BALANCED FIRE ATTACK

Using the Task Force Tips Automatic Fog Nozzles

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Preface

This booklet explains how to use the Task Force Tips Automatic Fog Nozzles to fight a confined structure fire with the least amount of water in the shortest possible time. The strategy and tactics presented are based upon the research done at Iowa State University by Floyd W. (Bill) Nelson and Keith Royer. Their research, beginning in 1951, is still valid today since it is based upon fundamental principles and scientific facts of fire behavior and water behavior. Also its usefulness is reinforced by current research in fire engineering. In other words, their research is just as valid today as it was when it was created, and it will be valid for the foreseeable future.

This booklet starts with a qualitative analysis of fire behavior, introduces the fundamental principle of fire fighting, and then explains how the Iowa Rate-of-Flow Formula was created to calculate the right amount of water. The validity of this formulas is proved by Thornton’s Rule. Then the Iowa formula is generalized by making time a variable so that the formula can be used for any fire attack no matter how many seconds it takes. The next chapter applies all this to the actual practice of fighting fires. The tactics of a combination attack leads to the “art of fire fighting.” This art relies upon the experience and judgment of the fire fighter to make the decisions needed for a balanced fire attack.

Finally, this analysis of fire attack is broadened to consider all the methods of fire attack. Bill Nelson’s guiding principle is used to explain how to choose the method of attack that best fits a given purpose.

Let’s begin with a qualitative analysis of fire behavior.

Chapter One – Fire Behavior

Fire behavior is defined as what happens in a structure when a fire occurs and the only controls are those factors built into the structure itself. Analysis of fire behavior is made from a qualitative point-of-view as distinct from a quantitative point-of-view. Quantitative analysis belongs to fire engineering in which fire behavior is quantified by formulas based upon scientific facts and natural laws. However, qualitative analysis must be derived from and be consistent with quantitative analysis. Thus quantitatively or qualitatively the elements of fire behavior must be the same.

First Principle

There are three principles (or processes) that limit or control fire behavior. The first is the Law of Conservation of Matter, and its companion, the Law of Conservation of Energy. Both laws state in simple terms that matter like energy cannot be created or destroyed.

The combustion process (fire) is a chemical reaction in which oxygen unites with (usually) hydrocarbon fuels. Oxygen is present in air (2l% by volume) and is in contact with fuels everywhere. Combustion does not begin until heat is added. When enough heat brings fuels up to their ignition temperatures, then fire begins and may become self-sustaining, that is, the fire will continue to burn until the fuel supply is exhausted.

Combustion becomes self-sustaining largely because the chemical reaction is exothermic, that is, it releases heat. This heat is not created but it is released when the bonds that unit the atoms in a molecule are broken. In fact more than enough heat is released if the combustion process becomes self-sustaining.

Remember that heat is energy, and energy cannot be created or destroyed. So how can we get rid of all the heat? Heat cannot be destroyed but it can be controlled by an equally powerful endothermic (heat absorbing) process. All fire fighters know what to do, but do you know how this is done?

The essential nature of the combustion process is that it is a

Hydrocarbon air diffusion flame process.

“Hydrocarbon” identifies the source of the fuels which are compounds of hydrogen and carbon. “Air” identifies the source of oxygen which is 21% of air exists as molecular oxygen—O_2 two atoms of oxygen combined. Almost all the rest of air is nitrogen which plays a passive role in the combustion process. “Diffusion” identifies the type of combustion in which the fuels are vaporized and fuel gases unite with the oxygen away from the burning surfaces. A diffusion flame is the moving area with oxygen on one side and the fuel vapors on the other side. This is where the chemical reaction takes place and light and heat are emitted.

Carbon is an unusual substance since it does not have a liquid phase, but changes from a solid to a gas at 6,000^{o}F. This temperature is much higher than most fire temperatures so carbon remains a solid throughout the entire combustion process. This fact leads to two types of combustion, smoldering or flaming.

In the early stages of a fire the easily vaporized elements are burned in flaming combustion that helps retain heat. Enhanced surface area permits oxygen to more inward to the carbon and oxygen unites with carbon to form carbon monoxide (CO). The time for smoldering is dependent upon the thickness of the fuel layer and its duration is measured in hours rather than minutes.

Thus a smoldering fire release heat at a very slow rate compared to flaming combustion.

Second Principle

The second principle (or process) is the rate of heat gain compared to the rate of heat loss. The rate of heat release could remain constant as the fire develops, but it doesn't. The rate of heat gain changes, as does the rate of heat loss. If the rate of heat release increases, this results in heat gain or rising temperatures and increasing volume of fire. At the same time, heat is continuously lost through conduction, convection, and radiation . If heat gain exceeds heat loss, or the reverse, then the result is net heat gain or net heat loss.

Heat gain or heat loss plays a key role in relation to three points important for fire behavior. The points are:

(1) the environmental point (E)
(2) the ignition point (I)
(3) the fire point (F)

In the following graph, temperature increases to the right and heat gain or heat loss increases upward. There is no scale for either axis on this graph

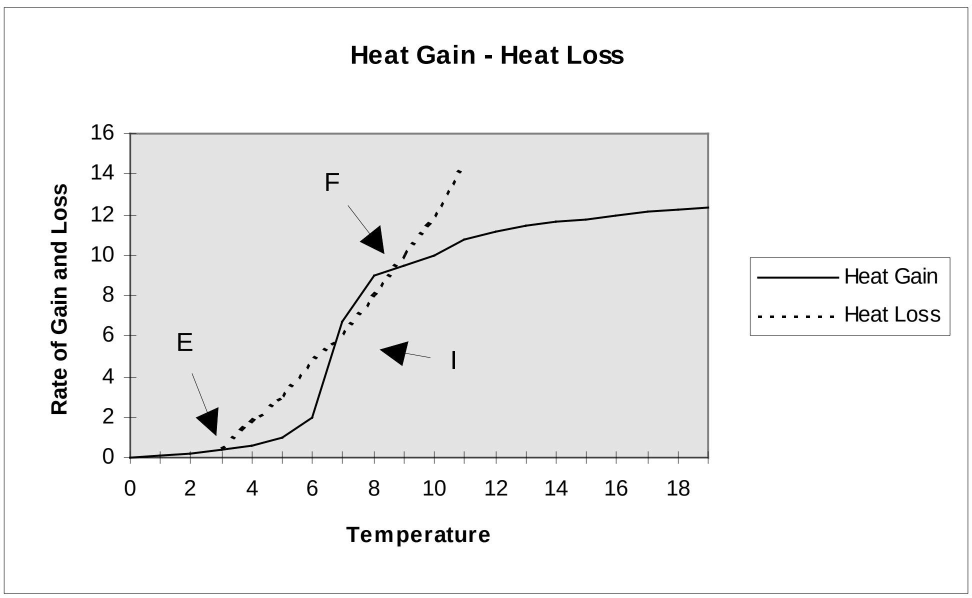

Figure I[i]

The environmental point (E) is the lowest point on the graph, is a dynamically stable point at which heat gain is exactly balanced by heat loss. This is where the two lines cross. Below Point-E the heat gain line is above the heat loss line that indicates that there is sufficient heat to maintain the environmental temperature.

Point-I is the ignition point where the two lines cross again indicating a balance between heat gain and heat loss. Between Point-E and Point-I the heat loss line is above the heat gain line. This indicates that Point-I is a dynamically unstable point. A greater heat loss makes it difficult at times to maintain a fire after ignition. Sufficient heat must be added for the fire to become self-sustaining.

From Point-I to Point-F (fire point) the heat gain line is above the heat loss line which indicates that Point-F is a dynamically stable point. There is enough heat to maintain the maximum fire temperature for a given fuel supply and oxygen supply. Above Point-F with heat loss greatly exceeding heat gain, this serves to maintain the maximum temperature for a given fire.

The following time temperature graph is typical of a structure fire, recognizing that there may be considerable variation for individual fires.

