Fire Streams and the Exponential Engine

By: Brian Brush
www.FireByTrade.com

As of late I have been fielding a lot of questions regarding apparatus set up and nozzle selection. It is encouraging to see such an interest in one of our professional foundations. I believe it means that firefighters are taking greater ownership in decisions which may have been more recently dictated to their departments by savy vendors. I enjoy assisting firefighters work through nozzle studies and flow testing because I know the value of these processes to a department and its members.

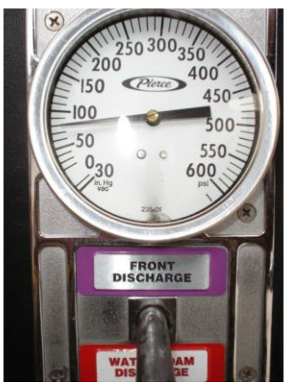
In 2005 my department conducted a year-long fire stream and nozzle study; the information collected and changes made as a result of it have made our operations more efficient and our operators more knowledgeable. Since that study I have been fortunate enough to train and network with firefighters from around the country and at the highest levels of education and experience in engine company operations. I am still very much a student of the game and continue to learn on a daily basis. With that said there seems to be recurring questions in many of contacts I have had lately. I believe that I may be better able to answer them to the masses rather than one at a time. So settle in for a little bit of rambling or pick off sections that you are seeking.

Fire Streams

IFSTA will tell you that a fire stream is the "*Stream of water or other extinguishing agent after it leaves the fire hose until it reaches the desired target.*" To me this is too narrow of a view on the fire stream. The stream of water leaving the fire hose on its way to the target is the end result of a system from the source to the nozzle. If a group or department wants to evaluate their fire streams they must be willing to analyze all parts of that system for influence and change. If you are given the chance to lead or be a part of a fire stream evaluation process or nozzle study you will fail the opportunity if you get trapped in a smooth bore versus fog focus.

Pressure and Volume

We have established that the fire stream is the end result of a system but it is also combination of pressure and volume. As it pertains to the fire stream, pressure is the delivery vehicle and volume is the extinguishing power. My experience is that the relationship between these two is generally not given the attention it deserves. It should be revisited early in the conversation so you have a clear idea of your goals.



Pressures

Let us start by discussing pressure; this simple concept seems to create the greatest turmoil in these processes. I like to review pressure in terms of necessary and unnecessary pressures. In order to deliver the goods (water) from the tank to the fire we need the right pump discharge pressure. The right pump discharge is the sum of necessary pressures. Necessary pressures include the friction loss, elevation loss or gain (+ or – 5psi per 10’) and the nozzle operating pressure.

Friction Loss Formula and Coefficients

$FL = CQ^2L$

C = Coefficient of the hose

- (Per IFSTA) 1 ¾” = 15.5
- (Per IFSTA) 2 ½” = 2

Q = Gallons per minute divided by 100

L = Length of hose divided by 100

Example using IFSTA coefficients: Friction loss created by 150 GPM flowing through 100’ of 1 ¾”
$FL= 15.5x1.5^2x1$ (35 psi per 100’)

One of the first mistakes many of us make is the assumption that numbers presented in books are representative of our line operations. When we began to utilize flow meters and pressure gauges in our field testing one of the first things we discovered was that our pump charts were inaccurate. It took very little detective work for us to track it down to inaccurate hose coefficients.

Hose coefficients vary based on manufacture, construction materials, age of hose and the biggest factor is internal diameter. The IFSTA coefficients referred to above are derived from internal hose diameters true to the referenced sizes. We discovered, as many in the industry are reporting that the internal diameters of our hoses are larger than labled. For example our 1 ¾" lines are closer to 1.9" and our 2 ½" lines are closer to 2.75". While this may seem "slight", when it comes to friction loss the effects are significant. By taking an overall average of all flow tested hose of varying ages and manufacture we found our overall our 1 ¾" coefficient is actually 11.5 and our 2 ½" 1.4

How much difference does this make?

Example using actual coefficients: Friction loss created by 150 GPM flowing through an 1 ¾" line
FL = 11.5 x 1.5^2 x1 (25psi per 100") 10 psi or 28% less

In the 2 ½" we see a similar difference.

Example using actual coefficients: Friction loss created by 250 GPM flowing through an 2 ½" line
FL = 1.4 x 2.5^2 x 1 (9psi per 100") as compared to 12.5 per 100' using the coefficient of 2. Again, a 28% reduction in the friction loss from expected to actual.

