From our earliest firefighter training and education, we have been taught about the “fire triangle” and “fire tetrahedron”; the transmission of heat; fuels, pyrolysis, and oxidizers; products of combustion; the classes of fires; and the stages of fire development in a compartment.

When fires occur in compartments, the science of fire becomes more complicated because the fire is no longer burning with an unlimited supply of oxygen (usually called “fuel controlled”). The development of a fire in a compartment is often limited by the amount of oxygen available (usually called “ventilation controlled”).

In a compartment fire, the stages of fire development include the following:

- **Incipient.** From ignition until the fire has grown enough to radiate heat back on the fuel and cause pyrolysis, leading to fire growth
- **Growth stage.** The fire begins to heat the entire space in the compartment, with combustion products spreading across the ceiling, leading to rollover.
- **Rollover.** the superheated combustion products at the ceiling begin to flame and flash over, when the convection and radiation from the fire now pyrolyze all the surfaces and contents of the room and cause their ignition.

However, the occurrence of flashover depends on the following two related factors:

- Does the fuel have enough energy to cause flashover conditions?
- Is the heat release limited by the supply of oxygen?

In either case, the fire may not reach rollover or flashover because of low-energy fuel or ventilation limits. Based on this, consider the following:
• A fully-developed fire is one in which all the fuel in the compartment is burning. It is ventilation controlled, with the rate of heat release dependent on the amount of oxygen present. Unburned products of combustion flow out of the compartment into adjacent spaces in the building; they may ignite them if there is enough oxygen present.

• A fire in decay stage is one in which much of the fuel in the compartment has been burned or one in which there is too little oxygen to support flaming combustion. If the fire is fuel-controlled at this point, the superheated products of combustion are present and spreading through other spaces in the building, waiting only for the fuel-oxygen mixture to be within the flammable limits to ignite and cause a smoke explosion. If the fire is ventilation-controlled at this point, the fire may produce little visible flame; produce unburned products of combustion; maintain high temperatures in the compartment; and ignite explosively when ventilation provides additional oxygen, causing a backdraft.

Your preferred firefighting text or reference book had detailed descriptions of these stages of fire development, with illustrations and diagrams. See also the research reports and videos from the Underwriters Laboratories’ Firefighter Safety Research Institute (UL FSRI) at http://ulfirefightersafety.org.

The development of a compartment fire is further complicated by the compartment itself. Are its surfaces noncombustible, fire resistive, or combustible?

• If the surfaces are noncombustible (i.e., concrete, steel, masonry) (photo 1), they provide no fuel to the fire, whose fuel is limited to the room’s contents.
• If the surfaces are fire-resistive (i.e., gypsum drywall board) (photo 2), they provide no fuel to the fire initially, but exposure to heat over time may cause them to fail, exposing more combustible materials, structural supports, and concealed spaces. Photo 3 shows structural steel concealed behind wood framing and gypsum drywall board in beam enclosures. The column will also be framed with wood and concealed with drywall board.
• If the surfaces are combustible (i.e., wood, draperies, wallpaper, low-density fiberboard acoustic tiles) (photo 4), they provide fuel to the fire, intensifying it, and leading to rapid exposure of structural supports and other combustibles.
Fire development may be most rapid in a compartment in which the surfaces are highly combustible or ignitable, including the following:

- Carpeted floors or walls.
- Heavily-waxed wood floors, wall paneling, or tongue-and-groove boards.
- Easily-ignited materials (i.e., fiberboard paneling, wallpaper, draperies, low-density fiberboard acoustic tiles) on walls and ceilings.

The use of highly combustible or easily-ignitable surfaces in a compartment leads to the following:

- Reduced time to rollover and flashover.
- Reduced time to burn-through of the combustible surfaces.
- Reduced time to exposure of the concealed spaces behind the combustible surfaces, which are not sprinklered in many construction types.
- Rapid ignition of the surfaces in the concealed spaces if they are combustible. Photo 5 shows the combustible low-density fiberboard acoustic tiles in the concealed space between the original plaster ceiling of a school and a more recent suspended ceiling system.
- Expansion of superheated products of combustion into the concealed spaces even if they are not combustible (photo 6).
- Extension of the fire through interconnected concealed spaces and into occupied spaces, with breaks in the fire resistive assemblies.
Understanding these concepts is essential to understanding the restrictions on building construction and maintenance in the building and fire codes, in preincident planning in structures, and in predicting the behavior and development of fires in buildings.

The next article will discuss these in more detail, including the result of fire breaking through into the interconnected concealed spaces that are hidden inside most buildings.

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