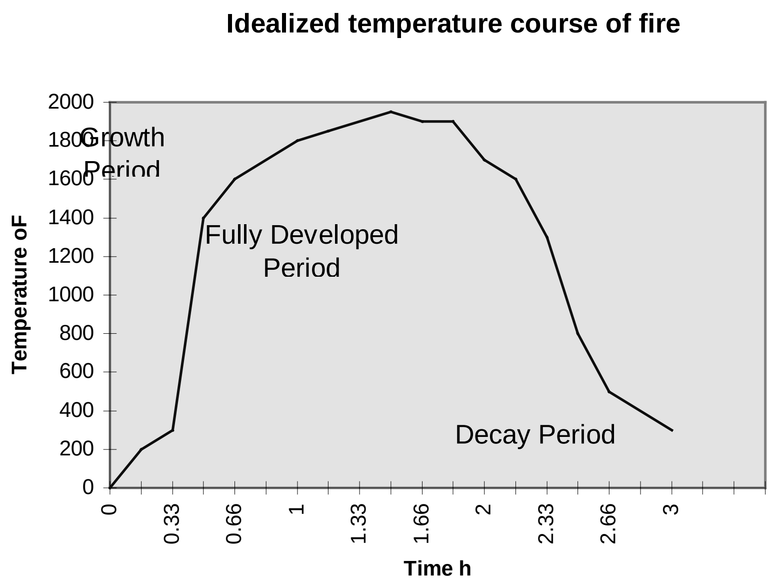

Figure 2[ii]

The graph clearly shows that net heat gain occurs early in fire development until the peak (or maximum) fire intensity is reached. Then net heat loss prevails as fuel supply is gradually exhausted. Thus fire behavior may be analyzed into the following growth stages.

(1) ignition
(2) growth
(3) flashover
(4) fully developed
(5) decay

Third Principle

The third principle introduces two controls on fire behavior. The rate of heat release is limited by

(1) the fuel surface area available
(2) the oxygen available

All the experts agree that a given fire at a given moment is controlled by either (1) or (2) but not both at the same time.

Please note that the fuel surface area is the limiting factor, not the heat content of the fuels. Fire engineers consider the heat content to be not a factor in determining the rate of heat release. Also note that if a fire is oxygen limited, then the fire is said to be ventilation limited.. That is, the limit is the amount of air available in the confined space, or limited by the air flow into that space.

In an article in the Society of Fire Protection Engineering Handbook (2nd Edition), Dr. Daniel T. Gottuk and Dr. Richard Roby classify fires into three kinds based upon the mode of burning and the ventilation available.[iii]

(1) smoldering
(2) Free (open) burning
(3) Ventilation limited

Since smoldering fires have little or no ventilation from outside the structure, these fires have a minimum of ventilation. Also free (open) burning fires are limited only by the fuel surface area available. So these fires have a maximum of ventilation. Thus Gottuk and Roby's classification is equivalent to the following for structure fires.

(1) Minimum ventilation (smoldering fires)
(2) Limited ventilation (oxygen limited)
(3) Maximum ventilation (fuel surface area limited)

Which type of structure fires do fire fighters usually encounter? To answer this question it is necessary to analyze fire behavior by dividing it into fire stages.

Nelson's Analysis

Floyd W. Nelson in his book, Qualitative Fire Behavior, presents an accurate and complete qualitative analysis of fire behavior. Nelson divides fire behavior into seven stages. They are:[iv]

(1A) Ignition – fire becomes a self-sustaining process
(1B) Early Explosion – usually ends further fire development
(2A) Flame Spread – rapid build-up of fire intensity and volume
(2B) Cool Smoldering – slow build-up of heat, temperature less than 1,000^{o}F
(3)Hot Smoldering – oxygen level below 15%, temperatures range from 1,200^{o}F to over 1,800^{o}F, almost completely confined fire
(4) Flashover – brief but spectacular stage in which the area becomes fully involved, occurs at 1,000^{o}F average ceiling temperature
(5) Steady State – partially open or fully open fire with ample fuel and oxygen, increasing severity, temperature between 1,400^{o}F and 1,450^{o}F
(6) Clear Burning – smoke clears, peak severity, temperatures above 1,500^{o}F
(7A) Post Attack Warm - 300^{o}F, thermal balance, easy overhaul
(7B) Post Attack Cool – lower temperature, thermal imbalance, difficult overhaul

This is a rather attractive analysis of fire behavior for the following reasons.

(1) Stage 1A – Ignition. Bill Nelson clearly states that flameover is the essential element of this stage in order for the fire to become self-sustaining. He says that "once flameover has occurred our theoretical fire moves into the second or flame spread stage."
(2) Stage 2A – Flame Spread. This name accurately describes the dominant feature of this state. There should be no question that rollover belongs to this stage since it is flame spread at the ceiling level. It is critical to realize that flame spread is usually limited by the amount of oxygen available, not by the availability of fuel. A Stage 2A fire may shift to cool smoldering or hot smoldering, or oscillate with flashover. Such volatility hardly justifies the name "“steady state”. This stage is anything but steady.
(3) Stage 2B – Cool Smoldering. The inclusion of Stage 2B as distinct from the hot smoldering stage is a significant contribution. If you have witnessed fires that you have not been able to classify using the three-stage analysis, probably you have witnessed cool smoldering fires. It is extremely important to realize that a 2B fire does not have all the conditions necessary to

produce a hot smoldering fire with backdraft potential. The 2B temperatures will range below 1,000^{o}F and such a fire usually progresses to flashover.

(4) Stage 3 – Hot Smoldering. Bill Nelson's major contribution is identifying a second type of explosion that can result from a hot smoldering fire. The first type is well-known, a backdraft. Bill Nelson names the second type as the Forward Induced Explosion, or blowout.

(5) Stage 4 – Flashover. Timewise, even though a very brief fire stage, its significance for fire safety and fire behavior fully justifies its inclusion in any analysis of fire behavior.

(6) Stage 5 – Steady State. Verified by 50 or more experimental fires that the temperature ranges between 1,400^{o}F and 1,450^{o}F. This fire progresses to a fully open fire. In other words, it moves steadily to the clear burning stage.

(7) Stage 6 – Clear Burning. The name itself suggests the distinctive characteristic of this fully open fire.

(8) Stages 7A and 7B – Post Attack Warm and Post Attack Cool. How a fire is controlled can be overhaul easy or difficult. The significant contribution here is recognizing the cause of the problem which is thermal imbalance.

One of the interesting things Bill Nelson has done is to create a time-temperature chart for his seven fire stages. The stages are place on the chart at the approximate temperature level using average ceiling temperatures as a guide. The time scale is indefinite since a fire may progress rather rapidly, or rather slowly, through the various stages. While fire development is usually from left to right on the chart, at times a fire may move from right to left.[v]

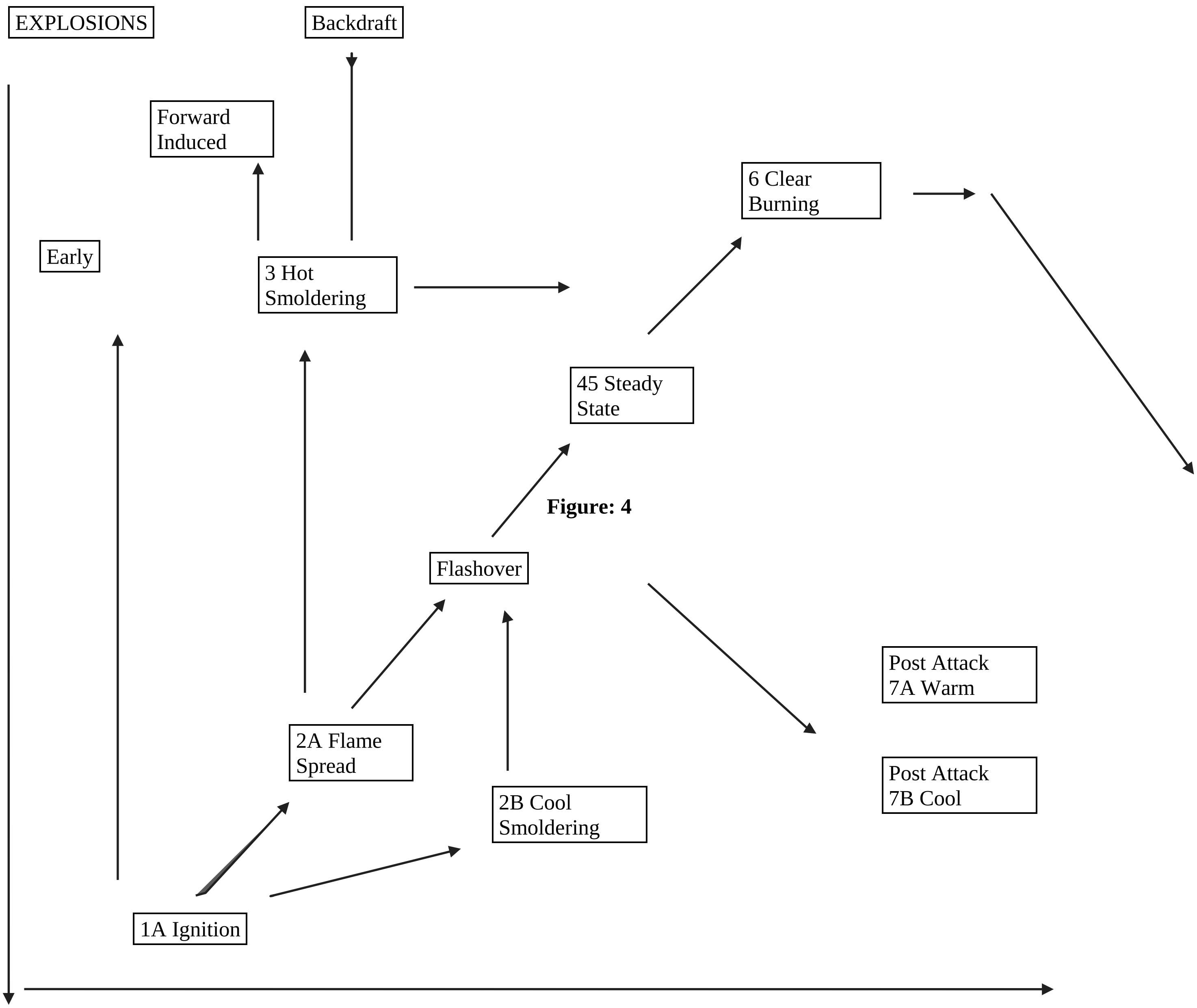
EXPLOSIONS
Backdraft
Forward Induced
6 Clear Burning
Early
3 Hot Smoldering
45 Steady State
Flashover
Post Attack 7A Warm
2A Flame Spread
2B Cool Smoldering
Post Attack 7B Cool
1A Ignition

