Fire Streams

by Jay Comella with Jeff Shupe

This chapter provides required knowledge items for the following NFPA Standard 1001 Job Performance Requirements:

FFI 5.3.10	FFII 6.3.2
FFI 5.3.11	
FFI 5.3.13	

OBJECTIVES

Upon completion of this chapter, you should be able to do the following:

- Identify the advantages of water as an extinguishing agent
- Identify the factors that affect the firefighter's ability to handle fire hose
- Describe the characteristics of the four nozzle types
- Identify the mnemonic device "ADULTS" as it applies to using a fire hose and nozzle
- Describe the three methods of fire attack
- Identify the three types of fire streams
- Describe the proper procedures for advancing a charged hose line
- Describe the proper procedures for advancing an uncharged hose line
- Describe the responsibilities of the three positions on a charged hoseline
- Describe the proper procedures for using a hoseline to perform hydraulic ventilation
- Describe the proper procedures for using hoselines during exposure and overhaul operations
- Identify the different types of master stream devices used by the fire service
- Identify the types of specialty nozzles used by the fire service
- Describe the basic care and maintenance of fire service nozzles

INTRODUCTION

Over the years the leading instructors of the fire service have repeatedly made statements such as "The greatest lifesaving action on the fireground is the proper placement of the proper size initial attack hoseline," and "As the first line goes, so goes the fire."

FFI 5.3.10 Such statements denote the critically important actions involved in the proper selection, deployment, and use of **hoselines**, **nozzles**, and **fire streams**. When applied properly, they diminish or extinguish the fire completely, reduce the temperature of burning materials, and stop the spread of fire. They directly affect lifesaving by extinguishing fire and inhibiting the products of combustion. They also allow all other fireground lifesaving functions to proceed more quickly, efficiently, and safely. The entire job revolves around the acts of stretching and advancing hose and operating the nozzle to extinguish fire. The members who perform this work are the tip of the spear of the fire service.

WATER AS AN EXTINGUISHING AGENT

Today's fireground is a much more volatile environment than that of the past. The flow rates of 95–125 gpm were deemed adequate at a time when fuel loads were lighter and comprised of so-called ordinary combustibles, such as wood, paper, and cloth (**cellulosic materials**). Quantities of combustibles have dramatically increased. Fuels are heavier and largely **hydrocarbon**-based (plastics); plastics are petrochemical products that behave like **solid gasoline** and generate large quantities of thermal energy. Higher heat release rates associated with plastics (discussed in chapter 5, Fire Behavior) bring a room to flashover more quickly. Couple these factors with better insulated buildings that inhibit fire from self-venting (tight building syndrome), and today's engine company most definitely faces a much more dangerous enemy than in the past.

FFI 5.3.10 Because the enemy has become much more dangerous, the weapon used to combat the enemy must be upgraded accordingly. Akin to the police evolving from the 38-caliber revolver to the 9 mm semiautomatic, the fire department also must make a more intelligent weapon selection. The hose and nozzle system is the engine company's weapon for attacking the fire. Most of the American fire service now considers 150 gpm (568 L/min) to be the minimum acceptable flow rate for interior structural fire attack. Many fire departments use a target flow rate of 180 gpm (681 L/min) to ensure an added margin of safety.

In his brilliant treatise on the art and science of applying water on fire,[1] the late Andrew Fredericks (a New York City Fire Department [FDNY] firefighter who was killed at the World Trade Center on 9/11), the foremost expert on engine company operations in modern times, further states that in addition to 150 gpm (568 L/min) being the minimum acceptable flow for residential fires, 250 gpm (946 L/min) is the minimum acceptable hand line flow for operations in commercial occupancies.

The establishment of robust, occupancy specific, minimum flow rates is in effect an extension of the Powell Doctrine to the fire service. The Powell Doctrine is the culmination of General Colin Powell's many years of battle experience, training, and study of the military arts. The doctrine is a set of guidelines meant to ensure the highest probability of success in the conduct of military operations. The essence is that once combat is joined, one must bring overwhelming force to bear upon the enemy in an extremely rapid manner (shock and awe) to ensure the highest likelihood of victory in the shortest duration. This in turn reduces the overall depletion of one's resources, both material and human.

The outcome of fireground operations depends on the outcome of the battle between the water the engine company delivers (gpm) and the fire's heat release rate. The flow at which the engine company can win the battle and kill the fire is defined as the critical flow rate. If the critical flow rate is not met, the battle will be lost. This dictates that the single most important characteristic of a hose and nozzle system is water flow capability. The water the engine company delivers must not merely meet theoretical flow rates; it must be sufficient to expediently overwhelm and kill the fire. Maneuverability of the hose and nozzle are important factors, but sacrificing flow for ease of use has proved to be suicidal in too many instances.

Water is an ideal fire-extinguishing agent. Besides the fact that it is readily available and inexpensive in most locales, it is efficient in terms of its fire-extinguishing capabilities. Water extinguishes a fire primarily through cooling, reducing the temperature of the burning fuel and the fire gases. In addition, water applied to unburned fuel surrounding the burning materials wets them, making it difficult, if not impossible, for the fire to spread.

Water has a high **specific heat** compared to other materials (pound for pound, it absorbs more heat than many other substances). Thus it takes more heat energy to raise the temperature of water compared to other materials. It takes one **British thermal unit (Btu)** of heat energy to raise 1 lb water 1°F. (You may be familiar with Btu in the context of air conditioners and the amount of heat energy they are capable of handling, it is a measurement of their **cooling power**.)

For every 1°F, 1 lb water is raised by a fire, it absorbs 1 Btu of heat energy. When the water turns to steam at 212°F, it absorbs an additional 970 Btu, called the **latent**

heat of vaporization. In fig. 16–1 for example, 1 lb water at 55°F heated until it turns to steam absorbs

$$157 \text{ Btu } (212 - 55) + 970 \text{ Btu} = 1{,}127 \text{ Btu}$$

Taken a step further, because 1 gal water weighs 8.3 lb, 1 gal water at 55°F turned into steam absorbs

$$8.3 \times 1{,}127 \text{ Btu} = 9{,}354 \text{ Btu}$$

When liquid water turns to steam, it expands approximately 1,700 times its original volume (see fig. 16–2). Although smothering by steam is a useful firefighting tactic in unoccupied buildings and equipment, it is neither safe nor desirable to generate large quantities of steam because of the danger to occupants and firefighters. In typical compartment (room) fires, firefighters must avoid creating steam by applying water properly and in the right quantities. Creating larger quantities of steam is dangerous and can lead to **steam burns**. This issue is discussed in the following text in terms of nozzle selection and fire streams.

Although an adequate flow rate cannot be sacrificed for ease of use, handling characteristics cannot be completely overlooked, either. The **nozzle operator** must exert enough force to resist the nozzle reaction. Nozzle reaction is measured in pounds of force and is a function of two factors: flow rate and **nozzle pressure (NP)**. An increase in one or both factors results in increased nozzle **reaction force (RF)**. The higher the nozzle RF, the more difficult the nozzle is to control. Because adequate flow rate is the ultimate goal of a well-conceived hose and nozzle system, the logical way to keep nozzle RF within the manageable range is to keep nozzle pressures low and avoid sacrificing flow. More than 75 lb (34 kg) RF is considered to be too much reaction force for a hand line. However, RF less than 45 lb (20.4 kg) is considered a sign of an ineffective stream.

Hoseline handling characteristics are a function of the following factors:

1. Flow rate
2. Hose size
3. Friction loss
4. Pump discharge pressure

Hand line maneuverability is determined by the pressure at which a given size line must be pumped to attain a desired flow rate. If hose size remains constant and flow is increased, pump discharge pressure must be increased to account for greater friction loss. This reduces maneuverability as the line approaches the stiffness of a pipe. Conversely, if hose size increases while flow remains constant, pump discharge pressure may be reduced because of lower friction loss requirements. This results in improved maneuverability because the line becomes more bendable.

The aforementioned parameters lead to certain conclusions about what constitutes a well-planned hose and nozzle system for residential fires. The hose should be capable of flowing between 150 and 180 gpm (568 and 861 L/min) with relatively low friction loss. The nozzle should have similar flow capability at a nozzle pressure that will maintain reaction force in the range of between 45 and 75 lb (20 and 34 kg).

Because of the pressures required to account for friction loss, the practical flow limit for 1½-in. (38-mm) hose is 125 gpm, whereas the practical flow limit for 1¾-in. (45-mm) hose is 200 gpm (757 L/min) (fig. 16–1).

Fig. 16–1. The 1¾-in. (45-mm) hose allows significantly higher flow than the 1½-in. (38-mm) line, yet size and weight differences are nominal.

NOZZLES

FFI 5.3.10 **FFII 6.3.2** The tool at the very heart of the entire fireground operation is the nozzle. It is the weapon with which members enter into close-quarter combat with the enemy. If the nozzle malfunctions or is improperly used, all other tools and tactics on the fireground are likely to become quite limited in their effectiveness in saving life and protecting property. All kinds of nozzles perform their all-important mission by providing some rather simple, uncomplicated, albeit incredibly necessary functions. They control flow, create shape, and provide reach. Because the functional requirements for a nozzle are relatively simple and yet immensely important, it intuitively makes sense to select the nozzle with the least complicated design and the fewest moving parts. The most low-tech choice in nozzle selection ensures the greatest degree of durability and reliability. Simple, durable, and low tech are all qualities that contribute to low initial and long-term costs. More importantly, these qualities lead to reliability, which leads to increased safety. The use and care of nozzles is covered under National Fire Protection Association (NFPA) 1962: *Standard for the Inspection, Care, and Use of Fire Hose, Couplings, and Nozzles and the Service Testing of Fire Hose*.

In the early days of fire service, hoses were leather and the first nozzle was nothing more than a piece of pipe on the end of the hose. The addition of a controlling device, or shut-off, between the male hose butt and the piece of pipe was the genesis of today's fire nozzle. The bore of the pipe, or **smooth bore nozzle (tip)**, was eventually tapered to improve hydraulic efficiency. The controlling device consists of a shut-off valve and a handle by which to control it. Over the years various valve and handle sizes and types have seen use. Most configurations fell by the wayside as the shut-off evolved into the modern incarnation: a quarter turn ball valve with a 1⅜-in. (35-mm) waterway activated by a bale-type handle.

The rule of thumb for smooth bore tip orifice size is that it should be one-half of the inside diameter of the hose. This equates to a ⅞-in. (22-mm) tip for 1¾-in. (45-mm) hose and a 1¼-in. (32-mm) tip for 2½-in. (65-mm) hose. However, many fire departments have had great success with slight variances from this rule. The 15⁄16-in. (24-mm) tips for 1¾-in. (45-mm) hose and 1⅛-in. (30-mm) tips for 2½-in. (65-mm) hose are the most common sizes, and practical experience proves they deliver efficient and effective fire streams.

The first **fog nozzle** was developed in 1863 by Charles Oyston of Little Falls, New York. Fog streams are fog nozzles, and fog streams went relatively unnoticed and had little effect on the fire service for quite some time. It was not until the post–World War II period that fog nozzles gained widespread use. This increased favor within the fire service was a result of wartime experiences gained by the naval services who successfully used fog streams to control shipboard fuel oil fires in confined spaces. The intervening years have seen combination nozzles, variable flow nozzles, constant gallonage nozzles, adjustable gallonage nozzles, and constant pressure nozzles (also known as automatic nozzles) all come into being.

After a relatively short-lived duration, the variable flow nozzle fell into disfavor. As its name indicates, it delivered varied flows by design. As the pattern selection changed, so would the flow. It soon became obvious that tying one's ability to achieve critical flow rate to stream selection was a distinct disadvantage in the design of the variable flow nozzle. This characteristic caused its use to decline and then cease.

The three other types of combination nozzles mentioned, constant gallonage, adjustable gallonage, and constant pressure, all remain in present day use.

