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Letters to the Editor

Flashover misconceptions

Christopher Flatley's article "Flashover and Backdraft: A Primer" (March 2005) further adds to the misconception of the phenomenon know as flashover. The definition of flashover stated in the article is a common definition presented in most fire science textbooks. This is not an accurate description of the mechanics of a flashover and could lead to fatal consequences for the unknowledgeable. All firefighters, fire officers, and fire chiefs must have a thorough understanding of the mechanics of a flashover to conduct a safe fire suppression operation. Let's look at the fallacies of this definition that add to the misunderstanding of flashover.

The author states: "Flashover by definition is 'the sudden involvement of a room or an area in flames from floor to ceiling caused by *thermal radiation feedback*.' Thermal radiation feedback is the energy of the fire being radiated back to the contents of the room from the walls, floor, and ceiling." This is not totally true. When the initial fire starts, and most fires start small except for explosions or large amounts of flammable liquid, the heat from this incipient and intensifying fire is transferred to the structure and contents of the compartment by conduction, convection, and radiation. If a fire starts on the cushions of a couch and starts to spread up the back of the couch and then to the drapes, shades, and blinds around the window behind the couch, this spread is mainly by conduction—that is, these materials being touched by the initial flames of the cushion fire. The contents and exposed combustible structural and trim materials are heated not only by "the energy of the fire being radiated back by the floor, walls, and ceiling," but also by conduction, convection, and direct radiation from the intensifying fire as well as the previously described radiation feedback.

The author further states: "When the contents of the room suddenly and simultaneously ignite, this is flashover." This is not accurate, because every object in the room has its own ignition temperature. It depends on the material used in its makeup (wood, plastic, fabric, for example), its form and surface area. There could be a difference of hundreds of degrees in the ignition temperature of different contents, so they all don't reach their ignition temperature simultaneously.

The key word and definition absent from the article, and which greatly adds to the understanding of flashover, is *pyrolysis*. Pyrolysis is the breakdown of the long-chain molecules of a fuel, because of heat, into gaseous shorter-chain molecules. The contents and exposed combustible structural materials are heated by conduction, convection, and radiation from the initial intensifying fire and break down into combustible gases. These gases fill the room or compartment and have their own unique ignition temperature. When these gases reach their own unique ignition temperature and ignite, we have flashover and fire from floor to ceiling.

In the section entitled "Preventing Flashover," the author states: "Proper ventilation can prevent a flashover .... This can be done by horizontal or vertical ventilation." Improper horizontal ventilation can cause more problems than it solves. It will admit air to the fire area that was previously oxygen regulated and greatly increase the rate of combustion and possibly flashover. Any firefighters in this compartment not protected by an operating hose stream will be in great danger. Horizontal ventilation *must* be coordinated with the positioning and operation of hoselines.

Vertical ventilation will release heat and combustible gases from the fire compartment without admitting air to the oxygen-regulated fire. Vertical ventilation does not need the coordination horizontal ventilation does and can be done as soon as possible.

A through understanding of flashover by all responders is essential for a safe efficient operation.

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Regarding Christopher Flatley's article, I would like to add a comment or two. He mentions that thermal radiation feedback "is the energy being radiated back to the contents of the room from the walls, floor, and ceiling." There is also some radiational heat transfer from the initial fire plume to nearby contents.

Pyrolysis of the unburned materials occurs at an increasing rate at the interface between the hotter upper layer and the cooler lower layer. Fire growth and radiant heat transfer increase until the lower-level materials simultaneously ignite and flashover occurs. The contents do not burn; the gases ignite. He references this later in the article when discussing backdraft : "... when oxygen is introduced and the hot gases will ignite ...." This should apply to flashover.

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I have found several technical inaccuracies in Christopher Flatley's article:

The article fails to accurately depict the phenomenon known as flashover. First, the article provides an improper definition of a flashover event. Using a vague definition of this phenomenon is the cause of the majority of the inaccuracies presented within this section. This definition assigns a premise that the phenomenon is "caused by thermal radiation feedback" and then explains that thermal radiation feedback is simply the energy of the fire being radiated back to the contents of the room from the walls, floor, and ceiling.

