



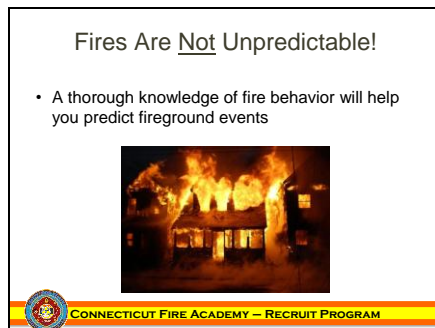
Slide 1



Slide 2



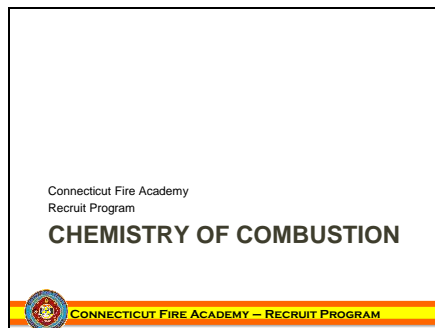
Slide 3



Some have said that fires in modern furnished homes are unpredictable

Nothing is unpredictable, firefighters just need to know what clues to look for

Slide 4







Slide 5

Chemistry

- Understanding the chemistry of fire will make you more effective
- Fire behavior is one of the largest considerations when choosing tactics



 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**


A basic understanding of how fire burns will give a firefighter the ability to choose the best means of extinguishment


Fire behavior and building construction are the basis for all of our actions on the fire ground

Slide 6

What is Fire?



- A rapid chemical reaction that produces heat and light




 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**

Slide 7



Types of Reactions


<p>Exothermic</p> <ul style="list-style-type: none">• Gives off heat 	<p>Endothermic</p> <ul style="list-style-type: none">• Absorbs heat 
---	--

 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**

Slide 8

Types of Combustion

<p>Flaming</p> <ul style="list-style-type: none">• Visible flame 	<p>Non-Flaming</p> <ul style="list-style-type: none">• Smoldering 
---	--

 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**

Non-flaming combustion can still damage structural components of a building

Non-flaming combustion produces the highest concentrations of toxic gases


Often found during backdraft or decaying fires




Slide 9

States of Matter

- All fuels must be converted to a gas before they will burn



 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**

Water is a simple example of the 3 states of matter


Solids must be heated to the point where they begin to decompose and give off combustible vapors

Liquids must be at a minimum temperature to give off enough vapors to burn

Slide 10

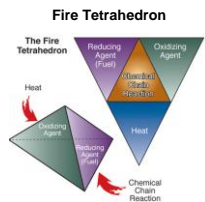
Requirements for Combustion

Fire Triangle




Heat
Oxygen
Fuel

Fire Tetrahedron



Heat
Fuel
Chemical Chain Reaction
Oxidizing Agent


 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**

If any part of the tetrahedron is removed, the fire goes out

If any part of the tetrahedron is amplified, the fire intensifies

Slide 11


Connecticut Fire Academy
Recruit Program
PROPERTIES OF FUELS

 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**


Slide 12


Types of Fuels

Organic



Inorganic



 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**

Inorganic fuels lack carbon and hydrogen atom bonds

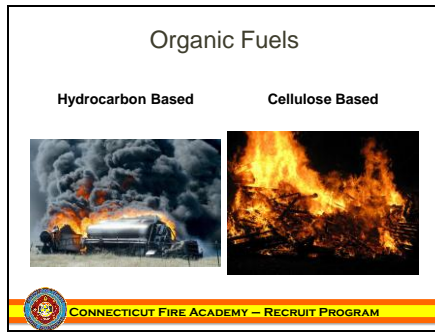
Inorganic fuel example- methane, flammable metals

Organic Fuel- wood & natural fuels

Organic fuels came from something that was alive at one point



Slide
13



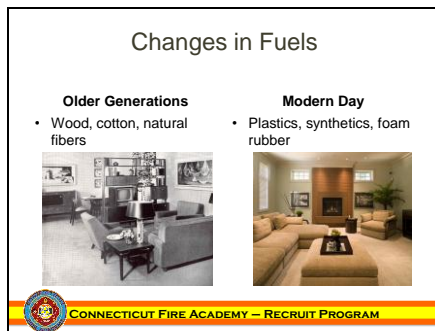
Hydrocarbon based fires are typically seen with large volumes of black smoke

