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LITTLE DROPS OF WATER: 50 YEARS LATER, PART 2

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As we learned in Part 1 (February 2000 Issue), the “indirect” and “combination” methods have been largely misunderstood and widely misapplied. By the 1980s, many fire departments, disillusioned by years filled with failed fire control efforts and painful burn injuries, abandoned the use of fog streams for interior firefighting. Some returned to solid stream nozzles that for years had been relegated to dusty shelves in fire station closets. Many others, heavily invested in fog nozzle hardware, instructed their firefighters to employ only straight streams during interior fire attack.

THE MODERN ENVIRONMENT

Today’s fireground environment is far more hostile and unpredictable than it was in the 1950s. One reason is the endlessly expanding role of plastics. Plastics, being derived from petrochemicals (hydrocarbons), burn vigorously given the opportunity and produce large quantities of dark, acrid smoke. Plastics may be found partially or wholly in furniture, window treatments, clothing, toys, sporting goods, floor coverings, wall coverings, countertops, electronics, major appliances, housewares, and hundreds of other consumer products. Significant amounts of plastic are used in building construction. Plastics are often expanded for use in seat cushions, pillows, mattresses, insulation, and packaging materials. Expanded plastics (also known as cellular or foamed plastics) may pose a significant fire hazard. “Some reports tell of fast-spreading, high-intensity fires and voluminous smoke production”. Many plastics used in interior furnishings and finishes are “thermoplastics.” Thermoplastics, unlike thermosetting plastics (or more simply thermosets), produce flaming drips when they burn, which may flow and extend fire to uninvolved fuels. Pools of burning liquid plastic generate additional quantities of smoke and flammable gases and make firefighting more hazardous. One firefighter from a busy engine company in the South Bronx inadvertently knelt on a molten plastic TV cabinet and was severely burned. He had to undergo multiple skin grafts and extensive rehabilitation.

Buildings today further contribute to the hazard because they are often well sealed and limit the opportunity for heat loss. A fire growing within a compartment (room) that loses little heat to the outside will become hotter faster and build up large quantities of toxic gases more quickly than a fire in a less insulated room of similar size. The widespread installation of wall and attic insulation, draft barriers, membrane roofing systems, and energy-efficient windows in new construction and renovations plays a significant role in the subtle (and not so subtle) changes in interior fire behavior that have been observed during the past two decades. Probably the most significant factor is the energy-efficient window (EEW). These windows, often called thermal pane windows, do not fail as readily as older, single-glazed windows. As a result, the highly heated, sooty smoke characteristic of today's plastic filled fire environment, since it cannot escape, will quickly fill the fire occupancy. Firefighters today routinely encounter brutal head conditions and, more and more frequently, a complete absence of visible fire. This phenomenon has been termed "black fire."

BLACK FIRE

A firefighter from a busy Bronx, New York, engine company related to me the following story. He was assigned as the nozzleman for the tour. His company arrived first due at a fire in a renovated multiple dwelling. On entering the fire apartment with a charged handline, he noted that heat conditions were severe and the apartment was filled with dense smoke. Unable to quickly locate the seat of the fire and anticipating that flashover was imminent, his officer ordered him to open the nozzle. As he directed the stream into the blackness, conditions improved somewhat, and the line was advanced through the apartment. The officer then ordered the nozzle shut down. As the smoke began to lift, he realized he was kneeling in the middle of the fire room! He stated that throughout the fire attack, he never saw so much as a lick of flame despite a well-advanced fire.

A friend of mine, a very experienced firefighter, described to me the next incident: At a recent training exercise in an acquired structure, student firefighters were preparing to advance a charged handline through the kitchen and extinguish a fire at the far end of the adjoining living room. He was assigned as the engine company officer to coach the students through the exercise and ensure their safety. The fuel materials consisted of an upholstered sofa on end, one or two seat cushions, and cardboard as kindling. After the fire was lit, he entered the house to check on fire conditions and verify that the ignition officer was safely removed to the outside. From the doorway between the kitchen and living room, he noted that flames were starting to roll across the living ceiling, but visibility was still good, and nothing seemed out of the ordinary. He then duck walked the 15 feet back to the entrance door and instructed the student firefighters to bring the line inside. In less than a minute, conditions in the kitchen and living room had changed drastically. Almost all visibility was lost, and dark smoke was banked down to within two feet of the floor in the kitchen and to within an inch or two in the living room. As they advanced the line into the living room, he was unable to see even a hint of fire at ceiling level. With a high heat condition and the very real threat of flashover, he told the nozzleman to open the line. This action more than likely saved them from severe burn injuries.

