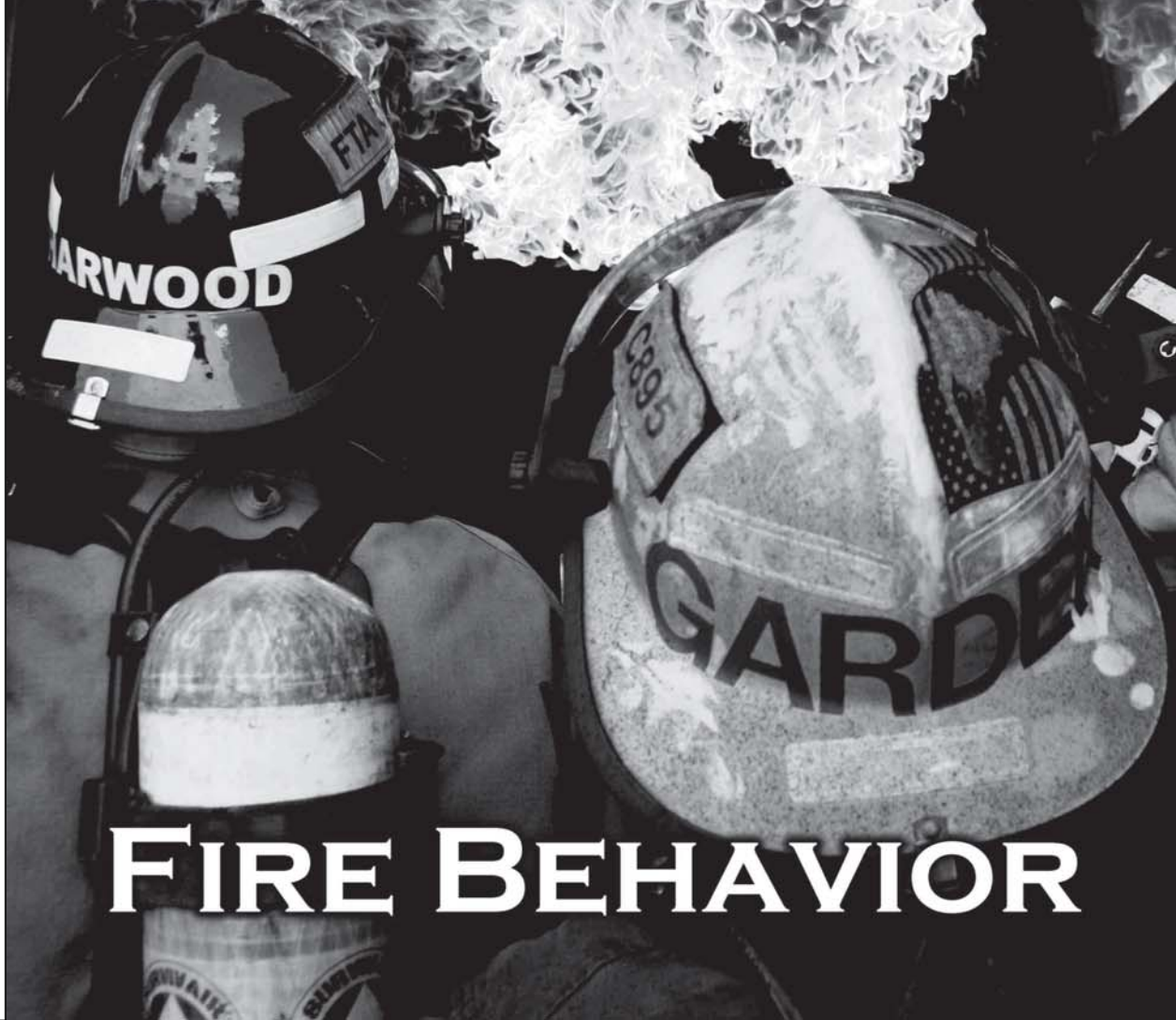




Missouri Division of Fire Safety
FIRE FIGHTER I & II



FIRE BEHAVIOR



UNIT OBJECTIVES

Upon completion of this unit of study, the student should be able to:

1. Identify the components of the fire triangle and the fire tetrahedron.
2. Know the three physical stages of fuels.
3. Define the different temperature values assigned to the different characteristics of fuels.
4. Identify the different sources of heat energy.
5. Identify the classes of fire.
6. Explain how heat is transferred.
7. Explain how the amount of oxygen can affect a fire.
8. Explain the phases through which a fire progresses and the conditions which may develop in those phases.
9. Understand how thermal layering occurs in a structure fire and why disturbing this layering of heat should be avoided.
10. Explain how finely divided fuels can create additional fire hazards.
11. Explain the different methods of fire extinguishment.



