

By MARK EMERY

# Grading the Fireground On a “Curve”

*A Benign-Looking Fireground Can Be a Deadly Fireground*

**T**wo National Institute for Occupational Safety and Health (NIOSH) fatality investigation reports, 98-FO7 and F2004-14, involve firefighters advancing into obscured-visibility, low-heat conditions. In both cases, as they began their advance, firefighters noted “near-zero” or “very-limited” visibility and tolerable heat conditions; in both cases, offensive entry was not coordinated with ventilation that was *complete* and *effective*; in both cases, firefighters did not know the location of the fire; in both cases, firefighters advanced deeper into the building searching for the fire; in both cases, conditions quickly deteriorated; and in both cases a hasty withdrawal ensued and bagpipes honored those who didn’t make it out.

The result was the death of a fire captain (98-F07) and the death of a firefighter (F2004-14). Although the unselfish actions of these brave men were heroic, when they died, they were the most valuable “thing” in each building. Unless something changes, this sequence of events will happen again. It could be happening today, right now. Unless you know which side of the fire-growth curve you are entering, advancing into zero-visibility conditions is a really bad idea.

## Background

Firefighters entering and advancing into limited or zero visibility has been a proud fire service tradition for a long time. However, there is a hidden danger that should not be ignored or dismissed. During size-up, a master craftsman fire officer must determine which side of the fire-growth curve he or she is looking at; entering and advancing on the wrong side of the curve has killed and injured many fine people.

There is a point on both sides of the fire-growth curve that look the same and “feel” the same yet one side *could* be considered “go” and the opposite side of the curve *should* be considered “no-go.” An excellent example of this phenomenon is the “Structural Collapse Fire Test” conducted in 2001 by the National Institute of Standards and Technology (NIST) at a warehouse in Phoenix, AZ. After viewing the video several times, and factoring accompanying time and temperature data, I came to a sobering conclusion: *a benign-looking fireground can be a deadly fireground*. To make this situation more disturbing, a thermal imaging camera will not reduce your risk.

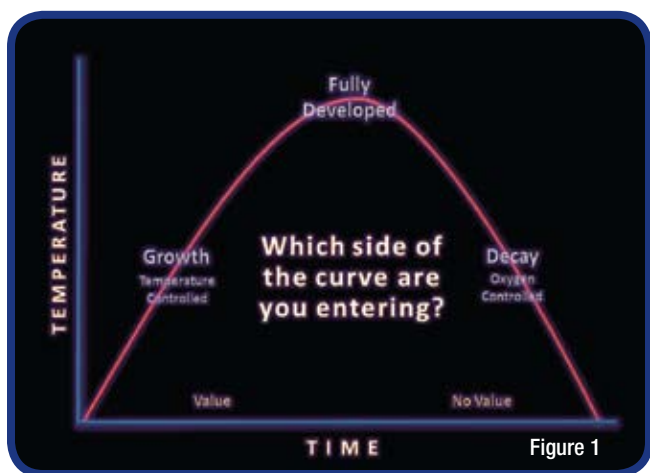
It is impossible to experience an intelligent and safe fireground operation if you don’t know what the problems are – in particular, *the most* significant problem. The purpose of the NIST fire test in Phoenix was to “develop data for evaluation of a methodology for predicting structural collapse.” The purpose of this article is to provide valuable nuggets that you can use immediately to ensure that a “routine” building fire does not lure you into a trap from which escape is unlikely.

It is my hope that this article will convince you and your fire department that problem identification during fireground size-up is the most important responsibility of a



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fire officer. A focused, systematic, master-craftsman size-up will ensure that problems are identified and that conditions are factored strategically – including determining which side of the fire-growth curve you are thinking of entering. It also is my hope that this article will convince you that the so-called “fast-attack” mode has no place on the contemporary fireground, especially when the only *verified* life-safety problem is the fire department. The term “fast attack” must be exterminated and buried deep, where nobody can find it. It is impossible to complete a meaningful size-up, develop an initial action plan, establish a water supply, coordinate entry with ventilation *that is complete*, ensure there is a two-out standby team and be “fast.” There is nothing *fast* about an intelligent and safe fireground operation.

inch lumber). Each triangular truss spanned the 50-foot building width and 15 feet separated each truss. The bottom cord of each truss was 10 feet above the floor and the peak of the roof was 18 feet above the floor. The fireload consisted of four stacks of 10 wood pallets.

