Government of
Northwest Territories

Northwest Territories Defensive Firefighter Training

SESSION 5

FIRE BEHAVIOUR
AND FIRE EXTINGUISHERS

Government of the Northwest Territories
Municipal and Community Affairs

First Edition (2025)

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SESSION 5 - FIRE CHEMISTRY AND FIRE EXTINGUISHERS

INTRODUCTION

Northwest Territories Defensive Firefighter Training (NWT-DFT) is a competency-based learning program for community fire departments operating at a defensive level of service. This workbook provides volunteer firefighters with the knowledge to apply to achieving 34 required skills. When successfully assessed, students and volunteer NWT firefighters will have met the basic requirements to appropriately respond to fire scenes at a safe distance from fires. Skills in the NWT-DFT program are to be assessed based on validated learning outcomes from the National Fire Protection Association (NFPA) 1001 standard.

LEARNING OUTCOMES

1. Identify the three properties needed for fire
2. Identify three types of energy that create heat
3. Describe the chain reaction that keeps fire going
4. Identify three kinds of heat transfer
5. Describe the four stages of fire
6. Identify when and why to use fire extinguishers
7. List extinguisher ratings, components, and maintenance requirements
8. Explain the purpose of four suppression agents
9. Skill Drill 5-1: Perform extinguishing a Class A or B fire

Digital versions of all books in the NWT Defensive Firefighter Training program are available for download and/or printing here:
https://communitylearning.learnworlds.com/defensive-fire

WHAT MAKES FIRE

When firefighters understand fire behaviour, they can fight fires more effectively and anticipate changing conditions. A fire needs three things to start: fuel, oxygen, and heat. These elements make up the fire triangle.

COMMON HOUSE FIRE FUEL SOURCES

- Wood and Paper: Found in furniture, structural components, and other paper or wood products
- Plastics and Synthetic Materials: Used in furnishings, electronics, and building materials
- Fabrics: Such as curtains, upholstery, and clothing
- Combustible Liquids: Including gasoline, kerosene, alcohols, and oils
- Electrical Wiring and Insulation: Faulty wiring or damaged insulation can ignite
- Gas Lines: Leaks from gas lines can lead to fires

Fire triangle properties

Fuel

All matter (solid, liquid, gas) can be fuel for fire:

- Wood from trees in a wildland fire (solid)
- Gasoline in a vehicle fire (liquid)
- Propane in a barbeque fire (gas)

Some fuels are less combustible than others. They can still burn but need more heat. For example, lighting a piece of paper with a match is easy, but trying to light a rock on fire is much harder. Rocks can burn with enough heat (like lava), but you can't start most rocks on fire with a match. It's important for firefighters to know what kinds of fuel are in the environment when fighting a fire.

Oxygen

Combustion needs oxygen. When we cover a candle with a glass, the flame goes out because the oxygen is removed. Some chemical reactions provide oxygen to fires by reacting with fuels when heated. They can be very dangerous. Materials like potassium nitrate, ammonium perchlorate, or hydrogen peroxide can be very destructive, even explosive. They are often controlled by removing the oxygen (see *Chemical Fire Causes Massive Explosion*, p. 6).

Heat

For ignition to occur, an initial heat source is needed. The heat source raises the fuel's temperature to its ignition point. For example, when you use a match to light a piece of paper, the heat from the match flame raises the paper's temperature to its ignition point. However, since most rocks are less combustible, the same match may not provide enough heat to raise the rock's temperature high enough for the rock to meet its ignition point.

WHAT MAKES FIRE

CHEMICAL FIRE CAUSES MASSIVE EXPLOSION

In 2023, A massive fire that engulfed a chemical warehouse in Perth (Australia) triggered an explosion so fierce it could be felt by residents living more than 35 km away. The fire broke out in a chemical factory at about 7:45 pm. The warehouse specialized in chemical blending, which likely involved various industrial chemicals. Fire crews battled the blaze for around an hour before the massive blast was triggered by a chemical reaction causing total loss of the property. Fire crews used sand and foam in an effort to extinguish the blaze, which burned for about 12 hours.

How does sand/foam affect the fire triangle?

9NEWS. (retrieved from: https://www.9news.com.au/national/perth-factory-blast-felt-35km-away/da4fac52-3e63-493c-9a74-6758f405dde0, 2024)

Ignition point and heat energy

Fire needs energy to start because it requires a certain amount of heat to raise the temperature of the fuel to its ignition point. This initial heat source provides the energy needed to break the chemical bonds in the fuel, allowing it to react with oxygen in the air.

