



Fire Protection Training

Procedures Handbook 4300

FIRE PHYSICS & CHEMISTRY

TOPIC: Physical Properties of Flammable and Combustible Liquids

TIME FRAME: 4 Hours

LEVEL OF INSTRUCTION:

BEHAVIORAL OBJECTIVE:

Condition: A written quiz

Behavior: Student will be able to describe how the properties of flammable and combustible liquids determine the relative hazards of the substance. Describe the NFPA divisions and subdivisions of flammable and combustible liquids. Describe how water and Class B extinguishing agents accomplish extinguishment of Class B fires

Standard: With a minimum of 70% accuracy

MATERIALS NEEDED:

- Chalkboard
- Audio visual equipment and transparencies
- Information sheet
- Glossary of terms

REFERENCES:

- NFPA No. 325M Fire Hazard Properties of Flammable Liquid Gases and Volatile Solids
- NFPA, Fire Protection Handbook, 17th Edition
- NFPA, Principals of Fire Protection Chemistry

PREPARATION: Flammable and combustible liquids are a part of our everyday lives. The potential for emergencies involving these materials is often underestimated; an underestimation that may lead to injury or death. The firefighter must have a basic understanding of the classification and properties of flammable and combustible liquids and gases to safely and effectively manage these types of incidents.



Fire Protection Training

Procedures Handbook 4300

PHYSICAL PROPERTIES OF
FLAMMABLE AND
COMBUSTIBLE LIQUIDS

PRESENTATION	APPLICATION
<p data-bbox="151 344 1000 485">I. FLAMMABLE AND COMBUSTIBLE LIQUIDS CAN PRESENT A SERIOUS FIRE HAZARD. THEY BURN RAPIDLY AND ARE SOMETIMES DIFFICULT TO EXTINGUISH.</p> <p data-bbox="228 810 781 842">A. Chemical and Physical Properties</p> <ol data-bbox="305 1020 764 1709" style="list-style-type: none"><li data-bbox="305 1020 537 1052">1. Flash point<li data-bbox="305 1089 516 1121">2. Fire point <li data-bbox="305 1335 667 1367">3. Ignition temperature<li data-bbox="305 1404 764 1436">4. Flammable/explosive limits<li data-bbox="305 1474 578 1505">5. Vapor density<li data-bbox="305 1543 558 1575">6. Boiling point<li data-bbox="305 1612 597 1644">7. Specific gravity<li data-bbox="305 1682 597 1713">8. Water solubility <p data-bbox="228 1749 1036 1885">B. The Relative Ease of Ignition of a Flammable or Combustible Liquid is Expressed as Its Flash Point. The Key is Flammable Vapors Will be Present if the Liquid is Warmer Than Its Flash Point Temperature.</p>	<p data-bbox="1143 527 1468 772">Initiate discussion among class regarding personal experience with incidents involving flammable/combustible liquid emergencies.</p> <p data-bbox="1143 884 1468 982">What is it that makes them so susceptible to fire?</p> <p data-bbox="1143 1157 1468 1297">This is due to certain chemical and physical properties they all possess.</p>



Fire Protection Training

Procedures Handbook 4300

PHYSICAL PROPERTIES OF
FLAMMABLE AND
COMBUSTIBLE LIQUIDS

PRESENTATION	APPLICATION
<ol style="list-style-type: none">1. Flash point is the lowest temperature at which a liquid fuel gives off sufficient vapors to form an ignitable vapor when mixed with air near the surface of the liquid2. At the flash point temperature, the ignited vapors will flash, but will not continue to burn when an external ignition source is present. If the temperature is below the flash point, the vapors cannot be ignited.3. Flash points can vary from below zero for gasoline to several hundred degrees above zero for vegetable oils.4. Determining flash points<ol style="list-style-type: none">a. The closed cup tester is recommended for determining flash points below 200oF (93oC), for other than viscous liquids, or film forming liquids.b. The liquid is placed into a test cup and submerged in water. The water is then heated slowly.c. Thermometers, one in the water and one in the liquid permit control of the heating rate.d. The test flame is periodically lowered into the vapor space of the test cup.e. When the liquid being tested first reaches a temperature where it is giving off vapors fast enough to create an ignitable mixture, there will be a visible flash as the test flame is introduced into the vapor space. The temperature, on the thermometer, in the liquid being tested is the flash point.	<p>What burns, the liquid or the vapor?</p>