Nozzle characteristics

Fog streams are characterized by small droplets of water in a dispersed pattern compared with the tight, compact stream of a smooth bore nozzle; the distinct droplets of water in a fog stream evaporate more readily, generating steam (figs. 16–2a and 16–2b). The kinds of nozzles available today, in descending order of simplicity and durability, are smooth bore, constant gallonage (single-gallonage) fog, adjustable gallonage fog, and constant pressure (automatic) fog (fig. 16–3). Fog nozzles are sometimes called **spray nozzles**, nozzles which can be adjusted to discharge a straight stream or fog pattern.

Fig. 16–2a. A firefighter using a spray nozzle discharging a fog pattern

Fig. 16–2b. A firefighter using a spray nozzle discharging a straight stream

Fig. 16–3. Left to right: $\frac{15}{16}$-in. (24-mm) smooth bore nozzle (180 gpm at 50 psi [681 L/min at 45 kPa]), constant gallonage nozzle (150 gpm at 50 psi [568 L/min at 345 kPa]), and an automatic nozzle (50–300 gpm [189–1,136 L/min]). (Courtesy of Jerry Knapp)

Smooth bore nozzle

SKILL DRILL

The smooth bore is the most low-tech of all nozzle designs. It consists of a ball valve shut-off device onto which is threaded the smooth bore tip, which is basically a piece of tapered pipe. Together, the shut-off and tip present a compact (7¾ in. [20 cm]) and lightweight (2½ lb [1.1 kg]) package. Genius lies in the simplicity of its design. It has only one moving part: the ball valve (fig. 16–4).

It is difficult to clog a smooth bore nozzle. It requires the least maintenance of any nozzle type and has the longest service life.

Smooth bore nozzles are by far the least expensive kind to purchase and maintain. Of all nozzles, the smooth bore requires the least amount of training for pump and nozzle operators to become proficient (fig. 16–5). The incredible reliability of the smooth bore nozzle is a significant safety feature. Because you can produce only a solid stream with the smooth bore nozzle, its use ensures that members and victims are not being exposed to the potentially debilitating or lethal effects associated with introducing a fog stream into the fire area.

The smooth bore nozzle is a safe and efficient weapon for combating interior structural fires. Therefore, it is the nozzle that is often taken into the most hostile work environment on the face of the earth—the interior of a burning building. Fog nozzles are appropriate for other uses, such as flammable-liquid fires, outdoor rubbish fires, vehicle fires, and the like. However, some departments use fog nozzles as their primary nozzle for **interior fire attack**. Fog nozzles used during interior fire attack must use the straight stream pattern to avoid the possibility of creating large quantities of steam from the vaporization of the fog droplets, scalding firefighters, and trapped occupants.

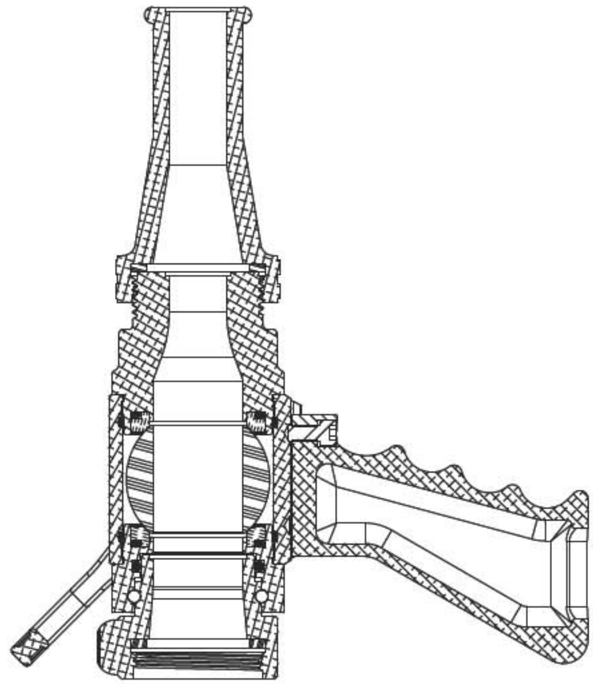

Fig. 16–4. Cut away of a smooth bore nozzle. (Courtesy of Elkhart Brass Mfg. Co.)

Fig. 16–5. California's Oakland Fire Department (OFD) members operate a 2½-in. (65-mm) hoseline with a 1⅛-in. (30-mm) smooth bore nozzle (266 gpm at 50 psi [1,007 L/min at 345 kPa]) during testing and evaluation. (Courtesy of Daryl Liggins)

Constant gallonage fog nozzle

The **constant gallonage fog nozzle** is the simplest, most reliable, least maintenance-intensive and, hence, safest member of the fog nozzle family. Of all fog nozzles, this type requires the least training. It does, however, require somewhat more training than the smooth bore nozzle. Constant or single gallonage indicates that this nozzle is designed to flow a specific gallonage when operated at the specific pressure for which it is designed, such as 150 gpm at 100 psi NP (568 L/min at 700 kPa). In addition to the 100-psi (700-kPa) model, constant gallonage nozzles also come in 75-psi (525-kPa) and 50-psi (345-kPa) models. The nozzle is 12¼ in. (311 mm) long and weighs 6.1 lb (2.8 kg). As the name suggests, there is the distinct possibility of introducing fog stream into the fire area. This has the potential to turn a still-tenable environment into one that is untenable in short order. As with all fog nozzles, when the water flows from the hose—through the shutoff, into the tip, to be broken into a spray stream—a clog point exists.

Adjustable gallonage fog nozzle

The **adjustable gallonage fog nozzle** takes fog nozzle technology to the next level of complexity. It has more moving parts and is more maintenance-intensive than the constant gallonage nozzle and, hence, has an increased potential for nozzle failure or malfunction. Using a flow-selection ring, the nozzle operator can choose a desired flow. This operation requires an increased level of training for both nozzle and pump operators. If the nozzle operator changes the flow setting, the pump operator must be informed so he or she can adjust pump discharge pressure to the appropriate level for the selected flow. It is possible to put the flow-selection ring on the wrong setting, so the nozzle's flow is less than the desired amount of water. So, in addition to possibly introducing a dangerous fog stream into the fire environment, there is a great potential for producing a flow that is less than the acceptable minimum. The adjustable gallonage nozzle is 12¼ in. (311 mm) long and weighs 5.6 lb (2.5 kg).

Automatic fog nozzle

Automatic nozzles originally were designed in the late 1960s by Chief Clyde McMillan of the Gary Fire Task Force, an auxiliary unit of the Gary Fire Department in Indiana. One role of the task force was to respond to large fires and put master streams into operation. Often, initial water supply was inadequate when transitioning to defensive operations. McMillan set about designing a master stream appliance nozzle that would produce a stream with good reach, even at the low flows available during the transitional phases of operations. He also wanted that same nozzle to be appropriate for the high flows achievable after augmentation of the water supply.

The automatic nozzle is also called the **constant pressure nozzle**. Constant pressure refers to the fact that the nozzle produces a stream of reach and appearance consistent with 100-psi (700-kPa) tip pressure regardless of the pressure actually coming into the base of the nozzle. This is accomplished by a baffle and spring arrangement. As a given amount of water enters the nozzle base, it puts the spring under a given amount of compression. This, in turn, moves a baffle that changes the nozzle's orifice size. As the amount of water flow fluctuates, so does the orifice size. The orifice is thus maintained at a size that, for the given amount of water, provides approximately 100 psi (700 kPa) nozzle pressure (NP). This allows the nozzle to create a visually attractive stream with good reach over an extremely wide range of flows. Often, the stream produced by the automatic nozzle looks good but doesn't contain much water. Remember, volume of water is critical to fire extinguishment.

The automatic fog nozzle is bulky (length: 13¾ in. [350 mm], weight: 6.5 lb [2.9 kg]). It is at the high-tech end of the spectrum of fire service nozzles (fig. 16–9). To be used properly, it requires more training for both nozzle operators and pump operators than any other nozzle type. It has the most complicated design of any nozzle and the most moving parts. Many automatic nozzles come with a shut-off that has a slide valve as opposed to a ball valve. A ball valve (on a smooth bore nozzle) has a completely unobstructed waterway, while the slide valve can become a significant clog point. Given the potential for clogging, the nozzle is equipped with a protective screen at its base to keep debris from entering the slide valve. Clearing the clog necessitates shutting down the hoseline, resulting in problems during a fire attack. The automatic nozzle is the most maintenance-intensive nozzle type.

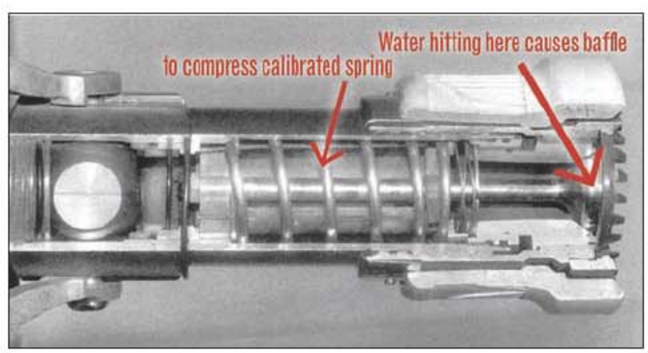

Fig. 16–6. Cutaway illustration of automatic nozzle.

Operating characteristics of smooth bore and fog (spray) nozzles

Smooth bore nozzles are simple to operate. To flow water, firefighters need only pull back on the bale and water discharges from the nozzle. The bale can be adjusted between the fully closed (the **bale** is in the forward position, farthest away from the firefighter) and the fully open positions (the bale is in the rear position, closest to the firefighter). Positioning the bale between these two extremes allows the firefighter discharge smaller amounts of water. To open or close the bale, move in a slow, deliberate manner (figs. 16–7a and 16–7b).

The bale of fog nozzles operates in the same way as a smooth bore nozzle. Typically, the nozzle has a rotational control to adjust the pattern from straight stream to the wide-angle spray also known as a **wide fog** (characteristically, a 100-degree angle). Turning the adjustable rotational control from left to right changes the pattern from a wide-angle fog to a narrow fog, and then finally to a straight stream (and shutoff in some cases) (figs. 16–7c, 16–7d, 16–7e, and 16–7f). Some fog nozzles use a lever-type control to adjust the pattern and open or close the nozzle. Some fog nozzles have a **flush feature** that allows small pieces of debris to be discharged.

Fig. 16–7a. Smooth bore nozzle in open position

Fig. 16–7b. Smooth bore nozzle in close position

Fig. 16–7c. Fog nozzle in open position

Fig. 16–7d. Fog nozzle in closed position

Fig. 16–7e. Fog nozzle adjusted to straight stream

Fig. 16–7f. Fog nozzle adjusted to wide fog

SELECTING THE PROPER HAND LINE SIZE

FFI 5.3.10 **FFII 6.3.2** The first step in planning a hose and nozzle system is to establish the needed flow for the occupancy type in question. The flow requirement is derived by determining the flow at which the engine company most often will overwhelm the heat generated by the encountered fuel load. To deliver the desired volume of water, parameters for hose selection are based on flow and friction loss characteristics. Parameters for selecting a nozzle to couple to the business end of that hose are based on flow and reaction force characteristics. This holds true for residential occupancies and for fires in commercial buildings.

Under most circumstances, a 1½-, 1¾-, or 2-in. (38-, 45-, or 50-mm) hand line suffices for a typical room and contents fire in a low-rise residential buildings and the **bread and butter** structures of the fire service: single- and two-family homes. This rule of thumb does not apply to high-rise residential structures or heavily involved residential structures. The company officer (following the particular fire department's standard operating procedures) decides what size hand line to use in a particular building.

As mentioned earlier, the minimum acceptable hand line flow for operations in commercial occupancies (including industrial and institutional occupancies) is 250 gpm (946 L/min). For this type of flow, 2½-in. (65-mm) hose is the line of choice. Friction loss at 250 gpm (946 L/min) is 10 psi per 100 ft (70 kPa per 30.5 m) of 2½-in. (65-mm) line. For the same flow in 2-in. (51-mm) hose, the friction loss is 50 psi per 100 ft (345 kPa per 30.5 M). Although a 2½-in. (65-mm) line is a substantial piece of equipment, it is not too heavy to aggressively advance as a hand line, as would be the case with 3-in. (76-mm) hose.