Hydrocarbons include any fossil fuel, plastics, and synthetics that use any part of oil in their makeup

Cellulose based typically have a grey to brown smoke

Examples include wood, straw

Slide
14

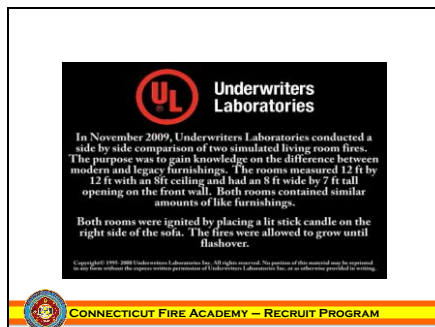


Rooms furnished with older, legacy type furnishings took much longer to reach flashover and didn't give off the volume of toxic smoke that modern furnishings do

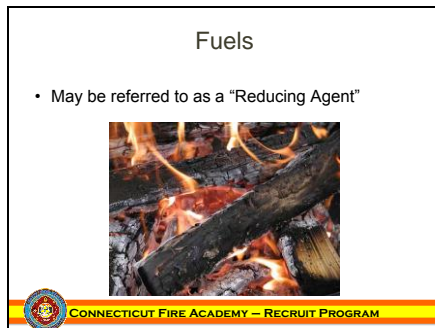
Modern furnishings can cause a room to reach flashover in 5 minutes or less

The toxic smoke produced can kill in less than a few minutes

Slide
15



Slide
16




Some texts refer to a fuel as a reducing agent




Slide
17

Solids

- Definite shape and size
- As it is heated, Pyrolysis occurs
 - The material decomposes and gives off flammable vapors



 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**

Fires involving solid fuels are the easiest to handle


The fuel must be heated and change state in order to burn


The fuel stays stationary

Slide
18

Liquids

- Has a mass and volume, but no definite shape
- Assumes the shape of the container
- Density compared to water



 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**

Fires involving flammable liquids are harder to control

The fuel can travel easily

Many flammable liquids are already found at or near their flash point so they may be giving off enough vapors to burn

Example of diesel fuel vs. gasoline


Water alone typically does not work well to extinguish them


Foam is often needed

Slide
19

Gases

- Has mass but not a definite volume
- Expand indefinitely



 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**

Gases are the hardest to handle

They are already in the required state to burn

As long as the concentration is right

They expand and travel indefinitely

Most gases are heavier than air so they collect in low areas and pool

They can pool enough to form an ignitable mixture

Lighter than air gases will dissipate shortly after escaping

Only 13 gases are lighter than air

Typically controlled by shutting off the fuel



They are typically allowed to burn



Slide
20

Orientation of the Fuel

- A solid fuel arranged vertically will ignite and burn faster than one arranged horizontally



CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM



Wall coverings burn easily but floors are often minimally damaged

Sides of furniture will spread fire faster than horizontal surfaces

Slide
21

Mass of the Fuel

- A denser fuel will take longer to ignite than a less dense material





CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM

Hay vs. pallets

Slide
22

Surface Area

- A fuel with greater exposed surface area will burn faster
- 1Lb. Of sawdust vs. a 1Lb. Block of wood




CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM




Slide
23

Ignition Temperature

- The minimum temperature to which a substance must be heated before it will spontaneously burn