This is the first clarification of necessary versus unnecessary pressures. If you take the time to truly evaluate the system you may see the over pumping of lines by a considerable amount. It would be inaccurate to say that the above example equates to over pumping by 28% because as pressure is increased you may be increasing flow which will have an increased friction loss and so forth. What we can clearly correlate is that pumping the line beyond what is needed to meet the necessary pressures of the operation will result in an increase of pressure at the nozzle and therefore increase nozzle reaction

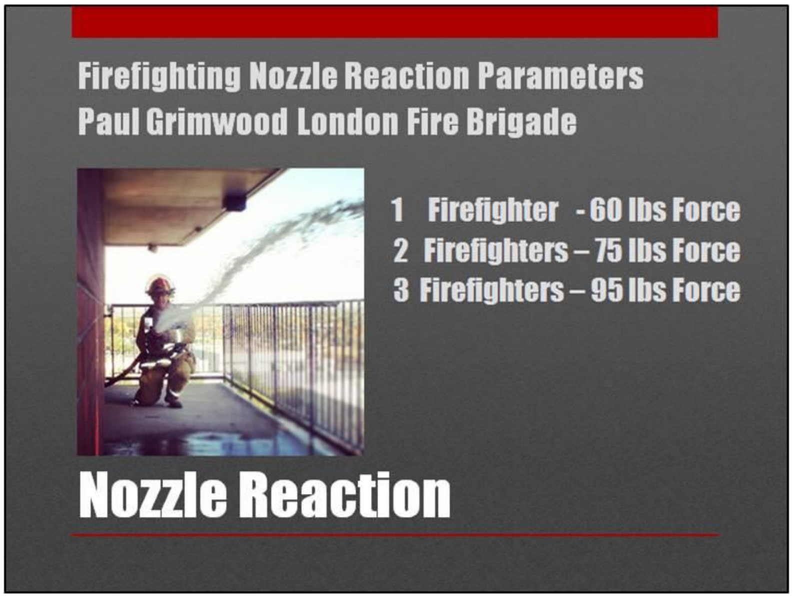
Nozzle Operating Pressure

The smooth bore nozzle may be viewed by some as “dated” by some but if you take a little deeper look at history you can see some very sound reasoning in the smooth bore nozzle.

Since we are discussing pressure we can begin with the operating pressure of the smooth bore which is a range from 40 to 60psi with 50psi as the optimal operation. This was important to our forefathers in the fire service as early pump systems were primarily lower pressure and could see significant fluctuations with more than one line being supported simultaneously. The solid stream and long tip provided accurate delivery of the fire stream at a great distance for firefighters with limited PPE.

As technology advanced, our pumps were able to provide higher and more consistent pressures. Lloyd Layman and various others brought the fog nozzle into the American fire service, vendors started to develop automatic nozzles and before we knew it there was a shift from a 50psi fire service to 100. Over the last 15 to 20 years an increasing number of firefighters and departments are beginning to question what has been gained by doubling our nozzle operating pressures. In many cases it is being discovered that for the most part the only true gain has been nozzle reaction which simply equates to more work on the nozzle firefighter.

"Arguments for and against the use of various nozzle designs often become nullified on the fire ground as crews find they cannot safely operate lines which exhibit high nozzle reaction forces" Captain David P. Fornell



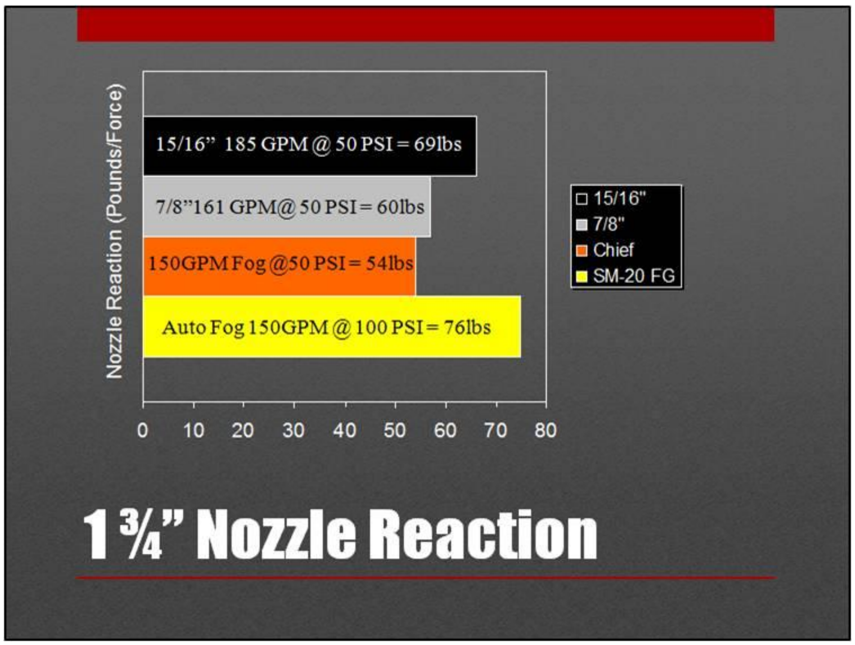
There have been several studies done over the last 20 years into nozzle reaction and how it effects hose line operations. The goal of these studies has been to identify how much nozzle reaction firefighters can comfortably handle while still being able to effectively advance and manage a hose-line. A study by Paul Grimwood outlined three working limits; 1 firefighter (60 force/lbs), 2 firefighters (75 force/lbs), and 3 firefighters (95force/lbs). I have been fortunate enough to work with firefighters across the country on hoseline operations and I can tell you that with good technique, practice, improved fitness and continued work, firefighters can easily operate lines with nozzle reaction forces beyond the above working limits but overall these working limits are very accurate for the majority of firefighters and the median level of training.