Fire Protection Training

Procedures Handbook 4300

PHYSICAL PROPERTIES OF
FLAMMABLE AND
COMBUSTIBLE LIQUIDS

PRESENTATION	APPLICATION
<p>5. Flash point is used as the primary basis for classifying flammable and combustible liquids.</p> <p>6. A flammable gas (i.e. natural gas, etc.) has a flash point so low that it is not routinely measured or utilized.</p> <p>C. The Fire Point is Usually a Few Degrees Above the Flash Point.</p>	
<p>1. The temperature at which a liquid fuel will produce vapors sufficient to support combustion once ignited.</p> <p>D. Ignition Temperature, Sometimes Called Auto-Ignition Temperature or Spontaneous Ignition Temperature Is the Minimum Temperature to Which a Liquid Must be Heated to Ignite Without Introducing an External Ignition Source.</p>	<p>What is burning/fire point?</p>
<p>1. The usual method of testing for the ignition temperature of liquids is to submerge a flask into a molten metal bath. The molten metal is then heated, which in turn heats the liquid in the flask. The temperature of the liquid when fire spontaneously occurs in the vapors is the ignition temperature.</p> <p>2. There are many variables in the determination of ignition temperatures. Practical situations present different conditions than those found in a laboratory. Thus, a hot exhaust pipe, a pan, or a hot surface in the presence of unconfined</p>	<p>What is ignition temperature?</p> <p>Does anyone know how ignition temperatures are determined?</p>



Fire Protection Training

Procedures Handbook 4300

PHYSICAL PROPERTIES OF
FLAMMABLE AND
COMBUSTIBLE LIQUIDS

PRESENTATION	APPLICATION
<p>flammable vapors may yield different results than those determined by laboratory tests.</p> <p>E. Flammable Limits</p> <ol style="list-style-type: none">1. The minimum and maximum percentage of a substance in air that will burn once it is ignited.<ol style="list-style-type: none">a. Most substances have an upper (too rich) and a lower (too lean) flammable limit.2. Flammable or explosive limits are usually expressed in terms of % by volume of gas or vapor in air.3. As an example of flammable limits and flammable range, consider the gasoline engine.<ol style="list-style-type: none">a. For it to start there must be at least 1.4 parts of gasoline vapors mixed with 98.6 parts of air.<ol style="list-style-type: none">(1) Less than 1.4 parts of gasoline vapor in air would not burn and is called "too lean" a mixture.(2) This smallest concentration of vapor that can be ignited is the lower flammable limit.b. The upper flammable limit for gasoline is 7.6% or 7.6 parts of gasoline vapor mixed with 92.4 parts of air. Over this concentration of vapor, the mixture would be "too rich" to burn, or above the upper flammable limit.	<p>Are these temperatures exact?</p> <p>Can anyone define the term Flammable/explosive limits?</p>



Fire Protection Training

Procedures Handbook 4300

PHYSICAL PROPERTIES OF
FLAMMABLE AND
COMBUSTIBLE LIQUIDS

PRESENTATION	APPLICATION
<p>4. The rate of flame spread for flammable and combustible liquids is slow where the mixture is near the lower or upper flammable limits. However, when the vapor-air mixture is halfway between the lower and upper flammable limits, there is rapid combustion in the form of an explosion.</p> <p>5. The wider the flammable range of a liquid, the greater the chance for ignition and a fire.</p> <p>6. The narrow flammable/explosive range of gasoline explains why there are not more fires involving gasoline.</p> <p>F. Vapor Density</p> <p>1. The density of vapor in relation to air, with air given a density value of "1".</p> <p>2. If the vapor density of a product is less than one the vapor will rise into the atmosphere.</p> <p>3. If the vapor density is greater than one then the vapors will tend to hug the ground and travel as directed by the terrain.</p> <p>4. All flammable liquid vapors are heavier than air and have vapor densities greater than "1".</p> <p>5. When most flammable liquid vapors are within their flammable range, the vapor-air mixture</p>	<p>Briefly show the different flammable/explosive limits between acetone, ethyl-alcohol and gasoline.</p> <p>(i.e. 1.4% - 7.6%)</p> <p>What is vapor density?</p>



