Tactical Ventilation

Venting actions by on-scene firefighters, used to gain tactical advantage during interior structural firefighting operations

By Paul Grimwood

Pics by Harvey Eisner

Throughout the 1980s London firefighter Paul Grimwood presented several controversial papers and articles, based mainly upon his own operational research and experiences as a firefighter both in the UK and the USA, that closely examined structural ventilation practices as carried out by firefighters around the world. His proposed concept of 'Tactical Ventilation' (a term he originally introduced and defined in 1989 through his book FOG ATTACK) was to encourage an increased awareness of 'Tac-Vent' Ops and PPV and present a safer and more effective tactical process for the ventilation of fire-involved structures by on-scene firefighters, paying particular attention to the influences of air dynamics and fire gas formations. Following work with Warrington Fire Research Consultants (FRDG 6/94) his terminology and concepts were adopted officially by the UK fire service and are now referred to throughout revised Home Office training manuals (1996-97).

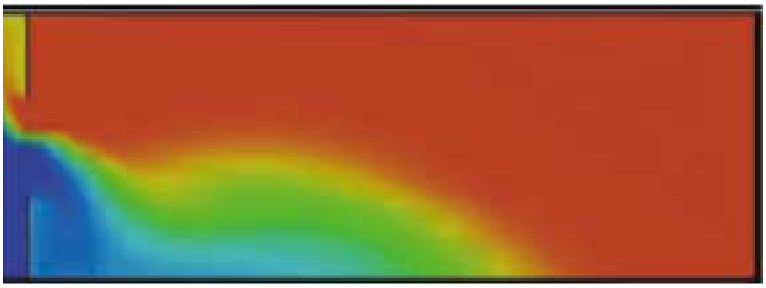
In 1984 he posed the question whether US style roof venting methods should be utilized at an earlier stage in the fire attack and discussed some previous UK incidents where venting may have helped. His thought-provoking five page article in 1985 described the tactical implications of using roof cuts to vent fire gases and discussed a wide range of tactical options used to create safer working conditions for firefighters and trapped occupants through the creation of openings in the structure. It was here, in 1985, where he first introduced and discussed the benefits of Positive Pressure Ventilation. In 1987 he called for a Home Office review of UK strategy and prompted some research into tactical venting methods and by 1988 he was describing how such tactics might have been used to save several large structures that had recently incurred major financial losses where it was thought a lack of ventilation had contributed to such loss. He wrote – 'over the past four years I have attempted to educate and prompt discussion on the topic of tactical ventilation by firefighters in fire-involved structures' and acknowledged that the recent interest by a Chief Fire Officer (John Craig of Wiltshire) in the theory and practice of 'Tac-vent Ops' was a major step towards national acceptance. He was personally involved with CFO Craig and the Wiltshire Fire Brigade in writing the first UK SOP document (Operational Note) on Tactical & Positive Pressure Ventilation in 1989.

One of the most difficult decisions a fire commander, or firefighter acting under SOPs, must surely make, whilst on-scene in the early stages of a structure fire, is whether to ventilate or not? Is the best option to 'pop' that window? Cut into that roof? Open the skylights? The strategy of venting fire buildings has been approached from many angles. In the USA it has long been accepted that the most viable approach for firefighters is to 'open-up' the building at an early stage of fire operations in an attempt at relieving conditions for firefighters and trapped occupants within. It is also seen as a method of preventing various forms of *extreme fire behavior*, rapid fire progress etc as well as controlling spread as the fire so often *mushrooms* and travels horizontally through attics, voids and cocklofts.

In contrast, the European approach has generally viewed early venting actions as a strategy fraught with problems. The burning rate of the fire iincreases as additional air is allowed to flow into the building and this effect counters the low-flow attack hose-lines that have been widely popular. The European philosophy is often based around low-flow attack lines, working from engine tank supplies, speedily deployed into effectively compartmented structures. The US approach generally has to deal with a more rapid and active form of fire spread, from larger compartments, in timber-framed property. The fuel-loading of US properties may also be somewhat higher in comparison.

However, what was starkly obvious to me, as a firefighter serving on both sides of the Atlantic, was that US firefighters utilized tactical venting actions too often whilst European firefighters resorted to such tactics on too few occasions! It is clear that both approaches have resulted in causing fatalities of both trapped occupants and firefighters alike.