NFPA STANDARDS

Successful completion of the information in this section is necessary to fulfill the requirements of the following sections of NFPA 1001-2008:

Fire Fighter I Standard

5.3.8* Extinguish fires in exterior Class A materials, given fires in stacked or piled and small unattached structures or storage containers that can be fought from the exterior, attack lines, hand tools and master stream devices, and an assignment, so that exposures are protected, the spread of fire is stopped, collapse hazards are avoided, water application is effective, the fire is extinguished, and signs of the origin area(s) and arson are preserved.

(A) Requisite Knowledge. Types of attack lines and water streams appropriate for attacking stacked, piled materials and outdoor fires; dangers — such as collapse — associated with stacked and piled materials; various extinguishing agents and their effect on different material configurations; tools and methods to use in breaking up various types of materials; the difficulties related to complete extinguishment of stacked and piled materials; water application methods for exposure protection and fire extinguishment; dangers such as exposure to toxic or hazardous materials associated with storage building and container fires; obvious signs of origin and cause; and techniques for the preservation of fire cause evidence.

(B) Requisite Skills. The ability to recognize inherent hazards related to the material's configuration, operate handlines or master streams, break up material using hand tools and water streams, evaluate for complete extinguishment, operate hose lines and other water application devices, evaluate and modify water application for maximum penetration, search for and expose hidden fires, assess patterns for origin determination, and evaluate for complete extinguishment.

5.3.10* Attack an interior structure fire operating as a member of a team, given an attack line, ladders when needed, personal protective equipment, tools, and an assignment, so that team integrity is maintained, the attack line is deployed for advancement, ladders are correctly placed when used, access is gained into the fire area, effective water application practices are used, the fire is approached correctly, attack techniques facilitate suppression given the level of the fire, hidden fires are located and controlled, the correct body posture is maintained, hazards are recognized and managed, and the fire is brought under control.

(A) Requisite Knowledge. Principles of fire streams; types, design, operation, nozzle pressure effects, and flow capabilities of nozzles; precautions to be followed when advancing hose lines to a fire; observable results that a fire stream has been properly applied; dangerous building conditions created by fire; principles of exposure protection;



NFPA STANDARDS

potential long-term consequences of exposure to products of combustion; physical states of matter in which fuels are found; common types of accidents or injuries and their causes; and the application of each size and type of attack line, the role of the backup team in fire attack situations, attack and control techniques for grade level and above and below grade levels, and exposing hidden fires.

(B) Requisite Skills. The ability to prevent water hammers when shutting down nozzles; open, close, and adjust nozzle flow and patterns; apply water using direct, indirect, and combination attacks; advance charged and uncharged 38 mm (1½ in.) diameter or larger hose lines up ladders and up and down interior and exterior stairways; extend hose lines; replace burst hose sections; operate charged hose lines of 38 mm (1 in.) diameter or larger while secured to a ground ladder; couple and uncouple various handline connections; carry hose; attack fires at grade level and above and below grade levels; and locate and suppress interior wall and subfloor fires.

5.3.11 Perform horizontal ventilation on a structure operating as part of a team, given an assignment, personal protective equipment, ventilation tools, equipment, and ladders, so that the ventilation openings are free of obstructions, tools are used as designed, ladders are correctly placed, ventilation devices are correctly placed, and the structure is cleared of smoke.

(A) Requisite Knowledge. The principles, advantages, limitations, and effects of horizontal, mechanical, and hydraulic ventilation; safety considerations when venting a structure; fire behavior in a structure; the products of combustion found in a structure fire; the signs, causes, effects, and prevention of backdrafts; and the relationship of oxygen concentration to life safety and fire growth.

(B) Requisite Skills. The ability to transport and operate ventilation tools and equipment and ladders, and to use safe procedures for breaking window and door glass and removing obstructions.

5.3.12 Perform vertical ventilation on a structure as part of a team, given an assignment, personal protective equipment, ground and roof ladders, and tools, so that ladders are positioned for ventilation, a specified opening is created, all ventilation barriers are removed, structural integrity is not compromised, products of combustion are released from the structure, and the team retreats from the area when ventilation is accomplished.

(A) Requisite Knowledge. The methods of heat transfer; the principles of thermal layering within a structure on fire; the techniques and safety precautions for venting flat roofs, pitched roofs, and basements; basic indicators of potential collapse or roof failure; the effects of construction type and elapsed time under fire conditions on structural integrity; and the advantages and disadvantages of vertical and trench/strip ventilation.



NFPA STANDARDS

(B) Requisite Skills. The ability to transport and operate ventilation tools and equipment; hoist ventilation tools to a roof; cut roofing and flooring materials to vent flat roofs, pitched roofs, and basements; sound a roof for integrity; clear an opening with hand tools; select, carry, deploy, and secure ground ladders for ventilation activities; deploy roof ladders on pitched roofs while secured to a ground ladder; and carry ventilation-related tools and equipment while ascending and descending ladders.