The key to efficiently using a 2½-in. (65-mm) line is proper nozzle selection. The 100-psi (700 kPa) combination nozzle effectively removes the 2½-in. (65-mm) line from many a fire department's arsenal of offensive weaponry because of the very high nozzle reaction force of 126 lbs (57 kg) while flowing 250 gpm at 100 psi (946 L/min at 700 kPa) nozzle pressure. Low-pressure nozzles (50-psi [350-kPa] tip pressure) impart significantly less reaction force."

Many departments successfully employ a 1¼-in. (32-mm) tip. Its 324-gpm (1,226-L/min) flow technically classes it as a large-caliber stream, making this size tip possibly better suited for use with master stream devices. A far greater number of departments use the 1⅛-in. (30-mm) tip. With a flow of 266 gpm at 50 psi (1,007 L/min at 350 kPa) nozzle pressure, it has a reaction force of 95 lb (43 kg). Although it is still crucial to keep nozzle reaction force low, it would be impractical to try to apply the previously cited 75-lb (34 kg) cap to flows from large-caliber hand lines.

Paired together, the 2½-in. (65-mm) line and the 1⅛-in. (30-mm) tip create a user-friendly, offensive, large-caliber weapon. Fredericks states the following:

> *No combination of smaller hand-lines can duplicate the volume, reach, and pure knockdown power of a single, well-placed 2½-in. line. In addition to its high-volume flows (between 250 and 320 gpm) and long stream reach, 2½-in. hose provides the following benefits when used with a 1⅛-in. solid stream tip:*
>
> . *Low friction loss per 50-ft length (only about 5 psi at 266 gpm).*
>
> . *Exceptional penetrating power due to hydraulic force of the stream.*
>
> . *Little premature water vaporization in highly heated fire areas.*
>
> . *Easy reduction to smaller hand-line(s) after knockdown, and much better maneuverability than 3-in. hose (sometimes used as a hand-line) or portable master-stream devices.*[2]

Using a 2½-in. (65-mm) line is indicated in situations in which fire conditions are likely to overwhelm smaller hand lines. Fredericks cites the oft-used mnemonic device ADULTS, which refers to scenarios requiring the use of 2½-in. (65-mm) line:

- **A**dvanced fire on arrival
- **D**efensive operations
- **U**nable to determine extent (size) of fire area
- **L**arge, uncompartmented areas
- **T**ons of water
- **S**tandpipe system operations

The ADULTS acronym is reminiscent of an anecdote related by retired Chicago Fire Department Battalion Chief Ray Hoff regarding proper hand line selection. On seeing an engine company stretching a 1¾-in. (45-mm) line toward a commercial occupancy exhibiting a heavy fire condition, Chief Hoff requested, "Would you please put that down and bring me an adult-size line?"

Advanced fire on arrival. When the engine company encounters advanced fire on arrival, the high flow available from 2½-in. (65-mm) hose is needed for rapid control. Even a private dwelling may exhibit a fire condition heavy enough to warrant the quick knockdown power of the 2½-in. (65-mm) line. This is especially true of extensive involvement of the first floor or front porch.

Although using master stream appliances is not recommended for occupied residential buildings, the same cannot be said of 2½-in. (65-mm) hose. The 2½-in. (65-mm) line coupled with the 1⅛-in. (30-mm) smooth bore nozzle is a large-caliber weapon that is aggressive, mobile, and offensive. It can rapidly darken down a heavy fire condition to allow an interior attack. This permits three tactical options:

1. The 2½-in. (65-mm) hand line can be advanced into and through the structure.
2. The attack can transition to the use of a smaller line with the big line left where it is.
3. The 2½-in. (65-mm) line can be reduced down to a smaller line to press the interior attack for final extinguishment.

Defensive operations. Whether operations are initially defensive or transition from offensive to defensive, smaller-caliber hand lines should not be used. The 2½-in. (65-mm) line is a much safer and more efficient alternative. The reach afforded by the larger line allows it to be operated from outside the collapse zone. Once its high-volume stream penetrates the fire area, it has a much greater effect on conditions than does a stream from a smaller line. The 2½-in. (65-mm) hand lines are much more mobile and easier to deploy than master stream devices. This allows streams to be brought to bear from a greater variety of locations.

Unable to determine extent (size) of fire area. If the engine company officer is unable to determine the extent (size) of the fire area, use a 2½-in. (65-mm) line. The high-flow stream allows for unforeseen contingencies. During the course of operations, it may be determined that the amount of fire encountered can be handled with smaller hose. As with the above-mentioned private dwelling scenario, the 2½-in. (65-mm) hose can be reduced to, or replaced by, a smaller line.

Large, uncompartmented areas. Fires in large, uncompartmented areas require levels of reach, penetration, and volume that are beyond the capabilities of smaller hand lines. In addition to wide-open floor plans, occupancies such as supermarkets, bowling alleys, warehouses, theaters, houses of worship, and the like often have high ceilings. High ceilings allow massive amounts of heated fire gases to accumulate. Once these flammable vapors ignite, they may prove to be too formidable for streams from smaller lines. The reach and tremendous cooling power of the 2½-in. (65-mm) line with 1⅛-in. (30-mm) tip allows operation from an entranceway into the rolling flame front of combustible gases beneath the ceiling. Once the hazard in the fuel-laden overhead area has been contained, the attack can be pressed deeper into the structure's interior.

Tons of water. At some fires, extinguishment simply requires tons of water. This is often the case for fires in piles of tires, junkyards, garbage dumps, and lumberyards, to name a few. A 2½-in. (65-mm) line with 1⅛-in. (30-mm) tip operating at 50 psi (350 kPa) NP discharges more than a ton of water a minute. The use of smaller lines in this kind of situation would be an exercise in futility.

Standpipe System Operations. Proper consideration for members' safety demands the use of 2½-in. (65-mm) hose and smooth bore nozzles for standpipe operations. For many years, NFPA 14, the *Standard for Standpipe Systems*, was based on the use of 150 ft (45 m) of 2½-in. (65-mm) hose equipped with a 1⅛-in. (30-mm) smooth bore nozzle at a 65 psi (455 kPa) standpipe hose valve outlet pressure. Depending on which version of the standard a given standpipe system was designed under, outlet pressures can be either 65 psi (455 kPa) (pre-1993) or 100 psi (700 kPa) (post-1993). Outlet pressures such as these simply do not meet the friction loss requirements for smaller-diameter hose, especially in conjunction with 75-psi (525 kPa) or 100-psi (700 kPa) nozzles.

Many standpipe systems have pressure-reducing valves that are not field adjustable. This means that no matter what pressure fire department pumpers pump into the system, outlet pressure does not rise above a given outlet's rated pressure. Retired New York City Fire Department Deputy Chief John Norman[3] admonishes that to use anything other than 2½-in. (65-mm) hose and smoothbore nozzles for standpipe operations is to misuse the standpipe system. Prior to becoming a member of the career fire service, Norman was a fire protection engineer and made his living designing sprinkler and standpipe systems.

Because of design configurations and conditions of standpipe systems, flow and pressure problems chronically plague operations. As stated by Fredericks, "A standpipe system is like a big black box which fire department Members did not design or install, do not maintain, and in most cases do not inspect or test yet Members expect to put water in one end and have it come out at the other end at the proper pressure and flow." Although certainly not an ideal situation, even at a low outlet pressure, the combination of 2½-in. (65-mm) hose and a 1⅛-in. (30-mm) smooth bore tip still can develop a usable fire stream.

In February 1991, the Philadelphia Fire Department had a disastrous experience dealing with a fire in the One Meridian Plaza building. At the time, the Philadelphia Fire Department used 1¾-in. (45-mm) hose and 100 psi (700 kPa) automatic fog nozzles for standpipe operations. Misadjusted standpipe hose valve pressures combined with the smaller hoseline size and pressure intensive automatic fog nozzles resulted in a weak stream with which to fight the large fire. Three firefighters were trapped in the building and killed. Firefighting forces were pulled from the building in anticipation of possible collapse; the fire consumed several floors until its upward progression was stopped by nine sprinkler heads in the partially sprinklered building.

METHODS OF FIRE ATTACK

FFII 6.3.2 For quite some time, firefighters have debated the various methods of applying a fire stream to attack a fire. Only one method existed by which to extinguish fire and that was to apply a solid stream of water directly to the burning solid fuels, commonly known as the "direct attack." This is one of several types of fire attack; it is described below along with three other types: the indirect, combination, and modified direct attack.

Indirect method of attack

Prior to World War II, direct attack was the long-established mainstay of the fire service. During the war Lloyd Layman, Chief of the Parkersburg Fire Department in West Virginia, became the commandant of the United States Coast Guard firefighting school. His duties included determining the best way of combating fuel oil fires in the confined below-deck spaces of ships. Toward this end he conducted extensive research and testing. A major part of his efforts consisted of a series live-fire tests aboard a decommissioned liberty ship.

Results of Layman's research and testing led to new theories about fire attack and eventually to the formulation of the **indirect method** of fire attack. He found that it was efficient to remotely inject a fog stream into an unoccupied compartment. To use this method, the space must be unoccupied, because it would rapidly become untenable upon the introduction of a fog stream. After the fog nozzle operates for a sufficient amount of time, it shuts down. The hatch through which the nozzle operated is then shut to preclude ventilation and confine the expanding steam. The steam is the major factor in extinguishment, through cooling as well as smothering. When water turns to steam, it expands by a ratio of 1700:1 (fig. 16–8). Water turns to steam at 212°F (100°C). Few fires only reach a maximum 212°F (100°C). What many people fail to realize is that at 1,000°F (538°C), a ceiling temperature easily reached at structure fires, the expansion ratio of water is 4,000:1.

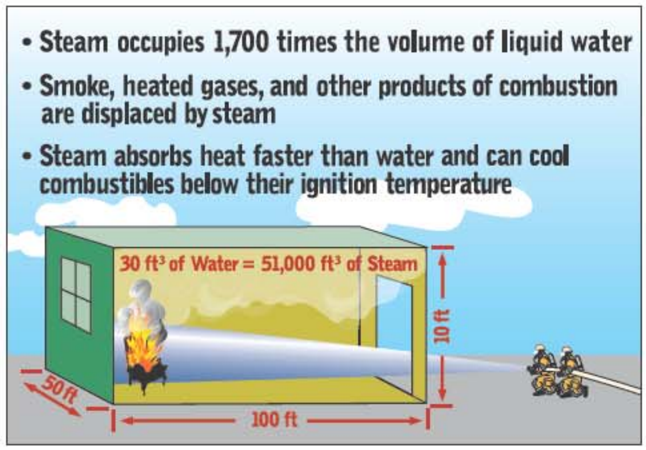

Fig. 16–8. When water turns to steam it expands by a ration of 1700: 1.

At the war's end Layman resumed his peacetime career as the Parkersburg, West Virginia, fire chief. This is when he began to transfer what he had learned about the efficient extinguishment of shipboard fuel oil fires in unoccupied confined spaces to the suppression of interior structural fires (fig. 16–9). He did, however, maintain the following tenets for the use of the indirect attack for fires in buildings.

- First and foremost, there must be no life hazard within the fire compartment. The term **life hazard** includes both building occupants and fire department members. The application of the indirect method of attack rapidly destroys the thermal balance of the fire compartment, making it an environment both untenable and unsurvivable.
- The ceiling temperature must have reached at least 1,000°F to have an environment conducive to the efficient conversion of the water fog into steam to cool and smother the fire.

- The water fog must be remotely injected into the fire compartment from the exterior, preferably from a window. The fog stream is held in a fixed position, because it is directed into the overhead area of the fire compartment. The injection of water fog into the overhead area results in the fine water droplets, rapidly vaporizing and expanding, which destroys the thermal balance and pushes a high level of wet heat down to the floor. Avoid ventilation to keep the voluminous amounts of expanding steam necessary for efficient extinguishment within the fire compartment.

Layman emphasized that if any of the above-listed tenets could not be fulfilled, a direct attack on the fire is then the proper course of action.

