

Another Look at Needed Fire Flows

By Larry L. Pierson Jr. (*Carolina Fire Rescue Journal*)

Introduction

From Firefighter to Incident Commander, we all must understand Needed Fire Flows (NFF). What lines need pulled on arrival? What kind of water supply rate do we need to sustain? When things are not working well, what do we base our new strategy on? What are all these formulas about, what are they intended for and what are their limitations?

Although there are multiple formulas from around the world, we will primarily discuss six; ISO, Iowa, NFA, Grimwood & Grimwood Heavy and Pierson. NFPA 1142 can also be referred to for water supply calculations needed for live fire evolutions. After determining total structure area and NFF, the percent involvement is applied to adjust for only the area involved in each of the formulas. There are enough texts and articles on the entire process of each but there are some important clarifications and points that should be made.

Volume & Area Based formulas

Volume based NFFs calculate volume or the cubic space of a given area such as $L \times W \times H$ (*Length x Width x Height*). These formulas provide a “3 Dimensional” matching of fire volume to amount of water needed to absorb the BTUs. As ceiling heights increase, so goes the fire volume and so goes the needed volume of water/steam to cool/exclude oxygen for the fire.

Area based formulas only calculate $L \times W$. This will simplify mathematics but will cause obvious differences when the same NFF is stated for a structure with 7' ceilings and another structure the same square footage that has 15' ceilings.

Both type formulas increase NFF at proportional rates to one another and as the size of the structure increases, NFF increases up to a point. At ceiling heights greater than 16½' (*represented by the teal vertical line in Fig 1*), area based formulas will begin to exponentially decrease NFFs in comparison to a volume

formula's continual increase.

Why is this 16½' mark so important? Because it is usually not the bread and butter, one or two room house fires that firefighters underestimate NFF. How tall is the ceiling in your local grocery store, textile mill, church sanctuary, superstore or other commercial facility? Most likely anywhere from 15 to 25 or more feet.



Figure 1

Application rates and stream types

Use too low of an application rate (*NFF*) and the fire is most likely going to control the scene, not the firefighters. Each fire and each compartment may require different stream types or patterns for the most effective suppression. There is no one stream type that is the best for every occasion but combination nozzles provide the dominant fire to stream type matching flexibility. There is a literal difference in the definitions but the difference between a straight stream and a solid stream is pretty much semantics. Most combination nozzles provide an effective straight stream with just as much reach and penetration.

While there are other situations such as standpipe operations where I would generally recommend the use of a solid bore nozzle, most *NFF* formulas are based on some level of steam generation and oxygen exclusion. If a firefighter selects a fog pattern that is too wide, penetration will likely not occur and steam will be produced without cooling the main core of the fire volume or causing other problems. Consider the following quotes:

1. **Fire Protection Handbook**, NFPA 18th Edition. Fire Streams - 10-242

"Solid streams, with a lower surface area to volume ratio, do not have as good heat transfer characteristics as spray nozzles and, consequently, are not as effective in absorbing heat."

2. Research paper from NIST Building & Fire Research lab website **"Anomalous effects of water in firefighting: Increased fire intensities by azeotropic distillation effects"**

"The greatest single effect of water in fire extinguishing applications is its great cooling capacity, particularly when used in fog or mist form"

3. **"Essentials of Firefighting"** 4th edition, pg 494

"Solid streams provide less heat absorption per gallon delivered than other type streams"

4. **"Fire Department Hydraulics"**- Mahoney

Chp 1 pg 2 -*"The absorption of additional heat reduces the volume of the liquid, with volume reduction continuing until the last drop of water has been converted to steam"*

Chp 4 Pg 83 -*"Skillful application of the water will not only absorb the heat in the immediate area of water application, but will produce large volumes of steam that will flow into remote areas and help control the fire."*

The methods of water application have been well studied and established. Just remember that if you choose to use a straight or solid stream, you should add some factor of an increased *NFF* than what the formulas provide. Firefighters need to train on recognizing which patterns match conditions.

NFF is just a number, it still has to make sense.

All the formulas have limitations and you may experience some results that will make your head shake and say "That just doesn't seem right." Flow rates may appear way too low and the alarm should sound off that a serious safety issue is at hand. Flow rates may appear excessive and to any firefighter with a little experience, they will recognize overkill even beyond an increased safety margin. The old saying "Big fire, Big water" is true but a trained person will recognize how big the fire is, how big it will get and how much water is needed.