I had an experience at a private dwelling fire several years ago that is eerily similar to the incidents described above. The occupants of an older, 2 1/2 -story, two-family home reported a smoke condition in the attic. We brought a charged handline up the stairs to the attic and were met with heavy, dark smoke. With no visible fire and a moderate heat condition, I thought the fire might be behind a knee wall or above a finished ceiling, but there were no void spaces present. Heat levels continued to increase. Crouching down, I could feel a significant amount of heat on my thighs and groin area (I was wearing a protective hood but only 3/4-length boots). After inching ahead slowly, I caught a glimpse of what looked like glowing coals at floor level. I opened the nozzle, sweeping the ceiling and floor. We then advanced the line toward the front of the house (the attic stairs were closer to the rear), and I was able to vent the attic through a small window that had remained intact during the fire. The fire itself involved a foam mattress and some clothing, which explains the dense smoke and intense heat. Because of the confinement of the fire in the attic with its limited ventilation opportunities, we most likely encountered a fire in the third (smoldering) stage of development. Because we entered the attic from below, the pressure of the heated gasses initially prevented intrusion of any significant additional oxygen. But had I not opened the line when I did, I believe it would have been just a matter of time before the attic would have "lit up" in flames.

COMPARTMENT FIRES

One recent *Fire Engineering* article cited a scientific principle known as "Thornton's Rule" as the basis for concluding that fires today are no more challenging and dangerous than in the past. I disagree with this conclusion and believe that the widespread use of plastics has significantly increased the hazards posed by interior fires. Let's examine Thornton's Rule, not from a theoretical, laboratory perspective but from one grounded in the reality of the fire floor. We'll begin by comparing the heat energy potential of various plastics vs. more traditional fuel materials. The heat of combustion (heat energy potential) of plastics is tremendous and ranges from approximately 16 kJ/g for polyvinyl chloride (PVC) to approximately 41-46 kJ/g for polystyrene and high-density polyethylene. Both polystyrene (rigid and expanded) and polyethylene are widely used in consumer goods and building materials. By contrast, paper, wood, cotton, jute, and other natural (cellulosic) materials have much lower heat energy potentials, in the range of 12-15 kJ/g. What Thornton discovered before World War I was that in any oxygen-regulated fire (compartment fires are generally oxygen- or ventilation regulated, whereas outside are fuel-regulated), heat of combustion will not vary significantly for a variety of organic liquids and gases. In the 1970s, further research by Hugget indicated that the heat of combustion for many organic solids is also relatively constant and is a factor of the oxygen available for consumption within the fire compartment. Although these laboratory findings viewed independently may indicate that plastics pose no more of a hazard to firefighters than the cellulosic materials of fires past, at "real world" fires, other factors (variables) add elements of dynamic complexity to the behavior of interior fires and suggest that the dangers faced by firefighters have increased dramatically in the past 50 years. These factors may be related to the fuel materials themselves (amount, flame spread rating, surface-to-mass ratio, arrangement, and heat release rate), the compartment (insulation, ventilation), and firefighting actions.

FUEL MATERIALS

Fire load (sometimes called fuel load) refers to the total heat energy potential of the combustible materials contained in a building (or compartment). Expressed in SI units as kJm2, under most definitions, the term *fire load* includes both the contents and any combustible structural components. As society has grown more affluent, families have introduced increasing amounts of combustible material into their homes and apartments. By some estimates, the average residential fire load is at least two times greater today than it was 50 years ago. Even if heat production doesn't vary significantly between plastics and cellulosics burning within a compartment, if the amount of combustible material increases, so, too, must the heat energy potential. This might be called the “more stuff, more heat” principle.