Fig. 16–9. The indirect attack as described by Lloyd Layman

Combination method of attack

The **combination method** of attack was developed by Keith Royer and Floyd W. Nelson during numerous Iowa State University test fires in acquired structures. They expanded on Layman's work and deemed it more efficient to rotate the fog stream in a clockwise direction hitting the ceiling, walls, and floor. They also deemed it appropriate to inject the fog stream through either a window or a doorway. The reason that they stated that the nozzle be rotated in a clockwise manner is that during their many test fires they were able to observe that clockwise nozzle rotation pushed products of combustion and extinguishment away from the nozzle operator. Counterclockwise nozzle rotation, they observed, would draw products of combustion and extinguishment toward the nozzle operator (fig. 16–10).

Like Layman, Royer and Nelson maintained that there must be no life hazard within the fire compartment (again referring to building occupants as well as department members). They also stated that ventilation should be as limited as possible to confine the massive amounts of steam generated by the combination attack to the fire compartment. As with the indirect attack, the combination method of attack required a ceiling temperature of a minimum of 1,000°F (538°C) to take advantage of water's expansion ratio of 4,000:1 at that temperature. Also, like Layman, they maintained that if the aforementioned parameters did not exist, a direct attack on the fire would be the best course of action.

Fig. 16–10. The combination method of attack requires a fog stream injected through a door or window and rotated clockwise to push products of combustion away from the nozzle operator.

Direct method of attack

The **direct method** of attack is simply the application of a solid stream or a straight stream directly on the burning solid fuels (fig. 16–11). This type of attack is used when the fire is relatively small: a single object or a small number of objects are burning and can be easily extinguished by applying the water directly on the burning materials. When several objects or an entire compartment is on fire, then the modified direct attack (described below) is called for.

Larger metropolitan fire departments have a long tradition of aggressive interior direct attack of structural fires. This is because they are most often tasked with the protection of a high life hazard in the form of dense concentrations of people in large buildings. Experience has proved time and again that the best way to protect life is to put out the fire in the most expeditious manner. Once the fire is extinguished, every other fireground activity (entry, laddering, search, rescue, removal, ventilation, etc.) can be performed more safely and efficiently. This results in greatly enhanced probabilities of safe outcomes for both building occupants and operating members.

Prior to the widespread use of breathing apparatus, evidence of the use of such aggressive tactics at more arduous fires was the presence of numerous members prostrate on the sidewalk and incapacitated because of smoke inhalation. It was realized that this risk was worth taking because of the likely reward of saving many lives and thus fulfilling the fire service's custodianship of the populace.

During and after the development of the indirect and combination methods of attack, most large fire departments never varied from their tried and true tactics of aggressive interior direct fire attack coupled with aggressive natural ventilation and aggressive primary search. With the advent and consequent widespread use of more efficient, user-friendly breathing apparatus, many smaller fire departments began to emulate the aggressive interior tactics of larger urban departments.

Along with this seemingly positive development came efforts by many to press into service for interior operations the indirect and combination methods of fire attack. The indirect and combination methods of attack are basically exterior or defensive operations. Combining defensive tactics with offensive interior operations is normally dangerous and counterproductive. Always keep in mind that Layman, Royer, and Nelson—the creators of the indirect and combination methods of attack—strongly stated that the indirect and combination methods should not be employed if a life hazard exists within the fire compartment. Even if the building is unoccupied prior to the arrival of the fire department, once members enter the building to operate, a life hazard exists in the building.

The foremost mission of the fire service is to protect life, which is why operating members enter burning buildings, plain and simple. Because the paramount mission of the fire service is to save life, members must make extreme efforts to access the area of the building near the seat of the fire. That is the area where victims are in the most extreme peril. All efforts must be made by engine company members to aggressively push the initial attack line in to extinguish the seat of the fire. All efforts must also be made by ladder company members to aggressively vent, enter, and search the building as near to the seat of the fire as possible. The parameters set forth earlier indicate a method of fire attack appropriate to deal with the life hazards of occupied buildings. A major facet is that it allows members to enter fire compartments for extinguishment, ventilation, and search. In conjunction, the chosen method of fire attack should be that which does the most to preserve the thermal balance of the fire compartment as well as to first preserve and the expediently improve the tenability of the fire occupancy.

Aggressive interior direct attack coupled with aggressive natural ventilation is best tactic for expediently improving the tenability of a fire compartment without compromising thermal balance. Combined with aggressive primary search, this is the operational doctrine that most greatly enhances the probabilities of survival for both victims and operating members. The synergistic effect of simultaneous operations, a combined arms approach if you will, allows the fire service to most completely fulfill its custodianship of the public's safety.

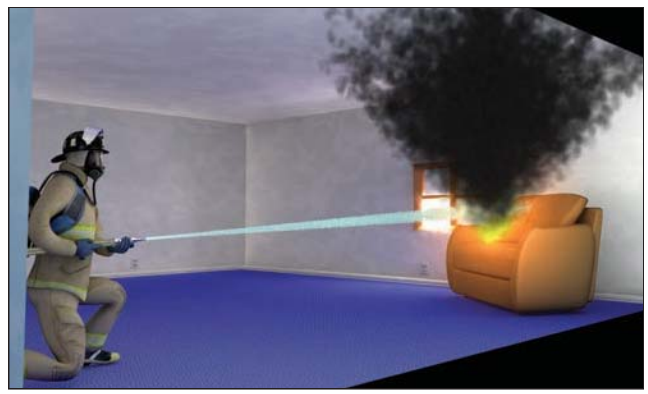

Fig. 16–11. A direct attack procedure

Modified direct method of attack

The **modified direct method** is a two step attack: the application of a solid stream or a straight stream is directed into the overhead area (the first step), out front ahead of the nozzle team. The nozzle must be moved vigorously in a clockwise or side-to-side motion, splattering the stream against the ceiling and upper walls. Breaking the stream up in this way causes large chunks of water to rain down all over the fire area, finding the seat of the fire in the burning solid fuels. The stream is then directed on to the burning solid objects in the room (the second step) to achieve knockdown and extinguishment. (If the stream was to be applied first directly onto the large group of burning solid fuels it would very likely forcefully push fire ahead of itself, into and then up a wall, then sending it rolling back across the ceiling above the heads of the nozzle team.)

It should be noted that some texts refer to the modified direct attack as a "combination attack." This is historically incorrect; the combination attack involves the use of a circling fog stream in an uninhabited compartment, as described above.

Applying the stream first into the overhead area simultaneously does two things. It cools the superheated area near the ceiling where flashover and other rapid fire progress phenomena are born while also dropping water down onto the burning solid fuels. The application of water onto the burning solid fuels quenches the fire at its source, the fuel-flame interface, and quells the production of flammable vapors.

All four methods of interior structural fire attack will accomplish extinguishment. However, only two of the four methods of attack are in keeping with the life-saving operational doctrine which places operating members in the fire compartment to perform extinguishment and primary search often in close proximity to the seat of the fire. The methods of attack that are most conducive to supporting this doctrine of operation is the direct attack and the modified direct attack.

FIRE STREAM TYPES

FFI 5.3.10 All three stream types (solid, straight, and fog) accomplish extinguishment when applied for sufficient duration and in sufficient volume that meet or surpasses the critical flow rate. In the case of fog streams, however, prior to extinguishment, conditions in the fire area—especially in the fire compartment itself—first worsen before finally improving. Upon initial application of the fog stream, scalding steam is produced because of a large degree of premature vaporization of the water fog. This excessive steam generation destroys the thermal balance of the fire compartment. As a result floor level temperatures increase and visibility is reduced. In addition to the quantitative increase of the heat at floor level, there is also a qualitative change in the heat. Because of excessive steam generation, conditions at floor level change from dry to wet heat, further multiplying the debilitating effects to firefighters and fire victims. All these factors lead to the existence of a period of decreased tenability between the time of first water application and the time of extinguishment and ventilation of the products of combustion and extinguishment (flame, heat, smoke, gases, steam, and air movement). This decreased tenability can be inadvertently caused when using a straight stream on a fog nozzle and changing the pattern to a fog while firefighters are in the fire area.

Much discussion revolves around the tenability of conditions within the fire compartment at floor level. This is because the floor level is where members operate and more importantly where victims wait to be rescued, unprotected and vulnerable. The potential to save human life is the major motivating factor that compels members to go into burning buildings in the first place. Hence, the fire service must focus attention on how its operations either increase or decrease the window of survivability in the area where human life is expected to exist.

This text also touches on the concept of products of combustion and extinguishment. Products of combustion, as well as the various methods by which to combat combustion, have differing consequences. Each method of fire attack and each type of fire stream affects the tenability of the environment in the fire compartment differently. Products of extinguishment include steam generation, air movement, visibility reduction, and temperature change. Hence, members of the fire service must be aware that the choices of method of fire attack and type of fire stream significantly affect the probabilities of survival for the civilians they vowed to protect from fire.

The amount of air, fire gases, and smoke pushed ahead of a fog stream is so voluminous that it quickly overwhelms the likely ventilation openings ahead of the nozzle in a residential setting (e.g., windows). Only so much product of combustion and extinguishment can be forced through the window(s) at any given moment. The significant portion of products that cannot be vented when forcefully pushed forward by the fog stream then impact the wall surface and roll back over and around the nozzle team. This phenomenon has been observed in innumerable building fires and tested at the Rockland County, NY Fire Training Center. The phenomenon known as **fog nozzle ricochet** is a major contributor to the destruction of thermal balance, excessive steam generation and accumulation, and loss of tenability. This phenomenon is not caused by a fog nozzle, but by the untrained use of a **fog stream**.

Another attribute of a hose stream that greatly affects both speed of extinguishment and member safety is the reach of the stream. A stream with greater reach allows members to apply water to the seat of the fire sooner and from a greater distance than does a stream of lesser reach. Ability to engage the fire sooner leads to quicker extinguishment and hence greater overall safety for everyone on the fireground. The greater distance also enhances safety; members need not be in as close a proximity to the seat of the fire to initiate extinguishment. The closer the nozzle team must approach the fire to initiate and accomplish extinguishment, the greater the compromise to their safety (fig. 16–12). A close approach to the fire in order to achieve extinguishment is dictated by the limited reach of a fog stream (the wider the fog, the closer that you have to get to the fire to extinguish it).

Fig. 16–12. A rather graphic illustration of the limited reach of a fog stream.

The superior efficiency and efficacy of solid streams versus fog streams is further evidenced in tests performed by William Clark, former FDNY battalion chief and director of Wisconsin's fire training programs. Clark's test results showed that at equal flow rates and with equal fuel loads:

- Solid stream extinguished the fire faster than did the fog stream.
- Solid stream required less total water to achieve extinguishment than did the fog stream.
- Solid stream led to less measurable runoff water than the fog stream.

Thus, it is not a great leap in logic to conclude that a solid stream applied at a high rate of flow causes flame, heat, smoke, and gas production to cease in the shortest amount of time, accomplished by using the least amount of water. Thus, the solid stream is the most efficient and effective in the limiting of property damage caused by fire, smoke, and water. Far more important, however, is the fact that it is the most effective, efficient, and expedient method for the fire department to attack and kill a dynamic, out of control, untenable physical phenomenon that is threatening the lives of victims. In this manner fire department operations return the environment to nonthreatening equilibrium in the shortest possible amount of time and preserve to the greatest degree any savable human life.

ADVANCING THE CHARGED LINE

SKILL DRILL

FF1 5.3.10 The efficiency and effectiveness of the advancement of the charged line is in no small way determined by the efficiency with which the dry hoseline is stretched and flaked prior to charging. A major factor in the efficiency of stretching is determined much prior to arrival at the fire building. Engine company apparatus design directly effects the proficiency with which engine company members can stretch and use fire hose. An apparatus design that highlights user-friendly attack hosebeds greatly facilitates the performance of the engine company's primary function, its reason for existence, the stretching, advancing, and use of fire hose to kill fire. User-friendly attack hosebeds are low enough so that even the shortest member of the fire department can reach the top layer of hose in the attack hose load while standing on the ground. They also provide ample room for sufficient lengths of hose to make up static attack hose loads capable of covering the distances of any foreseeable stretch in the response area. Static loads also allow the supply line and the attack line to, in effect, simultaneously stretch via the backstretch as opposed to supply and attack lines stretched sequentially with preconnected attack lines. This also has the advantage of placing the apparatus where the pump is most efficient: at the hydrant. This type of hose load is best situated in a section of the main, or rear, hosebed (fig. 16–13).

