UNIT V STUDY GUIDE

Process of Burning

Course Learning Outcomes for Unit V

Upon completion of this unit, students should be able to:

4. Describe and apply the process of burning.
   4.1 Analyse the three significant differences between the burning of solid fuel and the burning of gaseous and liquids fuels.
   4.2 Illustrate the hazards and harm of smoke exposure to individuals from the burning process.

6. Discuss various materials and their relationship to fires as fuel.
   6.1 Evaluate how char formation and melting occur and how they affect the burning rate.

8. Articulate other suppression agents and strategies.
   8.1 Define four classes of mechanisms by which fire retardant additives act to modify ignition and burning of solids.

Reading Assignment

Chapter 9:
Fire Characteristics: Solid Combustibles

Chapter 11:
Smoke and Heat Hazards

Unit Lesson

Several decades ago some fire instructors taught fire behavior and combustion based on construction techniques and materials used, as well as on the materials used in the manufacturing of furniture. These factors led instructors to state, “every fire is the same” using the fire triangle to illustrate their statement. On the other hand, some instructors then and today believe that, every fire is different and requires different types of extinguishment. Which statement is correct for today’s fire service? According to Madrzykowski (2013):

> Every fire is different—Yet from a science perspective, most fires share some basic similarities. The fire-heat release is due to exothermic, gas-phase, chemical reactions that produce heat and light, and they require three components to sustain the chemical reaction—fuel, oxygen, and heat. (p. 7)

Even though the fuel, oxygen, and heat to sustain chemical reaction have not changed, the materials used in the manufacturing of furnishings have changed. “In the 1950s, a wide range of synthetic materials called polymers became available for use in clothing, furniture, interior finish, and insulation” (Madrzykowski, 2013, p.8). The commercial introduction of different types of synthetic polymers, such as “polyester, nylon, and polyurethane foam became commonplace in homes” (Madrzykowski, 2013, p. 8) have changed the pyrolysis of combustible materials. In addition, today we find multiple synthetic polymers and flammability liquids in garages such as polyurethane foam, liquid fuels, gasoline, kerosene, glues, oil based stains, and charcoal lighter fluid. Each of these products and their physical characteristics has made firefighting more dangerous due to their volatility and flame spread rate. The pyrolysis of these products to form gaseous fragments is different today than in the pre-50s. Solid wood furniture with minimal glue and synthetic polymers has different characteristics than pressboard laminates with plastic finishes sold today. How is the gasification of these products different? According to Gann and Friedman (2015):

> During pyrolysis, chemical change occurs within the solid, and the chemistry of the volatiles is rarely the same as the chemistry of the solid. The ignition of the pyrolyzate from a solid is similar to the ignition of gases and vapors, except that heat losses from the fuel surface to the interior and to the surroundings can delay or prevent the ignition. (p. 171)

In other words, the chemical characteristics from these polymers differ as they go through different modes of decomposition during the pyrolysis process. Quintiere (2006) stated, “commercial polymers will contain additives for various purposes which will affect the phase change process. For some polymers, a melting transition may not occur, and instead the transition is more complex” (p. 20). Gann and Friedman (2015) described this process as: “unzipping, random scission, [and] elimination” (p. 156).

Other authors use other terms to describe decomposition during the pyrolysis of synthetic or commercial polymers. They describe the characteristics of polymer fuels, based on their change, as thermosetting plastics, thermoplastics, and elastomers (Gorbett & Pharr, 2011; Peters, 2007). Gorbett and Pharr (2011) suggested pyrolysis of “polymers undergo pyrolysis and leave behind a carbonaceous residue (char) in the presence of a sufficient heat source, but thermoplastics (soda bottle containers) melt when exposed to heat and vaporize, similar to liquids” (p. 113). Quintiere (2006) supports this statement adding that tars and gases are left behind during pyrolysis of solid synthetic materials based on the chemical composition. Why is this important in firefighting? As seen previously solids in a structure fire must gasify before ignition can occur as seen in pyrolysis. Pyrolysis continues until enough gases are formed to exceed the lower flammable limits in order for ignition to occur. Some synthetic materials gasify quicker than others and are suspended in the thermal layer of smoke. Gorbett and Pharr (2011) suggested these suspended solid pyrolysis products contribute to a backdraft. The authors wrote, “the major fuel constituent that drives the backdraft phenomenon is the incomplete solid pyrolysis products within the smoke layer” (p. 258). This is in contradiction to what many authors have supposed causes flashovers or backdrafts a decade ago. Several authors state that backdrafts are the result of carbon monoxide being suspended in the thermal layers (Salazar, 2000).

> Many textbooks incorrectly use the fact that carbon monoxide (CO) has a flammability range as proof that CO is the fuel behind the backdraft phenomenon. However, in reality the lower explosive limit (LEL) of CO is the most important factor when investigating this issue. Carbon monoxide requires a substantial mixture (12 percent) in air before it is flammable or explosive. (Gorbett & Pharr, 2011, p. 258).