The video and test data are more than interesting, for they reveal a tremendous “nugget” that all fire officers and training divisions should study and incorporate into their fireground size-up and development of a fireground strategy. The strategic nugget is revealed within 10 minutes of ignition.

Three thermocouple arrays recorded temperature at 12 points between the floor and the 18-foot roof peak; carbon monoxide was monitored one inch above the floor and three feet above the floor at two locations. The ignition source for the test was newspaper and an electronically controlled book of matches. No petrochemical fireload or accelerants was used.

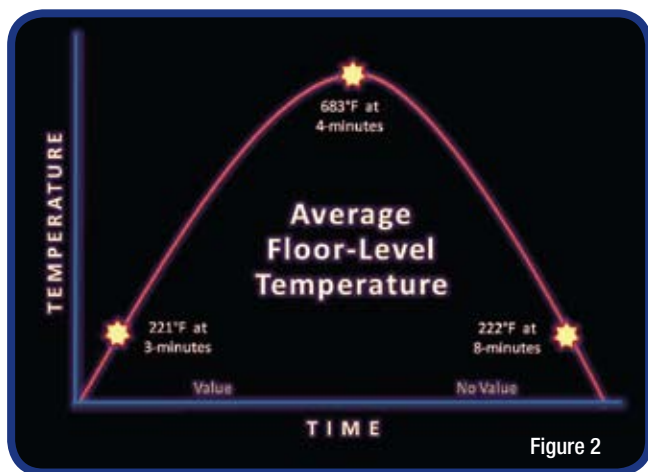


Figure 1

Figure 2

## The Test

The 2001 warehouse burn-test was performed by NIST in conjunction with the Phoenix Fire Department. A description of test procedures and test data was published in May 2003 and is available at [www.fire.gov/collapse/index.htm](http://www.fire.gov/collapse/index.htm). The website offers video of the event and a 66-page final report. This article will focus on the first test conducted in the front portion of the warehouse.

The front portion of the single-story, ordinary-constructed warehouse (masonry walls and wood roof) measured 50 feet wide by 90 feet long (4,500 square feet). The roof was supported by conventional wood trusses (the cords were two-inch-by-12-

## The Strategic Nugget

OK, let’s get to it – see if you can find the strategic nugget in the following data:

- At three minutes, 15 feet from the front door, the floor temperature was 196 degrees Fahrenheit; three feet above the floor the temperature was 351F. (The fire was getting traction for the climb to flashover.)
- At four minutes, 15 feet from the front door, the floor temperature was 892F; three feet above the floor the temperature was 619F. (The fire was feasting on fuel and oxygen.)
- At five minutes, 15 feet from the front door, the floor temperature was 457F; three feet above the floor the average temperature was 367F. (Lack of oxygen has interrupted the feast.)
- At nine minutes, 15 feet from the front door, the floor temperature at the front was 230F; three feet above the floor the temperature was 243F. (The fire was suffocating.)

As listed above, the numbers probably don’t reveal much to you; however, this data becomes significant when supported by photos and viewed on a rudimentary fire-growth curve (Figures 1, 2 and 3). Notice that the left side of the curve represents fire growth, evident by the steady rise in temperature as the curve climbs toward free-burning and flashover; the right side of the curve represents temperature decline and fire decay. The steady temperature rise is due to abundant fuel and oxygen; the temperature free-fall is due entirely to lack of oxygen. The decline side of the curve occurs for one of two reasons: the fire runs out of *fuel* or



Three minutes after ignition, there is plenty of fuel and plenty of oxygen so the temperature climbed steadily toward flashover.