Fig. 16–13. A bed of supply hose on the left and three beds of static attack hose loads. Static loads are not preconnected and are also known as dead loads. (Photo by Jay Comella)

In addition to apparatus design, policy makers determine the degrees of efficiency, effectiveness, and safety with which engine company members are able to perform their lifesaving function is through the levels of company staffing deemed adequate to protect the public from fire. The quantity and quality of well trained members in a company has an extremely significant effect on the outcome of the company's operation and by extension the outcome of the entire fireground operation. A successful outcome of a fire department operation equates to lives and property saved. Unsuccessful outcomes of fire department operations result in the loss of life and property that was salvageable upon arrival. Fire departments able to stop the shrinking of staffing at six members per company should be emulated in this respect. Company staffing directly relates to the efficiency of the work performed as well as death and injury rates in the fire service. Personnel is a fire department's most valuable commodity regarding mission capability.

Over the years staffing levels have shrunk in many departments as the budget axe has fallen time and time again. Governmental entities that have repeatedly tasked fire departments to do more with less have effectively increased the risks of injury and death to both department members and the citizens they are sworn to protect. In light of this negative external influence, the fire service's traditional organizational mind-set must change. Long accepted practice in many departments has been for engine companies to compete to get first water on the fire. The approach to a company's role within the entire fireground operation must change so that engine companies work in concert with one another, rather than in competition. Sufficient personnel must be committed to getting the first line to the seat of the fire before addressing the deployment of additional lines. Attack lines are best stretched in series, not in parallel. Even the better staffed, forward thinking departments take the approach that all but the simplest hose stretches or advances are, at a minimum, two-company evolutions.

POSITIONS ON THE LINE

Engine company officer

FFI 5.3.10 Ideally, if staffing levels allow, the engine company officer should not physically take part in handling the line. The officer bears overall responsibility for the operations of the company and member safety. Staffing levels that allow the engine company officer to be a true supervisor positively affect the highest order on the efficiency, effectiveness, and safety of engine company operations. By remaining physically uninvolved in the operation, the officer is better able to direct it. The officer must be able to avoid the potential tunnel vision when tied into the line and assisting with its movement. The officer's proper position is to the side of the line and opposite the nozzle operator. It is important that the officer is at the point of attack to observe and experience conditions as they are encountered by company members.

When unencumbered by the need to perform the physical labor of moving the hoseline, the officer is at liberty to move out ahead of engine company members to perform reconnaissance regarding the fire's location and nature. This in turn provides the information needed to perform the following:

- Properly direct members to the correct route to the fire, the size of line needed, the number of lengths sufficient to cover the entire fire area.
- Ascertain forcible-entry problems and life hazard.
- Perform search prior to arrival of line to the extent allowed by fire conditions.
- Confine fire by closing door if possible.

Confirming, to the extent possible, the location of the fire is necessary prior to initiating the hoseline stretch. Failure to do so can lead to many unwarranted mistakes:

- Stretching short
- Stretching long
- Stretching to the wrong location on the fire floor
- Stretching to the wrong floor
- Stretching via the wrong stair well
- Even stretching into the wrong building

The consequences of stretching short are obvious: failing to reach the seat of the fire. It is often wise to include one or two extra lengths in one's hose stretch estimate to err on the side of caution. However, realize that as the amount of excess hose increases, the difficulty in managing the hoseline and the potential for kinks also increases. Kinks in the hoseline lead to significantly reduced water flow. Stretching long can also lead to unduly high pump pressures.

Ensure that all doors through which the line is stretched and advanced are positively cocked open. A door closing on the line can severely hamper the stretch and/or advance, sometimes with dire consequences. This is especially true if the door closes over a dry line that is then charged while it is under the door. The door becomes, in effect, a hose clamp and little or no water gets to the nozzle. The charged line becomes an effective door chock that secures the door in the closed position. Those caught on the wrong side of the door in this situation are definitely in dire straits. As is so often the case, in fire department operations, the devil is in the details. The use of an inexpensive wooden wedge properly positioned to securely chock the door in the open position can quite literally mean the difference between life and death. Shakespeare addressed the importance of paying attention to detail thusly, "For want of a nail the shoe was lost. For want of a shoe the horse was lost. For want of a horse the battle was lost."

Hose should be stretched dry as far as is safely possible to avoid expending time and energy on undue labor. The hoseline must be charged before entering the fire area or that which may rapidly become the fire area. Prior to the line being charged, sufficient dry hose must be properly **flaked out** at the entrance to the fire area. Properly flaked hose is laid out so that the bights in the line are open enough to have the least propensity for **kinking** (fig. 16–14). The fire is often referred to as the enemy and the fire building as the battleground. The logical extension of this line of logic is that kinks are collaborators. Kinks rob valuable amounts of water flow from the attack hose stream. It is the duty of all personnel to remove kinks whenever they are found. Removing kinks is such an important consideration that it is responsibility of all personnel on the fireground, whether engine company or ladder company members, the newest probie or the chief of the department (fig. 16–15).

Fig. 16–14. Properly flaked hose greatly lessens the propensity for kinking.

The pump operator must be notified to charge the line only after it has been properly stretched and flaked out. To do so any earlier invariably increases the time necessary to get water on the fire. Whenever a hoseline is prematurely charged, the labor and time involved in advancing the line and removing the kinks increases dramatically.

Fig. 16–15. Kinked lines prevent maximum flow of water to the fire.

Prior to entering the fire area, bleed entrapped air from the charged line (fig. 16–16). The nozzle must be opened fully to ensure the attack line is supplied with sufficient water flow and pressure before commencing the attack. This is known as **bleeding the line**. At this juncture more than any other, the engine company truly reaps the benefits of having an officer in a purely supervisory role, free to coach, guide, and direct the members through prompt extinguishment and also be a custodian for their safety throughout the process.

Fig. 16–16. Nozzle operators should bleed the charged line prior to entering the fire area.

The officer must strive for the utmost possible awareness of conditions as the company prepares to enter the fire area and throughout the advancement of the line and extinguishment of the fire. Although senses are severely muted, the officer must make use of what little sensory input he or she is afforded. After advancement into the fire area begins, smell is negated with the donning of the self-contained breathing apparatus (SCBA) facepiece. Hearing can be affected by a cacophony of competing fireground noises. Sense of sight is severely diminished in most cases because of voluminous, thick, black smoke. Perhaps most damning is the fact that the total embunkerment of today's fire service severely dulls one's sense of feel and the ability to gauge temperature or increases in temperature.

Important audible stimuli that compete with other fireground noises include victims' muffled coughs, moans, and cries for help; crackling fire; falling or collapsing construction material; breaking glass; forcible-entry procedures; and operating saws. All these things give clues about the conditions that exist, how conditions may change, and how operations should be conducted. All this aural input must be constantly received and analyzed while the officer concurrently maintains the ability to continually monitor the handheld radio for vital communications. The remote microphone/speaker is an invaluable tool for tactical fireground communications.

Smoke impairs an officer's sight while advancing through the fire area. The most significant visual input to consider may, in fact, be that there is no visual input. Prior to entering the fire area, while observing the smoke issuing from it, may be the last opportunity to visually analyze conditions.

The personal protective equipment of today's operating forces has significantly curtailed the ability to feel the level of heat and discern rapid increases in heat in the operating environment. Prior to this development, the ability to receive this physical stimulus on one's skin from the environment was the gauge by which many veteran members of the fire service determined how and how long they could operate in a given environment. The time between feeling a painful heat stimulus and being able to remove oneself from the environment or take action to improve it is called **alarm time**. As the insulation from the environmental heat stimulus increases, the environmental temperature at which one feels heat inside the protective envelope also increases. This delay in becoming aware of high heat decreases alarm time, the window of opportunity one has to improve the chance to avert a catastrophic outcome.

Significant reconnaissance can be gained if the door to the fire area is open and conditions allow approach to the doorway without water application. At floor level one may be able to look under the smoke layer to ascertain the layout of the occupancy, location of victims, location of fire, and presence of potential obstacles in the path of the advancing line. Sweeping the beam of one's hands-free, forward-facing hand light under the smoke layer will aid immensely in this task (this is covered in greater detail in chapter 19, Search and Rescue). Of course, severe conditions warrant immediate stream application. Once the stream is operating, however, visibility is likely nil, even at floor level.

If the door to the fire area is closed, ensure the nozzle team is low and to the side of the doorway. The side of the doorway that is chosen will depend on a number of factors including the expected layout of the fire compartment, the layout of the area outside the entrance to the fire compartment, which way the door swings, and so forth. The nozzle team should be at an angle relative to the doorway that allows stream application, if necessary, when the door is opened.

The door can be opened once the nozzle team is ready with ample charged and bled line and forcible-entry issues have been addressed (fig. 16–17). The nozzle operator must be ready to flow water if conditions dictate. If a fog nozzle is being used it must be adjusted to the straight stream pattern. If possible take a few seconds to **stay low and let it blow**. It is beneficial to pause the operation briefly while the energy behind the pressurized, venting products of combustion diminishes somewhat. This is a wiser choice than occupying the doorway as soon as it is opened and being in the path of whatever may vent through it. The doorway used for access of the initial attack hand line may be the first ventilation opening to which the fire has access. The initial amount and pressure of the products of combustion that vent through this opening can be significant, and it is unwise to be directly in their path of travel. Of course, if fire venting through the doorway threatens members' position, immediately meet it with copious water from the hand line. If conditions allow a brief delay in water application, a quick look under the smoke layer reaps information beneficial to the operation.

Fig. 16–17. The nozzle team's position at a doorway prior to entering the fire area is critical for a successful operation.

In the past most members of the fire service were drilled with the mantra, "Don't open the nozzle until you see fire, never put water on smoke." This was fine back when dictum came into being. It was consistent with the type of fire and smoke conditions normally encountered during that time period. With the advent and proliferation of plastics, the amount and type of smoke has drastically changed. At many fires one cannot depend on seeing the fire at all, in which case it is common to use heat to indicate when to open the nozzle. The advent of full personal protective equipment negated that tactic. Now when a member feels heat it may be too late to open the nozzle in time to avoid burn injury. In the modern fire environment, the prudent method of determining when to open the line is to do so based on observation of the smoke condition before becoming immersed in its blinding cloak.

Prior to entering the fire area, the smoke condition must be rapidly observed and analyzed. Thick black smoke is heavily laden with unburned fuel. A compartment whose volume is full or nearly filled with thick black smoke contains a lot of ignitable fuel. Rapidly moving smoke is under pressure, a result of heat in the fire compartment; the higher the heat, the higher the pressure. Thick, black, rapidly moving smoke is a mixture of heat and fuel that only needs oxygen to complete the fire triangle. A fire compartment disgorging a heavy volume of thick, black, pressurized, **angry smoke** may contain black fire, which may also light up (cause rapid fire growth). If smoke conditions at the entrance to the fire occupancy are light enough to not indicate a potential rapid fire progress event, the line can be advanced, without flowing water, until either the fire is found or conditions indicate the need for stream application. Once fire is visually located, or angry smoke conditions are encountered, the nozzle must be opened to begin gaining control of the environment and improving conditions (fig. 16–18).

Fig. 16–18. Angry, black smoke usually indicates unburned fuel which could ignite within the fire compartment.

Let the water do the work. Long before members are ever close to the enemy, decide on proper weapons configuration and selection to ensure they are armed with a powerful, long-reaching, high-volume, hard-hitting attack stream. Open the nozzle as soon as the stream can affect conditions. Members need not be in the close proximity to the seat of the fire required by the short reach of a fog stream. The long reach of a solid or straight stream allows extinguishment to begin sooner and from a farther distance than does the short reach of fog streams. The time and distance aspects associated with solid streams are both factors in increasing the safety of operating members. Even when stream application is at an obtuse angle to the doorway of a room involved in fire, as when approaching the doorway from down a hallway, getting water into that room begins to improve conditions. It is unnecessary to wait until the members of the nozzle team are in the doorway to start getting water into the fire area (fig. 16–19).