The introduction of Positive Pressure Attack (PPA) ventilation in the 1980s provided a means of ventilating fire buildings by forcing heat, smoke



A window venting action is modeled here and demonstrates at 2 seconds, a gravity current forming with air (blue) entering into an under-ventilated room. The red region represents a mix of fire gases that are too rich to ignite. The green region shows an area of danger as fire gases mix with incoming air to form a flammable layer

and fire gases to move ahead of advancing firefighters and exit the structure at a pre-determined point. This attack strategy is still strongly viewed as potentially 'dangerous' by many fire authorities whilst others are staunch supporters. It is often viewed as a *secondary* form of tactical ventilation, used by firefighters in areas of limited resources and reduced crewing.

In the 1980s the Swedish Fire Service began to pay closer attention to *fire dynamics* and researched how various *ventilation profiles* were likely to affect compartmental and structural firefighting. Their approach raised our awareness and it became clear that firefighters were regularly operating without any necessary fore-thought or knowledge of how fire gases form, transport and ignite, and to what effects varying ventilation parameters had on the outcome of any particular event. It is evident that firefighters and fire officers should therefore gain a practical understanding and full appreciation of how compartment fires are likely to behave before implementing tactical venting actions of any sort.

In general, the current European approach places the *stabilization of interior conditions* ahead of tactical venting actions as a primary tactic and utilizes *fire isolation, or confinement,* tactics as a priority. However, it is equally important to apply risk-assessed principles in the decision making process and recognize exactly when an early tactical venting action will be a safer or more productive option. There will be times where releasing combustion products from a compartment/structure will be far more beneficial to building occupants and firefighters than any fire isolating actions. I can remember situations where firefighters were unable to ascend stair-shafts to effect primary searches of the upper floors because the skylight over the stairs had not been opened to vent heat and smoke. On other occasions I can attest to playing 'catch-up' with the fire as it mushroomed and spread through roof voids etc. I can also describe situations where too much venting or misplaced venting actions caused the fire to spread out of control, endangering lives. A Swedish scientific research study suggested that fire officers should gain a clear understanding of how *pressure build-up* develops within a fire building and how gases flow out through various types of opening in different situations. The causes of such pressure build-up may be divided into a number of categories – Inhibited thermal expansion – the buoyancy of hot gases – normal temperature difference between inside and outside air – wind – mechanical ventilation. It is important also to appreciate how openings may become inlets (for air) as these internal pressures move nearer equilibrium with the outside pressure. Eventually, as smoke and fire gases begin to clear from the vented area, air will enter and mix with the remaining gases and may allow the fire to intensify. It is possible that some form of flashover or backdraft may occur at this stage.

Tactical objectives

Any venting action demands fore-thought based on an intention – what is the objective? Venting actions should be based on the following three objectives –

1. Vent for Life.
2. Vent for the Fire.
3. Vent for Safety.

Venting for *life* situations recognizes SOPs where firefighters may create openings, or break windows, to gain access from an exterior position to carry out a primary search in a high-risk area of the structure. This may be bedrooms some way from the fire or it may be the area adjacent to the fire itself. This approach is often termed VES by firefighters (Vent – Enter – Search). It is a strategy that is often fraught with hazards but in turn, may reap great rewards for the search team. The venting and entry action, as with any tactical venting process, demands great *precision* (venting the correct windows); and *anticipation* of potential fire spread. Such an approach should also be *communicated* to the Incident Commander and also crews working on the interior where possible. The overall approach to venting should be carefully *coordinated* so that all affected parties are aware of what is taking place. Take note that the interior search should move from window to door and back to window and not into the corridor to any great extent, utilizing adjacent windows to repeat the access and search process. Openings are sometimes created above escape route stairways in medium-low-rise buildings to alleviate smoke conditions, enabling occupants to evacuate safely.

Venting for *fire* situations are often misapplied and careful thought should be given to the objective at hand. The main objective must be to improve interior conditions for firefighters by reducing heat levels and improving visibility. It is a common belief that windows should be vented in the area that firefighters are working – this is not so! The rule here is to vent windows ahead of the nozzle and near to the fire so that combustion products may be forced safely out of the structure.