Figure: 4

Using Floyd W. Nelson's fire stages produces the following analysis of fire behavior. Initially at ignition, and shortly thereafter, the fire is localized and free burning. As the fire plume extends to the ceiling and two layers develop in the room, the fire enters the ventilation-limited stage. At flashover and beyond while the roof or ceiling is intact, the fire is still ventilation limited. Once a steady state fire breaks through the roof, the fire makes a transition to open burning. Of course both a cool smoldering and a hot smoldering fire are ventilation limited with an absolute minimum of ventilation.

The relation ship between Gottuk and Roby 's analysis and Nelson's fire stages are shown in the following chart. The symbol "F" = free or open burning, the symbol "V" = ventilation limited burning, and the symbol "S" = a smoldering fire.

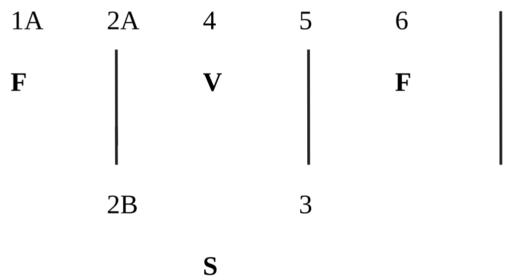

Figure 4

To answer the question posed earlier, probably most of the fires that you fight are the middle range of fires that are ventilation limited or smoldering fires with a minimum of ventilation.

Chapter Two   Fire Control

Bill Nelson in his book, Qualitative Fire Behavior, makes the following statement.[vi]

"In principle fire fighting is very simple. All one needs to do is put the right amount of water in the right place and the fire is controlled."

In reality fire fighting is not quite that simple as Bill Nelson recognizes when he adds

"However, the number of different situations one finds in structures often makes this task difficult."

This statement of principle is a profound statement that constitutes the fundamental principle of fire fighting. In essence "Balanced Fire Attack" is just another way of stating this principle. What is needed is the right amount of water, that is the heat releasing power of a fire must be balanced by the heat absorbing power of water.

There are two implications of the principle that the right amount of water must be used.

(1) There is not just one right amount that is suitable for all fires. The right amount varies as the size of the fire. For example, if five gallons is the right amount for a given fire, then ten gallons is the right amount for a fire twice as big.
(2) You cannot fight a confined fire effectively by using too little, or by using too much water. Common sense tells you that if too little water is used, you will have little effect upon the fire. This is confirmed by the following graph.

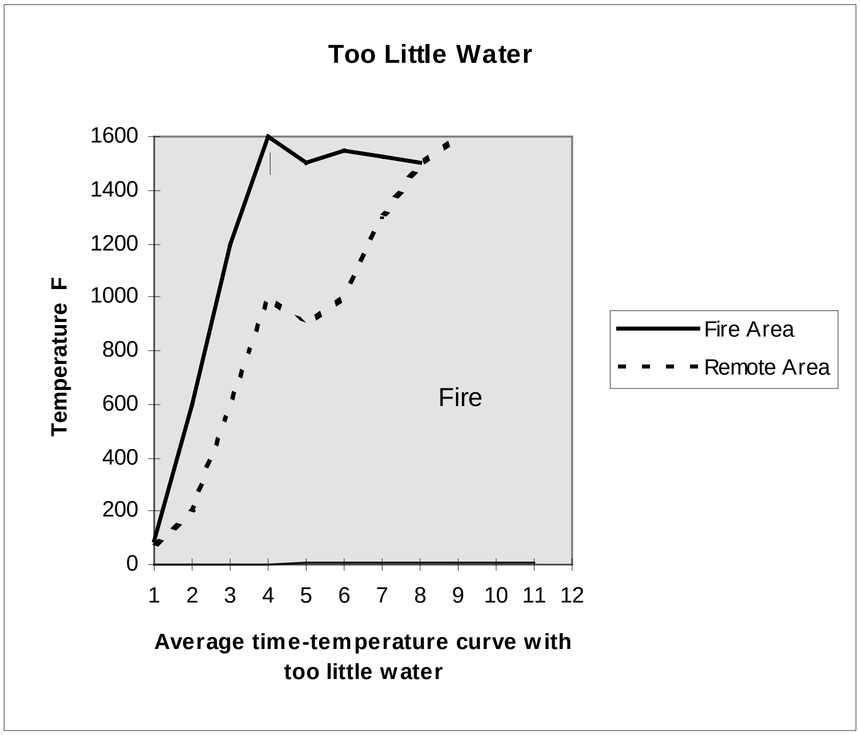

Figure 5[vii]

Note the leveling off of the temperature in the fire area but that the fire continues to burn out of control Also there is only a temporary slowdown in adjacent area.

If too much water is used, common sense tells you that you would gain control of the fire faster. However, this does not happen. Using two much water is counterproductive. It actually takes longer to gain control of the fire. The following graph indicates some of the problems that arise that may be described as resulting from thermal imbalance.

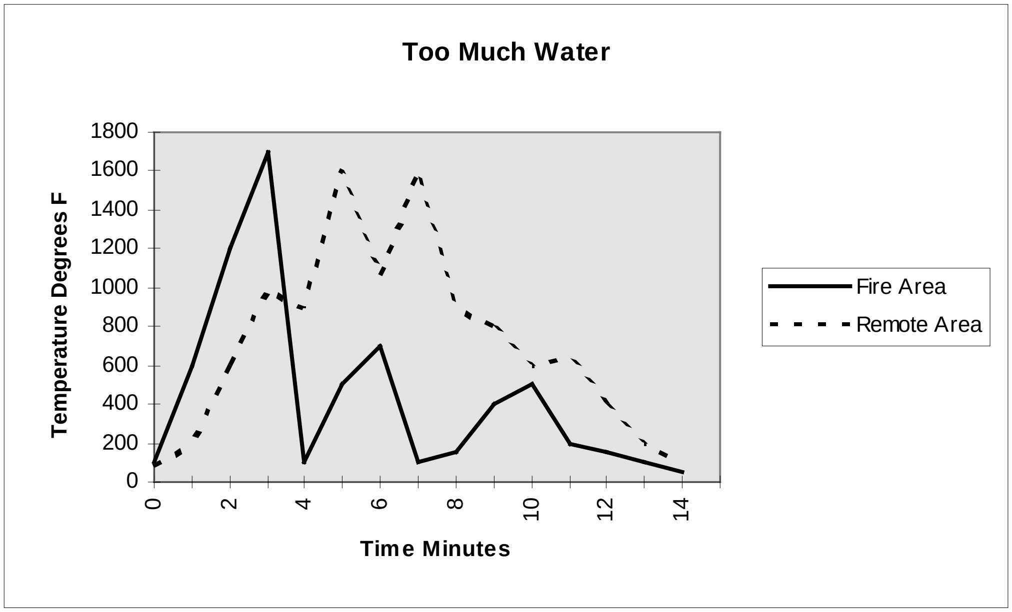

Figure 6[viii]

Thermal imbalance results in extreme turbulence, a disruption of the even layering of temperatures, blocking of the smooth flow of energy into and out of the fire. All this will delay overhaul, prevent extinguishing all the fire (hot spots), destroy visibility, and may even blow or spread products of combustion into adjacent area.