Fire Protection Training

Procedures Handbook 4300

PHYSICAL PROPERTIES OF
FLAMMABLE AND
COMBUSTIBLE LIQUIDS

PRESENTATION	APPLICATION
<p>will have close to the same density as air itself and will not sink.</p> <ul style="list-style-type: none">a. Because of this, flammable vapors will diffuse to the top of a tank, drum or room.b. This supports the importance of providing ventilation at floor level to prevent the accumulation of vapors within the flammable range. <p>G. Before We Can Thoroughly Understand Boiling Point We Must First Define Evaporation and Vapor Pressure.</p> <ul style="list-style-type: none">1. Evaporation<ul style="list-style-type: none">a. Because molecules of a liquid are always in motion (with the amount of motion depending on the temperature of the liquid) the molecules are continually escaping from the free surface of the liquid to the space above.b. If a liquid is in an open container , molecules (collectively called vapor) escape from the surface and the liquid is said to evaporate.2. Vapor Pressure<ul style="list-style-type: none">a. If the liquid is in a closed container, the motion of the escaping molecules are confined to a vapor space above the surface of the liquids.b. The pressure exerted by the escaping vapor is called vapor pressure. As the temperature of a liquid increases its vapor pressure increases.	<p>Can anyone define boiling point?</p>



Fire Protection Training

Procedures Handbook 4300

PHYSICAL PROPERTIES OF
FLAMMABLE AND
COMBUSTIBLE LIQUIDS

PRESENTATION	APPLICATION
<p data-bbox="303 327 561 363">3. Boiling Point</p> <ul style="list-style-type: none"><li data-bbox="380 468 1036 680">a. At the temperature which vapor pressure equals atmospheric pressure, the opposition to the liquid becoming a gas exerted by the atmosphere is neutralized and boiling takes place as bubbles of vapor form rapidly in the liquid itself.<li data-bbox="380 720 1040 825">b. The temperature at which vapor pressure equals atmospheric pressure is the "boiling point".<li data-bbox="380 863 1024 961">c. When the vapor pressure exceeds the external atmospheric pressure the liquid will boil.<li data-bbox="380 1104 1052 1745">d. Consider an uncovered pan of water heating on a stove.<ul style="list-style-type: none"><li data-bbox="456 1209 1036 1314">(1) At sea level it is being covered by a "lid" which weighs 14.7 PSI (atmospheric pressure).<li data-bbox="456 1352 1052 1497">(2) As the water is heated, its vapor pressure increases until it is equal to atmospheric pressure (14.7 PSI). This is the boiling point.<li data-bbox="456 1535 1029 1640">(3) As the vapor pressure exceeds the weight of the "lid" the lid is "pushed up" and the water boils.<li data-bbox="456 1677 1036 1745">(4) The lower a liquids boiling point the greater the liquids volatility. <p data-bbox="228 1776 1036 1843">H. Specific Gravity Is the Density of Liquids in Relation to Water, with Water Given the Value of "1".</p>	<p data-bbox="1143 396 1450 432">What is boiling point?</p> <p data-bbox="1143 999 1430 1066">Can anyone give an example?</p>



Fire Protection Training

Procedures Handbook 4300

PHYSICAL PROPERTIES OF
FLAMMABLE AND
COMBUSTIBLE LIQUIDS

PRESENTATION	APPLICATION
<p>2. This classification is subdivided into three parts.</p> <p>a. Class Ia</p> <ul style="list-style-type: none">(1) Flash point below 73o (22.8oC).(2) Boiling point below 100oF (37.8oC).(3) These are usually stored in pressure vessels or tanks.(4) The low boiling point makes these liquids doubly hazardous because of their volatility.(5) When Class Ia liquids are likely to be present in the atmosphere, explosion proof electrical equipment is used to prevent ignition of the vapors by sparks.(6) Examples of this group include:<ul style="list-style-type: none">(a) Ethylether(b) Ethylene oxide(c) Pentane <p>b. Class Ib</p> <ul style="list-style-type: none">(1) Flash point below 73oF (22.8oC).(2) Boiling point above 100oF (37.8oC).(3) This higher boiling point makes them less volatile.(4) Examples of this group include:<ul style="list-style-type: none">(a) Gasoline	<p>Have the students cite examples.</p>