 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**


This occurs without an outside ignition source

- Wood 572°
- Gasoline- 536°
- Carbon Monoxide- 1128°

Slide
24

Flash Point vs. Fire Point

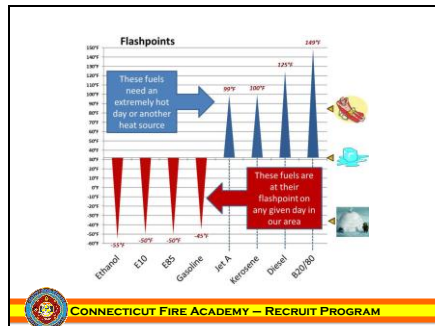
Flash Point	Fire Point
<ul style="list-style-type: none">• Temperature at which a liquid gives off sufficient vapors to form an ignitable mixture in air	<ul style="list-style-type: none">• Temperature at which a liquid gives off sufficient vapors to burn continuously after ignition for at least 5 seconds

 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**

Examples on the next slide


These are typically very close in temperature

Slide
25



Slide
26

Connecticut Fire Academy
Recruit Program
HEAT AS ENERGY


 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**




Slide
27

Temperature

- A measurement of energy
- Expressed in Fahrenheit or Celsius





 CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM

Slide
28

Heat of Combustion

- The total amount of heat released when a fuel burns



 CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM


Examples on next slide

Slide
29

Measuring Energy

- Measured in Btu's

Fuel	Common Unit	Energy in Btu's
Natural Gas	1 cubic foot	1,030 Btu's
Propane	1 gallon	91,000 Btu's
Gasoline	1 gallon	125,000 Btu's
Fuel Oil	1 gallon	140,000 Btu's
Firewood	1 cord	25,000,000 Btu's
Coal	1 lb.	13,000 Btu's

 CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM

These numbers assume the complete combustion of each material

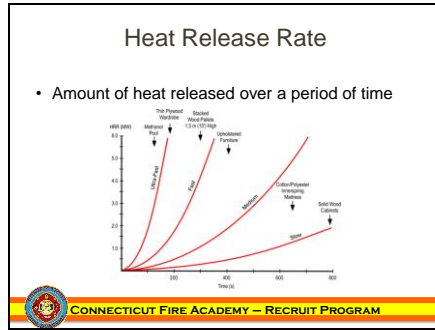
The rate at which they release this heat is dangerous

Heat release rate is discussed on next slide

A Btu is the amount of energy needed to raise 1lb of water 1°F

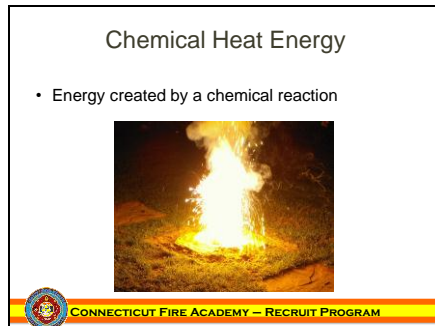


Slide
30



We can see that a typical plywood wardrobe burns almost as fast as a pool of methanol

Slide
31



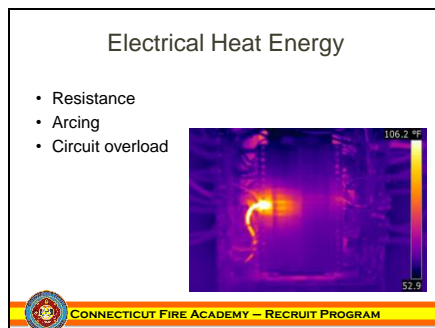
Example- sodium exposed to air

Slide
32



Example- compressing air into an SCBA cylinder
or rubbing sticks together to make fire

Slide
33



Arc welding is an example of heat caused by arcing

Resistance example- a dimmer switch for lights

Energy not sent to the light bulb is dissipated as heat

A fuse is an example of a circuit overload

A small wire only allows a certain amount of current to pass through. Any excess will cause the wire to fail

Multiple devices working off of one small circuit can cause heat to build up degrading the insulation of a wire. Eventually it will fail causing arcing and may start a fire




Slide
34

Heat of Decomposition

- As materials decompose, they give off heat




 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**

Fires in mulch piles are a good example

The mulch also acts as an insulating blanket keeping heat in



Slide
35


Connecticut Fire Academy
Recruit Program
CLASSES OF FIRE

 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**

Slide
36



Class “A”