Another important factor is flame spread. High rates of flame spread across exposed fuel surfaces decrease the safe operating time for firefighters before flashover occurs. The use of plastic materials as wall and ceiling coverings, as well as in furniture and furniture veneers, greatly increases the risk of rapid fire development and firefighter injury. “Very high surface flame spread rates have been reported – up to approximately 2 ft. per sec. (0.6m/s), or 10 times the rate of flame spread across most wood surfaces.” But let’s not forget that wood and other cellulosic wax and ceiling finishes also produce dangerously high rates of flame spread. Exposed wood surfaces, such as paneled walls, can contribute to rapid fire development, particularly when flammable glues or adhesives are used in the installation and the paneling itself is subject to delamination when exposed to excessive heat. In *Building Construction for the Fire Service, Third Edition,* Frank Brannigan details the extreme flame spread hazard posed by combustible acoustical ceiling tiles made of low-density fiberboard. Paints, coatings, and other surface finishes also play a role in flame spread, but to what extent is not well defined.

The surface-to-mass ratio of the fuel is another factor. Obviously, expanded plastics pose a significant hazard in this regard, but consider a rigid plastic form that is in common use as a storage place for everything from toys to videotapes to vintage record albums-the milk crate. Now commercially manufactured specifically for home and office storage applications, milk crates have a very high surface to mass ratio. Recently retired Fire Department of New York (FDNY) Deputy Chief Vincent Dunn believes that a variety of rigid and expanded plastic items, including several milk crates filled with toys, contributed to a flashover that fatally injured FDNY Captain James F. McDonnell in 1985. Another possible contributing factor in McDonnell’s death was the arrangement of the combustible material (also known as fuel “geometry”). Consider the impact on fire growth and spread of perhaps two dozen plastic milk crates stacked five and six high or even nailed to the walls of a typically sized bedroom or living room during a fire. Filled with plastic toys or other items, they might be likened, in the words of one fire officer, to “bombs” of solid gasoline. According to Vytenis Babrauskas, Ph.D., a leading researcher in the field of compartment fire growth dynamics, the most important factor in the speed with which a fire reaches flashover is the heat release rate (HRR). Put very simply: “If the HRR is high enough, flashover will occur. If it’s not, the fire won’t reach flashover...” Fuel materials that have high rates of heat release, including many plastics, generate significant heat early in the development of an interior fire before fire growth becomes strictly ventilation-regulated and heat production levels off, “The heat release rate is important during the growth phase of the fire when air for combustion is abundant and the characteristics of the fuel control the burning rate”. Cellular plastic items, such as foam-filled mattresses and furniture, are extremely hazardous in this regard. This is because of the characteristics of cellular plastics: They have a low density; they have very high heat release potentials; and they tend to liquefy and gasify (not char) when they burn. The *Fire Protection Handbook*, in discussing the heat release rate of upholstered furniture (encountered at virtually every residential fire and a major culprit in the "black fire" examples described earlier), states the following: "The HRR of upholstered furniture can, in the worst circumstances reach values of around 2,000 to 3,000 kW (2 to 3 MW) in a very short time, only 3 to 5 minutes after ignition." The *Handbook* continues by noting that the hazard is extreme "since it only takes about 1 MW to flash over a room with a normal-sized door opening." While one can never predict with absolute certainty the outcome of any compartment (room) fire based strictly on the composition of the fuels involved, the higher energy potentials and high heat release rates of modern plastic furnishings and finishes make early flashover and severe firefighter injury more distinct possibilities. In tragic testimony to the dangers posed by interior fires today, between 1985 and 1994 alone, approximately 47 firefighters suffered fatal injuries as a result of being caught or trapped by flashover and other "rapid fire progress" events.

ENERGY-EFFICIENT WINDOWS
Consider the following quote from an article written by Deputy Chief James Murtagh of FDNY more than 10 years ago: "Fires in buildings with energy-efficient, double-paned windows will contain smoke and fire for extended periods. This leads to delayed alarms and the development of large volumes of extremely dense, pressurized smoke which will bank down farther than normally expected. If the smoke is hotter than its ignition temperature, but too rich to burn, it may ignite suddenly when sufficient oxygen is mixed with it; if the gas-air mixture is within its explosive range bur below its ignition temperature, it may ignite suddenly when heat is added.