Nozzle reaction is the resultant pounds force push back of the combined volume and pressure leaving the nozzle. The only way to alter nozzle reaction is to alter the volume (GPM) or the pressure. Many people have used a variety of methods to demonstrate nozzle reaction like fish scales and rope but the actual force is calculated using the formulas below. As a rough rule of thumb the pounds force of nozzle reaction for a 100psi nozzle is ½ of the GPM.

Fog Nozzle Reaction
NR = .0505 Q √NP
NR (Nozzle Reaction)
Q= Gallons Per Minute
NP = Nozzle Pressure

Solid Bore Nozzle Reaction
NR = 1.57 D^2 NP
NR (Nozzle Reaction)
D = Diameter of tip
NP = Nozzle Pressure

On this nozzle reaction chart we can see the amount of nozzle reaction associated with four very common 1 ¾” nozzles. You can also see the side by side comparison of a 150 GPM at 50psi fog with a 100psi automatic fog. Flowing the same GPM there is a nozzle reaction difference of 21 lbs. At 100 psi and 150 GPM the nozzle reaction of 76lbs is at the working limit of 2 firefighters. Here is where you need to question if your department sees this as necessary or unnecessary pressure.



With good practices and techniques, firefighters can work beyond the outlined nozzle reaction parameters above. Without those practices, nozzle reaction forces beyond 60lbs typically begins to reduce the effectiveness of the single firefighter nozzle operator.

This is a very important piece of the puzzle when purchasing equipment for the engine staffed with three. A three person engine company translates to a two member first due attack line. I have seen it time and time again where departments are training, purchasing and writing policy for staffing that they do not have.

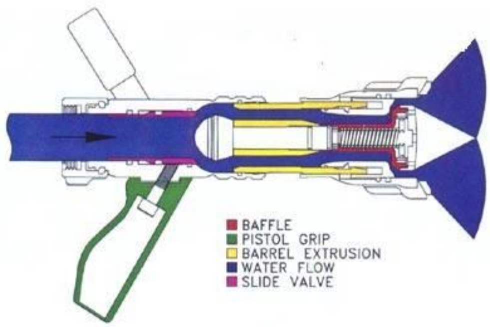
If you have ever stretched a line from an engine to the second floor bedroom as the nozzle firefighter with only one other person you will discover instantly that you must learn to operate that nozzle without the luxury of a back up firefighter behind you to assist in countering nozzle

reaction. The other member will almost always be working to tend the line through furniture, around corners and up stairs somewhere between your location and the front door.
If the 1 ¾" is your department's "90% of the time" and your engine company staffing is three members, you must identify what your firefighters are comfortable with in regards to operating a line by themselves, it may be surprisingly less than you assume.

The most common example of this is when departments purchase 15/16" smooth bores for their 3 person engine companies without testing them or comparing them to the 7/8" tip and they end up with nozzle firefighters struggling. The 15/16" tip was born in New York City where lines are staffed with a nozzle firefighter, back up, and door man. It is too often lost on departments that when the duties of a back up firefighter and door man are put on one person they are not the only ones who end up working harder.

A Case Study In Nozzle Reaction and Function

The advertised benefit of an automatic nozzle is a "wide operating range without stream compromise" Without getting too in-depth; this is achieved through an internal compensatory spring that adjusts with flow to maintain a constant nozzle pressure and steam. This type of nozzle essentially puts the flow rate in the hands of the pump operator and in the absence of a set department standard this becomes a very concerning unknown.



Our department primarily has 3 person engine staffing. In 2005 when we wanted to see if a nozzle study was needed at our department one of the first steps was to take 10 different engine companies, have them deploy and flow a 1 ¾" attack line and record the pump discharge pressure. At that time our department was using a 100psi automatic nozzle on all 1 ¾" attack lines. From the data collected we found that our average flow from these lines was 100 GPM. When the pump operators were asked why they pumped at their selected pressures almost all responses were not flow related, they were firefighter related. Nearly every operator stated they under pumped the lines initially to make it easier on the nozzle firefighter and they would increase the pressure if they called for more water.

Within this information is a very important finding. Our pump operators were acutely aware of the challenges of high nozzle reaction and they were attempting to address them for the nozzle firefighter hydraulically. Unfortunately in their good intentions is a risky business of not only under pumping (pressure) but by design also under supplying (volume) those firefighters entering the structure.

