# Foam Calculations

***By David F. Peterson***

A common emergency that firefighters encounter is flammable liquid spills and fires. Statistics even show that flammable liquid releases account for nearly 66 percent of all spills, and even if you have not already been to a flammable liquid fire, chances are very good that you will sometime in your career. Therefore, it behooves us to train for these emergencies, to handle them more efficiently and to keep our health and safety intact.

Perhaps the best weapon to handle flammable liquid spills and fires is Class B foam. There have been many fine articles written about foam and how to use it, yet many firefighters seem to misunderstand and are confused over foam technology. One author even referred to foam as the "Voodoo Science" because of the general feeling firefighters have concerning foam. In reality, Class B foam applications are fairly simple.

Some of the reasons for the firefighter aversion to using Class B foam may be from a lack of experience with it, both in training and in actual incidents. Not all flammable liquid releases require flowing foam, so the experience of using it at emergencies is not enough to give a firefighter a confidence level. Also, since foam concentrate is expensive (over $25.00 per gallon), fire departments do not train with it frequently enough to leave a lasting impression on the people who use it at spill scenes. Consequently, when Class B foam is needed at an emergency, the operations do not go as smooth as we would like.

Outside of the equipment used in producing finished foam and the proper techniques for applying finished foam, the most perplexing issue for firefighters is the calculations for the foam concentrate that is required at a spill. While there are foam formulas to figure the concentrate needed, many, if not most, firefighters will be hard-pressed to remember the formulas while in the midst of an emergency. The formulas are complex, and in times of stress the simpler operations can be made, the better off responders will be. Years ago the philosopher Thoreau stated that we must "Simplify, Simplify, Simplify!" This sentiment is also of value when it comes to foam concentrate calculations.

In order to understand the simple formula, it is important to know the components in a foam formula. The formula for calculating the needed foam concentrate at a flammable liquid release is as follows:

***Area X Critical Application Rate (CAR) X Eduction Rate (ER) X 15 = Foam Concentrate Needed.***

***"Area"*** refers to the area the spill occupies, usually in square feet. Area can be calculated by multiplying the length by the width of the spill. If the spill is in a circle estimate the length and width for a ballpark figure. (To be precise, and this is not a precise science, the area of a circle is 3.14 multiplied by the radius of the spill squared or $3.14r^2$.)

The ***"Critical Application Rate" (CAR)*** is the minimum flow of finished foam per square foot to extinguish a flammable liquid fire. The CAR was found for different fuels through extensive testing by the National Fire Protection Association (NFPA). The CAR for hydrocarbon fuels has been calculated to be 0.1 gallons per minute per square foot ($0.1 gpm/ft^2$) and the CAR for polar liquids, like alcohols, has been calculated to be 0.2 $gpm/ft^2$.

The third factor in the formula is the ***"Eduction Rate" (ER)***. Class B foam needs to be educted at a certain percentage mixed with water in order to produce an adequate foam solution to cover a spill or extinguish a flammable-liquid fire. For many foams the eduction rate for hydrocarbons is 3% (.03) and 6% for polar liquids (.06). Some Class B foams use 3% eduction rates for both hydrocarbons and polar solvents which simplifies the formula further. There is even one new foam on the market that is educted at 4% for both Class A and Class B foams.

The fourth factor in the foam formula is a safety concern that comes from NFPA 11-Standard for Low Expansion Foam. NFPA 11 states that we should have enough foam concentrate to flow finished foam for a minimum of ***15 minutes*** at the critical application rate.

There is one additional factor, which is not in the formula, that is called the ***"X Factor."*** The X Factor is the aeration expansion ratio that the nozzle produces. Since some fire departments may use non-aspirating nozzles with no aeration capability the X Factor was not put into the formula. If you do know the expansion ratio of your nozzle, or nozzle attachment, this factor can be added. For example, a Task Force Tip (TFT) will aerate, or expand, the foam solution at the nozzle by a factor of 4 (4:1). By adding the TFT nozzle attachment for foam operations, the expansion ratio is 8 to 1. This simply means that air has been added to the foam solution to expand it 8 times the original volume. Aerating nozzles and attachments greatly extend your foam supply by covering more of the spill.