If, on opening the doorway to the fire compartment or approaching the open doorway, a voluminous and angry smoke condition is indicative of a rapidly deteriorating environment, copious amounts of water from the nozzle must be swept back and forth across the ceiling out front and ahead of the nozzle team. A fire exhibiting such characteristics is an ominously volatile environment. The smoke is a large quantity of superheated fuel seeking enough oxygen to become ignitable. Members cannot afford to give any concern in this situation to the outdated cliché, "Don't put water on smoke." In these circumstances the characteristics of modern fuel loading (plastics) and the effects of tight building syndrome are likely combining to create a **black fire** scenario. Without any visual indicators, black fire has the potential to instantaneously transition into flashover. Water kills flashover. The tool to improve the environment is literally at the nozzle operator's fingertips. For members who have had both visual and heat sensing capabilities taken away, it is highly imprudent to push into this environment without preparing it to have a higher degree of human survivability. Sweeping the ceiling with copious amounts of water out front and overhead through the superheated fuel–laden smoke serves to sever the chain reaction of rapid fire development through the cooling effect of the stream.

The phrase concerning stream application, "sweep the ceiling with copious amounts of water," is purposefully used to convey the need for adequate water to kill the potential for flashover. Another phrase, "pencil the ceiling with the stream," has widespread exposure in the fire service. **Penciling** has numerous interpretations, one of which is to use limited amounts of water for short durations to delay flashover. When restoring control to an out-of-control environment at a building fire, the goal should not be to delay flashover or to cool fire gases just enough to hold conditions back from crossing the threshold of rapid fire progress phenomena. The greatest contributions an engine company can make to protecting the most savable human life in the shortest amount of time are bringing the highest practicable flow rate to the fire at the earliest opportunity and continuing stream application until extinguishment.

Fig. 16–19. A long stream applied to a fire area allows extinguishment to begin sooner and from a farther distance.

Once water has been applied to the overhead area of the fire compartment, the stream should be swept across the floor prior to advancing any farther (fig. 16–20). This is necessary to cool the scalding runoff created by applying water into the superheated upper areas of the fire compartment where temperatures can exceed 2,000°F (1,093°C). In a further attempt to reduce the potential for knee burns, members must advance so the knees are not in contact with the floor. If this is unfeasible, members must limit the time that knees are in contact with the floor by frequently raising them from the floor to interrupt heating. Knee injuries occur, even through bunker pants, because the insulating layer of the pants becomes thinner as it stretches and compresses when kneeling. Sweeping the deck with the stream can also blow debris out of the path of advance. This can include a wide range of things from hypodermic needles to all manner of feces. It is important to pay attention to the sound of the stream sweeping the floor. If it becomes quieter, there may not be any floor ahead of the nozzle team. There may be hole or an open stairway.

Fig. 16–20. Sweeping the floor with the water stream prior to applying it to the burning objects in the room (for final knockdown and extinguishment) removes debris from the path of the advancing nozzle team.

While engaged in active fire-suppression, the bale of the nozzle should be in one of two positions: either fully open or fully closed. Many fires can be extinguished with the hit and move technique, where the line is operated from a static position and then briefly shut down to ease advancement. However, fires of greater magnitude and/or intensity require the cooling power of a continuously operating stream throughout the advance. Small incipient fires can be extinguished with the bale cracked partially open.

Nozzle operator

SKILL DRILL

FF1 5.3.10 During the stretch the nozzle operator ensures sufficient lengths of dry hose cover the entire fire area are near the entrance to the fire area (fig. 16–21). This is always a minimum of 50 ft (15 m), or one length of line. The nozzle operator is responsible for carrying one folded length, often called the **working length** to the **drop point**. The drop point is the point near the entrance to the fire area where the working length is flaked out so that slack line can be advanced into the fire area. If more than one length of line is required to cover the fire area, it may or may not be carried by the nozzle operator. However, the nozzle operator must ensure that all necessary slack hose is flaked out as near as possible to the fire area entrance. Having sufficient slack line to cover the entire fire area prior to the advance pays off in the proficiency with which nozzle team advances through and extinguish the fire.

Fig. 16–21. The nozzle operator must ensure that sufficient lengths of dry hose reaches the entrance to the fire area.

The nozzle bale should be a slightly bent arm's reach out in front of the nozzle operator. The line should be on the side of the nozzle operator's dominant arm; however, there is a school of thought that the line should always be on one's right side because of the direction a burst length tends to rotate. Being on the dominant side puts the dominant arm to the rear, and this arm does the bulk of the labor in holding the line. For ease of explanation, further description refers to a right-handed nozzle operator.

The forward, or left, hand controls flow and directs the stream. The forward hand operates the bale (fig. 16–22a). Once the bale has been operated, the hand moves to the hose behind the last male hose butt. The hand must be in an underhand position on the hose (fig. 16–22b). This is the position from which the stream is directed by the forward hand. If the hand were to be left on the bale, nozzle, or hose butt, a hard-to-control kink would likely develop behind the hose butt. A further negative aspect of leaving one's hand on the bale is the likelihood of partially closing the bale and reducing flow. If the hand is placed on the hose in an overhand manner, there is great likelihood of forcing an unwieldy kink into the line behind the forward hand.

The rear arm creates the nozzle operator's stable base of control for the line. The line must be placed well up into the armpit of the rear arm and clamped against the body. Although still using one's hands to grip the hose, this method also brings into play the larger muscles of the chest, shoulder, and back. This staves off muscle fatigue longer than only depending on the smaller weaker muscles of the hands. Although not appropriate for all body types, some nozzle operators attain and maintain a position in which the rear knee is up off the ground all or most of the time. If the knee is kept up high enough, the inner thigh can be used to help clamp the hoseline against the body. Using the leg for this brings yet larger muscles and increased leverage into play to achieve rock solid control of the nozzle.

Fig. 16–22a. The nozzle operator's forward hand operates the bale.

Fig. 16–22b. Once the bale is operated, the forward hand should be placed under the hose behind the last hose butt.

Prior to operating the nozzle, the nozzle operator must expect that when the nozzle is opened up, reaction force must be overcome. The body must be in an attitude that reflects this. He should be leaning forward into the direction from which the nozzle reaction force will come, with the upper body positioned so the spine's angle roughly mimics that of the hoseline. In this manner the body is ready to receive, absorb, and overcome the nozzle reaction force once the line begins to operate.

In any fire that is past the incipient stage, advancing the hoseline takes members into a volatile high-heat environment. Members must be able to advance the line while operating in the lowest portion of the fire compartment (i.e., floor level). Using a solid stream maintains the thermal balance and preserves the floor area as the coolest portion of the fire compartment. Down on the deck is the safest place to be in the fire compartment should any rapid fire progress event occur.

The classic duck walking method keeps one low and keeps one's knees off the floor (fig. 16–23). However, this can be an awkward position to maintain and may not be the most efficient for achieving forward momentum. Some variation of the duck walk where one or both knees touch the floor at intervals may be more efficient. It is important to avoid having both knees on the floor all, or even a significant amount, of the time. Not only does it place one at a higher risk for knee burn injuries, but it is also harder to achieve both forward momentum and traction. It is also an unstable body position. To be on one's knees is to place oneself in a subservient position.

It is also important to ensure that the part of the foot in contact with the floor is the bottom of the foot, chiefly the toes and the ball of the foot. Some people end up on their knees with the tops of their feet in contact with the floor. This is a weak and unstable position and should be avoided. It is amazing how much more muscle mass can be brought into play when the bottom of the foot is used. It provides far greater traction, power, and stability.

Fig. 16–23. The classic duck walk keeps firefighters low and their knees off the floor.

While engaged in active fire-suppression, the nozzle bale should be in one of two positions: fully open or fully closed. Many fires can be extinguished with the hit and move technique where the line is operated from a static position and briefly shut down to ease advancement. However, fires of greater magnitude and/or intensity require the cooling power of a continuously operating stream throughout the advance. Small incipient fires can be extinguished with the bale cracked partially open.

During most of the advance, the stream should be directed outward and upward at an angle such that water is applied to the overhead area well ahead of the nozzle team. Sweeping side to side or rotating in a clockwise direction are the best patterns of nozzle movement (figs. 16–24a, 16–24b, 16–24c, and 16–24d). The nozzle must be moved in a rapid vigorous manner to physically distribute the water in the form of large drops by splattering the stream off the ceiling and upper walls (figs. 16–25a, 16–25b, 16–25c, and 16–25d). Using the nozzle in this manner is the most efficient for extinguishment, and it also has the tertiary benefit of lessening the reaction force burden that the nozzle operator must bear. If the stream were horizontal, the nozzle operator would receive the full reaction force burden. As the stream is angled upward from the horizontal, a greater and greater portion of the reaction force is directed into the deck. When the nozzle is moved vigorously to break up the stream, it significantly diffuses the energy of the reaction force.

Once the overhead has been cooled, the stream is applied directly onto the burning objects in the room to achieve final extinguishment . This is the modified direct attack.

Fig. 16–24a, b, c, d. The clockwise pattern of stream application is the most efficient method for extinguishment, and lessens the burden on the nozzle operator.

Fig. 16–25a, b, c, d. Rapidly moving the stream pattern side to side off the ceiling helps distribute water droplets to the fire area.

Backup position

FFI 5.3.10 In comparing the nozzle team to a vessel, the nozzle operator is the pilot and the backup is the engine room. The **backup position** does the lion's share of the physical labor and provides the bulk of the momentum to the nozzle team.

The backup person must be on the same side of the line as the nozzle operator (fig. 16–26). Backup should be like a tractor motor: always in low gear and always providing momentum to the nozzle operator without pushing him or her faster than he or she wants to go. The nozzle operator is an effective heat shield for the backup position and may become aware of extreme temperatures before the backup does. The nozzle operator may also become aware of holes in the floor or other obstructions before the backup position.

Fig. 16–26. The backup position does most of the physical labor in the nozzle team, and provides the bulk of the momentum.

The goal of the backup position should be to make the nozzle operator's job as easy as possible. Ideally, the nozzle operator should only have to think about operating the bale and directing the stream. To relieve the nozzle operator of the bulk of the reaction force burden, the backup must physically back up the nozzle operator. The backup must attempt to maintain physical contact with the nozzle operator throughout the advance and extinguishment. Through physical contact between the nozzle operator and the backup position, the bulk of the reaction force burden is transferred through the nozzle operator's body to the backup.

Another goal of a good backup is to keep the line straight behind the nozzle operator. Keeping the line straight helps make dealing with the reaction force manageable. The backup achieves this by treating the line as the first 5–8 ft (1.5–2.4 m) of hoseline behind the nozzle is a straight piece of pipe. Working together to move this section of line as if it were a straight piece of pipe, the nozzle operator and the backup person should be able to prevent any kinks directly behind the nozzle operator. Any bends in the line should occur behind the backup position. If the line bends between the nozzle operator and the backup, the nozzle operator's job gets much tougher (fig. 16–27).

Fig. 16–27. The backup position should keep a straight line behind the nozzle operator, moving the section like a straight piece of pipe.

The fact that the stream is predominantly directed outward and upward dictates that the hose usually trails from the nozzle at a downward angle. The hose trailing from behind the nozzle operator's armpit also naturally falls at a downward angle. While providing forward momentum, the backup position must also maintain the line's natural downward inclination. Many inexperienced backup people lift up the line behind the nozzle operator (fig. 16–28). This may make it easier for the backup, but it definitely makes things tougher on the nozzle operator. Lifting the line up behind the nozzle operator tends to force the nozzle tip down, making it harder to direct the stream into the overhead where it is needed for efficient extinguishment. Lifting the line while the nozzle is pointed upward also forces a bend into the line directly behind the nozzle operator, making it more difficult to deal with the nozzle reaction force.

Fig. 16–28. The backup firefighter should not lift the hose behind the nozzle operator.