The idea that a firefighter "can always call for more water" comes from the known that an automatic has that wide flow range. The reality is that the stream quality is maintained throughout that wide flow range and the nozzle operator typically does not identify one lacking volume. Additionally the nozzle firefighter knows that requesting more water increases pressure, making for a more difficult line to manage. As you can see these contributing factors all conspire together and that "call for more water" never comes.

Using the average of 100 GPM from that 100 psi automatic fog nozzle and the fog nozzle reaction formula, we discovered that our firefighters and operators have subconsciously shown that a nozzle reaction of 50lbs is a comfortable point. Since nozzle reaction is dictated by a combination of pressure and flow so it serves as the perfect point in the discussion to bring the two together.

With the finding that our firefighters felt most comfortable handling about 50lbs of nozzle reaction we had a starting point. The next step was to determine a target flow for our 1 ¾" attack lines as it was clear from this initial test that we did not have one. For the goal of the study we wanted to establish 150 GPM as the minimum flow for any interior attack lines.

Volume: A Starting Point

To begin to start talking about interior fire attack and target volume I think it is best to start the conversation with the line that most fire departments start with for fire attack. I am well aware that many departments use 1 ½" and 2" lines but most departments are using 1 ¾" as their "bread and butter" attack line. I will expand on this conversation later but at this point we will use the 1 ¾" as our starting point and my departments experience as a background.

Why 150 GPM? Nationally, 150 GPM has become the target flow for 1 ¾" attack lines. This number comes from NFPA 1710 (Organization and Deployment of Fire Suppression Operations by Career Fire Departments). The standard outlines that the first two attack lines in operation at any residential structure fire flow a minimum of 300 GPM combined. With the NFPA wording you could flow 100 GPM with your initial line and 200 GPM with a second line but the common sense approach and now industry standard has targeted 150 GPM as an interior attack standard.

Utilizing nozzle reaction parameters and a set minimum standard for volume, the rest of the process is relatively simple; find nozzles that flow greater than 150 GPM with nozzle reactions near 60lbs and put them in the hands of firefighters for them to find their preference.

Common 1 ¾" Attack Line Nozzles and Reaction Force

150 GPM at 50 PSI Fixed Gallonage Fog = Nozzle reaction force of 54lbs
7/8" Smooth Bore 161 GPM at 50 PSI = Nozzle reaction of 60lbs
150 GPM at 75 PSI Fixed Gallonage Fog = Nozzle reaction force of 65lbs
15/16" Smooth Bore 185 GPM at 50 PSI = Nozzle reaction force of 69lbs

At the end of 2005, following a full year trail period with a variety of nozzles the preference of our firefighters was the 7/8" smooth bore with a flow of 161 GPM at 50 psi and a nozzle reaction of 60lbs. The second and third choices were close, with the 150 GPM at 50 psi fog and the 15/16" smooth bore with a flow of 185 GPM at 50 psi. Ultimately department heads decided we would change from the 100 psi automatic fog nozzles to 150 GPM at 50 psi fog and 15/16" smooth bores on all our 1 ¾" attack lines. The change was welcomed and our efforts to educate and improve operations were overall a success, however, today I would ensure we saw the idea through completely. In seeing other agencies struggle with the similar "buyer's remorse" I hope a little more information may prevent it from happening to more.

The Fog Fixation

If a department has embraced a fog nozzle option at any point in recent organizational history it is very difficult to shift completely away from them. With sound parameters fog nozzles can easily meet the goals of improving engine company efficiency and reducing nozzle reaction. There are a few common trapping points that departments most often fall in with regards to making a nozzle change of this nature and keeping the fog as an option.

When a department that traditionally used 100 psi automatic nozzles faces these questions and challenges to reduce nozzle reaction they sometimes find the simplest answer is to just change to a low pressure automatic. It requires very little cultural change and if they feel a "wide flow range without stream compromise" has value, it keeps this as an option in operations.

The risk with changing to a low pressure automatic is that the treatment is only handling a single symptom; pressure. As long as "wide flow range" is an option, unknown or inadequate flow is an ever present threat. Low pressure fog nozzles for interior firefighting should have a fixed gallonage so that they provide the same volume indicators that a smooth bore does. With fixed gallonage nozzles, under pumped or kinked lines present with a poor or absent stream giving the nozzle firefighter pause before committing to an environment without appropriate GPM not compensating for and ultimately concealing it from them.

Fire departments that choose CAFS for some of their fire attack operations also often find themselves facing a bit of a challenge when it comes to fire stream selection. Most CAFS manufactures recommend that a 1” smooth bore tip be used for the optimal CAFS stream delivery. A 1” smooth bore on a 1 ¾” hose can make for a challenging line to manage. This often pushes these departments to using a “breakaway” or flip tip set up with a fog tip on top of the 1” smooth bore for exchange between the two. I see this as adding more complexity to the system. While the 1” tip may be the recommended tip size for CAFS I think it is incumbent on your organization to evaluate if this will truly work for your operations and staffing or if some give up in the quality of a foam stream may yield an overall safer and simpler operation like the use of a 7/8” smooth bore tip with a 150 GPM at 50 psi fog tip as a breakaway package that allows for greater versatility and more common operational field.