<p>Ordinary Solid Fuels</p> <ul style="list-style-type: none">• Wood• Paper• Cloth 	<p>Preferred Method of Extinguishment</p> <ul style="list-style-type: none">• Cool with water 
---	--

 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**

Slide
37

Class “B”

<p>Flammable or Combustible Liquids</p> <ul style="list-style-type: none">• Gasoline• Diesel• Kerosene 	<p>Preferred Method of Extinguishment</p> <ul style="list-style-type: none">• Shut off the fuel• Smother with foam 
---	--

 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**



Video example shows a person doused with rubbing alcohol. They try to extinguish it with water but its ineffective




Slide
38

Class "C"

Energized Electrical Equipment	Preferred Method of Extinguishment
<ul style="list-style-type: none">TransformersElectrical panelsElectric motorsThe fuel is the insulation and lubricants	<ul style="list-style-type: none">De-energize the equipment





 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**


Once the equipment is de-energized, it can be treated as a class "A" fire

Slide
39

Class "D"

Combustible Metals	Preferred Method of Extinguishment
<ul style="list-style-type: none">Burns at a high temperatureMagnesiumAluminumSodium	<ul style="list-style-type: none">Application of dry powderDo not use water!



 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**

Flammable metals are often water reactive


The video shows a car fire when water is applied to magnesium


Magnesium is often found in vehicle construction

Reinforces the need to proper PPE at car fires

Slide
40

Class "K"

Combustible Cooking Oils or Fats	Preferred Method of Extinguishment
	<ul style="list-style-type: none">Application of special agentsThe agents react to the fats and create a foam (Saponification)

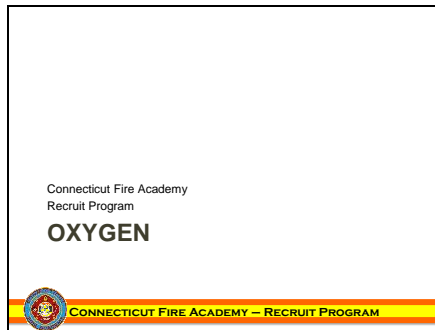


 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**

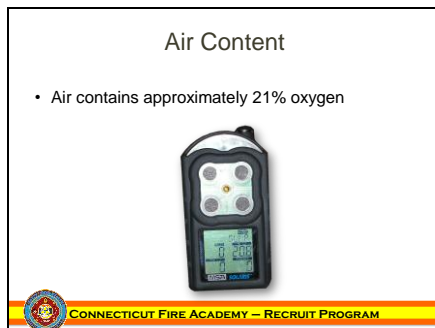
Video shows what happens when water is applied to a cooking fire (oil or grease)



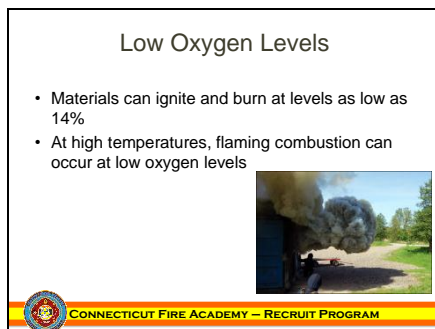
Slide
41



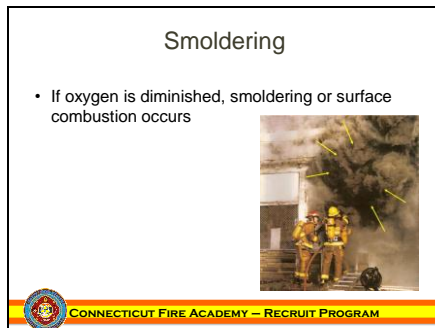
Slide
42



Slide
43



Slide
44





Smoldering fires produce the highest amounts of toxic and flammable smoke




Slide
45

High Oxygen Levels

- At high concentrations, fires can greatly intensify




 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**

High oxygen levels can be expected in medical facilities, pool stores

Slide
46


Connecticut Fire Academy
Recruit Program
SMOKE


 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**

Slide
47

Smoke Contents

- Smoke contains particulates, vapors, and gases



 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**

Smoke, in the right concentrations, can be considered fuel


Particulates are solid matter suspended in the atmosphere


Vapors are liquids suspended in the atmosphere

Slide
48

Toxic Smoke Gases

- Carbon Monoxide
- Carbon Dioxide
- Hydrogen Cyanide
- Phosgene



 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**

Much of this is covered during the SCBA & PPE lecture, but is worth reviewing




The Connecticut Fire Academy
Recruit Firefighter Program
Presentation Instructor Notes