The widespread installation of double-glazed, energy-efficient windows has added so many complicating factors to firefighting efforts in New York City that procedural bulletins have been changed specifically as a result. Fifteen years of field experience with these windows at literally thousands of fires indicates that (a) they do not fail as readily as older, single-glazed windows; (b) in multiple dwelling and commercial installations, the resistance to failure is increased because of the use of heavier-gauge aluminum or vinyl frames); (c) because they resist heat-induced failure, they often hide the location of the fire from firefighters assigned to perform ventilation and search operations from ladders and fire escapes; (d) EEWs are extremely difficult to break with firefighting hand tools; and (e) once the windows do fail or are vented, fire conditions often change dramatically. For a more complete discussion of the hazards and problems posed by EEWs see "Energy-Efficient Windows" on page 134.

FIREFIGHTING ACTIONS
Because of the behavior of EEWs, many times the first (and only) ventilation of the fire area is the door opening through which first-arriving firefighters begin their primary search and advance the attack handline. Once this door is opened, anticipate a dramatic change in fire conditions. Consider the following example. An engine company prepares to advance a charged 1 3/4-inch hand-line through the front door of an apartment. A long hallway connects the entrance door with the fire room deep the "flat." Volumes of dark smoke under considerable pressure are "pushing" out the open apartment door and rising up the stairway. As the nozzle team disappears into the murk, flame begins issuing intermittently from the top of the door opening. The nozzle team,

unaware of these conditions, continues to advance down the hallway toward the seat of the fire. Suddenly, heavy fire is "blowing" out the top half of the door opening, and the hallway has turned into a mass of orange flames. The nozzleman finally opens up, but not before he and the backup firefighter have sustained second- and third-degree burns. What happened? The fire burning within the unventilated (or poorly ventilated) apartment described above is akin to a flammable gas factory. Large amounts of heated, un-ignited combustion gases (carbon monoxide mostly) outflow from the main fire area (maybe a rear bedroom) and accumulate in the adjoining rooms and spaces. When the door to the apartment is opened (a ventilation opening), these fire gases travel along the ceiling toward this outlet. As the gases reach the entrance door, they begin missing with ever-increasing amounts of oxygen, causing the vapor-rich mixture to enter its flammable range. With the door kept open to permit advance of the handline, the intermittent flaming at the top of the door opening is soon replaced with solid fire. As increasing amounts of oxygen flow into the apartment through the open door, the flames travel back toward the main fire area, feeding on the ceiling gases, giving the appearance of a lit fuse. Sometimes termed "vent point ignition," the entire hallway is soon filled with fire, and the nozzle team is literally fighting for its life.

One question that may be asked is why the nozzleman didn't open up sooner. While rollover (flames appearing in the overhead smoke layers) is a reliable warning sign of impending flashover, it cannot provide warning if it goes unnoticed. Flames in the overhead may not be visible because of smoke once entry is made into the fire occupancy. The full encapsulation and exceptional thermal protection provided by the latest bunker gear and protective hoods may prevent firefighters crouching below from feeling heat radiating downward from above. In this case, the nozzle man never opened up because he didn't realize the severity of the situation.

Another question concerns the position of the entrance door. Should the entrance door have been partially closed behind the advancing firefighters to limit air movement and delay or prevent flashover? In my opinion, once a handline passes through a door opening, the door must remain fully open to prevent any interference with the movement of the line and to allow an influx of fresh air to aid in ventilation as the fire is knocked down. During the primary search, however, the question is more difficult to answer and is the subject of much debate within the ranks of FDNY. A veteran lieutenant assigned to a busy ladder company in the Bronx believes that at apartment fires, the door should be kept closed during the primary search (not locked or latched, just shut to limit air movement). The calming effect on a growing fire that results from the simple act of closing the door behind you can be quite astonishing.