If the right amount of water is used, the following graph shows quite a difference from the two preceding graphs.

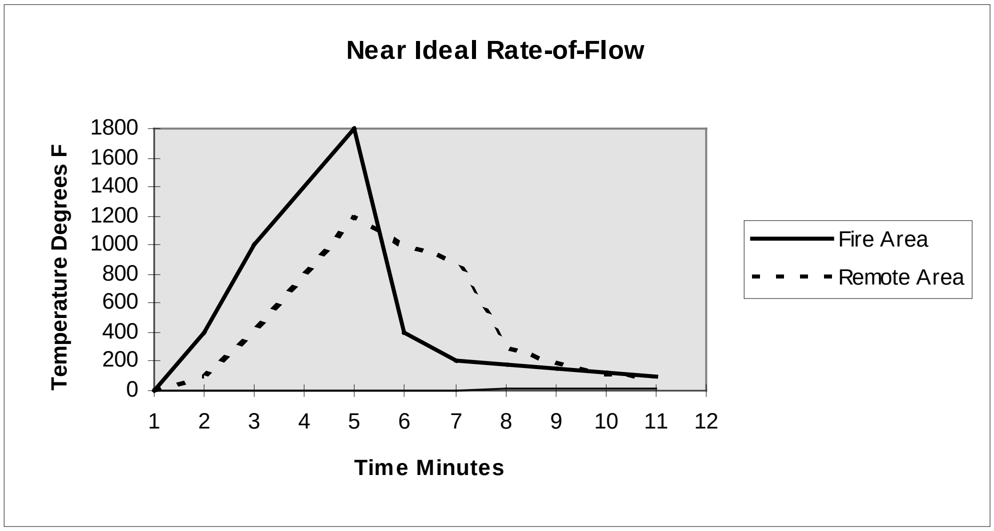

Figure 7[ix]

The rapid temperature fall in the fire area as well as in the adjacent area indicates that thermal balance is quickly restored. Fire control is achieved in about a minute with continued further decline in temperature as thermal balance is restored.

Why Use Water?

The major advantage of water is that it is the best heat absorbing substance that exists and that is also practical to use in fighting fires. The heat is absorbed when liquid water is converted to steam at 212°F (100°C). This physical change is endothermic (heat absorbing), absorbing 97l btus/pound of water. Since 212°F is well below the ignition temperatures of fuels, no problem arises in converting water to steam. If the right amount of water is used, then all the heat produced by the fire is absorbed by the steam. This heat is not destroyed. It is absorbed by the steam, and it must be retained by the steam if it is to remain a gas. This process is called the Latent Heat of Vaporization of water, and the capacity of water to absorb heat is much greater than that of most other substances. This is the big advantage that water has in fighting fires.

There are two more crucial facts about this process.

(1) One cubic foot of liquid water expands to 1,700 cubic feet of steam at 212°F. This powerful blast of steam can literally blast a fire out of existence. The steam displaces the contaminated atmosphere created by the fire, and deprives the fire of oxygen. For oxygen limited fires, steam can smother the fire quickly, as well as cool it below its ignition temperatures.

(2) The second fact is that the conversion of liquid water to steam does not raise the temperature of steam above 212°F. In other words, the steam does not become superheated. This fact results in a rapid drop of temperature in the fire area. It is crucial that fire fighters understand this fact. To repeat, steam does not become superheated in the fire attack. This is why using the right amount of water is so important. An effective fire attack with the right amount of water both cools and smothers the fire, quickly restoring the thermal balance that existed before the attack, but at a much lower temperature level.

For hundreds of years the only method for extinguishing fires has been to apply water directly to the burning surfaces using a solid stream nozzle. Since the beginning of this century, spray (fog) nozzles have been used to increase the effectiveness of water in extinguishing fires. The following principles govern the use of water spray.

(1) The rate of heat transfer is proportional to the surface area of the liquid. The best range for droplet size is between 0.01 and 0.04 inches diameter (0.3 to 1.0 mm), and the best results are obtained when drops are uniform in size. At a diameter of 0.01 inches, the surface area is increased by a factor of 1,400/1. So little drops of water do provide a great increase in surface area.

(2) The rate of heat transfer depends upon the temperature difference between the water and the surrounding air.

(3) The rate of heat transfer also depends upon the vapor content of the air. The higher vapor content the slower the rate of transfer.

(4) The rate of heat transfer depends upon the velocity of the water near the burning surfaces and the fire plume. There must be sufficient velocity for the water to be distributed evenly throughout the fire area.

As fire fighters we cannot do anything about (2) and (3), but we can do something about (1) and (4). Using a fog nozzle is more than 1,000 times more effective than using a solid stream nozzle. Also (4) requires us to distribute the water evenly throughout the fire area. So perhaps we should modify the fundamental principle to say

All one needs to do is put the right amount of water in the right place in the right way.

The "right way" means of course to distribute the little drops evenly throughout the fire area.

The Right Amount

How much water is needed to control a given size fire? The right amount of water is given by a formula that emerged from the research done at Iowa State University in the 1950s by the late Bill Nelson and Keith Royer. Keith Royer has explained how the formula was created in this way.[x]

1. "*Study of expansion ratios of water to steam indicates that one gallon of water will produce with a margin of safety 200 cubic feet of steam.*

2. *Study of heat production in relation to oxygen also indicates that one gallon of water will absorb with a margin of safety, all the heat that can be produced with the oxygen available in 200 cubic feet of air.*

These two factors lead to the formula: cubic area in feet divided by 200 equals the required gallonage of water for control of a specific area involved in fire."

The formula stated by Keith Royer is called the gallonage formula. It is:

$$Gal = \frac{VoL}{200}$$

where Gal = the number of gallons of water, Vol = the volume of a confined space in cubic feet, and 200 is the constant which is based upon the two facts in the preceding statement.

CHAPTER THREE - A VALID FORMULA

Anything is said to be valid if it is founded upon truth or facts. The validity of the gallonage formula depends upon the constant 200., whether this number is founded upon truth or facts.

(1) One gallon of water will produce 200 cubic feet of steam.
(2) One gallon of water will absorb all the heat produced by the oxygen in 200 cubic feet of air.

Please note that both facts produce the same number, which is remarkable indeed.

First Fact

Statement (1) is derived from the expansion ratio of water to steam at 2l2^{o}F which is 1,700/1. That is, one cubic foot of liquid water produces 1,700 cubic feet of steam. Since a cubic foot of water contains 7.48 gallons, dividing these two numbers gives:

$$\frac{1,700}{7.48} = 227 \text{ ft}^3$$

This number , 227, is rounded down to 200 to allow for 90% efficiency in converting water to steam. This is the first margin of safety build into the formula.

Second Fact

Statement (2) can be calculated theoretically by assuming complete combustion of hydrocarbon fuels that are converted to carbon dioxide and water. This number was confirmed in 1955 in an experiment conducted by Factory Mutual Laboratories. It was determined that one cubic foot of oxygen combined with ordinary fuels produced 535 btus.

Since air contains 21% oxygen and flame production stops when the oxygen level falls below 15%, only the amount of oxygen that is 7% of air is available for hydrocarbon air diffusion flaming combustion. Multiplying this number by the number of btus produced by one cubic foot of oxygen gives

$$535 \times 0.07 = 37 \text{ btus}$$

which is the amount of btus produced by one cubic foot of air. Since one gallon of water expands to 200 cubic feet of steam, multiplying gives

$$37 \times 200 = 7,400 \text{ btus}$$

which is the number of btus produced by 200 cubic feet of air.

One gallon of water converts to 200 cubic feet of steam at 212^{o}F, and each pound of water absorbs 971 btus at 2l2^{o}F. Since one gallon of water weighs 8.34 pounds, multiplying gives

$$971 \times 8.34 = 8,098 \text{ btus.}$$

Since $7,400 < 8,098$, the conclusion is that one gallon of water can absorb all the heat produced in 200 cubic feet of air. Note that there is a second margin of safety build into the formula, about 600 btus.