Four minutes after ignition, with abundant heat, fuel and oxygen, the fire is feasting as flashover temperature is reached. The average temperature throughout the warehouse three

feet above the floor is 936F. There should be no question that this is a defensive fire; nothing inside this building has more value than the firefighters outside.



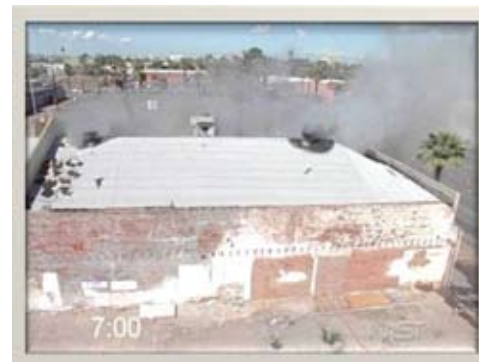
Five minutes after ignition, exterior conditions look similar to the three photos. Notice that the smoke that was venting along the top of the wall at four minutes has vanished.

the fire runs out of oxygen. (A third reason could be fire department intervention.) During the NIST warehouse burn, plenty of fuel and residual heat remained; the fire simply ran out of oxygen.

## The Unseen Evolution

What follows is the evolution of a fire within the 4,500-square-foot conventional structure in Phoenix. Pay close attention to time, interior temperature and exterior conditions during each progression of the fire. Pay particular attention to the fact that a no-value, high-risk, defensive fire can minutes later appear to be an acceptable-risk offensive fire. When a fire department arrives on the no-value side of the fire-growth curve and declares the mode offensive, firefighters will enter and advance toward a smoldering ambush. By opening the door and advancing, the trap has been set. More horizontal ventilation (breaking windows) will exacerbate the problem. Time, distance and horizontal ventilation become the enemy.

At the five-minute mark, after four minutes of increasing temperature and decreasing visibility, the temperature suddenly dropped to 477F – a 50% decrease between four minutes and five minutes. In case you missed it, a nugget has just been revealed. Viewed through a vehicle windshield, a fire officer would have no idea which side of the fire-growth curve is being considered. In fact, one minute after agreeing that the four-minute photo was a defensive fire, many of you would agree that a coordinated offensive operation looks feasible (if your size-up is based solely on conditions shown in the five-minute photo). Don't take the bait – although exterior conditions have improved, value within the building has not improved. Conditions will appear to “improve” as the minutes pass.



Seven minutes after ignition, the average temperature in the warehouse is 284F.

At seven minutes, the average temperature within the warehouse was lower than the temperature at three minutes. At seven minutes, this fireground does not look particularly intimidating (note the light, lazy smoke). Again, most of you would agree that a coordinated offensive operation would be feasible. Some seasoned fire officers might be thinking *backdraft*, but where are the signs? There's no puffing or sucking smoke, there's no pressure, the smoke is light colored and the temperature is low. So what's the problem, right?

If you are the fire officer who arrives and is sizing-up the seven-minute photo, you would have no idea that this fire-growth evolution has just occurred; you would have no idea how much time has elapsed; and you would have no idea which side of the fire-growth curve you are contemplating.

This sudden upward trajectory of fire growth was caused by opening the front door; opening this horizontal “damper” provided sufficient oxygen for the fire-growth curve to swing upward again. Had the door remained closed, the fire would have continued to smolder and conditions inside would have remained static. On the no-value, decay-side of the fire-growth curve, sometimes the best thing to do is nothing. Take advantage of the time provided by the static fire condition because there is no value and there is no hurry. The fire-growth clock has stopped. Establish your command post, summon and assemble additional resources, and draft your action plan. If you decide to open a damper (ventilate horizontally), make sure that everything is set up and ready to go and ensure that everybody knows what to do. On the back side of the fire-growth curve, vertical ventilation is a valid ventilation method; however, don't forget the roof structure was exposed to a hostile fire *before you got there* (look again at the four-minute photo).