At a fire in a multiple-dwelling in the Bronx, the first-due ladder company initiated a primary search with the apartment door closed. To complete the search, the firefighters had to pass the fire room. A 2 1/2 -gallon water extinguisher (commonly called the "can," carried by all FDNY ladder companies during primary search operations) was discharged on the fire, but the "can" firefighter was unable to pull the fire room door shut. When the engine company officer opened the apartment door to check on conditions, the fire roared out of the fire room and filled the hallway, trapping the search team at the rear of the apartment. As soon as the apartment door was closed, the fire retreated back into the room. This condition was observed again after the primary search had been completed and the handline was brought inside to extinguish the fire. The effect of open doors and windows is enhanced greatly during windy conditions. Depending on wind direction and velocity, extremely rapid fire progress may result. The fire service has an insufficient understanding of how wind and other weather-related factors affect fire behavior; much research remains to be done.

Another question concerns the issue of applying water on smoke. For years, it was considered taboo, but the volatile nature of the smoke produced by the contemporary fire environment requires that we rethink this approach. “Although this [applying water on smoke] flies in the face of traditional training, we must recognize that the fire environment has changed with the addition of plastics that generate high heat and dense smoke when they burn. This, combined with energy-efficient windows, may justify putting water ‘on smoke’ to prevent flashover in certain situations”. While this tactic should remain the exception and not the rule, if you find yourself lying in a hot, smoke filled hallway and that dread feeling in the pit of your stomach tells you that something very bad is about to happen, opening the nozzle may very well save your life.

FOG, FANS AND FOAM

Part 1 of this article described our 50-year experiment with fog streams and the mixed success they’ve achieved on the fireground. Although fog streams did not turn out to be the “magic pill” some had hoped, the jury is still out on other, more recent “advancements” in the art and science of interior fire control. Specifically, I’m referring to positive-pressure ventilation (PPV), Class A foam, and “offensive” water fog techniques.

-PPV

Does PPV have a place? I believe it does, particularly during overhaul, to reduce heat and humidity levels and clear the fire area of smoke. It has also shown much promise when used to pressurize stairways during high-rise fire evacuation. During the initial stages of a fire attack, however, it poses several problems.

First among these is the danger of pushing fire into uninvolved areas of the building. Another is the potential for violent acceleration of fire growth. At one training burn in an acquired structure, the local fire department wanted to experiment with PPV. The action of the fan on the fire suggested that someone had injected atomized gasoline into the fire area. Setting up a PPV fan also requires that a firefighter or firefighters be taken away from other important tasks and, considering the staffing levels of most engine and ladder companies, this becomes an important issue. If vent-enter-search (VES) operations are employed. PPV will drive heat and flame toward the searching firefighters and cause severe burns and other injuries as they scramble to dive out windows and escape serious burns.

One investigator suggested installing small nozzles on the perimeter of the fan to blow a water mist into the fire area (similar to the cooling fans seen on the sidelines during football games in warm weather). This introduces the very real danger of steam burns and is similar in effect to having a misplaced fog stream directed through a window opening while you are inside the fire building. As a result of these issues, many fire departments that practice PPV do so on a much more limited basis today than previously.

-*Class A foam*
The current buss in “progressive” fire suppression circles is Class A foam. Class A foams are not new – they’ve been around for almost a century. Used in wildland firefighting for many years, they have only recently been introduced into the arena of structure firefighting, A am not disputing some of the advantages offered by wetting agents in general and Class A foams in particular (better fuel penetration and the ability to cling to vertical surfaces), but they are not quite the panacea some salespeople would have us believe. In a fairly extensive study conducted by the National Institute of Standards and Technology (NIST) on the performance of Class A foam, testing showed that its most clear advantage over plain water was in the extinguishment of tire fires. In other tests, the advantages offered by Class A foam were less well defined. The NIST report also indicates that there are little quantitative data on the effectiveness of Class A foam vs. plain water in the extinguishment of interior structure fires and that more testing is required.