When departments elect to provide both a smooth bore and a low pressure fixed gallonage fog to their members it is important to aim for hydraulic parity. Our department selected the 150 GPM at 50 psi fog and the 15/16” smooth bore which provides the prime example of the hydraulic challenge for pump operators with two lines off.

200’ 1 ¾” Line Disparity:

50 psi Fixed gallonage fog at 150 GPM with a friction loss of 25 psi per 100’ = 100 psi pump discharge pressure

50 psi 15/16” Smooth bore at 185 GPM with a friction loss of 40 per 100’ = 130 psi pump discharge pressure.

Two lines off of the same panel with a 35 GPM and 30 psi difference between them.

This set up exceeds the NFPA standard of 300 GPM from two handlines by 35 GPM and the low pressure nozzles have a manageable nozzle reaction, the challenge comes in their combination. If the 15/16" tip is pulled first and the fog second you are essentially backing up your initial line with a lesser stream. As a pump operator any mix up between the two tips and you may be significantly over pumping one or under supplying the other. If you are intending on providing a smooth bore and fog option attempt to find hydraulic parity for target flow and pump operation.

Hydraulic Parity Examples

Example 1: Similar flow and similar nozzle reaction for a 200' 1 ¾" attack line

50 psi Fixed gallonage fog at 150 GPM with a friction loss of 25 psi per 100'(2) = 100 psi pump discharge pressure matched with 50 psi 7/8" Smooth bore at 161 GPM with a friction loss of 30 psi per 100'(2) = 110 psi pump discharge pressure. Pump both lines to the higher 110 psi PDP, while the fog will be over pumped it has the overall lowest nozzle reaction at 54lbs force at 50 psi so even with the extra pressure will still maintain a very manageable line.

50 psi Fixed gallonage fog at 185 GPM with a friction loss of 40 psi per 100'(2) = 130 psi pump discharge pressure matched with 50 psi 15/16" smooth bore at 185 GPM with a friction loss of 40 psi per 100'(2) = 130 psi pump discharge pressure. True hydraulic parity both nozzles with the same GPM rating at the same operating pressure.

Example 2: Similar target pump discharge pressure different flow for 200' 1 ¾" attack line

75 psi Fixed gallonage fog at 150 GPM with a friction loss of 25 psi per 100'(2) = 125 psi pump discharge pressure matched with 50 psi 15/16" smooth bore at 185 GPM with a friction loss of 40 psi per 100'(2) = 130 psi pump discharge pressure. Provides a lower or higher volume line selection option with the fog at a mid range pressure. Pump both lines to the higher pressure and see similar nozzle reaction forces and equal pump discharge pressure.

Volume: The Exponential Engine

I would say there are two questions I field more than any others when it comes to fire streams and apparatus set up. The first is, “How is your engine set up?” and the second, “How would you set up an engine”. I believe most the time people who ask the first question really want the answer to the second question. They are assuming that the way my fire department has the engine set up is the way I would want it if it was mine personally. Unfortunately, if you have been in the fire service for more than a day or two you should know that the power of line operators can be limited when it comes to purchasing, apparatus set up and “standardization”.

So rather than waste the explanation of how an engine is currently set up and what I would change I think it would be best to start with a blank sheet and explain one approach to setting up an a rig to maximize first due potential with the exponential engine approach.

Definition

As stated above, this is intended to address the masses and focus on first arriving engine operations. Before it is taken further I will explain my observation and therefore the context of today’s modern American engine company as it pertains to this piece.

- 3 person staffing (Operator, Officer, Firefighter)
- 2 person attack line (Officer, Firefighter)
- Water as extinguishing agent (No CAFS option)
- 500 gallon onboard tank
- 1 ¾” , 2 ½” and Engine mounted master stream as initial attack options

Exponential Attack

In various firefighting and fire prevention documents you can find that given appropriate fuel and air a fire will double in size every XX seconds or minutes. I have seen it referenced as fast as 30 seconds and as long as 2 minutes. The difference in time of 30 seconds to 2 minutes has never bothered me too much as I see both as relatively fast, the point that always has stuck with me from that adage is the term “double in size”.

When I consider something doubling in size I think of exponential growth and I believe that if we view the fire as an enemy, exponential growth of the enemy’s force is a power curve that must be addressed swiftly and with dominance. I think that most engaged firefighters would agree with that point, but how we attack swiftly and with dominance has many forms when it comes to fire streams.

There are firefighters pushing for greater volume on all initial lines with the use of intermediate lines and tips like 15/16” and 1” tips on 2” attack lines. Others are advocating for immediate fire stream application for the exterior if there is an opportunity with an interior follow up to “reset the fire” and interrupt that exponential growth. All of these ideas have merit as they are people attempting to find the right solution for their agencies to address the modern fire environment. Among these ideas I would like to present one more way to combat exponential fire growth and that is with an exponential fire attack plan.