This conclusion has been challenged by Jack L. Cottet in an article appearing in FIREFIGHTER NEWS. He said about the Iowa Rate-of-Flow Formula[xi]

> *"The testing that was done to determine the validity of this formula used only ordinary Class A materials, and as such, is no longer valid."*

This claim is dead wrong. What Cottet is talking about is the fact that since the 1950s the use of plastics has become widespread. It is true that the heat content of plastics is much greater than that of ordinary hydrocarbon fuels, cellulosics, that is, wood based products. However, the validity of the Iowa formula does not depends upon the type of fuels or their heat content, rather it depends upon the oxygen consumed. One of the most remarkable facts in fire engineering is that the rate of heat release is constant per unit of oxygen consumed, no matter what type of fuel is burning.

Thornton's Rule

Dr. Vyetnis Braubaskas, author of the tables in Appendix A of the 17th Edition of the NFPA Handbook, makes the following observation.[xii]

> *"Recently, however, increasing engineering use is made of the observation that the heat of combustion per kg of oxygen consumed in nearly constant for most organic fuels. It can be shown that the value of*

$$\Delta h^{n}_{c}/r_{o} \quad = \quad 13.1 \ j/kg \quad \text{for } O_2$$

> *is near constant.*

> Let's take two example of what Dr. Babrauskas is talking about., one is a wood product, cellulose; the other is a plastic, ethylene.

Cellulose: $C_6H_{10}O_5$

Heat of Combustion: 16.12 Mj/kg

Ratio of O_2 mass/fuel mass 1.184

16.12/1.184 = 13.6 Mj/kg of O_2

Ethylene C_2H_4

Heat of Combustion 47.17 Mj/kg for O_2

Ratio of O_2 mass/fuel mass 3.422

47.17/3.422 = 13.78 Mj/kg of O_2

Notice that the high heat content of ethylene (3 times as much) requires 3 times as much oxygen mass for combustion as compared to cellulose. The reason for this is that cellulose does contain some oxygen as one of its elements. Thus the rate of heat release is a near constant per unit mass of oxygen consumed. What is true for these two compounds is also true for almost all hydrocarbon compounds. This is truly an astounding fact about fires.

Another author, Dr. Frederick Clarke, in the same Handbook, concludes that Thornton's Rule is highly useful for engineering work as well as for fire fighting.[xiii]

> *"Examination of the heat of combustion tables in Appendix A will show that while the heat of combustion is quite different for different organic materials, the heat produced per equivalent of oxygen consumed is the same within about 10%. This fact, sometimes called Thornton's Rule, allows one to use oxygen consumption as a reasonable measure of the heat produced by a burning organic material."*

Notice the last sentence, that oxygen consumption is a reasonable measure of the heat produced by burning organic materials. This is exactly what the Iowa formula does. Thus the Iowa formula was valid when it was created in 1959 and it is valid today no matter whether plastics or ordinary fuels are burning. In fact the Iowa formula will be valid for the foreseeable future. It is almost certainly true that this formula will be the only valid formula that the fire service will have to work with.

Now one final question. Thornton's Rule provides the most practical way to measure the rate of heat release in laboratories for both small and large scale tests. How about actual structure fires? Does Thornton's Rule hold there as well? Clayton Huggett of the National Bureau of Standards, Washington, D.C., examined this very question in an article appearing in the 1980 issue of FIRE AND MATERIALS. Since most structure fires involve incomplete combustion, the question narrows down to what effect incomplete combustion has on Thornton's Rule.

After examining this question in detail for various fuels and products of combustion, Dr. Huggett reaches the following conclusions.[xiv]

1. *The rate of heat release in a fire can be estimated with good accuracy from two simple measurements, the flow of air through the fire system and the concentration of oxygen in the exhaust system.*
2. *The heat release from a fire involving conventional organic fuels is 13.1 kJ per gram of oxygen consumed, with an accuracy of ±5% or better.*

3. *Incomplete combustion and variation in fuel have only a minor effect on this result. Appropriate corrections can be made if necessary.*
4. *The oxygen consumption technique of heat release measurement is adaptable to a wide range of applications ranging from small-scale laboratory experiments to very large-scale fire system tests.*

Notice the third conclusion that fire behavior in an actual structure fire has only a minor effect upon Thornton’s Rule. So this is conclusive proof of the validity of Thornton’s Rule as a scientific law that governs fire behavior for structure fires.

CHAPTER FOUR - THE GENERAL RATE OF FLOW FORMULA

The gallonage formula gives the right amount of water for a given size confined fire.

$$(1) \qquad Gal = \frac{Vol}{200}$$

The next question is, what rate-of-flow must be used to apply the right amount of water? In other words, what is the needed fire flow (NFF)? The rate formula for water flow is

$$(2) \qquad NFF \times t = Gal$$

Where NFF = needed fire flow in gpm, t = time in minutes or fractions of a minute, and Gal = number of gallons or the right amount of water. Please note that time must be expressed in minutes (not seconds), This is the only tricky part of the formula.

Since both equations (1) and (2) equal the number of gallons of water (Gal), they may be combined into a single equation by eliminating "Gal". This process is called substitution.

$$(3) \qquad NFF \times t = \frac{Vol}{200}$$

This is THE GENERAL RATE-OF-FLOW FORMULA.

In the research done at Iowa State University, Keith Royer and Bill Nelson determined that confined structure fires could be controlled in 30 seconds or less. This lead to the Iowa Rate-of-Flow Formula, that is easily derived from the general rate-of-flow formula. Substituting ½ minute (30 seconds) for "t" in the general fomrula gives

$$NFF \times \tfrac{1}{2} = \frac{Vol}{200}$$

Dividing both sides of the equation by ½ gives

$$NFF \times \frac{\tfrac{1}{2}}{\tfrac{1}{2}} = \frac{Vol}{200 \times \tfrac{1}{2}}$$

Further simplifying this equation produces the Iowa Rate-of-Flow Formula.

$$NFF \times 1 = \frac{Vol}{100}$$

$$(4) \qquad NFF = \frac{Vol}{100} \qquad t = \tfrac{1}{2} \text{ minute (30 seconds)}$$

The time of 30 seconds should always appear in the Iowa formula since it valid only for this time.

There is a better way to write the Iowa Rate-of-Flow Formula using function notation.

$$(4) \qquad NFF(30 \text{ seconds}) = \frac{Vol}{100}$$

where NFF(30 seconds) is read “needed fire flow for 30 seconds”. This notation does not indicate the multiplication operation Also note that time may be expressed in seconds unlike the general formula. Also note that the constant “100” is the number of cubic feet of steam produced by ½ gallon of water. The reason for this is that if the flow rate is 1 gpm for 30 seconds, then ½ gallon of water is applied to the fire.

The general rate-of-flow formulas can be used to calculate the right amount of water for varying lengths of time. All this data is compiled in the following table. The ideal maximum time of 30 seconds was chosen based upon the research done at Iowa State University. The time of 10 seconds was chosen as the ideal minimum time needed to properly distribute water through the fire area by a combination attack.

Wiseman's Needed Fire Flow Table

Volume (cubic feet)	Gallons	Seconds 30	25	20	15	10	
1,000	5	10	12	15	20	30	small room
2,000	10	20	24	30	40	60	large room
3,000	15	30	36	45	60	90	
4,000	20	40	48	60	80	120	2 rooms
5,000	25	50	60	75	100	150	
6,000	30	60	72	90	120	180	
7,000	35	70	84	105	140	210	mobile
8,000	40	80	96	120	160	240	
9,000	45	90	108	135	180	270	
10,000	50	100	120	150	200	300	
11,000	55	110	132	165	220	330	
12,000	60	120	144	180	240	360	
13,000	65	130	156	195	260	390	
14,000	70	140	168	210	280	420	
15,000	75	150	180	225	300	450	small house
16,000	80	160	192	240	320	480	
17,000	85	170	204	255	340	510	
18,000	90	180	216	270	360	540	
19,000	95	190	228	285	380	570	
20,000	100	200	240	300	400	600	av. House
		(+10)	(+12)	(+15)	(+20)	(+30)	

Lines

- (solid) 1 - l.5 in.
- (dotted) 1 - 1.75 in
- (dash-dot) 2 - 1.5 in or 1 - 2 in

The lines added to the table indicate the standard flows for l.5 inch attack line (100 gpm), 1.75 inch attack line (150gpm) and one 2 inch attack line or 2 1.5 inch attack lines (200 gpm) Let's look at the data in the upper right of the table and the lower left to see what conclusions can be drawn.