The author is correct that these variables do radiate heat back to the contents of the room; however, he never mentions the upper gas layer, which is the most important variable regarding the transfer of radiant energy to combustibles within the room. The more dominant variables in determining flashover potential within a room include the heat release rate of the burning

fuel and secondary fuels, adequate air supply, and the radiant heat transfer mechanism of the hot upper-gas layer.

The article does mention the "air supply factor," yet it fails to explain the other two important variables. As a result of not explaining the effects of the upper layer and the heat-release rate of the compartment's fuel load, the entire discussion on flashover is greatly lacking.

A better definition that accurately addresses the issues in determining this phenomenon can be found in NFPA 921, *Guide for Fire and Explosion Investigations*: "**Flashover:** A transition phase in the development of a compartment fire in which surfaces exposed to thermal radiation reach ignition temperature more or less simultaneously and fire spreads rapidly throughout the space, resulting in full room involvement or total involvement of the compartment or enclosed space."[1]

The article also uses improper terms such as "black fire" and "black, black smoke" as being indicators of the flashover phenomenon. The most disturbing technical reference comes when the article inaccurately describes flashover as being driven by the air mixture, when it states, "This 'black fire' needs only the right mixture of air to ignite." This statement lacks scientific validity, especially since the phenomenon of flashover is driven by the autoigniting of the combustibles and has no link to the flammable limits of the upper layer. This can be seen by referencing just one of the several papers and textbooks available that have discussions regarding flashover.[2-7]

The article describes a rollover as an early sign that flashover conditions are developing. This description is very misleading because it leaves the reader with the assumption that every time a rollover is witnessed a flashover will follow. This statement can lead to confusion by firefighters, which may lead to eventual mistakes and possible injuries and deaths.

There is abundant research regarding the phenomenon of flashover that should have been referenced and reviewed for the preparation of this article.[1-7]

The discussion regarding backdraft states that carbon monoxide is a major fuel that drives this phenomenon. There is no scientific backing for the statement; in fact, numerous studies have disproved this theory.[8-11] These studies reveal that the major fuel constituent that drives the backdraft phenomenon is the incomplete solid pyrolysis products within the smoke layer. In addition, the article states: "CO will burn at a relatively low temperature (for fires anyway) and at almost any mixture." This statement leaves the reader with the thought that carbon monoxide is ignitable at any mixture; in reality, the LEL is the more important factor. Carbon monoxide requires a substantial mixture (12%) in air before it is flammable or explosive ... the author should have determined, pending further research, that studies have shown typical enclosure fires rarely have CO mixtures above 5 percent.[8-13]

The author also states that a smoke explosion and a backdraft are synonymous, which is probably the reason for the technical inaccuracies presented in this section. The thought that these two phenomena are synonymous is contrary to recent research and studies performed by Quintiere and Karlsson.[3] In their text, a distinction is made because a different type of fuel drives each

phenomenon. A smoke explosion relies on the actual gases produced during a fire (carbon monoxide and so on) that have collected in an adjacent smaller enclosure, whereas a backdraft relies on the incomplete solid pyrolysis products contained in the smoke layer. Therefore, the discussion in the article better describes a smoke explosion phenomenon than a backdraft. The approach in how to mitigate or prevent these phenomena is the important distinction. Each phenomenon should be approached differently because of the different types of fuel ....

An article with these technical inaccuracies adds to the misconceptions the author says he is trying to avoid. However, I do not fault only the author, because this is a widespread issue throughout the fire safety profession. I believe this is because much of the current fire research knowledge gained by fire safety professionals is based on independent learning. The primary media for this independent learning and current research are trade periodicals and journals like *Fire Engineering* .... Consequently, it must be the responsibility of the technical editors to critically review articles for their scientific validity, or these myths and misconceptions will continue.

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1 National Fire Protection Association. *NFPA 921 – Guide for Fire and Explosion Investigations*, NFPA, Quincy, MA. 2004.