Fire Protection Training

Procedures Handbook 4300

PHYSICAL PROPERTIES OF
FLAMMABLE AND
COMBUSTIBLE LIQUIDS

PRESENTATION	APPLICATION
<ul style="list-style-type: none">(b) Acetone(c) Ethyl (grain) alcohol <p>c. Class Ic</p> <ul style="list-style-type: none">(1) Flash point above 73oF (22.8oC) and below 100oF (37.8oC).(2) Boiling point is not taken into consideration with class Ic.(3) Examples of this classification include:<ul style="list-style-type: none">(a) Turpentine(b) Varnish(c) Brandy <p>K. Class II Liquids are Referred to as Combustible Liquids Due to Their Higher (over 100oF) Flash Points</p> <ul style="list-style-type: none">1. Flash point above 100oF (37.8oC) but below 140oF (60oC).2. Examples include:<ul style="list-style-type: none">a. Many cleaning solventsb. Some paint thinnersc. Kerosened. Diesel Fuele. (T-12b)	<p>Have students cite examples.</p>



Fire Protection Training

Procedures Handbook 4300

PHYSICAL PROPERTIES OF
FLAMMABLE AND
COMBUSTIBLE LIQUIDS

PRESENTATION	APPLICATION
<p>L. Class III Liquids are Referred to as Combustible Liquids Due to Their Higher (over 100oF) Flash Points.</p> <ol style="list-style-type: none"> 1. Flash point 140o (60oC) or above. 2. Class III liquids are divided into two categories. <ol style="list-style-type: none"> a. Class IIIa <ol style="list-style-type: none"> (1) Flash point 140oF (60oC) or above but below 200oF (93.3oC). b. Class IIIb <ol style="list-style-type: none"> (1) Flash point 200oF (93.3oC) or above. (2) Since these flash points are well above normal atmospheric temperature, Class III liquids do not present the flammable vapor hazard associated with Class I and II liquids. 	
<p>III. CLASS B FIRES (FLAMMABLE LIQUIDS)</p>	
<p>M. The Selection of Extinguishing Methods Should be Made with Caution Since There Are Many Factors That May Affect the Choice of Extinguishing Agents and the Method of Application.</p> <ol style="list-style-type: none"> 1. Water as an extinguishing agent <ol style="list-style-type: none"> a. Water may not be effective in fighting fires with low flash points. <ol style="list-style-type: none"> (1) Class I liquids 	<p>Who knows what effect water has on Class B fires?</p>



Fire Protection Training

Procedures Handbook 4300

PHYSICAL PROPERTIES OF
FLAMMABLE AND
COMBUSTIBLE LIQUIDS

PRESENTATION	APPLICATION
<ul style="list-style-type: none">b. The lower the flash point the less effective water will be.c. If water is used to put out a fire in an open tank of some fuel oils, there is a good possibility that frothing will occur and cause the liquid to overflow the tank.<ul style="list-style-type: none">(1) This frothing occurs when water, with its boiling point of 212oF (100oC) mixes with the burning oil and is rapidly converted to steam by the heat from the oil.(2) The frothing may be quite violent and could endanger the life of the firefighter particularly when solid streams are directed below the surface of the hot burning liquid.d. A fog pattern carefully applied has frequently been used with success in extinguishing such fires.<ul style="list-style-type: none">(1) The frothing occurs only on the surface. This frothing action of the water blankets and extinguishes the fire.e. This may occur in other liquids with a boiling point above 212oF.<ul style="list-style-type: none">(1) For example, certain asphalts have a small amount of low flash point solvent added for fluidity purposes, but because of the viscosity this frothing action may occur.f. Much of the effectiveness of using water will depend on the method of application. Proper nozzles and coordinated hose lines can be used to sweep the flames off the surface of the liquid.	