(1) Full flow from a 1.5 inch attack line (or larger) far exceeds the flows needed for a small or average size room fire (1,000 cubic feet or 2,000 cubic feet) Flows of 30 gpm and 60 gpm applied for 10 seconds is all that is needed. Remember that applying too much water is counterproductive. Thus flows for room size fires must be reduced well below the standard flows for 1.5 inch attack lines (or larger) in order to apply the right amount of water and at the same time distribute it evenly throughout the fire area.

(2) At the opposite corner of the table, the flow from a 1.5-inch attack line is not enough for a fully involved small house fire of 15,000 cubic feet. Likewise a 1.75-inch attack line is sufficient for a small house fire but not for an average size house of 20,000 cubic feet. The problem here is that using a single attack line to attack a house size fire runs into serious problems in distribution. It is not likely that the water could be distributed throughout the fire area within the ideal maximum time of 30 seconds.

The conclusion should be obvious. Multiple attack lines are needed. This means 4 1.5 inch lines covering all sides of a house and flowing 400 gpm. Three 1.75-inch lines would also be adequate provided the water is distributed equally throughout the house.

Chapter Five - Tactics of a Combination Attack

The Iowa Rate-of-Flow Formula is intended to be used to calculate flows for confined fires where most of the water is converted to steam so that the fire is attacked in two ways: (1) First by cooling the burning fuels below their ignition temperature; (2) Second by smothering the fire by depriving it of needed oxygen. There are three constraints that must be adhered to in order to make an effective balanced fire attack.

(1) The water must be distributed throughout the fire area. This requires about 10 seconds. This time constitutes an ideal minimum constraint.
(2) The length of time that a steam blanket can hold limits the time available for an effective fire attack. This time, 2 to 3 minutes, constitutes an ideal maximum constraint.
(3) Within the upper and lower constraints, if the right amount of water is exceeded, then an effective fire attack is disrupted. This variable constraint is caused by too great a rate-of-flow or by application for too long a time.

Constraint One

In constraint (1) the proper distribution is by the combination attack. Keith Royer has described how to do *this*.[xv]

> *The proper distribution of water for on the initial application is very important and the nozzle operator must understand what result is trying to be accomplished. The fog pattern is adjusted so it will just reach across the area involved. The nozzle is placed inside the area and rotated following the contour of the area-striking as much of the perimeter of the area as possible with the outer surface of the fog stream, across the floor, up the size, across the ceiling, etc. This rotation is as violent as it is possible for the nozzle operator to make it. In placing the nozzle inside the area, it should be inside the window or other opening about an arm's length. The purpose of rotating the nozzle is to obtain steam production over as much of the area as possible. When the water strikes any of the heated surfaces in the room momentarily, it creates a steam blanket. If the nozzle rotation is rapid enough, the steam blanket will hold until the nozzle has a chance to get around to the spot again. If the rotation is too slow, the steam blanket will not hold and the fire that has been knocked down will build up before the nozzle passes its way again."*

Bill Nelson and Keith Royer strongly recommend that the rotation be clockwise as viewed from the nozzle operator's position. From many experiments it was determined that a clockwise rotation is more effective than a counterclockwise rotation. They say that:

1. Clockwise rotation is safer since it drive smoke, gases, and flames away from the nozzle. Counterclockwise rotation does just the opposite.
2. Clockwise rotation produces steam with an active rolling action. Counterclockwise rotation produces steam with an inactive and lazy action.
3. A clockwise rotation produces a faster knockdown time.

The scientific principle that explains this difference is not known. It should be noted that Bill Nelson and Keith Royer have not expressed a preference for using an outside window or an inside door. An attack from either position should work just as effectively as the other.

Constraint Two

Constraint (2) implies that the combination attack is useful for confined fires only. A confined fire is highly vulnerable to an effective fog attack that hits the fire where it is vulnerable-that is, in the amount of oxygen available. So what is a confined fire?

Dr. John A Campbell in his article, “Confinement of Fire in Buildings”, in the 17th Edition of the NFPA Handbook, states that the burning rate of a compartment fire after ignition is determined either by (1) the fuel surface area available to the combustion process, or by (2) the amount of oxygen available for combustion. When a fire cannot get sufficient air to maintain the burning rate associated with fuel surface controlled combustion, it will burn at a ventilation controlled rate. He adds:[xvi]

> *Considerable ventilation area is required for a fully developed fire to turn at a fuel-surface rate. For example, over lone-fourth of the wall area would have to be open in a 20 by 20 ft. room (6.1 by 6.1 m) with an 8 ft ceiling (2.4 m) and an exposed combustible surface of 800 sq- ft (74.3 m^2) of ordinary combustibles. Many, if not most, building fires will be ventilation controlled at least during the time in which containment is a consideration.”*

Thus even if a fire is burning out two windows and an interior door of a room, the fire is still ventilation controlled .As a consequence the Iowa Rate-of-Flow Formula is useful for determining the right amount of water for most building fires. There are two exceptions.

1. The first exception occurs at ignition, or early flame spread stage, well before the hot layer of gases banks down to floor level. For these fires a direct is preferred. Probably too much water will be used as measured by the Iowa formula, but without causing a great deal of water damage.
2. The second exception is the steady state fire when it breaks through the ceiling or roof. Such a fire moves steadily toward a fully open fire. However, even though only the walls are left standing, there is still obstruction to the free flow of air into the fire. Thus a fire is still ventilation limited to some extent even up to the peak intensity.

Constraint Three

Constraint (3) deals with the amount of water used to fight a fire. Before the attack, uncontrolled fire behavior is best described by saying that it is thermal balance. There is a balance between the energy being provided and the energy being released. At a given height in the fire, horizontally, temperatures are equal, or in balance. For a given vertical section, temperatures continuously increase from bottom to top which constitutes a balance or layering of temperatures. So overall, the combustion process exists in a steady state, or thermal balance.

If the right amount of water is used in a fire attack, then within a few seconds the steam condenses and appears as a white cloud that drifts upward and out of the structure. Thermal balance returns quickly once fire control is achieved. Keith Royer describes this situation as follows:[xvii]

> *“If at the conclusion of the knockdown the fire area is left with an even ceiling temperature of 300^{o}F, conditions will be ideal for natural ventilation and easy and efficient overhaul. The lifting forces of the warm air (thermals) will be in balance throughout the area and we can say that we have left the area with the same thermal balance that was developed as the fire built up but at a somewhat lower temperature.”*

Let’s summarize the rationale for a balanced fire attack. First too little water has little effect upon the fire and no effect at all in adjacent areas. Second the right amount of water provides the only really effective fire attack brining the fire under control in a short period of time. Third, using too much water is counterproductive, and causes thermal imbalance. Thermal imbalance results in extreme turbulence, a disruption of the even laying and distribution of temperatures, and blocking the smooth flow of energy into and out of the fire. Visibility is destroyed. Thermal imbalance will delay overhaul, prevent the extinguishment of all of the fire, and may even blow or spread products of combustion into other areas of the structure.

Variable Flow Nozzles

How can a balanced fire attack be made using the right amount of water consistent with these three constraints? Let's turn to the NFF table at the end of the previous chapter.

Data in this table demonstrates that a 1.5 inch line flowing 100 gpm is limited in its ability to provide a balanced fire attack. At the ideal minimum constraint of 10 seconds, the 1.5-inch line flows too much water for any fire less than 3,000 cubic feet. The situation is even worse for 1.75-inch and 2 inch lines with limits of 5,000 cubic feet and 6,000 cubic feet. Thus to properly execute a balanced fire attack for smaller fires, the NFF must be reduced below 100 gpm.

Immediately certain types of fog nozzles must be discarded as unsuitable. These are the nozzles that provide a single rate-of-flow and have a ball type of shut-off valve. Attempting to reduce the flow by opening the ball type valve part way creates extreme turbulence within the nozzle that has serious effects upon the quality of the fire stream.

The nozzles that are suitable for a balanced fire attack are those that provide different rates-of-flow. One type uses a ring to manually select various flows. Another type uses a slide shut-off valve with six detent stops. The slide valve does not cause any disturbance within the nozzle at lower flow rates.

The Art of Fire Fighting

The art of fire fighting relies upon the judgment and experience of the nozzle operator and the officer in command. This art demands more than just opening up a fog nozzle full force and blasting away at the fire. Such a “bulldozer” approach is counterproductive. It disrupts an effective fire attack, causing thermal imbalance and unnecessary water damage. Before flowing water, the artist must top a moment and think.

The first decision is choosing the purpose of the attack. This chapter is limited to a combination attack whose purpose is to control the fire. A critical factor is whether the available fire flow meets the NFF for control of the fire. If the fire is confined, and once the point-of-attack is chosen, then there are four things that the nozzleman (and officer) must decide.