5.3.16* Extinguish incipient Class A, Class B, and Class C fires, given a selection of portable fire extinguishers, so that the correct extinguisher is chosen, the fire is completely extinguished, and correct extinguisher-handling techniques are followed.

(A) Requisite Knowledge. The classifications of fire; the types of, rating systems for, and risks associated with each class of fire; and the operating methods of and limitations of portable extinguishers.

(B) Requisite Skills. The ability to operate portable fire extinguishers, approach fire with portable fire extinguishers, select an appropriate extinguisher based on the size and type of fire, and safely carry portable fire extinguishers.



NOTES	STUDENT GUIDE
	<p>I. Understanding Fire Behavior (<i>Essentials p. 85</i>)</p> <p>A. To be effective when combating fires, fire fighters must understand:</p> <ol style="list-style-type: none">1. The process of combustion2. How fire reacts in different materials in different environments3. How fires are classified4. What extinguishing agents are needed for different types of fires5. Developing conditions which can lead to extreme fire conditions which can trap and kill fire fighters <p>B. Fire fighters must be able to read a fire, recognize what is happening and predict potential fire behavior</p> <p>II. The Science of Fire Behavior (<i>Essentials p. 86</i>)</p> <p>A. All fires involve a heat-producing chemical reaction between some type of fuel and oxygen or a similar substance</p> <ol style="list-style-type: none">1.2. Oxidation can be slow, such as oxygen combining with iron to form rust3. Oxidation can be instantaneous such as an explosion of a fuel gas



NOTES	STUDENT GUIDE
	<ul style="list-style-type: none">4. Kinetic energy is produced by the release of a fuel's potential energy during combustion<ul style="list-style-type: none">a.b. Fire is an exothermic reaction that releases energy as heat and lightc.d. Converting liquid water to steam is an endothermic reactionB. Combustion modes<ul style="list-style-type: none">1. Combustion: rapid and self-sustaining chemical process yielding heat and usually light2. Flaming combustion involves fuel being oxidized in the gas phase<ul style="list-style-type: none">a. Solid and liquid fuels are heated to produce vapors which then mix with oxygen to burn3. Some solid fuels can oxidize at the surface<ul style="list-style-type: none">a. Non-flaming or smoldering combustionb. Burning charcoal or smoldering fabricC. The fire triangle<ul style="list-style-type: none">1.2. Provides an explanation of non-flaming or smoldering combustion



NOTES	STUDENT GUIDE
	<p>D. The fire tetrahedron</p> <ol style="list-style-type: none">1. Accurately explains flaming combustion2. Represents elements necessary for combustion to occur<ol style="list-style-type: none">a.b.c.d. <p>E. Heat: the form of energy that raises temperature</p> <ol style="list-style-type: none">1. Energy is the capacity to do work<ol style="list-style-type: none">a. Potential energy: energy possess by an object that may be releasedb. Kinetic energy: energy possess by a moving objectc. When a fuel burns, kinetic energy is released as heat and light2. Temperature: measurement of kinetic (heat) energy intensity<ol style="list-style-type: none">a. Heat energy will move from higher temperature objects to those of lower temperatureb. British Thermal Unit (BTU)<ol style="list-style-type: none">(1) Unit for heat measurement



NOTES	STUDENT GUIDE
	<ul style="list-style-type: none">(2)c. In engineering and scientific work, temperature is measured in "joules"d. Temperature may be measured using different scales<ul style="list-style-type: none">(1) Fahrenheit scale<ul style="list-style-type: none">(a) 32°F: freezing temperature of water(b) 212°F: boiling temperature of water(2) Celsius scale<ul style="list-style-type: none">(a) 0°C: freezing temperature of water(b) 100°C: boiling temperature of watere. When a fuel is heated, its temperature increases<ul style="list-style-type: none">(1) Additional heat causes pyrolysis (chemical decomposition of a substance from heat) in a solid fuel(2) Additional heat causes vaporization of liquid fuels <p>3. Ignition of fuels</p> <ul style="list-style-type: none">a. Piloted ignition: occurs when an external heat source starts combustion in the fuel and oxygen mixture



NOTES	STUDENT GUIDE
	<ul style="list-style-type: none">b.<ul style="list-style-type: none">(1) Autoignition temperature:<ul style="list-style-type: none">(2) The fuel is chemically heated to where combustion starts(3) A fuel's autoignition temperature is always higher than its piloted ignition temperature4. Sources of heat energy<ul style="list-style-type: none">a. Chemical heat energy:<ul style="list-style-type: none">(1) Heat of combustion(2) Self-heating or spontaneous heating<ul style="list-style-type: none">(a) When a material's temperature increases without external heat(b) Produced slowly through oxidation(c) Heat production must be enough to raise the material's temperature to its ignition temperature(d) The air supply around the material must be enough to support combustion(3) Heat of decomposition: as organic materials decompose, heat is released