Just 10 seconds after the venting action occurs and a clear flammable layer (green) exists near the ceiling but clear air is prominent in the lower regions of the room. This situation could possibly lead to a 'rollover' if there is an ignition source available

It is a fact that most compartment fires are burning under *ventilation-controlled* conditions as firefighters advance in – the fire is searching for air. Any negative pressure conditions created (ie; a vented window) will draw the fire towards the new air supply and if this behind or adjacent to the hose-crew then that cannot be a good thing. Also, this addition of air will cause the fire to achieve a greater rate-of-burn, increasing its *heat-release-rate*; it may actually become hotter! Therefore it is essential that firefighters crewing the hose-line have adequate flow at the nozzle to deal with any escalation of the fire. Finally, pay close attention to wind force and direction prior to creating an opening. An opening on the windward side of the structure, in particular, may cause the fire to head rapidly in the direction of advancing firefighters!

Venting for *safety* is reserved for situations where fires are burning in an *under-ventilated* state. The fire may be developing slowly, due to a 'sealed' structure or compartment, presenting a heavy (probably hot) smoke build-up within a confined space. In this situation careful attention must be paid to door-entry procedures and it may well be a viable action to vent a compartment from the exterior prior to gaining entry.

The decision to create openings within a fire involved structure to gain tactical advantage should be carefully considered for the outcome may be irreversible. Under certain circumstances such actions may prove most effective whilst in others they may prove disastrous. In some situations the openings will serve to release combustion products whilst others may simply provide dangerous airflows heading in towards the fire. It is often the case that the most influential (dangerous) opening a firefighter can make is at the point of entry to the structure. This opening is often seen as a necessity and is not considered as part of the venting plan. However, the airflow provided at this point of entry may serve to intensify the fire and may indeed allow it to escalate beyond the capability of initial attack hose-lines.

Tactical openings made to release combustion products may serve to reduce smoke-logging, lower compartmental temperatures, prevent flashovers and backdrafts and generally ease the firefighting operation. However, it is also possible that such openings may achieve undesirable and opposing effects, causing temperatures to rise with resulting escalations in fire spread leading to flashovers, backdrafts and smoke explosions.

Window venting actions – safe or not?

Whenever a window is breached by firefighters the immediate result will generally be to clear some combustion products from inside the room served by the opening. This is likely to raise the smoke interface away from the floor, particularly near the window itself. There will also be an inflow of air into the room and this may be positive or negative. Such an airflow may serve to assist trapped occupants to breathe but it may also cause a fire to increase in intensity. Such an airflow into the opening could possibly cause either of two unwanted events – a backdraft or a flashover (*there is potential of a 'flashover' being induced by an increase in compartmental ventilation where the heat loss rate increases as more heat is convected through the opening. However, there is a point beyond stability where ventilation may cause more energy to be released in the compartment than can be lost and this condition of 'thermal runaway' may lead to 'flashover'*). Additionally, the movement of combustion products through the opening may create a reduction in room pressure that actually 'pulls' heat and smoke, and possibly fire itself, from adjacent areas. In general, there is usually a brief improvement in local conditions in the vicinity of the window but this may only be temporary. The conditions elsewhere in the structure may worsen because of this venting action.