Mechanical Energy	**Mechanical energy ignites a fire by converting to heat through friction, like using a bow drill to start a campfire.** *This heat helps maintain the temperature needed for the fire to start. The burning fire then creates its own heat (chemical energy), if there is also enough fuel and oxygen to keep it going.*	
Electrical Energy	**Electrical energy produces heat when it encounters resistance, like in an overloaded circuit.** *This heat helps maintain the temperature needed for the fire to start. The burning fire then creates its own heat (chemical energy), if there is also enough fuel and oxygen to keep it going.*	
Light (thermal) Energy	**Light energy produces heat when absorbed by fuel. This is how a magnifying glass can focus sunlight to create heat.** *This heat helps maintain the temperature needed for the fire to start. The burning fire then creates its own heat (chemical energy), if there is also enough fuel and oxygen to keep it going.*	

FIRE TRIANGLE SCENARIOS

Read or listen to the following scenarios and write down your answers:

- Determine the main source of fuel.
- Determine the most likely heat source that causes the fuel to reach its ignition point.
- Determine where the fire is getting its oxygen from to burn.

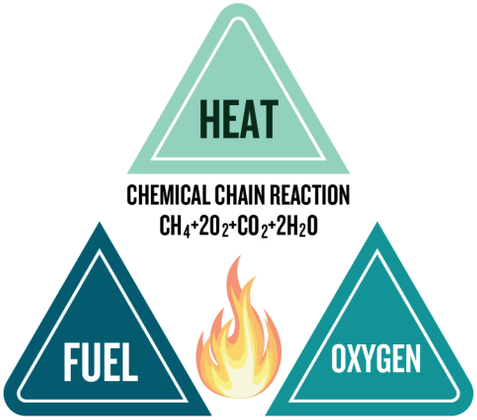
A bush fire started on an extremely hot day in windy, dry conditions. The fire was not human-caused nor was it caused by lightning.		
Fuel:	**Heat:**	**Oxygen:**
A woman was making popcorn in her microwave. She sat down to watch TV and a few minutes later notices a fire inside microwave.		
Fuel:	**Heat:**	**Oxygen:**
A family went to visit their cousins in the winter and left their home with the woodstove going. When they returned, they saw flames shooting out their chimney.		
Fuel:	**Heat:**	**Oxygen:**
A teenager had only one electrical wall outlet in her room. She had an extension cord connected to it that was damaged. One day while blow drying her hair, she saw that the extension cable was on fire.		
Fuel:	**Heat:**	**Oxygen:**
A man had been having some recent car trouble with his engine overheating. One day he was driving his car down the road when it stopped. The engine was smoking, and when he popped the hood flames started shooting out.		
Fuel:	**Heat:**	**Oxygen:**

CONTINUOUS CHAIN REACTION

Combustion is a chemical reaction between fuel and oxygen that produces heat and light. This reaction releases a new kind of energy - chemical energy - that generates more heat. The heat keeps the temperature high enough for the fuel and oxygen to keep reacting in this chain reaction.

Chemical energy

Combustion releases chemical energy that sustains a fire. It's the energy stored in the bonds between atoms and molecules. During combustion, this energy is released when fuel reacts with oxygen. Once a fire is ignited, this chemical reaction becomes the fourth part of the fire triangle, turning it into a fire tetrahedron (three-dimensional triangle).



Disrupting the reaction

Fire suppression involves stopping a fire by removing one of its three essential components: fuel, oxygen, or heat. Removing one of these disrupts the chemical reaction that keeps the fire burning. For example, pouring water on a campfire cools it, removing heat. Placing a lid on a burning pan cuts off oxygen. Fire extinguishers use agents (chemicals, foam, water) to cool and smother fires, removing heat and oxygen. By eliminating one component, the fire is extinguished.

Pyrolysis

The process of breaking down materials using heat without oxygen. For example, when wood is heated, it breaks down into gases, liquids, and char. In firefighting, the gases can ignite and cause the fire to spread rapidly. Firefighters may add water to cool the materials to prevent further pyrolysis and gas production.

Oxidation

The process of burning fuel reacting with oxygen in the air, producing heat and light. Firefighters aim to disrupt the oxidation process by removing one of the fire's essential components—fuel, oxygen, or heat—to extinguish the fire.

Thermal Layering

Refers to the formation of layers of different temperatures in a burning building. Hot gases rise to the ceiling, creating a hot upper layer, while cooler air stays near the floor, forming a cooler lower layer. Thermal layering can be disrupted by cooling the hot gas layer with water.