Unit 6.1
Chapter 6
Fire Behavior

Slide
49

Ladder Gases

- Acrolein - 450°
- Benzene - 928°
- Hydrogen Cyanide - 1004°
- Carbon Monoxide - 1128°



 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**


The “ladder” gases simply demonstrate why we see fingers of fire in smoke

The lower temperature gases light off faster

These gases burning also accelerates the heating of the other gases

Slide
50


Connecticut Fire Academy
Recruit Program
FIRE DEVELOPMENT


 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**

Slide
51

Fuels

- Most fires involve solid fuels
- Ignition temperature of wood varies due to density and water content




 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**


Older homes may have wood that has had time to dry longer

Slide
52

Radiant Heat

- Walls, ceilings, and floors absorb radiant heat
- Heat that is not absorbed is radiated back into the room increasing the rate of combustion



 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**



Radiant heat effects the compartment, but is also the biggest factor in exposures burning



Slide
53

Convected Heat

- Hot smoke becomes buoyant
- The heat transfers to the other materials
- Nearby fuels pyrolyze causing fire extension





CONNECTICUT FIRE ACADEMY — RECRUIT PROGRAM

This causes fires to travel from lower floors to upper floors even without direct flame contact

Slide
54

Thermal Layering

- Heated gases rise and form layers
- Water applied to a fire creates steam
- Steam rises, displacing the heated gases at ceiling level downward



CONNECTICUT FIRE ACADEMY — RECRUIT PROGRAM

This is why we apply water at the ceiling level first



It cools the gases before they get driven down on top of advancing crews

Ventilation also prevents the gases from being driven down onto crews

Slide
55

Incipient or Ignition Phase

- When sufficient heat, fuel, and oxygen come together to create combustion
- Development depends upon amount, type, and configuration of fuels



CONNECTICUT FIRE ACADEMY — RECRUIT PROGRAM

Very little heat in the room



Occupants can safely escape

Fire easily extinguished by a small portable fire extinguisher

Slide
56

Growth

- Fire begins to influence the environment within the compartment
- Growth is limited by fuel and oxygen present
- Pockets of flame may be visible in the smoke



CONNECTICUT FIRE ACADEMY — RECRUIT PROGRAM

This is where a noticeable thermal layering begins

Occupants still have the ability to escape


Victims located within the room are still viable




Slide
57

Rollover

- Heated gases (smoke) ignite across the ceiling level



 CONNECTICUT FIRE ACADEMY — RECRUIT PROGRAM

Rollover typically precedes flashover


It can be a warning sign to flashover, but thick, dark smoke can prevent it from being noticed by crews crawling on the floor

The heat then radiates into the room bringing everything up to its ignition temperature

Slide
58

Flashover

- All combustible materials in the room ignite
- Temperatures exceed 1000 degrees
- Unprotected civilians have little chance of survival


 CONNECTICUT FIRE ACADEMY — RECRUIT PROGRAM


The fire will continue as long as fuel and oxygen remain

Firefighters have only seconds to escape without injury

Several videos to follow

Slide
59



 CONNECTICUT FIRE ACADEMY — RECRUIT PROGRAM

- NIST flashover video
- Small compartment fire development

Slide
60



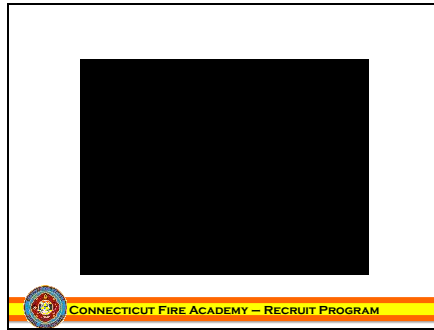
TheBravestOnline.com

 CONNECTICUT FIRE ACADEMY — RECRUIT PROGRAM

- Fire from Huntsville, TX
- 2 story wood frame multiple dwelling
- Fire can be seen developing then flashing over
- Note the volume of fire present after flashover
 - Also note how rapidly the fire knocks down