Fire Protection Training

Procedures Handbook 4300

PHYSICAL PROPERTIES OF
FLAMMABLE AND
COMBUSTIBLE LIQUIDS

PRESENTATION	APPLICATION
<p>g. Water may be used to blanket and extinguish fire when the flammable liquid has a specific gravity of 1.1 or heavier and is not water soluble.</p> <p>(1) The application of water must be applied gently to the surface of the liquid.</p> <p>h. Solid or straight hose streams can be used to keep tanks and other equipment exposed to flammable liquid fires cool.</p> <p>(1) If improperly used hose streams will</p> <p>(a) Cause a spill fire to spread</p> <p>(b) Will intensify a fire when directed into open containers of flammable and combustible liquids.</p> <p>i. Fires in water soluble flammable liquids (i.e. ethyl alcohol) can be extinguished by dilution with water, or by application of alcohol-type foams (which resist the break-down that occurs with regular air foams).</p> <p>j. Most flammable liquids are lighter than water and will float to the surface if mixed with water.</p> <p>(1) Some flammable liquids are heavier than water, such as carbon disulfide, (which has a specific gravity of 1.3 and a flash point of -22oF (-30oC)).</p>	<p>What effect will proper water application have on Class B fires with a specific gravity of greater than "1".</p>



Fire Protection Training

Procedures Handbook 4300

PHYSICAL PROPERTIES OF
FLAMMABLE AND
COMBUSTIBLE LIQUIDS

PRESENTATION	APPLICATION
<ul style="list-style-type: none">(2) Since carbon disulfide is heavier than water, fog patterns gently sprayed onto the surface of burning carbon disulfide will cover the surface, excluding the air needed for combustion.k. Water is not the most effective method of extinguishing Class B fires.2. Halon as an extinguishing agent<ul style="list-style-type: none">a. Halon does not extinguish by excluding oxygen, but by inhibiting the combustion process.b. Disadvantages of Halon<ul style="list-style-type: none">(1) Usually available in small quantities for small fires(2) Relatively expensive(3) Linked environmentally with depletion of ozone layer.3. Carbon dioxide as an extinguishing agent<ul style="list-style-type: none">a. Carbon dioxide is an inert gas, which extinguishes by smothering the fire (diluting oxygen and fuel vapors enough to halt combustion)<ul style="list-style-type: none">(1) Below the lower flammable limit4. Dry chemicals as an extinguishing agent<ul style="list-style-type: none">a. The chemical compound in dry chemical extinguishers consists principally of:<ul style="list-style-type: none">(1) Sodium bicarbonate,(2) Potassium bicarbonate,	



Fire Protection Training

Procedures Handbook 4300

PHYSICAL PROPERTIES OF
FLAMMABLE AND
COMBUSTIBLE LIQUIDS

PRESENTATION	APPLICATION
<ul style="list-style-type: none">(3) Ammonium phosphate, or(4) Potassium chlorideb. Dry chemicals extinguish by smothering, inhibiting flame propagation, and radiation shielding.5. Foams as extinguishing agents<ul style="list-style-type: none">a. Aqueous film forming foam (AFFF) floats on fuels that are lighter than water.<ul style="list-style-type: none">(1) The vapor seal created extinguishes flame and prevents re-ignition.b. "Alcohol Foam" should be used on fuels that are water soluble or "Polar Solvents".<ul style="list-style-type: none">(1) Examples are: Alcohol, lacquer thinners, and ketones.(2) These fuels cause other foam agents to break down and lose effectiveness.c. Other foam agents currently used include:<ul style="list-style-type: none">(1) Fluoroprotein, and protein which extinguish by cooling and blanketingd. Do not mix different foaming agents	



Fire Protection Training

Procedures Handbook 4300

PHYSICAL PROPERTIES OF
FLAMMABLE AND
COMBUSTIBLE LIQUIDS

SUMMARY:

The NFPA classifications of flammable and combustible liquids and gases, their physical properties and hazards are all vital factors to be considered when choosing the proper extinguishing agent and/or methods.

EVALUATION:

A written quiz.

ASSIGNMENT:

To be determined by the instructor(s).