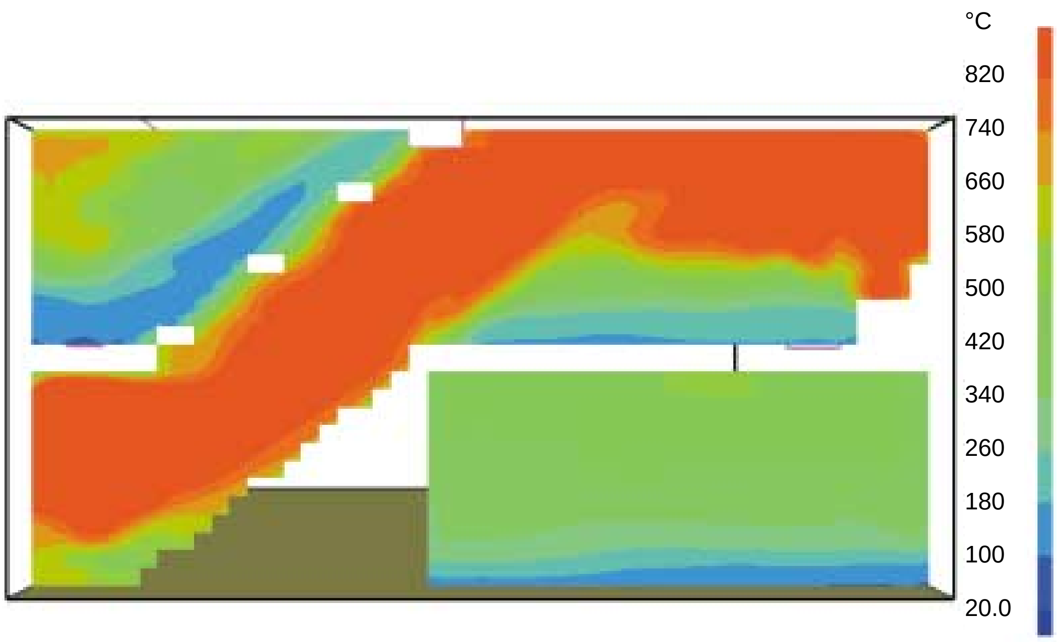
The hazards associated with initiating *rapid decompression* in a fire-involved structure exist and may have dramatic influences on fire spread and extreme fire behavior. In the January 2000 edition of Fire Engineering magazine Brian White, a Captain with FDNY, put forward his own theory of a phenomena he termed – **high-pressure backdraft**. It was Mr. White's belief that wind effects upon buildings sometimes created excessive pressures to form within, as air entered through various openings on the windward side of a structure. He further suggested that when an opening was created elsewhere in the structure, the sudden unleashing of pent- up pressure sometimes worsened the effects of any rapid fire development as it stirred a large mass of high-velocity air-movement through the structure. He described several scenarios where rapid decompression of a structure occurred as windows failed, or vented, causing major increases in the burning-rate that were greater than normally anticipated '*fanning' effects* created by wind movement alone. I have also written extensively on this phenomenon since 1992 (Fog Attack), suggesting that great forces of *momentum and inertia* may be created by *negative pressures* that develop within structures during fire situations. One such example is related to the negative pressure that often exists *behind* firefighters as they advance into a fire involved floor of a high-rise structure causing the fire to be 'sucked' out of the apartment or floor to head directly into the stair-shaft. This negative pressure may be substantial and is a by-product of natural stack effects in the stairway itself. On occasions this effect can cause a negative pressure in the fire area itself to cause outside windows to break inwards, allowing exterior winds to intensify fire conditions.

At a high-rise apartment fire in Houston, Texas where a Fire Captain was killed in 2001, it was reported –

'They exited the apartment and headed down the hall, but a nasty thing happened when they opened the stairwell door, sources say. The stairwell acted like a ferocious maw, sucking heat and smoke down from the burning apartment. For Jahnke and Green the effect was overwhelming. The smoke grew thick as a blindfold; a torrent of hot air whirred past. The captains reportedly tried to beat a retreat by following their hose out of the apartment and down the hallway, a task made brutally complicated by the coiled, irregular pathway of their lifeline.

The violent shift in the air current created high confusion by sucking the heat away from the fire. To Jahnke it seemed as if they were headed toward the fire, not away from it, as they followed the path of the hose, Hauck says' . . .

In July 1990 FDNY firefighters experienced similar effects when a fire on the 51st floor of the Empire State building created a reversal of smoke



The venting action at the DCFD Cherry Road fire demonstrates this hazard

and super-heated fire gases as firefighters approached from the *vented* fire-tower stairs. The natural stack effect in the stairway, coupled with an exterior wind estimated to be gusting to 60 mph, caused the outside windows to fail with a subsequent reversal of fire, heat and smoke into the stairs behind the advancing firefighters.

In 1988 a team of firefighters in London were caught as they approached a high-rise fire from the stair-shaft. As firefighters began to attack the fire in a five-roomed apartment on the 16th floor the opening of two stairway lobby doors on the fire floor allowed the negative pressure to reverse flows, drawing superheated gases and fire into the stairway. The fire extended three levels above and two levels below the fire floor in the stairway! Several firefighters were burned. During the mid-1980s another fire in the UK took a firefighter's life under extremely similar circumstances as midlands firefighters battled a high-rise blaze.