NOTES	STUDENT GUIDE
	<ul style="list-style-type: none">(4) Heat of solution: heat released when a substance is dissolved in a liquidb. Electrical heat energy can be produced by:<ul style="list-style-type: none">(1) Resistance heating:<ul style="list-style-type: none">(2) Overcurrent or overload: when current exceeds the design limits of a conductor(3) Dielectric heating: result of a pulsating current on nonconductive materials, such as in a microwave oven(4) Arcing: high temperature electric discharge across a gap or through a medium, can range between 2000° and 7000°F<ul style="list-style-type: none">(a) Static electricity(b) Lightning(5) Sparking: when arcing occurs and particles spatter away from the arcingc. Mechanical heat energy<ul style="list-style-type: none">(1) Friction: as objects move against each other and generate heat(2) Heat of compression: occurs when gases are compressed (diesel engines)d. Nuclear heat energy: generated by atoms splitting apart or combining



NOTES	STUDENT GUIDE
	<ul style="list-style-type: none">e. Solar heat energy: heat generated by the sun <p>5. Heat transfer</p> <ul style="list-style-type: none">a. The transfer of heat between fuels determines the growth of a fireb. Heat moves from warmer objects to cooler objects depending on the temperature difference and the conductivity of the materialsc. Conduction<ul style="list-style-type: none">(1)(2) Occurs when materials are in contact with a heat source(3) Depends on the area being heated, the temperature difference between the heat source and the material heated, and the thermal conductivity of the materials(4) Insulating materials slow the point-to-point transfer of heat energyd. Convection<ul style="list-style-type: none">(1)(2) Hot air and combustion by-products become buoyant and rise



NOTES	STUDENT GUIDE
	<ul style="list-style-type: none">e. Radiation<ul style="list-style-type: none">(1)(2) Responsible for most fire development and spread(3) Radiation is the cause of most exposure fires and cause damage some distance away(4) Radiant heat energy increases dramatically as the heat source increases(5) Doubling the heat source temperature increases radiant 16 times(6) Radiant heat energy can travel through vacuums and air spaces that would decrease conduction and convection heat transferf.6. Passive agents absorb heat and do not take part in combustion<ul style="list-style-type: none">a. Fuel moisture slows heat absorption and thus slows ignition and burningb. The role these passive agents helps explain how some fires develop and progressF. Fuel<ul style="list-style-type: none">1. The material being oxidized or burned in the combustion process



NOTES	STUDENT GUIDE
	<ul style="list-style-type: none">a.b. Most common fuels are organic and contain carbon<ul style="list-style-type: none">(1) Hydrocarbon-based fuels, such as petroleum products and plastics(2) Cellulose-based fuels, such as wood and paperc. Fuel combustion is influenced by the fuel's physical state and its distributiond. <p>2. Physical states of fuel</p> <ul style="list-style-type: none">a. Gaseous fuel<ul style="list-style-type: none">(1) Most dangerous because already in the state which can ignite(2) Have mass but no shape or volume(3) Vapor density<ul style="list-style-type: none">(a)(b) A vapor density of greater than one indicates the vapor will settle below air(4) Examples<ul style="list-style-type: none">(a) Methane (natural gas): vapor density = 0.55



NOTES	STUDENT GUIDE
	<p>(b) Propane (LPG): vapor density = 1.52</p> <p>(c) Carbon monoxide: vapor density = 0.96</p> <p>b. Liquid fuel</p> <p>(1) Have mass and volume but no shape except for the shape of the container in which contained</p> <p>(2) Uncontained, liquids flow downhill and can pool in low areas</p> <p>(3) Specific gravity</p> <p>(a)</p> <p>(b) A specific gravity of less than one indicates the material will float on water</p> <p>Gasoline: specific gravity = 0.72</p> <p>(c) Using water to fight a fire involving liquids lighter than water can spread the burning fuel</p> <p>(d) A specific gravity of greater than one indicates the material will sink on water</p> <p>Mercury: specific gravity = 13.56</p> <p>(4) Liquid fuels must be vaporized in order to burn</p> <p>(a) To vaporize, liquid must overcome atmospheric pressure</p>



NOTES	STUDENT GUIDE
	<p>(b) When heated, vapor pressure and the vaporization rate increases</p> <p>(c) Vaporization rate is determined by a fuel's vapor pressure and the heat applied to it</p> <p>(5) Flash point</p> <p>(a)</p> <p>(b) Typically used to indicate a liquid's flammability hazard</p> <p>(c) Flash points</p> <p>Gasoline = -40°F</p> <p>Diesel = 143°F</p> <p>Ethanol = 55°F</p> <p>Vegetable oil = 620°F</p> <p>(6) Fire point</p> <p>(a) The temperature at which a liquid fuel produces sufficient vapors to support continuous burning once ignited</p> <p>(b) Usually a few degrees above the flash point</p>