To summarize, the following formulas can be used at spill scenes involving flammable liquids.

- For hydrocarbon spills such as gasoline the formula is: ***Area X 0.1 $gpm/ft^2$ X 0.03 X 15 = foam concentrate needed***
- For polar liquid spills such as ethanol the formula is: ***Area X 0.2 $gpm/ft^2$ X 0.06 X 15 = foam concentrate needed***

Now, the chances of a firefighter accurately calculating these formulas while at a flammable liquid spill with fire are fairly low. There is just too much to recall especially in the middle of a stressful situation. There is a better way!

To follow Thoreau's wisdom, the above formulas can be simplified by doing the multiplication of the known components to:

- Hydrocarbons — ***Area X 0.045***

- Polar Solvents — ***Area X 0.18***

Because this is not an exact science, we can round the numbers up, which turns out to be another safety factor in our favor. The formulas then become:

- Hydrocarbons — ***Area X 0.05***
- Polar Solvents — ***Area X 0.2***

We can also express the above formulas in division. The formulas then become:

- Hydrocarbons **— *Area /20***
- Polar Solvents — ***Area/5***

These formulas are now in a manageable and easily recalled context that many firefighters have found very useful at flammable liquid emergencies.

To reinforce the use of the simplified formulas the following examples can be reviewed.

**How much foam concentrate is needed to cover a 20' X 20' spill of gasoline?**

Full formula is: Area X CAR X ED X 15 = Foam concentrate needed

1. Area=400 square feet
2. CAR=0.1 pgm/$ft^2$
3. ED=0.03
4. 400 square feet X 0.1 gpm/$ft^2$ X 0.03 X 15 minutes = 18 gallons of foam concentrate

Simplified formula is: Area/20

1. 400 square feet divided by 20 = 20 gallons of foam concentrate

The second result here is higher because of rounding but still on the safe side.

**How much foam concentrate is needed to extinguish an alcohol fire that is 30' X 40'?**

Full formula is: Area X CAR X ED X 15 minutes = Foam concentrate needed

1. Area = 1200 square feet
2. CAR = 0.2 gpm/$ft^2$
3. ED = 0.06
4. 1200 square feet X 0.2 gpm/$ft^2$ X 0.06 X 15 minutes = 216 gallons of foam concentrate

Simplified formula is: Area/5

1. 1200 square feet divided by 5 = 240 gallons of foam

Remember, in the above examples the "X Factor" was not part of the formula. With a nozzle attachment that has an expansion ratio of 8X your foam supplies will go eight times farther.

One last concept to realize with foam operations is what your limitations are. In other words, how big of a flammable liquid spill will your available foam concentrate reserves cover? This spill area can be calculated before an incident by using the following formulas.

- For hydrocarbons: ***Area = foam concentrate reserve X aeration factor of your nozzle divided by 0.045*** or ***Area = gallons of foam X 8/0.045***

- For polar liquids: ***Area = gallons of foam X 8/0.18***

As an example, if you have 20 gallons of foam concentrate and you have a gasoline spill, how big of an area can you blanket with foam?

1. ***Area = 20 gallons X 8/0.045***
2. ***Area = 3,555.56 square feet or 59.6' X 59.6'***

You are limited to an area of approximately 60' by 60' for hydrocarbon spills.

Another example: If you have an ethanol spill and 20 gallons of foam concentrate, what are your limitations in terms of the area you can cover?

1. ***Area = 20 gallons X 8/0.18***
2. ***Area = 888.89 square feet or 29.8' X 29.8'***

You are limited to an area of approximately 30' by 30' for polar liquid spills.

Knowing your limitations is important because it would be wasted time, effort, and foam to initiate foam operations on a spill that is larger than you can cover alone. The fire may burn back and consume the foam that you applied if you did not completely cover the area. It would be prudent to elect to wait until more foam arrives before you begin foam operations.

It is hoped that these simplified formulas work for you and the "voodoo science" of foam operations has been demystified. Still, to stay adept at foam operations, practice is required, both with calculating foam concentrate needs and with your foam-producing equipment. Additionally, keep your limitations in mind. Familiarity through training and drilling is the key to handling flammable liquid releases efficiently and safely.