Slide
61



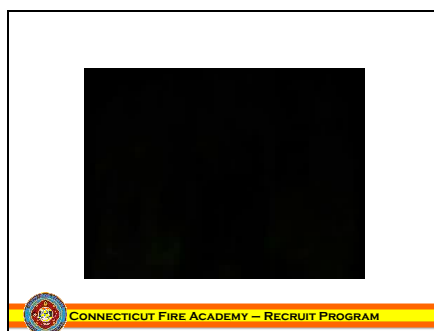
- Training fire
- Shows how flashover can be brought on by improper ventilation
- There is initially no ventilation
 - Opening the front door supplied oxygen and allowed the heated gases to escape
 - This is necessary and acceptable on the fireground because we have to get in somewhere!
 - Placing the PPV fan in the front door acted like a “bellows” on the fire, causing it to intensify and flash over
 - This is especially true with the lack of ventilation at any other part of the building
- PPV fans should never be used during fire attack, **ESPECIALLY** after crews have entered the house and with no adequate ventilation opposite the crews & fan

Slide
62



- Note the smoke conditions on the front porches
- Predict what was going to follow
- Fire is easily visible from a “B” side window, but it is more important to predict where the fire will spread

Slide
63





- Note that the smoke is venting quickly
 - This indicates a decent heat condition on the 2nd floor
- Venting in this manner may have to be delayed if there is no engine company on that floor or if they are delayed




Slide
64

Signs of Flashover

- High heat
- High volume of dense "velvety" looking smoke
- Fingers of flame in the smoke




 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**


- Some visible signs may not be obvious while operating inside the building

Slide
65

Fully Developed

- When all combustible materials in the room are burning
- Maximum heat and large amounts of gases are released
- Fire is ventilation controlled




 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**

Slide
66

Decay


- Fuels are consumed or oxygen levels are decreased to a level where they can not support combustion
- Visible flame is reduced
- High concentrations of heat may remain


 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**

Slide
67

Backdraft

- Explosion that occurs when oxygen is introduced to a compartment which still has high heat and combustible gases



 **CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM**



- Flashover and backdraft are often confused
 - Backdraft occurs from oxygen being introduced into a room which is oxygen deprived
 - The result has a concussive, explosion type of effect
 - Flashover is caused by heating of the contents
 - Not explosive in nature



Slide
68

Signs of Backdraft

- Little visible flame
- Smoke stained windows
- Pressurized turbulent smoke
- "Breathing" building



CONNECTICUT FIRE ACADEMY — RECRUIT PROGRAM

- When confronted with suspected backdraft conditions, vertical ventilation is a priority

Slide
69



Sandö
National Fire College
Sweden



CONNECTICUT FIRE ACADEMY — RECRUIT PROGRAM

- Training fire showing the concussive nature of a backdraft
- The signs of backdraft are not visible in this video



Slide
70



CONNECTICUT FIRE ACADEMY — RECRUIT PROGRAM

- St. Johnsbury, VT
- 3-4 story taxpayer
- Some signs of backdraft are visible around the 2nd floor area

Slide
71



CONNECTICUT FIRE ACADEMY — RECRUIT PROGRAM

- Battalion Chief being caught in backdraft
- Signs of backdraft are not really present