On December 18, 1998, tragedy struck the NYC Fire Department a mere 7 days before Christmas claiming the lives of 3 fire fighters. At 0454 hours Brooklyn transmitted box 4080 for a top floor fire at 17 Vandalia Avenue in the Starrett City development complex. The sprawling complex is located on Brooklyn's south shore in the Spring Creek section. The 10 story 50 x 200 fireproof building is used as a senior citizen's residence. 'As the Lieutenant and fire fighters arrived at the door, a sudden change in the wind direction forced an estimated 29- MPH wind gust into the apartment, and a 2,000 degree fireball into the hallway'.

With the memory of 3 fire fighter's funerals fresh in their minds, NYC's Bravest were called upon yet again to battle a 4 alarm hi-rise fire in the posh Upper West Side of Manhattan. This time, 4 civilians were to lose their lives. In a virtual repeat of the fire that killed 3 fire fighters 5 days prior, the hallway and stairwell were converted into a 2000-degree smokestack. Within minutes fire was showing through the 19th floor apartment's windows; clouds of black smoke billowed up along the buildings 51-story facade. Unlike the fire on Vandalia Avenue, this building was not required to have sprinklers in the hallways, only a firehose and standpipe in the stairwell. Many residents on the upper floors were lucky in their attempt to leave the building. They took the stairway early enough to avoid being disabled by smoke and heat. But for 4 others the timing just wasn't right. Between the 27th and 29th floor, 4 people died of smoke inhalation.

In 2001 several tower occupants were rescued from the roof of a UK high-rise fire as the fire was reportedly 'sucked' out of an apartment and into the stair-shaft, causing firefighters to retreat and re-group.

However, if crews are advancing a hose-line into a room where there is fire then such an outlet will generally serve to assist their advancement by removing heat and steam to the exterior. A recent research project carried out by Swedish scientists demonstrated the likely effects of a localized window venting action.

A situation has been noted where venting actions have often resulted in devastating effects. Some buildings are designed with a normal point of entry through the front at ground floor level, whilst having the rear basement spilt-leveled so that it too appears at ground level from the rear of the structure. Where initial openings made at ground level (front) for entry are followed by venting (or further entry) actions at the rear basement level, rapid fire propagation has often occurred. Usually, this situation occurs whilst firefighters are occupying the space.

It is always essential to consider the wind direction and any effects this is likely to have on fire spread. This is particularly important where wind is entering the point of entry – such an effect may be either useful or hazardous to interior firefighting crews advancing on the fire. A further situation that may lead to unfavorable conditions could occur where ventilation openings are made in a room *adjacent* to the fire compartment. Where airflows are set up through the fire compartment itself the conditions may improve but where the natural path of ventilation is through a room adjacent, temperatures and smoke-logging may actually increase throughout both compartments.

Remember – in any situation, what is your *objective* in creating an opening? Temporary relief may occur at the point of opening but if such a venting point is not ahead of an advancing hose-crew – think twice? If it is a point of entry you are creating then risk-assess the situation and again apply the *objective* test – is there a better point of entry? What will be achieved in creating this opening?

Roof Ventilation – A Viable Option?

Battalion Chief Frank Montana (FDNY) describes how tactical venting actions on roofs should be approached –

In NYC we do not vent peaked roof private dwellings in the early stages of the fire. We, instead use our available manpower to aggressively attack the fire and to simultaneously initiate an interior search both on the fire floor and above the fire. If needed, later arriving units will open the roof. On a flat wood joist roof private dwelling, we would initiate roof ventilation early in the operation because venting the roof will greatly improve interior conditions and allow aggressive interior attack as well as search. For multiple dwellings, we would quickly open the stair bulkhead and skylight. This prevents fire mushrooming and allows for victim survival as well as an aggressive interior attack and search. If the fire was on the top floor of a wood joist roof, we would cut over the fire area to prevent fire spread in the cockloft. If the fire were spreading in the cockloft, we might try a trench cut along with positioning lines to stop the fire. On commercial buildings, with metal deck roofs and metal bar joist supports, there is usually not much point to cutting the roof. We would just open any existing openings like skylights and try and vent horizontally. The hazards of cutting these roofs usually outweigh the benefits. The same goes for poured or plank gypsum board roof. We don't cut them. They are too hazardous. We have lightweight wood truss floor beams and roof beams and light weight metal C joists to deal with now. The lightweight wood truss fails without warning early in a fire and the C joist turns to limp spaghetti when exposed to the fires heat. Cutting roofs supported by these joists is not a great idea. The problem is that often, we are unaware that they are present. There is no warning sign that lightweight metal or wood truss or c joists are in place. The first indication of their presence may be discovered when the roof man cuts the roof or when the roof or floor collapses. We try to identify these buildings and put them into the dispatch info transmitted when we are notified to respond. Then there is the problem presented by membrane roof covering with its fast spread. (Fire-fighters have been chased off of these roofs by fast spreading fire.) In addition, depending on the type, it is sometimes difficulty to cut. As you might imagine, we don.t cut many concrete roofs. For our buildings, with our types of construction and using our aggressive interior attack and search tactics, roof ventilation makes good sense in many instances. It is dangerous as is entering a building without a hose line to search, but the rewards are often great. (Saving life) The roof man should be an experienced and well trained firefighter.