NOTES	STUDENT GUIDE
	<p>(7) Boiling point</p> <ul style="list-style-type: none">(a)(b) The temperature where a liquid turns into a gas at a given pressure <p>(8) A liquid's surface area will influence the amount of vapors produced</p> <p>(9) Solubility</p> <ul style="list-style-type: none">(a) Describes how a liquid will mix with water(b) "Polar solvents," such as alcohol, mix readily with water(c) Fires involving polar solvents can make water-based extinguishing agents ineffective as they mix with the burning liquid <p>c. Solid fuels</p> <ul style="list-style-type: none">(1) Have definite size and shape(2) When heated, solid fuels decompose and create combustible gases which ignite with sufficient oxygen (pyrolysis)<ul style="list-style-type: none">(a) Water vapor is first driven off as wood is heated(b) With continued heating, pyrolysis begins at around 400°F and combustible vapors are produced



NOTES	STUDENT GUIDE
	<ul style="list-style-type: none">(c) The vapors ignite when temperatures reach between 1,000°F and 1,300°F(3) Size and shape of fuel particles influence ease of ignition and rate of burning<ul style="list-style-type: none">(a) Surface-to-mass ratio: surface area of the fuel in proportion to its mass(b)(c) More of the fuel is exposed as the surface area increases(d) Dusts from solids and mists from liquids pose possible explosive hazard(4) The proximity and orientation to a heat source will affect the ignition of the fuel<ul style="list-style-type: none">(a) A vertical solid fuel will burn more rapidly than a fuel laying horizontallyc. The chemical content of a fuel influences its heat of combustion and heat release rate<ul style="list-style-type: none">(1) Heat of combustion is the amount of energy released when a fuel burns<ul style="list-style-type: none">(a) When plastics and synthetics burn more heat energy is produced than when wood burns(2) Heat release rate is the energy released per unit of time when a fuel burns<ul style="list-style-type: none">(a) Depends on the type, quantity, and orientation of the fuel



NOTES	STUDENT GUIDE
	<p style="text-align: center;">(b) Increases as more fuel is involved in fire</p> <p>G. Oxygen (oxidizing agent) (<i>Essentials p. 103</i>)</p> <ol style="list-style-type: none"> 1. In addition to oxygen, other materials (oxidizers) can release oxygen to support combustion 2. <ol style="list-style-type: none"> a. Materials can ignite and burn in as low as 14% oxygen atmospheres b. Surface combustion and smoldering can continue at very low oxygen levels 3. <ol style="list-style-type: none"> a. Increased oxygen supply will accelerate combustion making a fire burn more intensely b. Some materials may burn only in oxygen enriched atmospheres c. Fires in oxygen enriched atmospheres are more difficult to extinguish 4. Fuel vapors must be mixed with air (oxygen) in the proper ratios in order to burn <ol style="list-style-type: none"> a. Flammable limits/range - b. Most substances have a lower and upper flammable limit <ol style="list-style-type: none"> (1) Below the lower flammable limit, the fuel vapor concentration will not support combustion - "too lean"



NOTES	STUDENT GUIDE
	<p>(2) Above the upper flammable limit, the fuel vapor concentration is too great and not enough oxygen is present to support combustion - "too rich"</p> <p>c. Flammable ranges can vary depending on the ambient temperature and atmospheric pressure</p> <p>H. Self-sustained chemical reaction (<i>Essentials p. 105</i>)</p> <ol style="list-style-type: none">1. As a fuel burns, fuel and oxygen molecules break apart and form free radicals<ol style="list-style-type: none">a. Free radicals are electrically charged, reactive parts of moleculesb. Free radicals combine with oxygen producing new combustion products and increase the speed of the oxidation reaction2. Certain extinguishing agents inhibit the chemical chain reaction to form a stable substance and stop combustion3. Separates fire from slower oxidation reactions such as rust<ol style="list-style-type: none">a. Slow oxidation reactions do not produce heat fast enough to reach ignition or become self-sustaining4. Surface or smoldering combustion involves oxidation at the fuel's surface without the chemical chain reaction found with flaming combustion



NOTES	STUDENT GUIDE
	<p>I. Products of combustion (<i>Essentials p. 107</i>)</p> <ol style="list-style-type: none">1. As multiple fuels burn in structure fires, complex chemical reactions occur resulting in numerous combustion products2. Heat: product of combustion responsible for fire spread3. Toxic smoke:<ol style="list-style-type: none">a. Contents of smoke vary depending on what is burningb. Mixture of gases, vapor, carbon particles (soot), and other products generated by the burning materialsc. Fire gases<ol style="list-style-type: none">(1) Carbon monoxide (CO)<ol style="list-style-type: none">(a)(b) By-product of incomplete combustion of carbon-based fuels(c) CO is a flammable, colorless, tasteless and odorless gas which is toxic even in small quantities(d) Exposure to CO decreases the ability of the blood to carry oxygen to the tissues(e) The more CO in the air and the longer the exposure, the greater the danger