Refer to the 14x70 mobile home fire in Fig.1. The *NFA* formula calls for 327gpm (14x70)/3. That is at 100% involvement so we are definitely into a defensive mode with an exterior attack (*Reminder that accuracy for NFA is questionable after 50% involvement*). For 327gpm, at least two 1¾" lines or one 2½" and an 1¾" will be required to actively engage in suppression. While this is definitely not a dramatic overkill, the fire is most likely going to be confined, contained or knocked down with one 1¾" line. The Pierson and Grimwood heavy formulas result in an *NFF* of 137gpm and 144gpm respectively. Iowa results in a *NFF* of 69gpm which is quite low. Any of these should be considered starting at a minimum of 150gpm. I cannot recall a mobile home fire in my career that could not be controlled with one 1¾" flowing and the other 1¾" staffed for backup. If a proper application rate, nozzle selection and other tactics are used, an engine with a 1,000 gallon tank will most likely not go empty.

Again referring to Fig.1, the 40'x40' building with a 16½' ceiling has a total cubic volume of 26,400Ft³. Next the 38'x38' with 20' ceilings has a total of 28,800Ft³, larger than the first but the *NFA* formula actually decreases the *NFF* compared to the smaller structure. These are the instances that show a difference between area and volume formulas. If a *NFF* result doesn't seem quite right, adjust it.

More about Iowa

The Iowa formula (*Royer/Nelson*) is based on principles of water turning into a volume of steam. The conversion of water to steam absorbs BTUS and the expanding steam displaces oxygen, thereby affecting the fire from two sides of the fire tetrahedron. The first results were studied using fog patterns from external positions with multiple lines covering each opening. The parameters for the tests called for a relatively sealed environment in an attempt to convert all water to steam, expand into all spaces within and deplete oxygen. These studies derived from applications for shipboard firefighting where compartments were generally sealed and the need for excess water needed to be limited (*Filling a ship with water is not such a good idea*).

One of the key points of the application concerns compartmentation of a structure. Quote from Royer -*"Using the cubic volume of the total structure is another common misapplication of the formula."* Only the largest single open area of the structure should be used. This does not take into account other water that may be needed for other parts of the structure or for exposures.

One of the "safety margins" already built into the formula is providing only a 90% efficiency rate of converting water to steam. This fact shows that the formula was built with a more realistic approach that each application/conversion will not be perfect.

Water will only have a suppression effect on surfaces it touches or the spaces that steam travels into. If a crew is conducting interior attacks, they suppress a room and move to the next. Even if a crew is conducting exterior attacks, the stream will only have effect on what room it touches from each window or door.

More about Pierson

This is based on most of the same principals and science as the Royer Nelson studies that built the Iowa formula and parts of the Grimwood application type. Iowa was not calculated to account for PPV fans, vertical ventilation, wind, construction type, various fire loads, and other factors. After reviewing multiple structure fires and live fire evolutions over my career, Iowa seemed too low and NFA seemed too high for some applications. NFA and Grimwood also did not allow for the volume factor when ceiling heights increase.

The Pierson formula calculates $L \times W \times H$ but is divided by 50 instead of 100 as in Iowa. This will always result in twice the NFF as Iowa. After beginning to apply this formula, I began to study Paul Grimwood's research and formulas. I was surprised to find the similarity between Pierson and Grimwood Heavy which

came within just a few GPM difference until the ceiling heights increased. (Refer to Fig1).

More about Grimwood

The Grimwood formulas are also based on various fog pattern techniques and derive from a large research base of actual fires and experiments. The formula is very similar to Iowa and Pierson but must be converted from metric units of measure. Make sure that you use length in meters times width in meters to give meters². If you use feet times feet and then convert feet² to metric you will get a different answer. It is important to note that the result is liters per minute, not gallons per minute. All calculations provided in the table have been converted to imperial measure (feet, gallons etc.).

The formula also has two fire load categories; Normal ($M^2 \times 4$ or Square Meters $\times 4$) (*basically an empty room*) and Heavy ($M^2 \times 6$ or Square Meters $\times 6$) (*basically the room is full of flammable contents such as a couch, chair and other typical items*). More on Grimwood's applications can be found at www.fire-flows.com. It is certainly worthwhile reading.