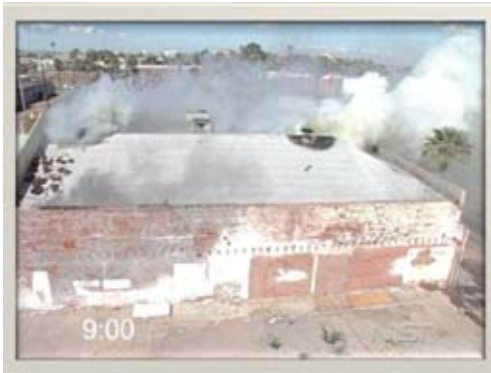
As pointed out by NIST and the Phoenix Fire Department, no accelerants or petrochemical-based fireload were present inside the warehouse. Had petrochemical-based fireload (plastics, flammable liquids, foam rubber, nylon carpeting, etc.) been present, the average Btu output would have doubled and the impact to the



Eight minutes after ignition, the two glass doors at the front of the warehouse were broken to simulate forcible entry by firefighters. The palm tree is directly across from the six-by-10-foot front glass door.



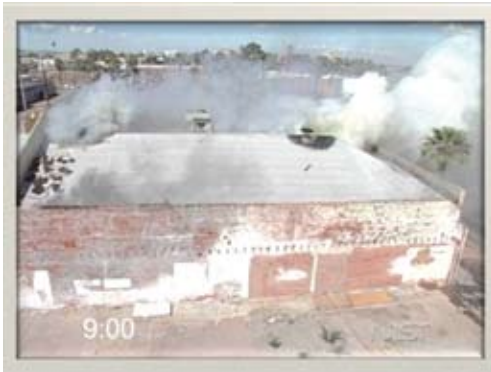
Fifteen minutes after ignition, fire is raging inside the warehouse, the interior is falling apart and roof collapse is imminent.



Nine minutes after ignition, one minute after the front door was opened, roof smoke increases. Notice the reappearance of smoke along the top of the wall.



Eighteen minutes after ignition, 10 minutes after the front door was opened, a large area of the roof has collapsed. So much for the so-called "20-minute rule."



Eleven minutes after ignition conditions continue to deteriorate and temperatures at the ceiling begin to climb once again. Fire is visible from the roof. Increasing heat is evident by the pressurized smoke.

triangular gravity resistance system more severe.

As mentioned earlier, the primary focus of NIST was to gather data related to building collapse. The focus of this article is fire behavior and enhancing size-up. It was sobering for me to discover that I could arrive at a building fire, view all four sides of the structure, nail my size-up of smoke conditions (color, pressure, etc.), confirm by thermal imager that the temperature is relatively low and be 100% wrong in determining value and declaring the operational mode as offensive. I could be 100% wrong if I failed to determine which side of the fire-growth curve I was on.

How does a master craftsman fire officer determine which side of the fire-growth curve is being observed? The chart at the top of page 79 depicts cues you can use.

Of course, the easiest point on the fire-growth curve to size-up is when the fire is free-burning (at the top of the curve). Because both sides of the curve can look and feel the same, the challenge is to identify whether you're on the *growth* side or the *decay* side of the curve. Unfortunately, admiring a fire through the windshield will not reveal which side of the curve you are observing.



At 13 minutes, the fireground looks similar to the photo taken at four minutes.

## Strategic Significance

Watch the clock on the warehouse video (or use the photo sequence provided here). Notice that the fire looked "better" at seven minutes than it did at four minutes. (Recall that until the front door glass was removed, the fire was static.) If you were to arrive at the warehouse fire and you were looking at the seven-minute conditions, you would think you have arrived early and that there could be value. You would even get suckered into believing that occupant survivability is high.

What you would not know is that fire growth stopped at the five-minute mark and that the fire is static. So long as nobody horizontally ventilates the warehouse, the fire will remain static, as fire growth is impossible because of the lack of oxygen. Three minutes after the horizontal "damper" (the glass door) at the front of the warehouse was opened, the temperature started to climb at a thermocouple array 75 feet away. Thirteen minutes after ignition, thermocouple data transmission was lost due to structural failure on the interior.