Slide
72

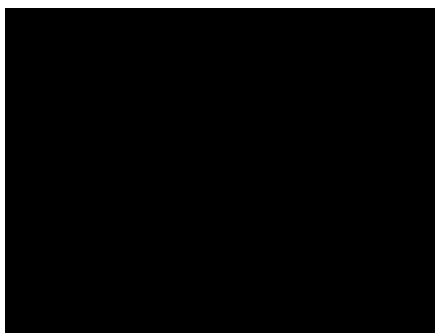


Slide
73



- Attic fire that backdrafted
 - A.k.a. “cockloft explosion”
 - Heat and pressure built up in the attic space because the ventilation is limited
 - Once something introduces oxygen (failed sheetrock, small vent opening, etc.) the attic backdrafts
 - This causes the ceiling in the upper floor to collapse on crews underneath
 - Note that it was powerful enough to cause the chimney to separate from the house
 - These are NOT common on peaked roof buildings
 - They typically have better ventilation
 - These typically occur on flat roof buildings

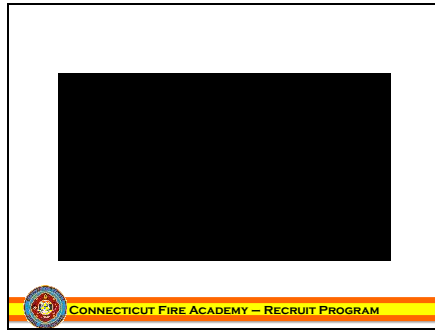
Slide
74



- Minor backdraft occurs at a private dwelling
- Wind can hide the signs of impending backdraft



Slide
75



- No signs of backdraft visible

Slide
76



- Texas fire in private dwelling

Slide
77



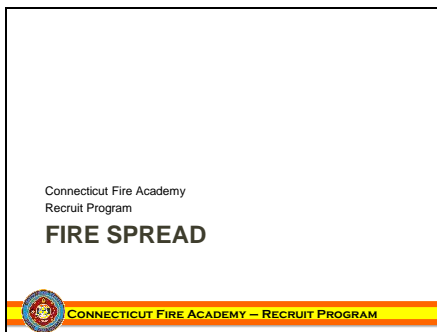
- Harrison, NJ
- Signs of backdraft present quickly followed by explosion

Slide
78

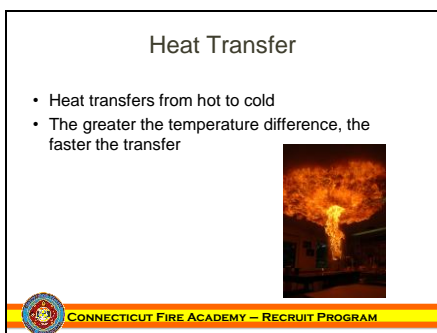




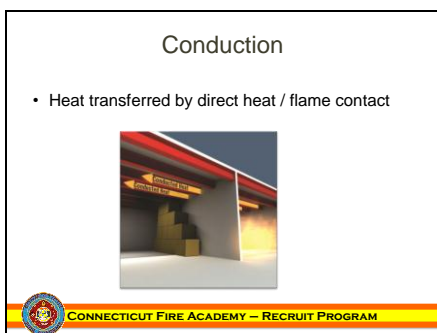
Slide
79



Slide
80

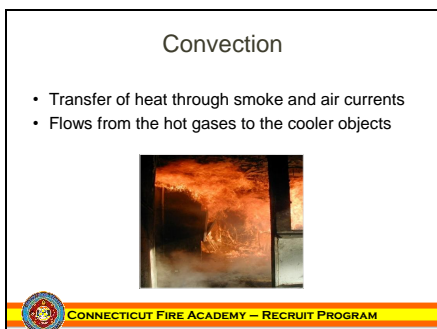


Slide
81



•Direct flame contact to an object or a heated object transferring heat to another

Slide
82




•Typically how fires travel from lower floors to higher ones




Slide
83

Radiation

- Transfer of heat in the form of an invisible wave
- Travels in all directions in a straight line



 CONNECTICUT FIRE ACADEMY — RECRUIT PROGRAM

- Typically the biggest concern with exposures

Slide
84

Size of the Compartment

- The size of the fire room / area will dictate how fast the fire will develop



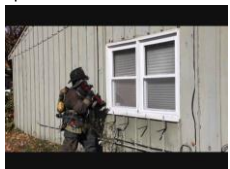
 CONNECTICUT FIRE ACADEMY — RECRUIT PROGRAM


- Obviously fires of equal size would behave differently in the two occupancies shown