In addition to incomplete information on the effectiveness of Class A foam, there are other issues to consider. I hate to be a pessimist, but my experience with Class B foam systems installed on municipal fire apparatus hasn’t been good. They often don’t work properly when you need them, especially when they’ve been dormant for months at a time. And having been a firefighter in two paid municipal departments, a combination department, and a small volunteer department, I also understand the issue of budgets. Many fire departments lack funds to maintain basic necessities like turnout gear and SCBA, let alone to invest in Class A foam systems. Other questions must be answered as well. If a foam system is purchased, will it be adequately maintained? Will firefighters be permitted to use foam during routine training sessions to ensure proficiency in proportioning and application techniques, or will this prove too costly? Have your firefighters been properly trained to extinguish fires using water plain first so that when the foam system fails, fire suppression efforts can continue uncompromised? While there is no doubt that the use of Class A foam will continue to expand, there exists to date insufficient scientific data and actual field experience to provide a true cost-benefit picture of the effectiveness of these agents in interior structure fire attack.

LITTLE DROPS AGAIN
As a result of two Swedish firefighters being killed in a flashover in the early 1980s, fog nozzle techniques were devised to counter the effects of fire gas ignition and prevent injuries from flashover and backdraft. Termed “offensive” or “three-dimensional” water fog application, these techniques have been explained in great detail in the writings of Paul Grimwood, a retired 26-year veteran firefighter from the London Fire Brigade. Grimwood was kind enough to address my questions and concerns about “3-D” fog techniques. Although I agree with his assessment of the modern fire environment and its attendant hazards-particularly the volatile nature of fire gases and the increasing

hazards of flashover and backdraft-I disagree with several of the specific tactics he advocates.

The brief examination of 3-D water for techniques contained here is taken from a pamphlet entitled “Flashover & Nozzle Techniques” prepared by Grimwood. Offensive fog application requires that small (around 400 micron) droplets produced by special fog nozzles be directed into the overhead gas layers in short bursts or “pulses.” The objective is to suspend the droplets in the gases to cool them and retard their ignition (in other words, putting water on smoke as a preventive measure). While ideally 3-D fog application will prevent ignition of the fire gases, Grimwood states that the technique is suitable for both pre- and post-flashover fires. As the water fog turns to steam and expands in volume, it is accompanied by a corresponding decrease or contraction in volume of the fire gases, reportedly avoiding the debilitating effects associated with steam production caused by fog streams during interior firefighting efforts. In addition, by avoiding contact between the water and the heated walls and ceiling (opposite of what the combination method of attack requires), unwanted steam production is further reduced, thereby maintaining tenable conditions for the nozzle team.

Offensive fog techniques require rather precise execution for success. Grimwood states that firefighters employing 3-D fog techniques should be “extremely well practiced in nozzle handling and ‘pulsing’ actions”. Given the wide spectrum of distractions faced by the modern fire service (EMS, haz-mat, technical rescue, and so on) and the youthful look of many fire departments, handline and nozzle techniques must be kept as simple and straightforward as possible. Regardless of its reported effectiveness, offensive fog application does not fit this description. I believe a more traditional approach is in order.

INTERIOR DIRECT ATTACK

Fifty years after Layman’s “Little Drops of Water”, it’s time to admit that fog streams are not the answer. I strongly advocate a return to the time-tested direct method of attack. Its simplicity and effectiveness, coupled with the level of safety it affords the nozzle team, is a good fit with the unpredictable fire grounds of the new millennium. While solid streams are preferable, straight streams may be substituted, provided that fire flows are not compromised. The following tactics and techniques will ensure success when employing an interior direct attack: Due to the volatility of today’s fires, a minimum fire flow of 150 gpm is recommended for residential fires. This flow is easily achieved using 1 3/4-inch hose, provided friction losses are accurately determined and correct pump discharge pressures are used.