1. The nozzle operator must select the appropriate flow. Certainly for one-room or two-room fires the operator should select the first or second detent stop or the smaller flows on the volume control ring.
2. The nozzle operator must adjust the fog pattern so that the fire stream just reaches across the fire area. A straight stream with a 50-foot reach is surely too great for a one-room fire.
3. The operator must distribute the water evenly throughout the fire area. The most effective way to do this is by a combination attack with a clockwise rotation of the nozzle placed just inside the opening to the fire area.
4. The nozzle operator must have a reasonable expectation as to when fire control will be achieved. The operator must shut down the nozzle when flames are blacked out and white condensing steam appears and begins to drift up and out of the structure.

These are the four key elements of a balanced fire attack. In summary they are:

1. **Adjust the fog pattern to provide the proper reach.**
2. **Adjust the fog nozzle to provide the proper flow.**
3. **Distribute the water properly throughout the fire area.**
4. **Shut down the nozzle at the proper time.**

It should be evident that there is much more to fire fighting than just opening and shutting a nozzle aimed in the general direction of the fire. The art of fire fighting using a balanced fire attack requires a rather careful thoughtful handling of the nozzle. Essentially the nozzle operator is balancing the power of water (endothermic) with the power of the fire (exothermic). The artist is capable of achieving fire control in the least possible time, with a minimum amount of water, and with a minimum of risk.

In this analysis of fire attack, most fire fighting can be handled with flows of 25, 50, or 75 gpm. The tactics for providing these flows do not lie in using different size attack line. There is certainly no need to change the lines you are currently using Furthermore, there is no need to go back to using booster lines for the initial fire attack.

The solution lies in using two types of fog nozzles that are available today, the variable flow nozzle, and the automatic nozzle with detent stops. Flows must be reduced below what is considered standard flows for the attack lines in use today. The reader should be impressed with the fact that very little water is needed to control the typical structure fire in the U.S.that is a one room fire in a one or two family dwelling. The Iowa Rate-of-Flow Formula is the only formula that can determine the right amount of water for such fires. The validity of the formula is established by Thornton’s Rule which states that the heat release rate for hydrocarbon fuels is 13.1 Mj/kg of molecular oxygen consumed. This near constant is the foundation for really effective fire fighting using a balanced fire attack.

100 psi Midrange Performance at Detent Positions, 1.75 inch hose

Length	Pump	Flows in gpm (Rounded to nearest 5 gpm)					
ft	psi	6	5	4	3	2	1
150	125	110	105	100	80	55	35
150	150	145	140	125	95	65	45
150	175	175	170	155	115	75	50
150	200	210	200	175	130	80	50
200	125	100	95	90	75	50	35
200	150	130	125	115	95	65	45
200	175	155	150	140	110	75	50
200	200	180	170	160	125	80	50
300	125	85	85	80	70	50	35
300	150	110	105	100	85	60	45
300	175	125	125	120	100	70	50
300	200	145	145	135	110	80	50

Chapter Six – Methods of Fire Attack

A question that generates one of the most heated debates in the fire service is

What is the best method of attacking fires in Structures?

The question itself is the cause of the controversy since fire fighting is much too varied and complex to have one method of fire attack that can solve all of our fire fighting problems. Instead the question that should be asked is based upon the guiding principle of fire attack stated by Bill Nelson in his book, QUALITATIVE FIRE BEHAVIOR.[xviii]

"Each officer and nozzleman must understand fire behavior, must determine the purpose of their attack on a given day, and choose the method of attack which will best fit that purpose."

This principle implies that there is no one best method of attack that will fit all purposes. You must make a choice, choosing the method of attack that best fits a given purpose on a given day. So the question that should be asked is

What method of attack will best fit a given purpose?

Let's bring in the knowledge of fire behavior as needed, and consider first the purpose of a given fire attack.

The Purposes of a Fire Attack

What is the purpose of a fire attack? On first thought it might seem that there is only one purpose, namely to extinguish the fire. However, there are several different purposes that govern fire attack.

While it is true that one purpose of a fire attack is to extinguish the fire, this usually occurs with smaller fires in the beginning stage of fire development. Even in this case, the situation may arise where direct access to the fire is blocked. This situation requires a different method of attack Also if a fire attack would scatter burning materials around, again a different method of attack is required. So even in the simplest situation where the purpose is to extinguish the fire, different methods of attack may have to be used.

Not always is the purpose of a fire attack to extinguish the fire. In a multi-story building with a fire burning on the first floor, a dangerous situation is created. Flammable gases can accumulate in the upper floors with a lack of oxygen for flaming combustion.

In such a situation, extinguishing the fire on the first floor is the wrong thing to do. What should be done is to produce quantities of steam over a long period of time, say several minutes. The steam will move into the upper floors, condense, and cool the area, thereby preventing th spread of the fire to the upper floors. So the purpose of this attack is not to extinguish the fire, but to use the fire to produce the steam necessary to eliminate a dangerous situation on the upper floors. This purpose may be described as a holding action.

Another purpose is to control or knock-down a fire. Control does not mean extinguishing the fire. In fact an initial attack on a well-developed fire, if nothing is done after the initial attack, the fire will begin to develop again. This occurs because of the accumulation of char. In other words, the initial attack does not usually extinguish the fire. Further work is required in order to extinguish the fire.

Another situation occurs rarely, but when it does occur it is the first priority at any fire. This is a rescue situation. In this case, the purpose is to go in and rescue (or recover) victims trapped in a burning building. Extinguishing or controlling the fire may be completely disregarded, or at least is not the primary purpose of the attack. Fire fighters want to force their way in, secure the victims, and bring them outside as quickly as possible. The method for doing this is usually different from the method of attack in a non-rescue situation.

Finally, for the largest fires that a fire department may encounter it may not be possible to control or extinguish the fire in a reasonable length of time. The purpose in this case changes to stopping the spread of the fire either within the building or to other buildings. This purpose is usually described as a defensive operation. Now let's consider the various methods of fire attack.

The Methods of Fire Attack

The purpose of a given fire attack may change depending upon what type of fire we are confronted with, how big the fire is, etc. So let's begin with Bill Nelson's analysis of the various fire stages.

1A Ignition. Fire becomes a self-sustaining process.
!B Early Explosion. Usually ends further fire development.
2A Flame Spread. Rapid build-up of fire intensity and volume.
2B Cool Smoldering. Slow build-up of temperature, less than 1,000°F
3 Hot Smoldering. Oxygen level below 15%, temperature ranges from 1,200°F to over 1,800°F almost completely confined fire.
4 Flashover. Brief but spectacular stage in which the area becomes fully involved in fire. Occurs at 1,000°F average ceiling temperature level.
5 Steady State. A partially open or fully open fire with ample fuel and oxygen supply, increasing severity, temperature range from l,400°F to 1,450°F.
6 Clear Burning. Smoke clears, peak severity, temperature above 1,500°F

Let's begin with the smaller fires (1A) in which the purpose is to extinguish the fire..

(1) Type 1A. Purpose: extinguish. The method is a direct attack. In which water is applied to the base of the flames, or the "seat" of the fire. A straight stream from a fog nozzle is usually big enough to cover the entire fire area with but little movement of the nozzle. A wider fog pattern may also be used but the stream must have sufficient reach to directly hit the burning surfaces. A short burst of water is almost always sufficient to extinguish the fire.

(1A) Type 2A: Purpose: extinguish. Suppose a fire involves a wider area in a room. In this case, the direct attack cannot be made by simply pointing the nozzle at the base of the flames. The nozzle must hit all the burning surfaces, moving in a 180° arc centered at the point of access. This is a direct 180° attack.

(1B) Type 2A. Purpose: Holding Action. In certain circumstances it may not be possible to get close enough to the center of a fire to make an effective direct attack. This situation occurs frequently in a structure (maybe multi-story) with a central hallway. In other words, you've got to fight your way down the hallway. For several decades, considerable controversy existed on how to do this. Many departments used a wide-angle fog pattern to force their way in. Considerable thermal imbalance was created by this method of attack. Gradually it was learned that using a straight stream produced less thermal imbalance and hence was more effective as a holding action. Method of attack—direct attack with a straight stream.

(2) Type 1A, 2A. Purpose; extinguish. If direct access to the fire is blocked by contents, panels, or whatever, then a different method of attack must be used. Nelson calls this method SSOC, an acronym for "straight stream off the ceiling". The idea is to hit the ceiling with the water so that the water spreads along the ceiling and falls down upon the fire. Note that this is not an indirect attack, but a direct attack. The nozzle may have to be moved around to cover the entire fire area. The SSOC method may also be used in case you wish to avoid scattering loose materials around if you hit them directly with a straight stream The spray off the ceiling would not have enoughforce to scatter the materials.