Slide
85

Ventilation and Fire Behavior

- How, When, and Where we ventilate can help or limit fire spread




 CONNECTICUT FIRE ACADEMY — RECRUIT PROGRAM

- As much as proper ventilation can help fire attack, improper ventilation can hamper it

Slide
86

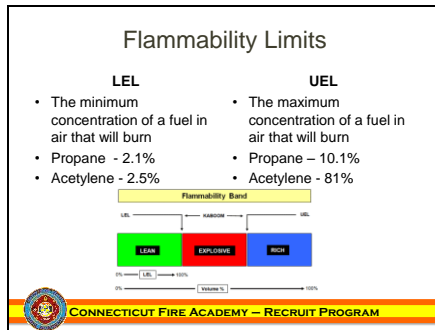
Gas Fuel Fires

- Knowing the fuels vapor density will help predict potential ignition sources
- Vapor density is measured against air
 - <1 gas will rise
 - >1 gas will sink

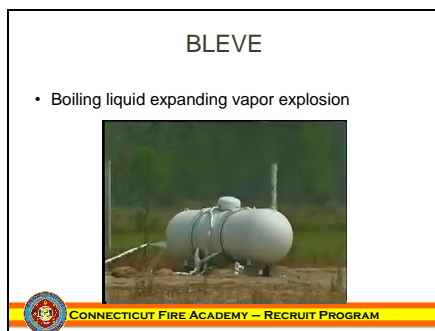
 CONNECTICUT FIRE ACADEMY — RECRUIT PROGRAM



Slide
87

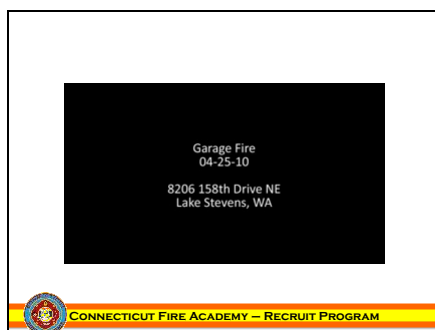


Slide
88



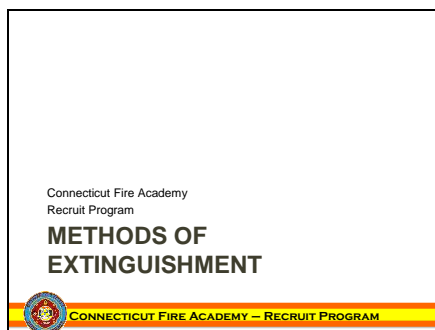
•BLEVE video

Slide
89



•20lb LP tank explosion at a garage fire

Slide
90







Slide
91

Cooling

- Use water to cool the surface temperature of the fuel
- Enough water must be applied to overcome the heat being produced




 CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM


•Typically the best for class “A” fires

Slide
92

Fuel Removal

- Close valves / pipes supplying flammable liquids or gases
- Allow a combustible material to consume itself




 CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM


•Typically the best means for flammable gas fires

Slide
93

Smothering

- Separate the surface of the fuel from the air supporting combustion




 CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM


•Typical for combustible liquid fires

Slide
94

Oxygen Exclusion

- Eliminate the oxygen supporting combustion



 CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM

•Must be applied until the fuel is shut off or it has cooled enough to prevent re-ignition





The Connecticut Fire Academy
Recruit Firefighter Program
Presentation Instructor Notes

Unit 6.1
Chapter 6
Fire Behavior

Slide
95

Chemical Flame Inhibition

- Agents interrupt the chemical chain reaction
- Effective on liquid and gas fires


A photograph showing a firefighter in full gear using a hose to extinguish a fire. A large plume of white smoke is visible from the fire.

CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM

• Fires typically won't flare back up after dry-chem is applied

Slide
96

Connecticut Fire Academy
Recruit Program



CONNECTICUT FIRE ACADEMY – RECRUIT PROGRAM