NOTES	STUDENT GUIDE
	<ul style="list-style-type: none">(f) Higher concentrations may be rapidly fatal without producing significant warning symptoms(g) Has a wider flammable range and lower ignition temperature than methane or propane(h) CO will remain for a time after fire extinguishment <p>(2) Carbon dioxide</p> <ul style="list-style-type: none">(a)(b) Acts as an asphyxiant by displacing oxygen and as a stimulant, increasing respirations <p>(3) Hydrogen cyanide (HCN)</p> <ul style="list-style-type: none">(a) Produced by the burning of wool, silk, nylon, polyurethane, and products containing nitrogen(b) A chemical asphyxiant which prevents the body from using oxygen at the cellular level <p>(4) Hydrogen chloride</p> <ul style="list-style-type: none">(a) Produced by the burning of polyvinyl chloride, building materials, and furnishings(b) Mixes with water to form hydrochloric acid and corrosive to human tissue



NOTES	STUDENT GUIDE
	<p>(5) Sulfur dioxide: toxic and corrosive</p> <p>(6) Hydrogen sulfide: produced by the burning of rubber, wool, silk, and some synthetic materials</p> <p>(7) Formaldehyde: severe respiratory irritant</p> <p>(8) Depending on the materials burning, any variety of other gases may be produced</p> <p>d. Smoke contains particulates which can be inhaled into the trachea and lungs and cause eye irritation and respiratory distress</p> <p>J. Classes of fires (<i>Essentials p. 110</i>)</p> <ol style="list-style-type: none">1. Fires are classified by the type of fuel involved which determines what is needed for extinguishment2. Class A<ol style="list-style-type: none">a.b. Cooling is the normal extinguishment method3. Class B<ol style="list-style-type: none">a.b. Oxygen exclusion, cooling, fuel removal, and chemical flame inhibition used for extinguishment4. Class C<ol style="list-style-type: none">a.



NOTES	STUDENT GUIDE
	<ul style="list-style-type: none">b. Opening electrical circuit safest extinguishing methodc. If necessary to extinguish before de-energizing, a nonconductive extinguishing agent must be used <p>4. Class D</p> <ul style="list-style-type: none">a.<ul style="list-style-type: none">(1) Aluminum(2) Magnesium(3) Potassium(4) Sodium(5) Airborne metal dusts can be an explosion hazard(6) Found in some industrial and storage facilitiesb. Special extinguishing agents are normally required for specific fuels<ul style="list-style-type: none">(1) No single agent is effective on all types of metals(2) React violently when water is applied <p>5. Class K</p> <ul style="list-style-type: none">a.



NOTES	STUDENT GUIDE
	<p>b. Require a special extinguishing agent which turns the burning oils into a soapy foam</p> <p>III. Fire Development in Compartments (<i>Essentials p. 112</i>)</p> <p>A. Fires develop significantly differently in compartments (enclosed spaces) than in an unconfined area where heat is dissipated into the atmosphere</p> <ol style="list-style-type: none">1. In a compartment, radiant heat is not only absorbed by the compartment and contents but is also reflected causing a temperature increase2. Hot smoke and gases rise and further heat upper areas of the compartment3. As other fuels are heated, more flammable vapors are produced and the fire extends4. If enough oxygen is available, fire development is controlled by the characteristics and configuration of the fuel (fuel controlled)5. Fire development often reaches the point where it is limited by the available air (ventilation controlled) <p>B. Compartment fires develop in a series of stages</p> <ol style="list-style-type: none">1. The changes between the stages are not clearly separated in an actual fire situation and there are numerous variables involved2. Not every fire develops through each of the stages



NOTES	STUDENT GUIDE
	<ul style="list-style-type: none">3. Incipient stage<ul style="list-style-type: none">a. Begins with ignition when the three elements of the fire triangle come together and combustion begins<ul style="list-style-type: none">(1) The fire is usually small and confined to the fuel ignited and may be self-extinguished(2)b. Development depends on the characteristics and configuration of the fuel<ul style="list-style-type: none">(1) Radiant heat warms adjacent fuels(2) A plume of hot gases and flame rises(3) Hot gases spread horizontally as the plume reaches the ceiling<ul style="list-style-type: none">(a) Fire fighters refer this as "mushrooming"(b) Scientists refer to it as a "ceiling jet"(4) Heat transfer begins to increase the room's overall temperaturec. Occupants can easily escape during the incipient staged. Transition to the growth stage can happen very quickly4. Growth stage<ul style="list-style-type: none">a.