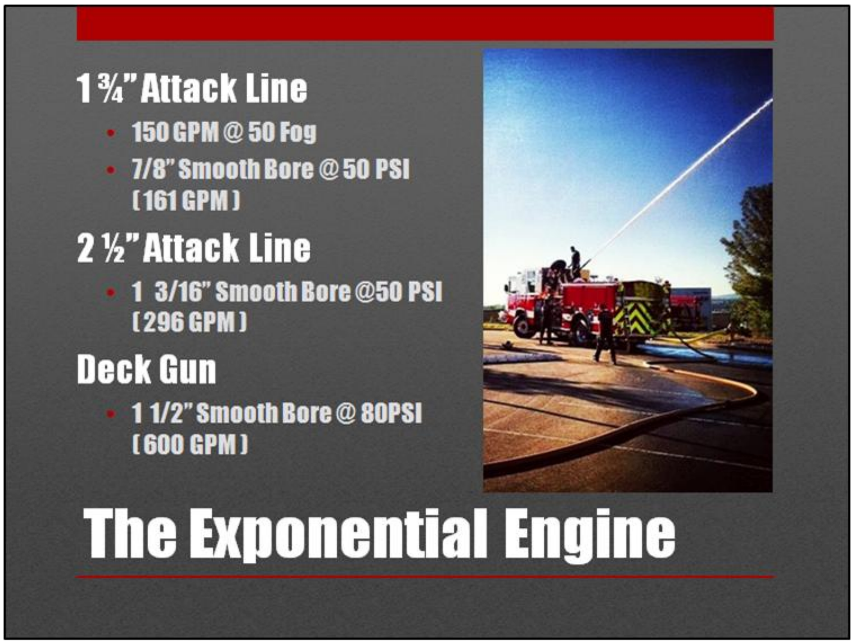
The idea of the exponential engine set up came to me while I was sitting in a class at FDIC being delivered by Chief Curt Isakason from Escambia County Fire Rescue. Chief Isakson was speaking about the importance of rapid water application and he instantly shifted my thinking when he began to discuss fire stream flows in terms of gallons per second versus gallons per minute.

Have you ever heard this before? *“If you take the XXXX fire formula, a typical bedroom fire only takes 40 GPM to control. It is over kill to take a 150 GPM fire stream to such a minor fire”* I know I have and it always frustrated me that this type of debate would even occur. To be honest I always struggled with articulating an sound counter until I began to consider the importance of exponential fire growth and gallons per second.

Let us say that a fire does in fact double in size every 30 seconds. If a current bedroom fire takes 40 GPM to control doubles in 30 seconds, 30 seconds from now it requires 80 GPM and at 1 minute it requires 160 GPM. A 150 GPM stream is a 2.5 gallon per second stream. At 2.5 gallons per second, 40 gallons of water is delivered to that bedroom in just 16 seconds of operation. At 30 seconds of operation 75 gallons of water would be delivered to that room likely resulting in total room cooling not just fire control.

Chief Isakson's message to shift the language fire streams to gallons per second could not be more appropriate. If the statement that a fire doubles in size every 30 seconds is wrong so be it, but you cannot argue that fire behavior in enclosed structures is changing faster than ever before and our windows of opportunity which were once measured in minutes have been reduced to seconds.

So if we are dealing with exponential fire growth, limited staffing and rapidly changing fire conditions the entire fire service should be evaluating their fire stream systems from the source to the nozzle not just a few inspired firefighters because we need to find ways to leverage our efforts at every point.



To provide a very brief overview before I expand on the idea, every engine company should be designed with a first due "Plan A" to attack whatever you have with all you have. Setting up a rig for with a plan for extended operations or waiting for the cavalry to arrive before you act only puts you closer to engaging a different fire than the one you are currently seeing (catch up). Variables will forever exist and nothing is set in stone but we are firefighters so plan for a fight.

1 ¾"

One of the biggest pushes out there is greater volume from initial lines. Many fire departments are choosing 15/16" smooth bores or 185 GPM fogs, some even experimenting with 2" hose and 1" tips for the foundation of their fire attacks. If training, district construction and staffing make these viable options great; you are taking big weapons to the fight early on.

In my experience the initial handline for residential fires (a room or rooms on fire) for most fire departments is the 1 ¾".

The benefits of the 1 ¾” attack line is that it supports a good fire flow for these size fires and it is very maneuverable for working on the interior of smaller compartmentalized occupancies. I think it is important to play up these strengths of the 1 ¾” and be cautious of the diminishing returns that the 3 person engine company encounters when too much is asked of this line. If our minimum interior attack fire flow is 150 GPM then the key operational range for the 1 ¾” attack line is between 150 and 185 GPM. Working above this range in volume starts to creep into high friction loss ranges and nozzle reaction forces especially if nozzles are used with operating pressures greater than 50psi.