VALUE SIDE OF THE FIRE-GROWTH CURVE	NO-VALUE SIDE OF THE FIRE-GROWTH CURVE
You can see through the windows	You can't see through the windows
Water vapor on inside surface of windows	Inside surface of windows look "fuzzy"
Paper signs are still affixed to inside surface of windows	Anything stuck to inside surface a window has burned away or shows evidence of heat
Curtains, vertical blinds, etc. are still there	Window coverings have burned away or heat damage is evident
Exterior doors are cool to the touch	Exterior doors are warm/hot to the touch
<b>(At top of door)</b>	<b>(At top of door)</b>
Thermal image camera shows no residual heat on doors and walls (especially metal doors and walls)	Thermal image camera reveals residual heat on doors and walls (especially metal doors and walls)
No evidence of smoke stain around upper portion of rollup doors and around any exterior void/penetration where smoke could exhaust under pressure	Discoloration caused by smoke around upper portion of rollup doors and around any exterior void/penetration where smoke could exhaust under pressure (see wall discoloration in 5-minute photo)
The fire is reported by someone inside the occupancy	Thermal column was reported from across town; you don't see a thermal column while responding
Occupant greets you on arrival and says "the building has been evacuated"	Witness claims that "there was lots of fire when I called 911 a few minutes ago"
When in doubt, assume you are on the no-value side until investigation proves otherwise	If a fire has been smoldering for a long time you should see oily residue (creosote) buildup on the inside surface of windows

## The Strategic Dilemma

While reading the following *hypothetical* scenario, refer back to the series of test photos of the warehouse fire (or better yet, sit at your computer and view the NIST video while reading this section), factor the test data and imagine that a team of firefighters has forced entry through the front door of the warehouse at the precise moment that the eight-minute photo was taken.

Imagine that a team of firefighters with a charged hoseline has just entered through the front door. Based on the test data and



firmed with a thermal imaging camera. The team advances 15 feet from the front door and the team leader re-evaluates conditions: visibility is still zero, he doesn't sense uncomfortable heat and the thermal camera shows that the temperature has actually dropped a few degrees. The team leader can hear a chain saw operating above – vertical ventilation is in progress, but not complete.

### 15 FEET FROM THE FRONT DOOR, 3 FEET ABOVE THE FLOOR

3 min. 351F	4 min. <b>892F</b>	5 min. 457F	6 min. 320F	7 min. 277F	8 min. 243F	9 min. <b>230F</b>	10 min. 214F	11 min. 208F	12 min. 199F
	Top of Curve				FFs Enter Door	FFs Advance			

accompanying video, entry conditions would have been zero visibility and tolerable heat (approximately 230F three feet above the floor). No smoke is venting out of the door; although dense, the smoke is calm (there is not enough heat to generate positive pressure inside the 4,500-square-foot warehouse). There is no evidence of hostile fire conditions. These observations are con-

After advancing nearly 45 feet, the team leader reports to the incident commander that the team cannot locate the fire. (Because we have the test data and the test video, we know fire cannot be located because there is no fire to locate; the flames are gone because of lack of oxygen.) A second team with a hose-line appears and, shoulder to shoulder, the two teams advance,

### 44 FEET FROM THE FRONT DOOR, 3 FEET ABOVE THE FLOOR

3 min. 469F	4 min. <b>1,312F</b>	5 min. 543F	6 min. 345F	7 min. 295F	8 min. 262F	9 min. 239F	10 min. <b>219F</b>	11 min. 230F	12 min. 303F
	Top of Curve				FFs Enter Door	FFs Advance	FFs Advance		

75 FEET FROM THE FRONT DOOR, 3 FEET ABOVE THE FLOOR									
3 min. 204F	4 min. <b>602F</b>	5 min. 431F	6 min. 324F	7 min. 279F	8 min. 257F	9 min. 225F	10 min. 217F	11 min. 466F	12 min. <b>565F</b>
	Top of Curve				FFs Enter Door	FFs Advance	FFs Advance	FFs Advance	FFs Retreat

searching for the fire. (The first team leader thinks to himself: *Zero visibility, low heat confirmed by the thermal imaging camera – this is basic firefighter stuff, just like during recruit school. What could possibly go wrong?*)

