1,25

In this formula, L pm = litres per minute and Vol = volume of a confined space in cubic meters. Note that the 3m (10ft) ceiling height gives a formula identical to the Iowa rate-of-flow formula. The 2,5m (8 ft) ceiling height is almost within 90 per cent of the Iowa formula.

What is the significance of this finding? First, these two formulas were created ,36 years apart and in different countries. This is a perfect ex ample of the convergence of scientific research upon the same set of facts and principles. It is sale to say that the Iowa-Grimwood formula will be the only valid formula that fire services will have to determine the right amount of water to use in a fog attack when the tire fully in volves a confined space.

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