What is key to remember is that nozzle ratings are just “ratings”, when closed all nozzles flow 0. A 150 GPM or 2.5 gallon per second nozzle may seem “inferior” to one that flows 185 GPM or 3 gallons per second, but if the nozzle firefighter can comfortably flow that nozzle for 30 seconds at a time around a corner while actively playing it they are delivering 75 gallons to the fire environment. A nozzle firefighter that is struggling with a 185 GPM or 200 GPM nozzles that can only operate it for 10 to 15 seconds at a time without fatiguing, and has poor stream movement is potentially ineffectively applying only 30 to 50 gallons to the fire environment at a time.

This is why I think the foundational line of the exponential engine company should be the 1 ¾” line so it can be rapidly deployed and easily maneuvered into position in the fire building with a nozzle flowing 2.5 gallons per second from a 150 GPM at 50 psi fog or 7/8” smooth bore with a nozzle reaction of 60 lbs force or less.

2 ½”

"I will not dispute that 2 1/2-inch hose is difficult to use, but no combination of smaller hand lines can duplicate the volume, reach, and pure knockdown power of a single, well-placed 2 1/2-inch line.” Andy Fredericks

At this point I don’t see the need to review ADULTS or get really detailed into when we should pull the 2 ½”. I think if you have hung on this long in the article you can recognize a fire that demands the 2 ½”. The struggle seems to come when the discussion shifts from when to how, especially with the 3 person engine. The most common concerns are that it is such a bigger and heavier line; in these concerns about the use are the keys to its use but we need to have more realistic expectations.

The 2 ½" attack line is not an 1 ¾" accept that and move on. The 1 ¾" is the lightweight fighter; it can skip around the ring quickly for all 12 and with great agility. The 2 ½" is the heavy weight fighter, it will move slower but with purpose, there can't be wasted energy and it is hoping for a early knock out so it doesn't have to go the distance. In short the 2 ½" can be used very effectively with limited staffing it will just be a little slower and for not nearly as long of an engagement but the punch it delivers is a big enough benefit that it is worth it.

Attack whatever you have with what you have and understand the purpose of gallons per second.





Arrival Nozzle opening 10 seconds of flow 20 seconds of flow 30 seconds of flow

The series of pictures above is a single firefighter putting a 2 ½" attack line in to service on a working fire while his officer sets up the line for advancement after the knock down. The nozzle is an 1 1/8" smooth bore and the line operated for about 30 seconds from the parking lot before it was shut down and advanced into the stairwell for follow up. In that 30 seconds 132 gallons was delivered and it made a significant difference on that fire. While a second alarm was instantly called for on this fire, the quick action and rapid delivery of water prevented this fire from growing to the point where those resources were needed.

While working with another firefighter recently we reviewed this video and his comment was "That is a great example of using what you have. Too often we drive around in fire engines and act is if we don't have tanks of water" His point, my point and Chief Isakson's point is that if you view the 2 ½" as a 250 gallon per minute line then your thinking will inherently fall to flowing for minutes, and you will talk yourself out of using it because you believe you do not have the ability to support it. If you look above at the effect that 132 gallons delivered over 30 seconds had on that fire and you imagine your 500 gallon tank allowing for that kind of knock down to be followed up almost 3 more times you should see that you are not giving yourself near enough credit for your capabilities and you are just sitting on your opportunity to make a difference.

The above attack used an 1 1/8" smooth bore which flows 265 GPM or 4.4 gallons per second which is impressive but the idea of an exponential engine is exponential increases and we started with a 150 and 161 GPM line so the goal would be to put at least a 300 GPM 2 ½" into service as our next option delivering 5 gallons per second. In order to place a 300 GPM attack line into service nozzle selection is very limited. A 100psi fog nozzle delivering 300 GPM would have a nozzle reaction of 150lbs force and would be extremely difficult for any firefighter to utilize in anything other than a fully defensive position. At this time I am unaware of any manufactures making a 50 psi fogs over 300 GPM. At 50 psi the 1 3/16" smooth bore delivers 296 GPM or 4.9 gallons per second with 111lbs of nozzle reaction and the 1 ¼ smooth bore delivers 328 GPM or 5.5 gallons per second with 123lbs of nozzle reaction.

Of these tip choices I personally would feel comfortable with either as a weapon just as I would with the 150 GPM at 50psi fog or the 7/8” smooth bore on the 1 ¾” attack line. There is one thing I did find particularly interesting about the 1 3/16” tip when you apply our true 2 ½” friction loss coefficient compared to the 1 1/8” tip with the traditional IFSTA based coefficient.

