Course Learning Outcomes for Unit II

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

1. Identify physical properties of the three states of matter.
   1.1 Explain how the three states of matter are characterized.
   1.2 Examine potential and kinetic energy related to the states of matter.

2. Categorize the components of fire.
   2.1 Demonstrate heat release during combustion.
   2.2 Apply fuel-lean, stoichiometric, and fuel-rich combustion.

4. Describe and apply the process of burning.
   4.1 Outline ideal and realistic flame temperatures.

Reading Assignment

Chapter 3:
Physical and Chemical Change

Chapter 4:
Flow of Fluids

Unit Lesson

It is challenging to use “pen and ink” to describe fire behavior or combustion.

Many can describe the visible appearance of smoke and the light that fire creates. What about the physical and chemical change? Do we truly understand physical and chemical changes in fire behavior or combustion? Do we understand that the outcome of combustion reactions is determined by thermodynamics? Do we understand adiabatic flame temperature? Does this occur as the maximum possible temperature for combustion is reached during flashover? Gann and Friedman (2015) suggested adiabatic flame temperature “is the highest possible temperature for the combustible mixture because all the possible chemical heat is released and all of that heat is applied to raising the temperature of the mixture” (p. 41). In other words, there has to be a correct mixture of fuel and all oxidizers in order to be completely consumed.

What is the physical and chemical change regarding fire behavior or combustion? Some would explain the concept by the fire tetrahedron of fuel, oxygen, heat, and the uninhibited chemical reaction that sustains fire. According to the International Fire Service Training Association (IFSTA) (1998):

> Fire is a rapid chemical reaction that gives off energy and products of combustion that are very different in composition from the fuel and oxygen that combined to produce them. To understand the reaction we call fire, how it grows, and its products of combustion, we need to look at some basic concepts from physical science (p. 33).

In other words, there needs to be a chemical change in order to have combustion. What makes up combustion? Is it fire gases? Is it flame? Is it smoke? Corbett and Pharr (2011) suggest that combustion is reaction and oxidation at the molecular level. Merriam-Webster (n.d.) defines combustion as “a chemical reaction that occurs when oxygen combines with other substances to produce heat and usually light” (para. 2).

Gann and Friedman (2015) state “Combustion is an exothermic chemical reaction between a fuel and an oxidizer resulting in the generation of substantive heat and often light” (p. 79). Nonetheless, combustion, according to these authors always involves oxidation at the molecular level. In addition to understanding oxidation we need to understand fuel lean and fuel rich related to the physical science of combustion.

Can we detect the physical and chemical change in fire behavior by observing live fire training in acquired structures? Some may agree; whereas, others may not. Live fire in acquired structures provides one of the greatest learning environments to gain experience, cognitive understanding and to experience the elements of fire and the energy that are released (Padgett, 2012). In acquired structures firefighters can see, first-hand, the air track (direction, velocity, and turbulence) of smoke and the energy of fire. In live fire training do we observe a stoichiometric mixture of fuel and oxygen?

Points to Ponder

Pre NFPA 1403, during a live fire training exercise a chair made from a wooden frame, foam and fabric was set on fire inside an acquired structure. The acquired structure was wood frame with wood siding that was labeled “B.” No other objects were placed in the fire room. Firefighters observed the propagation of flames from the seat of the chair to the back of the chair as the radiant heat began to cause the fabric to give off smoke. Flames then involved the fabric on the back of the chair and then part of the floor. The smoke initially decreased at the ceiling level and then rapidly started to develop. As heat continued to build, the flames grew in magnitude then began to roll across the ceiling. As the flames rolled across the ceiling more and more smoke began to build. The smoke was lighter in color at first and the wall behind the chair was still visible through the smoke as the chair continued to burn. The light-colored smoke quickly became black and obscured the wall. Air movement could be seen low to the floor which appeared to be drawn towards the fire. The black smoke became a little turbulent and banked down to the floor as the fire was no longer visible. The smoke appeared to be thicker and thicker, almost like black soot, with an increase in heat which led to a flashover of the room. Then within just a few minutes the entire structure was involved with turbulent smoke and flames issuing from all the openings.

What chemical changes occurred in that live training fire? Was this the stoichiometric mixture of the chair oxidizing during the combustion process when the solid fuel of the chair pyrolysed, creating gaseous fragments that are different than the structure of the chair? Corbett and Pharr (2011) state that a stoichiometric mixture is a chemical condition where the proportion of reactants is such that there is no surplus of any reactant after the chemical reaction is completed” (p. 33). In other words, it is the ideal mixture where complete combustion occurs. What happened to the floor? The walls? The entire structure? Was this an endothermic reaction? Was this heat of gasification of a solid? Was this direct molecular contact through conduction? Understanding physical and chemical change in order to reduce injuries or death is critical for firefighters and leaders in the fire service.

Through this unit you will gain understanding of “Physical and Chemical Change.” You will evaluate the states of matter; explanations of how molecular behavior leads to the material properties we sense. You will analyze phases of change as related to fires. You will examine heat generation and the nature of combustion products from a fire. Through these principles you will understand the transition that occurs from the growth of the fire to the fully developed fire where flashover occurs, as seen in the live fire training. In addition, you will identify the “Flow of Fluids” in relation to Newton’s laws of motion and gravitation. Also, you will discover the calculation of pressure drops in a standpipe and a stairwell, as well as learn about viscosity, buoyancy, and turbulence in fires.

References

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

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

IFSTA. (1998). *Essentials of firefighting* (4th ed.). Stillwater, OK: Oklahoma State University Fire Protection Publications.

Merriam-Webster (n.d.). *Combustion*. Retrieved from http://www.merriam-webster.com/dictionary/combustion

Padgett, K. (2012, May). *Live-fire training in acquired structures: Everything you need to know about conducting safe live-fire training in acquired structures*. Retrieved from http://www.firefighternation.com/article/training-0/live-fire-training-acquired-structures.

Suggested Reading

Flammability box - Fuel lean combustion 1 - YouTube
https://www.youtube.com/watch?v=LkBrb3uAwnw
May 7, 2013

Learning Activities (Non-Graded)

Reflection Paper

For this activity, you are asked to prepare a reflection paper. Reflect on the concepts you have learned during your readings. What do you understand completely? What did not quite make sense? The purpose of this assignment is to provide you with the opportunity to reflect on the material you have read and to expand on it. If you are unclear about a concept, either review it in the textbook or ask your professor. Can you apply what you have learned to your career? How?

This is not a summary. A reflection paper is an opportunity for you to express your thoughts about the material you are studying by writing about it. Reflection writing is a great way to study because it gives you a chance to process what you have learned and increases your ability to remember it.

Use these guidelines as you reflect on the course material:

- What are your thoughts about the main topics?
- Why are these concepts important?
- How do they apply to your career or future career?
- Can you apply them to your professional life? How?

Write at least two pages, using APA style. This is a nongraded activity, so you do not have to submit it. If you have any difficulties with the unit content, contact your instructor for additional explanation and discussion.

Review What You Have Learned

The Challenging Questions at the end of Chapter 3, on page 46, will help you evaluate gases, liquids and solids related to heat.

Review What You Have Learned

The Challenging Questions at the end of Chapter 4, on page 75, will help you evaluate Newton's three laws of motion. In addition, the viscous effects play an important role in water flow through pipes in fire control systems. As you formulate an answer for each question, ask yourself how you can apply this information to your current job in the fire service.

These are a 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.