2 Drysdale, D. *An Introduction to Fire Dynamics*, 2nd Edition, John Wiley & Sons, 1999.

3 Quintiere, J., B Karlsson. *Enclosure Fire Dynamics*, CRC Press, 1999.

4 Kennedy, P. "Flashover and Fire Analysis – A discussion of the practical use of flashover analysis in fire investigations," *Investigations Institute*. 2003.

5 Drysdale, D. "The Flashover Phenomenon," *Fire Engineers Journal*, November 1996.

6 DeHaan, J., D. Icove, *Forensic Fire Scene Reconstruction*, Brady, 2003.

7 Thomas, P. "Selected Papers: Fire Research Station 1951-1986," *Building Research Establishment*, 1986.

8 Gojkovic, D. "Initial Backdraft Experiments," Lund University, 2000.

9 Fleischmann, C., P Pagni,. "Exploratory Backdraft Experiments," *Fire Technology*, 4th quarter, 1993.

10 Sutherland, B. "Smoke Explosions," University of Canterbury: Department of Engineering, March 1999.

11 Gottuk, D., M., Peatross, et al. "The Development and Mitigation of backdraft: a real-scale shipboard study," *Fire Technology*, July 1999.

12 DeHaan, J. "The Dynamics of Flash Fires Involving Flammable Hydrocarbon Liquids," *The American Journal of Forensic Medicine and Pathology*, 17, 1996.

13 Babrauskas, V., R. Peacock, "Heat Release Rate: The Single Most Important Variable in Fire Hazard," *Fire Safety Journal*, 18-19

Chris Flatley responds: I thank my colleagues for their interest in my article. As evidenced by their responses, the commonly accepted definition of the flashover may be incomplete. Pyrolysis is a term not mentioned in the Fire Department of New York publications referenced. However, when the material is raised to its ignition temperature, pyrolysis is what is occurring. The material is giving off the flammable vapors needed for ignition. I agree that every material has its own ignition temperature and that, depending on its form and surface area, the materials will reach ignition temperature at different times. So, what then is the cause for the room and contents to ignite so rapidly? In a flashover, the contents do not ignite individually; they ignite collectively.

The flammable vapors given off by the burning material will collect at the ceiling level and form a rich fuel mixture. It is in this layer that rollover will occur. Rollover is a warning sign of flashover. I never suggested that flashover will always be preceded by rollover, nor will rollover always be followed by flashover. Members operating in the fire area may not see a rollover. If it is seen and recognized, it is an indication of the developing fire condition.

My description of the smoke as "black fire" was to illustrate the point that firefighters are taught not to open a hoseline on smoke. They need to find the open flames before operating the hoseline. The point was to liken this super hot fuel-loaded smoke to fire and [to point out] that operating the line on this type of smoke is permissible since it is so dangerous.

This article was prompted by discussions with my firefighters and their understanding of the events that lead to flashover. My goal was to provide a field-level understanding every firefighter can remember. Whether an event is actually a smoke explosion or a backdraft, depending on what type of fuel is present, is less important than recognizing the dangers of the event.

When I was promoted, the chief of department reminded those of us who were promoted that the department would provide us with the firefighters and that it was our personal responsibility to return them to their families at the end of the tour. This is something that I hold true. Anyone who has led or ordered people into harm's way understands that fact. If this article has left any doubt, then I hope this discussion has cleared that up. Nothing should compromise the safety of firefighters.

Glenn Corbett, SFPE, technical editor,* Fire Engineering*; professor of fire science, John Jay College; and assistant chief, Waldwick (NJ) Fire Department, responds: Flashover is a defining moment in the history of a fire. Unfortunately, there is no standard definition of this phenomenon that has been accepted by all "fire" people. Firefighters often define flashover in terms of full-room involvement, whereas fire protection engineers may describe it in terms of radiant heat flux at floor level. Others see fire leaving a compartment as defining flashover, and some use ceiling layer temperature as the critical characteristic of flashover. Flashover is in the eye of the beholder. ■