Shackelford (2009) supports Gorbett and Pharr in that carbon monoxide, “is flammable and has a very wide flammable range of 12.5% to 74%” (p. 55). Gorbett and Pharr (2011) stated that studies by Bryner, Johnsson, and Pitts, 1992; Icove and DeHaan, 2009; Babrauskas, 2003; and Gottuk, 1999 have shown that standard enclosed fires infrequently have CO mixtures above seven percent. The authors write:

> Therefore, the misconception has no basis or scientific support. Pitts (1994) has performed several small-scale and large-scale studies regarding the production of CO and has found volume percentages on the verge of the lower flammable limit of CO, but no one has related these findings to being a fuel in the backdraft phenomenon. (p. 258).

Therefore, during pyrolysis of solid combustible materials there are polymers that will form without the loss of molecules or that will split out molecules (Gann & Friedman, 2015). The authors also state that this is referred to as addition polymers or condensation polymers. As a result, the burning properties of these polymers are considerably different during decomposition made from multiple materials.

> Points to Ponder
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> Units respond to an upholstery store fire involving large amounts of polystyrene foam and other materials stored in the back of the store. Upon arrival, heavy black turbulent smoke was towering above the store spurting volatiles into the atmospheres. No visible fire was showing and all the front windows were intact. The front door was open and black smoke was pouring out of the upper third of the door. Units pulled a pre-connect and advanced the hand-line to the front door. Units made entry approximately five feet into the structure when they noted blackened soot starting to adhere to the SCBA face mask. Conditions inside were super-heated from the radiation.

In the scenario what is the principle contributor of the fire spread? Is it the polymers from the polystyrene foam? Is pyrolysis increasing from the temperature of the products burning? Is autoignition possible? Is the gasification rate leading to a flashover or possible backdraft with the front door opened?

From the textbook we will learn pyrolysis of a solid to form gaseous fragments can be characterized by a heat of gasifcation. During pyrolysis chemical change occurs within the solid, and the chemistry of the volatiles is rarely the same as the chemistry of the solid. In addition, the authors discuss that the burning rate depends on the radiant flux to the surface. Early in a fire this flux comes from the local flames; later, most of the flux is derived from the hot surroundings. In addition, you will explore toxic gases and how they fall into two classes: (1) Asphyxiant (narcotic) gases, mainly CO and HCN that deprive the body of oxygen. The effects are dose related—that is, a function of the volume fraction of the gas and the duration of exposure. Oxygen depletion and carbon dioxide increase the effect. And (2) Irritant gases can have acute, instantaneous effects on the senses and upper respiratory tract as well as long-term effects on the lungs. Prominent irritant gases include the halogen acids, nitrogen oxides, formaldehyde, and acrolein.

References

Gann, R., & Friedman, R. (2015). *Principles of fire behavior and combustion* (4th ed.). Burlington, MA: Jones & Bartlett.

Corbett, G., & Pharr, J. (2011). *Fire dynamics*. Upper Saddle River, NJ: Pearson Education.

Madrzykowski, D. (2013). Fire dynamics: The science of firefighting. *International Fire Service Journal of Leadership and Management (7).* pp. 7 – 15.

Peters, E. (2007). Plastics: Thermoplastics, thermosets, and elastomers. In M. Kutz Editor (Ed.), *Handbook of materials selection*. New York, NY: John Wiley & Sons.

Quintiere, J. (2006). *Fundamentals of fire phenomena*. Hoboken, NJ: Wiley and Sons.

Salazar, J. (2000). *Instructor's guide to accompany firefighter's handbook essentials of firefighting and emergency response.* Stamford, CT: Delmar Thomas Learning.

Shackelford, R. (2009). *Fire Behavior and Combustion Processes.* Clifton Park, NY: Delmar.

Suggested Reading

As you view these videos remember that firefighters work in uncontrolled environments during emergency situations. Some of the tactics do not follow FESHE curriculum guidelines and outcomes for incident command, scene size-up, or fire attack. This course is about fire behavior and combustion. The purpose of viewing these videos is to watch and learn from applying the concepts and key terms used in this unit.

Fire Near AIG Campus
Observe the fire in relationship to Chapter 9 and the pyrolysis of solids to form gaseous fragments.
https://www.youtube.com/watch?v=Cg9PWSHL4Vg

Bowling Green Ave Dwelling Fire 2/26/14 Morrisville, PA.
Observe the fire in relationship to Chapter 9 and the pyrolysis of solids to form gaseous fragments.
https://www.youtube.com/watch?v=I-PF5igB1AE

Paterson Fire 3rd Alarm Heavy Fire Throwback to Summer 2000.
Observe the fire in relationship to the smoke and heat hazards to the firefighters as related to narcotic gases and irritant gases.
https://www.youtube.com/watch?v=SvlHPj0DZJQ

Learning Activities (Non-Graded)

Review What You Have Learned

The Challenging Questions at the end of Chapter 9, on page 172, will help you evaluate the difference between a material and a product, as well as the upper and lower extremes of moisture in wood.

Review What You Have Learned

The Challenging Questions at the end of Chapter11, on page 211, will help you evaluate why is an exit sign in a smoke-filled room less visible when the ceiling light is more intense. In addition, read to understand that the principal gaseous products of room fires are H2O and CO2. Incomplete combustion generates CO and a mix of partially oxidized organic molecules. Nitrogen-containing fuels generate HCN, NO, and NO2. Halogen-containing fuels generate hydrogen halides.

These are non-graded activities, so you do not have to submit them. However, if you have difficulty or questions with the concepts involved, contact your instructor for additional discussion and/or explanation.