The backup position takes a grip on the line so that the forward hand is underhand and the rear hand is overhand (fig. 16–29). The backup grabs the line where it naturally falls, at downward angle from the rear of the nozzle operator. After the forward hand is wrapped around the line, it is slid up the line fast and hard to make positive contact with the nozzle operator. This brings the forward forearm into contact with the nozzle operator. Leaning forward then brings the shoulder into contact with the back or trailing side of the nozzle operator, further solidifying physical contact. As forward movement occurs, space between the two bodies slightly fluctuates. Simultaneously, at a minimum the backup's forearm must stay in contact with the nozzle operator to physically provide momentum. Depending on the backup's body position, the rear hand can pull the line in against the leg. This applies friction to the line to assist with gripping the line.

Fig. 16–29. The correct position for the backup firefighter behind the nozzle operator.

The backup must be in a low compact position. The downward angle of the line behind the nozzle operator dictates that if the backup can attain and maintain a body position lower than that of the nozzle operator, it benefits the biomechanical efficiency of the operation.

The backup position needs to apply force outward and upward along an angle approximating that of the hoseline and through the body of the nozzle operator, as if trying to push forward a piece of pipe that is screwed into the base of the nozzle. He or she should face forward with eyes scanning to monitor whatever visual clues exist regarding conditions ahead of and around the nozzle team. The backup should lean into the direction needed to apply force, with the spine approximating the angle of the hoseline. The nozzle operator and the backup drive forward with the hoseline, focusing their energy outward along an upward angle similar to the way that football players drive a blocking sled or the way in which rugby players provide motive power to a scrummage.

The backup position is the engine room of the nozzle team. The power plant truly resides in the muscles of his lower body. To make efficient use of the calves, thighs, and gluteus he or she must push off of the floor with the bottoms of his feet. Having the tops of the feet in contact with the floor effectively negates a significant amount of the potential to harness the power of the muscles of the lower body.

If the nozzle operator needs to direct the stream horizontally or downward, the backup can facilitate this by raising the line accordingly so that the first section of hose, from behind the nozzle to behind the backup, is maintained in a straight line (fig. 16–30). If the nozzle operator turns to the left the backup's movement must swing through a wider faster arc. This is so that as the nozzle is turning to the left the hose behind it will move correspondingly to the right to avoid the occurrence of any bends directly behind the nozzle operator (fig. 16–31). If the nozzle operator turns to the right the backup's movement must swing through a wider faster arc. This is so that as the nozzle is turning to the right the hose behind it will move correspondingly to the left to avoid the occurrence of any bends directly behind the nozzle operator (fig. 16–32). If the two members are working in concert as if to move a straight piece of pipe, there will be no bends between them.

Fig. 16–30. As the backup firefighter lifts the hose, the nozzle operator can direct the stream downward.

Fig. 16–31. As the nozzle moves to the left, the back-up firefighter moves the hose to the right.

Fig. 16–32. As the nozzle moves to the right, the backup firefighter moves the hose to the left.

Door position

FFI 5.3.10 Although perhaps not apparent, one of the most important positions on the attack hoseline is that of the door position. The **door position** has two primary responsibilities: to ensure the smooth and sustained movement of hose to the set of the fire and to eliminate any kinks in the hoseline. This is a critical firefighting position that ensures the hoseline is not be starved of water because of a kink and is not hung up under a door or caught on some obstruction. Although this may not be a glamorous position, it is nonetheless an essential job that must be performed.

The term "door position" refers to the physical location of this firefighter as the hose moves through the structure to the fire. The door position is *not* with the nozzle operator and the backup; this firefighter is at least a length or two behind them. If assigned to this position, it is important to avoid the tendency to *move up* on the hose to the nozzle operator and the backup position. They depend on the door position to stay back.

Once the hoseline has been initially stretched and charged, the door position must **chase kinks** and take them out of the hoseline. While doing this, the door firefighter positions the hose for advance. The excess hose on the outside of the structure is arranged in large loops on the front lawn or sidewalk to avoid kinks and ease movement into the building (fig. 16–33). The loops help the advance by allowing the hose team to only pull on the last few lengths of the hose as they move in on the fire, not the entire hoseline starting at the engine. The portion of the hose from the engine to the front of the building does not move; only the last few working lengths of the hose move with the final advance on the fire.

Fig. 16–33. Arranging hose in loops in front of the building entrance reduces kinks and allows easier access of the hose into the building.

If the fire is on the first floor of a building, the door firefighter should position the hose in front of the building so that it can move easily through the doorway (fig. 16–34). This entails keeping the hose in a straight path as it enters the building (as it comes out of the loops) and doesn't get caught under the door (that is why this title position has been termed the *door position*). It may be necessary to also move objects out of the way to avoid the same problem.

Fig. 16–34. Door position moving hose through a door.

As the working lengths of the hoseline move inside, the door firefighter must assist in its movement. This position takes finesse; it is important for the door position to give the nozzle operator and backup position just enough hose to keep it moving and help them advance at the proper speed to the seat of the fire. Too much **push** on the hoseline creates kinks in the hose because the nozzle team is moving slower into the fire area than the hose is pushed. Too little push on the hose and the backup position has difficulty moving the hoseline forward, forcing the nozzle operator to pull on the hose instead of controlling the nozzle.

Once the hoseline has been properly positioned and is advancing into the building, the door position may advance forward along the hoseline to help move it through the structure. The door firefighter must remain mobile, moving back and forth between the front door and a length behind the nozzle, looking for kinks or possible hang-up points.

When advancing a hoseline up a stairwell and down a hallway in larger structures, the door position may help the nozzle operator and the backup position by creating loops in the hose to ease the advance inside the building (fig. 16–35). These loops are usually located a length behind the nozzle so as to not affect the operation of the nozzle.

Advancing hoselines up stairwells inside multiple dwellings and commercial buildings or through large area buildings is covered in detail in chapter 20, Basic Fire Attack. Such hose stretches require precise estimates of how much hose is required to get to the seat of the fire (fig. 16–36). Occasionally, firefighters and fire officers underestimate the number of lengths needed to get to the fire. In such cases, a hoseline may need to be extended.

Fig. 16–35. A firefighter can create loops in the hose to ease advance inside the building.

Fig. 16–36. Stretching hoselines into multi-story buildings requires precise estimates of length needed to reach the fire.

Many smooth bore nozzles are actually a series of **stacked tips**, essentially a set of decreasing nozzle tips threaded into each other. Some fog nozzles can also be **broken down** in similar fashion. To extend the hoseline, additional hose and *another* nozzle are brought to the nozzle attached to the end of the hose. With the attached nozzle shut down, the tip or tips are removed until the 1½-in. (38-mm) outlet of the nozzle is exposed (depending on the size of the original hose). New hose and the new nozzle are attached. When completed and the hose has been flaked out, the original nozzle can be opened, charging the line. The original nozzle now becomes a control valve. Some departments use 2½-in. (65-mm) attack lines to knock down the fire and later bring in 1¾- or 1½-in. (45- or 38-mm) hose as a **mop-up line** for overhaul purposes. In such cases, the same procedure is used to attach the mop-up hoseline to the original attack line (fig. 16–37).

Fig. 16–37. The stack tips on a 2 1/2-in. smooth bore nozzle can be removed allowing a smaller hoseline to be attached. The 2 1/2-in. then functions as a gate valve.

HYDRAULIC VENTILATION

FFI 5.3.11 Some fire departments use fog nozzles exclusively for fire attack as well as ventilation. This type of ventilation process is known as **hydraulic ventilation.** It is where firefighters use the power of a fog fire stream to exhaust heat, smoke, and gases from a room or an enclosure after a fire has been controlled and/or extinguished.

Fog streams are effective for helping to ventilate fire buildings and have been used effectively throughout the fire service for many years. In fact, in some cases a fog stream used for ventilation is more effective than fans because of its ability to move greater amounts of air. This may be because of the location of the fire in the fire building, or wind conditions, or other circumstantial items. It is quick and easy to employ because the attack hose and nozzle is all that is needed and is right there in the fire room or area as soon as the flames are being controlled. After the fire is darkened or extinguished, and the area is checked and ready for ventilation and overhaul, then firefighters need only to find an opening for venting the environment to the outside—usually through a window or door. While ventilation is taking place, overhaul can also begin.

Mechanical ventilation is most effective with fog streams from fog nozzles. This is because of the ability to change the shape of the stream from a straight stream to a wide-angle pattern that resembles a hollow cone. Smooth bore nozzles can also be used to ventilate fire rooms, but the speed of the water leaving the nozzle is not as fast as that from fog nozzles, and the ability to adjust the stream pattern is less accurate than a fog nozzle. The fog stream is able to function as a ventilation tool because of some laws of nature. Because we live in a positive pressure atmosphere (14.7 psi [100 kPa] at sea level), as a fog stream takes on a wider angle, a low pressure point exists where the stream comes out of the nozzle. It is at this point where the room air, smoke and heat, and the whole environment are drawn to that low pressure point and then carried along the jets of water that form the steam's umbrella pattern and are exhausted from the building.

To perform a nozzle vent using a fog nozzle, the nozzle operator must ensure that the nozzle is in the straight stream position and aimed at the open window or door. Once the nozzle has been opened, the stream is adjusted so that the fog pattern fills the window or door without hitting the wall and running onto the floor, causing water damage (fig. 16–38). Similarly, a smooth bore nozzle is aimed at the opening and is opened, making sure that the water is leaving the building and not ending up on the floor. Additionally, smooth bore nozzle streams should be rotated *within the inside perimeter of the window or door*, which increases the volume of smoke moved by the stream (fig. 16–39).

In the past, some fire training programs have taught that nozzles must first be placed outside the opening, opened, and then brought back into the building. It should be positioned to ensure that water damage is held to a minimum because there is a possibility of water hitting the interior surfaces of the room. However, such procedures take time to accomplish; if properly done, the procedures described in the previous paragraph ensure minimal water damage.

Fig. 16–38. Venting out a window with a fog pattern

Fig. 16–39. Venting through a window with a broken spray stream from a smooth bore nozzle

When a wide-angle fog stream is directed out a window or door, it can ventilate an average size room or two in a matter of a few minutes depending on the volume of smoke inside the building. For the stream to be most effective, the window or discharge opening should be completely free of any glass, debris, curtains or screens so the water can flow freely without any thing to stop it.

As a safety precaution when ventilating by fog stream, it is important to watch for changes in smoke and heat conditions in the fire area. In some cases firefighters have knocked down flames and moved quickly to begin hydraulic ventilation before the fire has been controlled.

In these situations, the room clears of smoke and heat after a minute or so; but soon after, a rush of fresh smoke and/or heat is drawn to the nozzle, because the fire reignites and grows intensely from being fanned by air currents created by the fog streams. Any undetected fire in walls and ceilings grow in volume and intensity and may burst through and fill the room with flame. This testifies to the adverse nature of a fog stream's ability to push or pull (depending on the nozzle's location and what it is doing at the time—either attacking a fire or ventilating), which firefighters must know.

Mechanical ventilation is not limited to just fire operations. The power of a wide fog stream makes it able to direct vapors away from serious exposures where there may be a life and/or property concern. An example of this could be illustrated where there is a gas leak near an occupied building. The stream may be used to push or force vapors away to make a temporarily safer condition. It can also be used to divert liquids such as in hazardous materials incidents.

Note: It should be emphasized that this type of ventilation is absolutely no substitute for actual ventilation—where there is a need to force entry and open windows, roofs, doors, shafts, or use other means necessary to rid a building of fire products and to create a safer atmosphere inside.

EXPOSURE PROTECTION

FFI 5.3.10 Exterior exposures need to be considered for protection from fire extension. Many exterior exposures become involved where the fire building is heavily involved and there is a tremendous amount of convective heat or radiant heat being given off. Remember, convective heat is the air and atmosphere around a fire. If an exposure building is located within a few feet of a raging fire, the superheated air and gases may be all that is necessary to ignite an exposed building. However, where there is plenty of fire coming out of a fire building, there is plenty of radiant heat; it travels equally in all directions from the heat source, in this case the fire. In the past, many people in the fire service believed that to stop convected heat from traveling to an exposure, you would direct a fog stream between the buildings for protection. In many of those cases, the exposure buildings burned to the ground! The cause of this was the radiant heat's ability to penetrate a curtain of water fog. Most fire departments that have experienced this have realized that an exposure stream must be played *onto an exposure surface* to keep it cooled below its ignition temperature. Otherwise, there is good possibility that the exposure will reach its point of ignition.