(2A Type 2A, 4, 5. Purpose, Holding Action. If a fire is burning on a second floor and close access is not possible from either the inside or outside, then the SSOC attack may be modified to achieve a holding action. The nozzle operator must move from one edge of the room to the other, in a circle or a straight line, all the while pouring water into the window. Bill Nelson calls this a WIN attack. While this may not achieve the complete coverage of a direct 180^{o} attack, it can come close and should be quite effective as a holding action.

(3) Type 2A, 4, 5. Purpose, Holding Action. In the case of a multi-story building with a fire burning on the first floor, and flammable gases accumulating in the upper floors, the purpose of an attack is to engage in a holding action. The method of attack is an indirect attack. The fog pattern must be adjusted so that it does not hit any walls or the ceiling. Also the water must not be applied directly to the fire itself. The fog pattern will have to be carefully worked back-and-forth at the ceiling level to obtain the maximum steam production. The steam will dilute the flammable gases on the upper floors, condense, and cool the area. This will stop the spread of the fire to the upper floors. Then the first floor fire may be extinguished by an appropriate method.

(4) Type 2B, 3, 4, 5. Purpose, control. If a fire fully involves a room or confined space, or is a smoldering fire, the purpose of the attack is to knock down the fire in the shortest possible time. The method of attack may not extinguish the fire because of the presence of char. The method of attack is a balanced combination attack with a clockwise rotation of the nozzle. This method of attack should achieve control near the ideal tactical guideline of 10 seconds.

(4A) Type 2A, 4, 5. Purpose; control. When a fire involves multi-rooms of a structure and not enough attack lines are available to attack each room at the same time, a progressive attack may be used. This is not a new method of attack, rather it is simply using a given method of attack in sequence, one after the other. The progressive attack can be used very successfully with the combination attack.

The progressive attack can also be used on a single confined space where requires a greater flow than that provided by the available attack lines. In this case, the progressive attack can begin with a combination attack in the front of the space and proceed to a SSOS attack in the rear.

(5) Type, any. Purpose, rescue. While it rarely occurs, a rescue situation deserve top priority for any fire department. If victims are trapped in a building, the purpose is to make a rescue (or recovery) and bring the victims outside as quickly as possible. The method of attack is a bulldozer attack. The idea is to force your way in with as much water as possible, protecting the rescuers, removing the victims, and backing out as quickly as possible. The method of attack involves grouping two or more lines together to bulldoze your way in. One of the lines may be needed to protect the entrance, another line to protect the hallway, and a third line to go with the rescue team. This much concentration of lines is not usually used in a non-rescue situation.

There have been a number of statements appearing in fire magazines in recent years that have stated that the research done in the 1950s and 60s did not deal with the issue of life safety. This is not true.

Chief Lloyd Layman, who initiated the change-over from solid stream nozzles to fog nozzles and introduced the "indirect method of fire attack" to the fire service, wrote this in his book, *Attacking and Extinguishing Interior Fires."* He said that he had been asked frequently about the effect of steam from an indirect attack upon occupants trapped in a building. He replied that he had never heard of any adverse effects. He added:[xix]

"The much more rapid flame suppression with indirect application makes it possible to reach endangered persons more quickly so as to be able to remove them to safety and render aid as necessary."

Likewise Bill Nelson has made exactly the same comment about a rescue situation. He said:[xx]

"Some individuals have warned that it is dangerous to use fog to fight fires in room of structures where people may still be trapped in other parts of the building. This is certainly true where the bulldozer attack might be used or where fog lines are used that are larger than necessary for a

particular open area. Such lines will push a considerable amount of products of combustion, steam, and fresh air ahead of them. However, if if proper size lines are used and handled in the proper manner, the products of combustion and steam forced into remote areas will be cooler than those originally being forced there by the fire. In other words, immediate application of proper rates of flow of water can help occupants trapped in a building, rather than endangering them."

(6) Type, 5, 6. Purpose; Stop fire spread. The final method of attack is used when the fire is in control and the fire department is unable to gain control and extinguish the fire within a reasonable length of time. These are larger fires, and the operations are usually described as being defensive in nature. The purpose of the attack is to prevent the spread of the fire within the building or to other buildings. This method of attack may be called a <u>deluge attack.,</u> in other words, surround and drown.
A deluge attack means using large master streams as well as multiple hand lines. Direct access may not be possible because of the danger of collapse. Bill Nelson has an apt description of these operations.[xxi]

"*All kinds and sizes of streams are put into operation and simple throw water in the general direction of the building. This type of attack take a bit longer because the fire must burn through the roof before it can get at the water."*

This completes the analysis of six methods of fire attack. The reader should remember that Bill Nelson assigns the pure indirect method of attack to a limited role, a holding action in a fire in a multi-story building. However, the indirect method has been incorporated into the combination attack. A combination attack, of course, means both a direct and an indirect attack upon a fire. So the indirect attack is still around and is highly useful.

Also if a combination attack is made properly, such an attack can indirectly control or extinguish fires in adjacent areas, that is, in areas where no water is applied directly. This is an indirect effect that occurs frequently. So both the direct and indirect methods of attack are very important and useful methods of attack.

Methods That Don't Work

Let's consider two methods of fire attack that do not work, and a third that may or may not work.

(1) The first method is called <u>outstanding fire fighting.</u> This name certainly is not intended to be complimentary. It means standing still outside a structure and projecting a straight stream through the nearest available opening. The result—an almost complete waste of water, as indicated by the following statement by Bill Nelson.[xxii]

"The fire will set up convection current around the fire stream and burn merrily on."

I like the use of the word "merrily". This clearly indicates that the fire is in control and that this method of attack is not working. The error, of course, is the failure to make any attempt to distribute the water throughout the fire area. In fact it would be impossible to do this at some distance from the building. No matter whether the attack is direct, or indirect, water must be distributed thoroughly to control the fire.

(2) The second method is a <u>wide-angle fog attack.</u> This means opening the nozzle to at least a 60^{o} pattern as you advance into the fire area. With the short reach of the stream and the amount of entrained air, the result is the creation of extreme turbulence that upsets the thermal balance. In other words, the attack may very well "push the fire around". These problems are compounded by the fact that entirely too much water is being used. Thus what we have is a "bulldozer" attack using a single attack line.

This method of attack is what Bill Nelson was complaining about when he used the phrase, “dark decade of thermal imbalance”. Gradually fire departments learned that instead of pushing the fire inside, if they attacked from the opposite direction, then they could push the fire outside. This lead to the principle that the fire must be attacked from the unburned side of the structure. Further improvement was made by switching to a straight stream that produced less thermal imbalance. Thus we have arrived at a current method of attack, using a direct attack with a straight stream.

(3) Some fire departments consider the direct attack with a straight stream to be the best method of attack, hence the only method of attack really needed by any fire department. However, you must realize that this idea is based upon “a misunderstanding and misapplication of scientific principles.” The origin of this method of attack is in the misuse of fog nozzles that occurred in the 60s and 70s, the wide-angle fog attack. The problems encountered lead to the creation of new tactics that required artificial ventilation to compensate for the use of too much water. The use of a straight stream is designed to mitigate the problems encountered with thermal imbalance and limited ventilation.

By contrast a combination attack using the right amount of water does not require artificial ventilation since natural ventilation by steam removes the heat from the fire area. Even the combination attack does not work for all fires. In fact there is no one best method of fire attack that will work for all fires. All methods have their place in the arsenal of methods of fire attack. It all depends upon the purpose of the attack, and choosing the best method that fits that purpose on a given day.

However, there is one aspect of the direct attack that needs to be addressed. If fire department policy is to always make an interior attack, this leads to a dangerous situation in certain cases. For routine fires usually there is no problem For non-routine fires, this method places fire fighters at risk of injury or death by collapse or flashover. All too many times each year tragic incidents are reported, needless death or injury caused by over reliance upon one method of fire attack.

Bill Nelson’s guiding principle, choosing the best method of attack for a given purpose certainly includes careful consideration of the safety of the fire fighters involved. If fire fighters realize that they have a choice of the methods of fire attack, then surely they can choose the method that best insures their safety and survival on the fire ground.

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[xviii] Floyd W. Nelson, QUALITATIVE FIRE BEHAVIOR, p. 107, ,,,
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[xxi] Floyd W. Nelson, QUALITATIVE FIRE BEHAVIOR, P. 109.
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