NOTES	STUDENT GUIDE
	<ul style="list-style-type: none">b. Characterized by rapidly increasing heatc. Fire begins to influence the compartment's environment as it progresses to the growth staged. As the fire plume develops, it draws air from the surrounding space into the columne. The compartment design and ventilation influences the firef. The walls and ceiling of the compartment affect the fire plume by controlling the amount of air and increasing the depth of the hot gas layer createdg. The growth stage will continue if enough fuel and oxygen are availableh. Thermal layering established<ul style="list-style-type: none">(1) Also referred to as "heat stratification" and "thermal balance"(2)(3) Hottest gases tend to accumulate at upper layers and mushroom horizontally(4) Radiation from the hot gas layer heats the surfaces of the compartment and its contents(5) Higher pressure in this hot layer pushes downward and out through any openings<ul style="list-style-type: none">(a) Lower pressure in cooler layers draws air in from outside of the compartment



NOTES	STUDENT GUIDE
	<ul style="list-style-type: none">(b) Where the hot and cooler gases meet, the pressure is neutral (neutral plane)(c) The neutral plane exists at opening where hot gas exits and cooler gas enters(6)(7) Poor visibility and possible burn injuries can result from disrupting the thermal balancei. Flames may be seen moving in the hot gas layer above the neutral plane<ul style="list-style-type: none">(1) Burning of these gases indicates they are within their flammable range(2) Classified as fire gas ignition(3)j. Rollover/flameover is a condition where fire gases at a compartment's top ignite and flames roll across the ceiling<ul style="list-style-type: none">(1)(2) Involves only the upper layer of fire gases(3) Generally precedes flashover but may not result in flashover



NOTES	STUDENT GUIDE
	<ul style="list-style-type: none">(4) Fire fighter must immediately take action to possibly delay flashover and exit the area as quickly as possible(5) Most fire fighters who claim to have survived a flashover were actually exposed only to rollover <p>k. Flashover</p> <ul style="list-style-type: none">(1) Flashover is the transition between the growth and fully developed fire stages and is not a specific event such as ignition(2)(3) As the fire burns, the hot gases at the ceiling level cause radiant heating of the combustible materials(4) In order for flashover to occur:<ul style="list-style-type: none">(a) The fuel must have enough heat energy to develop flashover conditions(b) Sufficient oxygen must be present to reach flashover(5) Just before flashover:<ul style="list-style-type: none">(a) Temperatures rapidly increase(b) Additional fuels are becoming involved(c) Fuels are giving off combustible gases due to pyrolysis



NOTES	STUDENT GUIDE
	<p>(6) Temperatures generated during flashover can exceed 1500°F</p> <p>(7)</p> <p>Structural fire fighting protective clothing and SCBA will be destroyed by flashover</p> <p>(8) Flashover develops rapidly with little warning</p> <p>(a) Research has shown that time to flash-over from open flame can be as short as 1.5 minutes in residential fire tests or it may never occur</p> <p>(b)</p> <p>(9) Fire fighters' exposure to flashover has increased in recent times due to:</p> <p>(a) Better protective equipment</p> <p>(b) Faster notification of fires</p> <p>(c) Better insulation in structures causing heat retention</p> <p>(d) More combustible furnishings</p> <p>(10) Signs of potential flashover:</p> <p>(a) Rapid heat buildup</p> <p>(b)</p> <p>(c)</p>



NOTES	STUDENT GUIDE
	<p>(d)</p> <p>(e) Significant bidirectional airflow (air in - smoke out)</p> <p>(11) Flashover survival techniques:</p> <p>(a) Pay attention to the fire and recognize the warning signs</p> <p>(b) Avoid disorientation</p> <p>(c) Remain calm and think</p> <p>(d) Full protective equipment</p> <p>(e) Know the "point of no return"</p> <p>(i) A fire fighter can travel 2.5 feet a second without a hose and has about two seconds to exit an area when flashover occurs</p> <p>(ii) Escape is possible if within 5 feet from an exit</p> <p>(12) If flashover does occur:</p> <p>(a)</p> <p>(b)</p> <p>(c)</p> <p>5. Fully developed stage</p> <p>a. The fully developed stage occurs when all combustible materials in a compartment are involved in fire</p>



NOTES	STUDENT GUIDE
	<ul style="list-style-type: none">b. The burning fuels are releasing the maximum amount of heat possiblec. The fire may become ventilation controlled and large amounts of unburned gases may be producedd. Hot, unburned gases flow into adjacent spaces and ignite as they enter an area where there is more air <p>6.</p> <ul style="list-style-type: none">a. As the available fuels are consumed, the rate of heat release begins to declineb.c. The remaining glowing embers can result in moderately high temperatures for some timed. Possibility of backdraft or smoke explosion<ul style="list-style-type: none">(1) As a fire burns, large amounts of hot, unburned gases can collect in unvented areas without enough oxygen to ignite(2)(3) The more the fuel/air mixture is confined, the more violent a backdraft will be