Another point to consider about exposure streams is their size. Smaller hand lines like those used for interior firefighting do not provide the amount of water needed to cool the side of an exposure in most cases. Remember, if there is a large amount of flames, there must be a large amount of water used for cooling. Exterior exposure lines of 2½ in. (65 mm) should be considered for maximum cooling efficiency. After the fire has been contained or knocked down, this exposure line can be reduced to more mobile hand lines that handle the lesser amount of fire.

As a matter of safety when protecting exterior exposures, hoselines should be positioned so that in the case of any possible collapse, firefighters are not in any collapse zones. Larger streams have greater reach and allow firefighters to operate at safe distances under heavy fire conditions.

When selecting an exposure hoseline, choose a stream big enough to do the job. If the fire is severe, use an effective volume of water and stop the fire. Don't gamble or believe that a small amount of water from a lighter hand line controls a large amount of fire—it won't work!

HOSELINE USE DURING OVERHAUL

FFI 5.3.3 One of the basic steps of firefighting is overhaul. It generally takes place after the main body of fire has been controlled or extinguished. In this process firefighters use tools to open walls, ceilings, and floors and to examine furniture and anything that looks like it may contain any hidden fire. A hoseline should be present in an area where there has been fire damage and should be in the possession of an assigned firefighter. In many cases overhaul begins quickly with the knockdown of flames. As firefighters are afforded better personal protection from turnout gear, they sometimes approach or move into a fire area quickly without realizing the amount of fire yet to be extinguished. This example and others make overhaul one of the more dangerous times of a working fire, even though the bulk of flames has been knocked down.

FFI 5.3.13 Overhaul operations generally require less water volume and pressure than fire attack operations, therefore 1¾- or 1½-in. (44- or 38-mm) hoselines are usually adequate. Follow your department's guidelines for hose selection with overhaul.

Depending on the amount of damage from a fire, the use of water during overhaul should not be excessive. Realistically, there are fires where a little amount of water is used for actual extinguishment compared to the amount used for overhaul, predominantly because of unusual conditions within the structure. In so many cases, firefighters risk their personal safety to get as close to the fire as possible to extinguish it with a good, quick hit from the hose stream, then shut the line down quickly and move in for the final kill, only to flood the room out 10 minutes later with a deluge after overhaul! The result is little fire damage but great water damage. Water use should be used carefully.

One of the first things firefighters should look for during overhaul is any structural damage from the fire. A deadly combination is a fire-damaged structural framing system, the added weight of several firefighters working with their tools, and the added live load of water that may have not drained away or has collected in clothing and furniture. This new live load has resulted in structural collapse and firefighter fatalities in the past.

It is important that an attack hoseline is never left unattended while firefighters are actively opening walls, ceilings and floors to search for hidden fire. Many ceilings have been opened or "pulled" and flames have come rushing out and down to the floor, catching unsuspecting firefighters. When this happens there should be someone ready with the hoseline to extinguish the fire. Firefighters have also fallen through fire–weakened floors and have needed protection from any debris burning around them.

During extended overhaul operations where there is plenty of debris, such as plaster and lath, dry wall, or other wall and ceiling materials, the hoseline can become buried; and if there is a need for the line, it may be difficult to locate. Even if the hoseline is found, the nozzle may still be buried and inaccessible in time of need. Again, it is important to keep a firefighter with the hoseline just for any unexpected situations.

MASTER STREAM DEVICES AND SPECIALIZED NOZZLES

Master stream devices

FFII 6.3.2 When an incident commander has ordered firefighting forces to assume defensive operations because the fire has taken possession of the building, **master stream devices** are employed to contain the fire (when there are no living people, including firefighters, inside the building). Master stream devices, by definition, flow in excess of 300 gpm (1,136 L/min). There are a variety of master stream devices used. Although care must be exercised with all nozzles, flowing such large quantities of water makes them dangerous when misused. Master stream devices must never be pointed at people. They must be operated within manufacturer's recommendations; for example, master stream nozzles must not be operated outside their specified range of elevation angle and lateral (side to side) movement. Nozzle reaction is substantial for such devices; and operating them outside the specified ranges can make them unstable, allowing them to move and injure people. They should never be overpressurized.

Elevated master stream devices include **ladder pipes** used on aerial ladders and monitor nozzles used on tower ladders. Each of these devices is capable of flowing in excess of 500 gpm (1,893 L/min). Their advantage is that they can apply water from above (e.g., through a collapsed roof) or through an upper-floor window.

The ladder pipe is a nozzle attached to the rungs of an aerial ladder. Some ladder pipes are detachable, others are permanently attached, or prepiped. The detachable models use supply hose from engine companies on the ground to provide water. These models also typically use a camlock system for attachment. Always follow manufacturer recommendations for attachment and use (fig. 16–40a, 16–40b, and 16–40c).

Once an aerial ladder has been raised, it is controlled (raised up and down, moved side to side) using halyard ropes or, in the case of newer models, using electronic remote controls. A firefighter should never be positioned on a ladder to operate a ladder pipe, it is simply too dangerous.

Tower ladders typically use mounted **water monitors** (also known as a **water cannon** or **water turret**) controlled from the platform (bucket). These master stream devices have individual control valves that allow them to be opened and closed slowly (fig. 16–41). Before operating these nozzles, make sure that there are no obstructions or dangers in the path of the stream (such as power lines). Powerful streams such as these, flowing at more than 1,000 gpm (3,785 L/min), can knock down walls.

Deck guns are mounted on the top of engine companies. They are used to apply water from the ground onto burning piles of debris, over walls, and sometimes into unoccupied buildings to get a quick knockdown. Some devices are permanently mounted to the engine; others can be detached and moved to a location on the ground and supplied with water at that location (figs. 16–42a, 16–42b, 16–42c, and 16–42d).

Fig. 16–40a. A permanently mounted ladder pipe

Fig. 16–40b. A detachable ladder pipe

Fig. 16–40c. Electronic controls for ladder pipe

Fig. 16–41. A tower ladder water monitor and control valve

Fig. 16–42a. A deck gun on apparatus

Fig. 16–42b. Locking device

Fig. 16–42c. Handle to raise and lower nozzle

Fig. 16–42d. Attaching nozzle to base

Deck guns have a rotating wheel so that they can be adjusted up and down, angle, and swivel so the nozzle can be adjusted side to side. Locking devices secure the nozzle in position. A key safety issue is making sure that the deck gun is securely attached to the engine, particularly if it is a detachable model and has not been reattached properly after use. These nozzles also often have a base, which can be taken off the engine and used on the ground. The base often has spiked feet (to dig into the ground) and a securing chain/strap to attach it to a fixed object. **Deluge guns** are portable monitors that are similar to detachable deck guns except that they are always used on the ground (fig. 16–43). The same safety issues apply here as well.

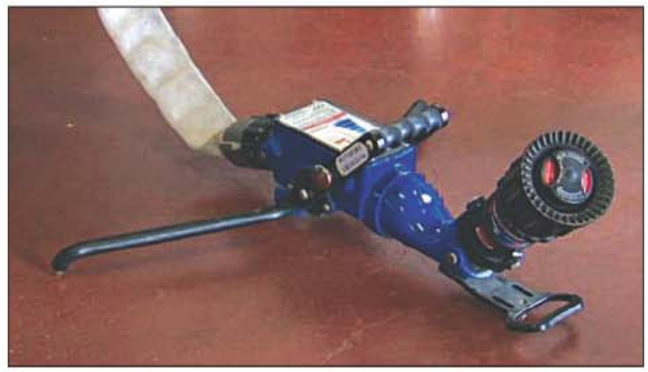

Fig. 16–43. A non-apparatus mounted deluge gun is a portable monitor that is always used on the ground.

Specialized nozzles

Over the years, specialized nozzles have been developed to deal with specific fireground problems. One such problem is that of hidden fire in void spaces and inaccessible areas. **Piercing nozzles** apply water to hidden spaces such as in wall and floor cavities (fig. 16–44). These tapered nozzles have a pointed end that can be driven through a wall or floor surface to penetrate the void space. The nozzle is charged and discharges a fog spray into the burning void space, creating large quantities of steam. This nozzle has been used to fight fires inside attics, walls, and floors.

Fig. 16–44. A piercing nozzle applies water to hidden spaces such as in wall and floor cavities.

The **distributor**, more commonly known as the **Bresnan distributor** after inventor FDNY Battalion Chief John J. Bresnan, is a spinning 1½- or 2½-in. (38- or 65-mm) nozzle with multiple orifices pointed in different directions, spraying water in all directions. (Bresnan also invented the hose roller for passing hose over a roof's edge and improved the **swinging harness** for fire horses who pulled fire apparatus in the 19th century. He was killed at a fire in 1894.) These nozzles are used primarily for basement fires where normal fire attack is not possible, and they have been used on attic fires as well (fig. 16–45). A hole is cut in the floor and the nozzle is lowered into the basement, just low enough to clear any overhead obstructions to get the widest possible distribution. The hose is secured to an object at the point of entry to the floor. In addition, a gate valve should be located between the last two sections of hose before the nozzle (50 ft [15.2 m] before the nozzle) to control flow to the nozzle.

Fig. 16–45. A Bresnan distributor is used primarily for basement fires where normal fire attack is not possible.

The 2½-in. (65-mm) **cellar pipe** (a common model is named after its inventor, Baker) are used in similar situations as the distributor nozzle (fig. 16–46). These nozzles, however, have a directed stream that can be pointed in any direction through the use of a lever at floor level. Some of these pipes have control valves attached to them; if no gate valve is attached, one must be inserted between the last two sections of hose before the cellar pipe. Similar nozzles are used to fight fires under shipping piers as well.

Fig. 16–46. Cellar pipes have a directed stream that can be pointed in any direction underneath a floor.

CARE AND MAINTENANCE OF NOZZLES

Although nozzles are designed to be used in a rough environment, take care to keep them fully operational at all times (fig. 16–47a, b, and c). Nozzles must not be dropped or thrown. After each use they must be cleaned and inspected. Inspection procedures include checking that the waterway is clear of obstructions, the bale works properly, there are no dents or nicks in the tip of the nozzle, and there are no missing parts. Worn out gaskets must be replaced.

A fire stream is the heart of all fire attacks. Knowledge of the correct volume of water, the proper attack method, and the best nozzle to use are essential to become an effective firefighter. Practice what you have learned in this chapter to ensure that you are prepared for meeting the fire head on as the "point of the firefighting sword."


Fig. 16–47a. Nicks and dents on a nozzle


Fig. 16–47b. A blocked waterway inside a nozzle


Fig. 16–47c. Replacing a worn out gasket in a nozzle

NOTES

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3. Norman, John. *Fire Officer's Handbook of Tactics*. Fire Engineering, 1998.
4. Clark, William. *Firefighting Principles and Practices*. Fire Engineering, 1991.
5. Fornell, David. *Fire Stream Management Handbook*. Fire Engineering, 1991.

QUESTIONS

1. Describe why the needed flow rates of handlines have increased over the years.
2. How does the Powell Doctrine apply to firefighting tactics?
3. When presented with various nozzle selections, list some of the advantages and disadvantages of each.
4. List advantages of the 2½-in. (65-mm) attack line.
5. When a life hazard exists in a structure, identify which method(s) of attack are appropriate and why.
6. How does the direct attack method differ from the modified direct attack method?
7. Explain how the indirect and combination attack methods extinguish a fire.
8. According to William Clark's test, which stream was found to be most effective in extinguishing an internal structure fire?
9. How does company staffing relate to advancing hose lines?
10. When positioning the hoseline into operation, what are some of the mistakes that should be avoided?
11. Which position on the hoseline is responsible for ensuring that enough hose is stretched to cover the entire fire area?
12. Describe proper positioning of the nozzle operator while flowing an attack hoseline.
13. What is the goal of the backup position on an attack line?
14. The door position is one of the most important positions on the attack hoseline. What are the door positions responsibilities?
15 How would you perform hydraulic ventilation with either a smoothbore or fog nozzle?
16. When would master stream devices be employed?
17. Bresnan and Baker nozzles are most often used for what type of fires?