More about NFA

The NFA formula is based on a variety of table top scenarios in which students at the fire academy and other experienced officers were asked to place hoselines down for various fires. After several results were collected, the average gpm for all lines in comparison to the area of the structure came close to the area involved divided by three. It is important to note that decisions on which lines to choose would have been based on previous knowledge and applications derived from some aspects of the Iowa formula.

NFA is probably one of the easiest to calculate on the fireground. A length and width totaling 1,000 is easily divided by 3 resulting in a NFF of 333gpm rate.



Figure 2 *Firefighters may be exposed to superheated gasses while trying to protect exposures. (Courtyard of the Shafer Dorms, Warren Wilson College 2003. 3 of 4 dorms were involved with fire on arrival, the 4th was defended with ground mount deck guns, elevated streams, other master streams and handlines)*

Exposures and massive defensive operations

Iowa and the Grimwood formulas do not have specific applications built in for determining NFF for exposure protection. For ISO, refer to: <http://www.isomitigation.com/downloads/ppc3001.pdf>. NFA provides 25% of the total NFF for each exposure including upper floors (up to 5) and NFPA 1142 provides exposure protection considerations (*considered an exposure if it is within 50' and structure is more than 100F²*).

There are a few issues that need to be considered for exposure protection.

- 1. What is the size or vertical surface area of fire threatening the exposure?*
- 2. What is the size or vertical surface area of the exposure that needs protected?*
- 3. What is the distance from the hostile fire to the exposure?*
- 4. What are the height comparisons between both?*
- 5. What is the wind direction and speed? Is weather forcing hostile fire toward the exposure or away?*
- 6. Is the area that firefighters must work to defend the exposure in a potential collapse zone? Streams which*

project farther will have to be employed to reduce firefighter's risk.

7. What are the two types of construction involved and what construction features such as windows, bay doors or a solid masonry wall apply?

8. Remember, at some point firefighters also become exposures. Just because they are performing exterior operations doesn't mean that they won't receive burns, breathe in superheated gasses or be exposed to an IDLH environment.

All of these factors contribute to a realization that one application rate will not be effective for every exposure scenario. Providing 25% of the total NFF for an exposure does not work in every case. A long facility 200' by 25' wide with 12' ceilings would have an NFA NFF rate of 1,667gpm. An exposure on the 25' wide side would require an NFA exposure flow rate of 417gpm (1667x.25). That is probably excessive for the 25' side but far too little for the 200' side if the entire side is burning. NFPA 1142 provides detail that includes the construction class which will have effect on the exposure. Each rate is a starting point that can be adjusted for the wide variety of conditions.