Positive Pressure Ventilation – PPV

As a post fire strategy the use of Positive Pressure Ventilation (PPV) by trained and experienced operators is generally proven to safely and effectively remove smoke and dangerous gases from within the fire compartment and structure, enabling firefighters to complete overhaul and mop-up operations with ease. When used to force-vent a structure/compartment during the actual fire attack stage PPV has been found to relieve conditions for firefighters; improve visibility; remove smoke and dangerous gases quickly and effectively and reduce temperatures within the structure. However, such use of PPV demands a more intensive level of training and a comprehensive understanding of fire behaviour, air dynamics and fire gas transport within a structure. Before using PPV during the *attack* stages of a fire it is imperative to know where the fire is located; to what stage the burning regime has developed and if the fire compartment is in an *under-ventilated* state.

Where the fire exists in an under-ventilated state or where any warning signs preceding backdraught are apparent then PPV should not be used if the structure is likely to remain occupied. It is well established that the addition of air into an under-ventilated compartment could possibly trigger a *backdraft*, *smoke explosion* or even a *flashfire*. If the fire has reached a ventilation-controlled regime, with steady-state burning, it may be safe to initiate PPV but firefighters should be aware that the air-flow from the fan/s could still possibly create a build-up of dangerous gases or combustion products within compartments. This could occur as super-heated wall and ceiling linings and hot embers/'bulls-eyes' combine in the increased air-flow to form a hazardous environment. Also, firefighters should gain an understanding of how air-dynamics in stair-shafts and corridors could potentially create negative pressures that may actually 'pull' fire, smoke and gases into such areas. The potential for fire spread into other areas where elements of structure have been breached always remains a concern and PPV should be used in association with firefighters operating thermal image cameras (TICs) to monitor any such fire spread into internal shafts or roof voids. The siting of adequately sized smoke outlet points is of course a major factor of any successful PPV operation.

A more recent adaptation of Positive Pressure Attack has seen firefighters use isolation tactics inline with PPV. This entails *'safe-zoning'* areas by confining the fire and venting dangerous gas formations in adjacent compartments from the structure prior to opening and entering the fire compartment itself. For example, where a crew advances in and locates a well advanced room fire behind a closed door they may decide to ventilate the structure, using PPV, and clear any gases prior to entering the room for fire suppression.

Tactical ventilation or fire isolation tactics? – two options that both offer major benefits to the firefighter. The choice in any situation is down to careful risk-assessment by *balancing potential risks versus likely gains and applying the 'objectives' test as described above*. In some situations an early venting action relies heavily on adequate resources, equipment and manpower on-scene to ensure a safe and effective outcome. To be in a position to operate effectively there must be a pre-plan that is documented by SOPs and firefighters must have early and safe access to roofs, in the form of aerial appliances. Where cutting tools and power saws are not available it may still be possible to utilize existing openings, skylights over stair-shafts etc, to ventilate effectively for Life. APF

Paul Grimwood served 26 years as a professional firefighter, mostly within the busy inner-city area of London's west-end. He has also served in the West Midlands and Merseyside Brigades as well as lengthy study detachments to the fire departments of New York City, Boston, Chicago, Los Angeles, San Francisco, Las Vegas, Phoenix, Miami, Dallas, Metro Dade Florida, Seattle, Paris, Valencia, Stockholm and Amsterdam. During the mid 1970s he served as a Long Island volunteer firefighter in New York State USA. He has four books in six languages and over 100 technical papers on firefighting strategy published. He can be reached at www.firetactics.com