NOTES	STUDENT GUIDE
	<ul style="list-style-type: none">(4) Backdraft potential can be reduced by ventilating the building at the highest possible point to allow the gases to escape before entering an area(5) Fire burning above the hot gas layer may develop backdraft conditions at the upper levels of a compartment(6) Backdraft indicators<ul style="list-style-type: none">(a) Smoke under pressure(b)(c) Fire confinement and excessive heat(d) Little or no visible flame(e)(f) Smoke-stained windows(g) Muffled sounds(h) Inwardly drawn smoke (sucking phenomenon)(i) Sudden inrush of air when opening is made(7) Backdraft effects vary depending on:<ul style="list-style-type: none">(a) Volume of flammable products of combustion(b) Confinement



NOTES	STUDENT GUIDE
	<p>(c) Where ignition occurs</p> <p>(d) Speed of air and fuel mixing</p> <p>C. Factors affecting fire development in compartments</p> <ol style="list-style-type: none">1. Fuel type<ol style="list-style-type: none">a.b. Mass and surface area affect fire development of the fuelc. Fire fighters should be alert to how different fuels affect fire growth2. Location and availability of addition fuels<ol style="list-style-type: none">a. Building layout determines the proximity of additional fuels<ol style="list-style-type: none">(1) Large, open building areas can provide exposure to additional fuels(2) High fire loads can be minimized by separating fuel in compartmentsb. The quantity and combustibility of the fuel present can rise the potential for fire spreadc. The combustibility of the building's construction is significant to fire spreadd.



NOTES	STUDENT GUIDE
	<ul style="list-style-type: none">3. Compartment size and height<ul style="list-style-type: none">a. Typically a fire in a large compartment develops slower than in a small compartmentb. A high ceiling can allow a large amount of smoke and gases to accumulate while lower fire conditions are less4. Ventilation<ul style="list-style-type: none">a. Greatly impacts fire development and spreadb. Fire personnel must always consider potential opening that can change fire ventilationc. If windows break or are opened, the increased ventilation will draw fire into uninvolved areas5. Compartment's thermal properties<ul style="list-style-type: none">a. Insulation increases the heat retained inside a compartment and speeds burningb. Surfaces that reflect heat also increase the speed of burningc. The greater the conductivity of the area's surface, the faster fire spread will be6. Ambient conditions<ul style="list-style-type: none">a. High humidity and cold temperatures hamper smoke movementb. High winds greatly can change fire behavior



NOTES	STUDENT GUIDE
	<p>7. Changing conditions</p> <ul style="list-style-type: none">a. Tactical operations will change fire behavior both negatively and positivelyb. As the building itself changes from burning, the fire development will change<ul style="list-style-type: none">(1) Windows breaking and roof consumption(2) Fire burning through walls exposing more fuel <p>IV. Fire Control Methods (<i>Essentials p. 130</i>)</p> <ul style="list-style-type: none">A. Any type of fire control involves removing one or more of the elements of the fire tetrahedronB. Temperature reduction<ul style="list-style-type: none">1.2. Cooling with water will not reduce vapor production in low flash point flammable liquids enough to stop burning3. Water can be used by control burning gases and reduce the temperature of hot combustion by-products4. Reduces the potential for flashover



NOTES	STUDENT GUIDE
	<p>C.</p> <ol style="list-style-type: none">1. The simplest fuel removal method is to allow a fire to burn until the fuel is consumed<ol style="list-style-type: none">a. Frequently used with fires involving pesticides or other hazardous materialsb. Used to prevent further environment damage through runoff2. Can be done by shutting off the fuel flow with flammable gases or liquids <p>D.</p> <ol style="list-style-type: none">1. Flooding an area with a gas such carbon dioxide to displace oxygen to stop combustion2. <p>E.</p> <ol style="list-style-type: none">1. Some extinguishing agents interrupt the combustion reaction and stop flame production<ol style="list-style-type: none">a. Dry chemicalsb. Halogenated agents, such as Halon and Haltron2. These agents are usually effective for gas and liquid fuels



NOTES	STUDENT GUIDE
	<p>V. Fire Behavior Summary</p> <ul style="list-style-type: none">A. It is vital that fire fighters understand fire behavior for their own safety and proper extinguishment techniquesB. Many fire fighters have been injured and killed because they let their guard down and did not heed the warning signs that indicated a deadly change in a fire's behaviorC. Only through proper interpretation of why a fire is burning in a particular fashion, what is burning, where the fire is burning, and how the fire will react can fire fighters be successful in their battle against it