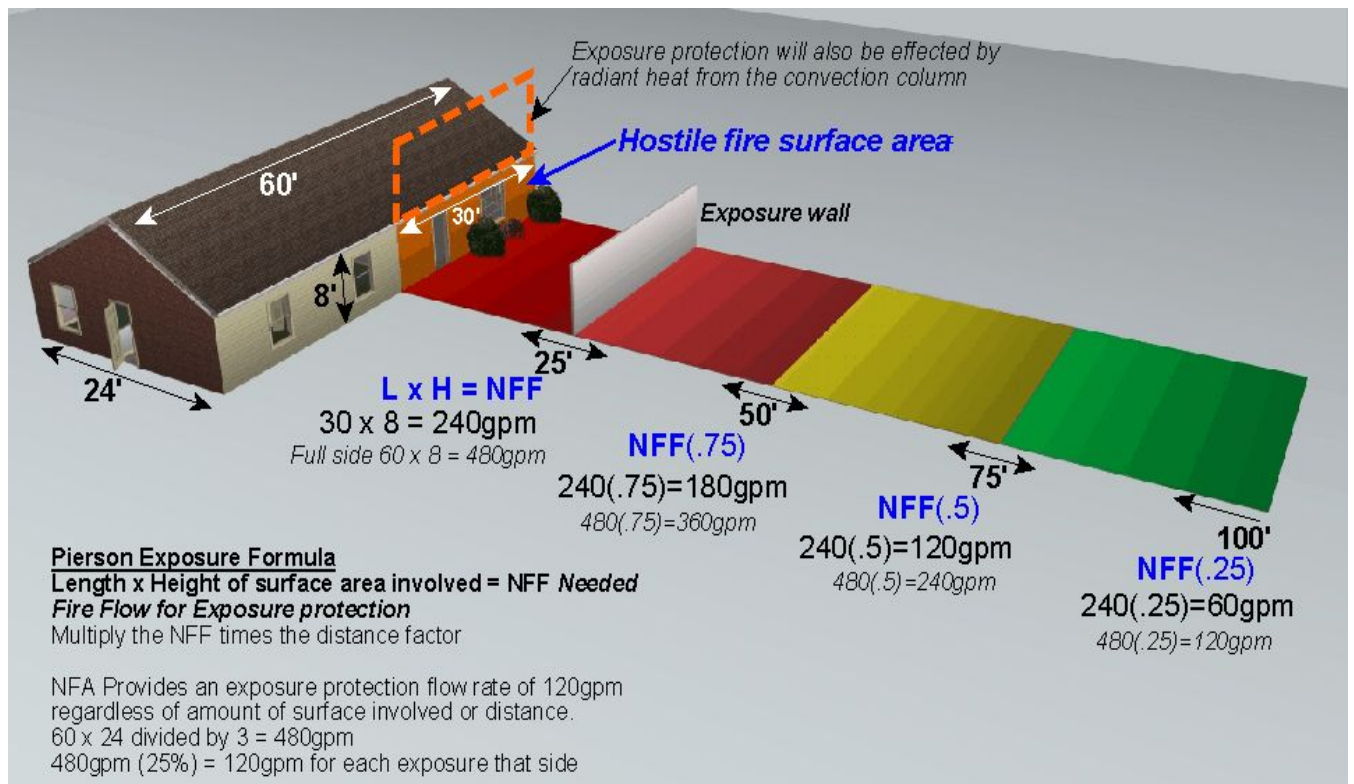


Figure 3

Figure 3 Provides an example that could also be used to determine the exposure flow rate in comparison with the formula from the NFA. This formula looks at the amount or surface size involved and the distance. Figure the length and height of the structure's side and if the exposure is within around 25', the result (Ft² surface) is your exposure's NFF rate. As the distance between the exposure and hostile fire increases, less water will be needed so the NFF is multiplied by a distance factor.

Another factor in defensive operations also involves large facilities. Even master streams can only reach so far. If you have a commercial structure 1,000' long and 600' wide that is fully involved then any



FIGURE 4 - Some defensive operations with exposure protection can easily require rates into the thousands of gpm. If the NFF for an exposure seems too low or isn't working, crank it up. (Beacon fire, Swannanoa, 2003. One structure suffered damage to vinyl siding at almost 200' away)

thrown out the window. In such cases we are looking at what we can do with the perimeter.

Summary

It is important to remember that the NFF is an application rate. The nozzle may only have to be opened for 5-10 seconds but it must be flowing the NFF rate.

Preplans can state NFF and display the NFF for various % of involvement.

You will likely need a NFF that is greater than what you would calculate on arrival. You must anticipate the size of the fire when the total NFF will actually be in use or the sustaining water supply is established. In one scenario, you arrive at 25% involvement. Will the involvement be at 50% by the time lines are deployed? Stay ahead of the game.

None of the formulas are perfect. None of the formulas are wrong. None of the formulas ingrain every factor that the fireground gives us. None of the formulas tell you exactly what you should do. To gain accuracy with a formula, complexity will generally be increased.


Avoid the phrase “formulas are not for the fireground.” The IC or Operations Chief may be able to calculate a formula better than the task involved first arriving firefighter or officer. Formulas should be used in table top scenarios, training sessions and provided with photo comparisons when you ask a firefighter or officer “What lines would you pull?” These scenarios and training are carried forward for fireground use and decision making.

Every person on the fireground needs to understand the NFF concept. Except for those rare fires that make us go “wow” when we arrive, take control of the fire, not the other way around. When the fire begins to control us, we step back and control it through


confinement. Study all these formulas and strategies so you can be an informed and educated firefighter.



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Volume 
$$\frac{\text{Length} \times \text{Width} \times \text{Height}}{100} = \text{GPM rate}$$

 Pierson
$$\frac{\text{Length} \times \text{Width} \times \text{Height}}{50} = \text{GPM rate}$$

Surface  National Fire Academy
$$\frac{\text{Length} \times \text{Width}}{3} = \text{GPM rate}$$

 Grimwood
$$\text{Length(meters)} \times \text{Width(meters)} \times 4 = \text{LPM rate}$$

Grimwood (Heavy Load)
$$\text{Length(meters)} \times \text{Width(meters)} \times 6 = \text{LPM rate}$$