One firefighter told me that when his department flow tested its 1 3/4-inch preconnected handlines using its standard pump discharge pressures, the average flow was only 84 gallons per minute (gpm). While in theory 84 gpm, properly applied, will extinguish a significant amount of fire, a flow this low allows no room for error and does not provide any reserve to handle unforeseen contingencies. Commercial building fires demand a minimum fire flow of 250 gpm, and this is best delivered through 2 1/2-inch hose using solid bore nozzles. Other parameters that deserve consideration include the minimum effective reach of stream (50 feet for streams used in residential firefighting) and the nozzle reaction burden. Nozzle reaction forces should be no greater than 60 to 70 pounds. Field tests have indicated that a reaction force exceeding 70 pounds is very difficult for a single firefighter to handle. Realizing that a backup firefighter is most often a luxury and that even when present he will often be positioned well behind the nozzleman to pull hose around corners and feed it forward to the nozzleman as he advances, the reaction burden that can be safely handled by a single firefighter becomes a very important safety issue. Since nozzle reaction is a factor of the weight (volume) of water being discharged and the nozzle pressure, nozzle reaction can be made more manageable by reducing flow volume (an unwise decision) or decreasing nozzle pressure. The only effective means of reducing nozzle pressure without adversely impacting firefighting effectiveness is to employ solid stream tips or low-pressure fog nozzles.

Unlike each of the fog firefighting methods that involves the application of water into the heated overhead to cool the gases, direct attack goes to the root cause of the problem-the source of gas production. David Fornell, in *Fire Stream Management Handbook*, uses the analogy of a propane cylinder leaking a jet of burning gas. The heated solid furnishings and finishings within a burning room are likened to the leaking cylinder; flammable carbon monoxide is substituted for the propane gas. In controlling a leaking and burning LPG cylinder, the goal is to control the fuel supply-the cause of the problem, as opposed to first extinguishing the burning gas-merely a symptom. The goal of the interior direct attack is to apply water *directly* on the heated solid materials within the fire area, reducing their temperature and halting the production of flammable carbon monoxide gas. “In any space containing heated gases which are likely to flash over or in any area already flashed over, cooling the heated solid material providing the fire’s fuel must take place to successfully stop the fire. Getting water onto the heated materials, however, is often easier said than done.

In addition to using the reach afforded by solid and straight streams, the ceiling and upper walls may be used to redirect the stream when heat conditions or obstructions (partitions, piles of stock, partially closed doors) make application immediately to the base of the fire impossible. Sweeping the ceiling with the stream in a side-to-side or clockwise motion also helps eliminate the threat posed by the heated gases without excessive unwanted steam production and violent disruption of the thermal balance characteristic of the indirect and combination methods. Unlike 3-D fog application, which involves cooling the gases with very small water droplets, sweeping the ceiling with a straight or solid stream causes an action that the late Floyd Nelson termed “rattling the fire’s chain.” “Inside the area of the flame, the chemical reactions that take place are often referred to as chain reactions. These chain reactions depend on a smooth flow of oxygen and a smooth flow of fuel vapors to continue their act of combustion”. Nelson calls it the “straight stream off ceiling” attack, and he states that it is highly effective in disrupting the flow of oxygen and fuel, thereby reducing the threats of rollover and flashover.

In addition to agitating the gas layers, using the ceiling to break up the stream creates coarse droplets that will rain down on the burning solid materials and start the cooling process. Unlike the fine droplets that compose spray streams, the droplets created by splattering stream on the ceiling will be larger and heavier and less likely to vaporize prematurely or be swept away by convection currents. There is another reason for initially directing the stream at an upward angle anytime a fire has progressed to the point where flames are traveling across the ceiling. If a solid or straight stream were to be directed immediately into the lower portion of a well-involved room, the expansion of the water to steam could cause a violent displacement of burning fire gases, which might result in burn injuries to the nozzle team. The stream itself might cause burning debris to scatter, and unwanted steam creation would be increased. (This should not be confused with the action of sweeping the floor with the stream periodically during the advance to push aside glass and debris and cool heated objects and scalding water runoff.)

Lastly, the importance of patience on the part of the nozzle team must be stressed, before entering the fire occupancy with a charged handline, pause momentarily, and observe the smoke venting through the door opening. Try to get a read on the its pressure and temperature, and pay attention to its color. Veteran firefighters know the importance of “lying low and letting it blow.” By waiting briefly at the door, the severity of fire conditions can be gauged, and burn injuries caused by the sudden ignition of fire gases can be prevented. Sometimes, by looking back and studying the proven tactics and techniques employed by firefighters of generations past, we can best learn methods for staying alive at the fires we confront today.