Based on conditions and the drop in temperature, both team leaders believe that they entered the warehouse early on the fire-growth curve. They believe that somewhere something has been smoldering for some time, perhaps hours, filling the warehouse with smoke. (Of course, we know that they are correct – something is smoldering, not for hours, but for just a few minutes.) Three minutes after entering, their thermal imaging camera shows that the temperature has continued to drop. Both team leaders are confident that conditions are improving, even though visibility is still zero.

It has been three minutes since the team forced entry and began to advance into the warehouse. Now 75 feet from the front door, the team leader is suddenly aware of heat. They still have not located the fire. The teams advance for another minute until both team leaders sense that the temperature is uncomfortable; this is confirmed by the thermal imaging camera. Team members are also aware that the heat is uncomfortable. The team leaders direct the teams to withdraw. As each team follows its hose-line toward the door, the incident commander orders all interior teams to withdraw. (The incident commander has noticed smoke where there hadn't been smoke when he arrived. Smoke could be seen coming from roof, along the top of the walls — *and from the front door.*)

On their way down the ladder after completing vertical ventilation, the truck company reports that roof conditions are deteriorating. Inside the warehouse, firefighters scramble to withdraw, but are hampered by zero visibility, rapidly increasing heat, and chunks of ceiling and other debris falling around of them. No need to check the thermal imaging camera, each team member is acutely aware that it is uncomfortably hot. Inside the warehouse, confidence is being eroded by panic. Although the teams never do locate fire, the fire locates them.

### Call to Action

Perhaps your most important consideration during the size-up of a fire within a building is determining on which side of the fire-growth curve you have arrived. Entering and advancing on the no-value side of the curve can place your firefighters at great risk. It is imperative that the significance of the fire-growth curve be embedded into your long-term memory so that it can be conjured at three in the morning during size-up. Don't rely on what you see through

the windshield; don't rely on your thermal imaging camera.

On the fire-growth side of the curve, value diminishes as the curve ascends; on the decay side, there is no value. Anybody or anything that is *unprotected* on the decay side is history. On the growth side, value diminishes as minutes pass and temperature rises toward flashover. After flashover, the fire will free-burn until it depletes available oxygen or it runs out of stuff to burn. Horizontal ventilation on the decay side of the curve, usually the result of a random act of (fast attack) tactical violence, is like lighting a fuse. As firefighters advance, the fuse smolders. Once the proper fuel/air mixture is achieved, fire growth is resuscitated and the curve turns upward again.



However, as shown by the NIST data, even as the building falls apart, temperatures three feet above the floor don't change much. As shown by NIOSH fatality investigation reports, it is not unusual for experienced, competent fire officers to be seduced by the combination of low heat, limited visibility and the illusion of value. Recall from the NIST photos that the warehouse conditions are not intimidating on the decay side of the curve (until after being horizontally vented). Your thermal imaging camera will tell you what the temperature is, but

it won't tell you which side of the curve you are on. Recall that there is a point on each side of the fire-growth curve where the temperature is the same. On the value side of the curve, there can be low temperature and decent visibility; on the no-value side, low heat will be accompanied by obscured visibility.

Remember how a wood-burning stove works: Ideal burn conditions within the stove feature *vertical* ventilation (an *open flue*), *horizontal* ventilation (an *open damper*), and *heat and fuel* between the two. Even with the flue wide open, if the damper is closed, the fire will not grow. Review the carbon monoxide data in the NIST report. You will discover that if heat hasn't killed unprotected occupants on the growth side of the curve, carbon monoxide will kill them on the decay side.

My thanks to the Building and Fire Research Laboratory (BERL) and the National Institute of Standards and Technology (NIST) for providing the photos for this article. I would also like to thank NIST and the Phoenix Fire Department for conducting the test that led to the conclusions posited by this article.

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