Friction loss per 100’ of 2 ½” hose flowing 265 GPM from a 1 1/8” smooth bore tip using the IFSTA coefficient of 2 is 14 psi

Friction loss per 100’ of 2 ½” hose flowing 296 GPM from a 1 3/16” smooth bore tip using actual coefficient of 1.4 is 12 psi

Technically if you are using IFSTA based coefficients and modern 2 ½” hose you could just go replace all the 1 1/8” tips on your attack lines with a 1 3/16” and you would be flowing over 300 GPM or 5 gallons per second from your lines without anyone even knowing. Furthermore the very low operating pressure you may find the opportunity to eliminate a step for your pump operator. It only requires a pump discharge pressure of 68 psi to flow a 150’ attack line with an 1 3/16” tip flowing right at 5 gallons per second. I have seen this operating pressure to be nearly idle for many modern fire pumps. Imagine if you set up a preconnected 5 gallon per second attack line to the point that it could be supported at idle. Imagine the speed which big water could be applied if all your pump operator would have to do when they got out of the cab would be to pull the tank to pump eliminating the need to throttle up.

I know we clearly outlined working limits for nozzle reaction and the fact that this plan is intended for the 3 person engine company but if you remember the challenges of a bigger heavier line are also the keys to its use.

When you are advancing or dragging a line, friction is your enemy because you want the line to move forward into position with as little resistance and work as possible. When you are flowing a line friction becomes you friend because you can use it to absorb and counter nozzle reaction. The bigger and heavier a line the more friction is present and well trained operators can capitalize on that friction to serve as a back-up man in absorbing and grounding nozzle reaction. Additionally the larger diameter hose creates a more solid pipe and allows for more line to be moved ahead of the body resulting in greater stream movement without exaggerated body movement.

In all these pictures the single operator is flowing between 265 and 300 GPM using line weight, the ground, a curb, wall or good body form to handle the higher nozzle reaction. As stated above this makes it a much less mobile line when compared to the 1 ¾” and it will most likely only be operated in a hit and move process but what is compromised in mobility is made up for in stream reach, punch and an extinguishing power that has been doubled without any staffing changes.

The Deck Gun

The deck gun might be a regional term, I have also heard it called the monitor or the “Stang” but we are talking about the engine mounted master stream. Most engine mounted master streams fog, or a stack of smooth bore tips have a flow range of 500 to 1000 GPM.

If we review our progression, the 1 ¾” flowing 2.5 gallons per second is a rapidly deployed and highly mobile attack line for a room or rooms of fire. The 2 ½” attack line flowing 5 gallons per second is our heavy weight fighter looking for the big knockdown against the big opponent of a full residential floor on fire, commercial occupancy fire or any of the ADULTS situations. Finally we have the deck gun for those marginal situations where you arrive to find an entire building on fire and rapid application of your entire tank at 10 gallons per second is required to nuke the fires progress and prevent extension to exposure occupancies.

2.5 gallons per second doubled is 5 gallons per second. 5 gallons per second doubled is 10 gallons per second so our target rating for a deck gun would be 600 GPM. The point of picking 600 GPM as the target flow for the deck gun goes beyond just the goal to double the volume of our previous attack level. Engine mounted master streams outfitted with a series of stacked smooth bore tips are most commonly found with an 1 3/8”, 1 ½”, 1 ¾” and a 2” tip.

Smooth Bore Tip Sizes and Stream Volume at 80psi

1 3/8” 500 GPM – 1 ½” 600 GPM – 1 ¾” 800 GPM – 2” 1000 GPM

When a smooth bore of these diameters are used as master streams the operating pressure is 80psi and because the apparatus is the platform of operation nozzle reaction is not needed to be considered. Most of the times I check engines with these stacked tips I find that the full stack is in place with the 1 3/8” on top. Two reasons for this are because they came that way or because the engine has a 500 gallon tank and to use a 500 GPM tip would give nearly a minute of operation before a supply is needed.

Once again this is thinking in minutes and trying to make what you have last over making what you have matter. I recommend the 1 ½” tip as the first up on the deck gun. Having tried this on a variety of different engines I have found this 10 gallon per second stream to be the highest volume, best quality stream that can be delivered strictly from tank supply. As you begin to move to the 1 ¾” and 2” tips a lot is being asked of the unsupported pump and internal plumbing and the lager tip size reduces the stream reach and pin point accuracy that you find in the 1 ½” tip.

Exponential Engine Summarized

There are hundreds of potential options and combinations for means of fire attack at the disposal of today’s firefighters; this approach is just one of them. My belief is that while there are hundreds of options, the three person engine can really only perform one action and this is one way to attempt to simplify and maximize the effectiveness of these actions.

Conclusion

It is difficult to try to find a point to stop this type of conversation because there is so much there is really so much that must be discussed. To be honest the goal of this piece is not to conclude anything, but to create more and deeper conversation on the topic. The few pages of opinion thrown down here will hopefully just lead you to investigate ideas and thousands of pages of real information from Lloyd Layman, Andy Fredericks, Dave Fornell, Aaron Fields, Dennis Le Gear and Curt Isakson. If you take nothing else from this it should be that blind acceptance is dangerous and inquiry is powerful. Find out why you are using what you are using, how it works, and what opportunities exist to make things better.

FIRE BY TRADE

HARD WORK ALWAYS WORKS