Smoke Colour

The colour of smoke can indicate what is burning. For example, black smoke often means burning synthetic materials (usually thick and toxic). White smoke usually indicates burning wood or paper. Grey smoke can indicate a mixture of materials burning, often seen in structure fires where various items are involved.

HOW FIRE SPREADS

We now know how a fire starts - when enough oxygen is present and a fuel source's temperature rises to its ignition point. We also know that for a fire to be sustained, combustion must take place during a continuous chain reaction using chemical energy. To better understand fire behaviour, it is important to also know how a fire spreads using heat transfer.

Heat Transfer

Convection

The transfer of heat by the movement of a gas or liquid from hotter areas to cooler areas. In a structure fire, hot air rises to the ceiling, causing heat to spread throughout the area.

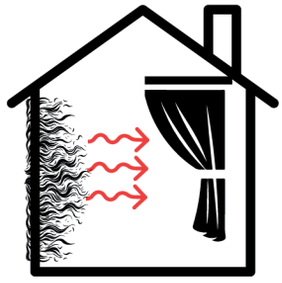
EXAMPLE: The air in a cabin's attic or loft is much warmer on a summer day; as the air in the cabin warms up, it rises and creates a convection current.

In a house fire, hot air and smoke can rise and spread via convection currents, causing fire spread to upper floors or adjacent rooms.

Radiation

The transfer of heat in the form of invisible electromagnetic waves. The radiant heat from a fire can cause highly combustible materials to ignite without direct contact.

EXAMPLE: Feeling the warmth of the sun on your skin. The heat is transferred from the sun to you through radiation, even though the air around you might be cool.



During a living room fire, heat can radiate across the room and ignite curtains.

Conduction

The transfer of heat between solid objects that are in direct contact with each other. Heat transfers from the warmer object to the cooler object. Conduction can cause heat to travel along hot metal materials in a building and ignite combustible materials in another part of the building.

EXAMPLE: When you touch a metal spoon that has been sitting in a hot pot of soup, the heat from the soup is transferred to the spoon and then to your hand.

During a house fire, heat can be conducted through metal beams or pipes that run through the walls.

STAGES OF FIRE

Fires go through different stages, each with their own behaviours and ways of spreading heat. By understanding fire behaviour during different fire stages, you can be better prepared.

Incipient Stage	This is the initial stage where the fire has just ignited and is small, with minimal heat, smoke, and flames.	
Growth stage	The fire starts to spread and intensify as it finds more fuel and oxygen, becoming more dangerous. This stage sees the fire spreading to nearby combustible materials by heat transfer.	
Fully developed stage	At some point during fire growth everything that can burn is burning. The fire reaches its peak intensity, consuming all available fuel and oxygen, making it extremely hazardous. All modes of heat transfer are usually being used. Temperatures are at their peak.	
Decay stage	The fire begins to diminish as it runs out of fuel or oxygen, but it can still reignite if conditions change. There might be hot spots that could start burning again if more fuel or oxygen becomes available. Mainly conduction and convection continue to transfer the remaining heat until the fire is fully extinguished.	

FLASHOVER: Can occur if heat becomes so intense that all combustible materials ignite simultaneously. Nearly instant transition from growth to fully developed stage.

BACKDRAFT: Happens when a fire uses up most of the oxygen in a space causing it to smolder. When air is re-introduced, there is still enough heat and fuel to cause the fire to reignite explosively. Most often happens during decay phase.

SMOKE EXPLOSION/FIRE GAS IGNITION: Occurs when unburned combustible gases (produced by a fire) accumulate in closed in space and then mix with air, leading to an explosive ignition when they encounter a heat source. Most often happens during growth or decay phases.

EXTINGUISHING FIRE

Common types of fire suppression systems include water-based systems, which cool and smother flames, taking away heat and oxygen. Gas-based systems deprive fires of oxygen. Chemical-based systems interrupt the chain chemical reaction of fires. Defensive firefighters use these methods to attack fires from a safe distance.

When to use fire extinguishers

Fire Stages

Fire extinguishers work best in the incipient stage, which is right after a fire starts. At this point, the fire is small, and there are minimal heat, smoke, and flames. Using a fire extinguisher during the growth stage is less effective and can be risky. It's never safe to use a fire extinguisher during the fully developed or decay stages.

Chemical Agents

Fire extinguishers often use chemical agents, especially when water isn't suitable:

- Electrical: Water can increase electrocution risk.
- Flammable liquids: Water can spread the fire.

Classifications and ratings

CLASS OF FIRE	TYPE OF FIRE	APPROVED FIRE EXTINGUISHER
A Ordinary combustibles	Wood, paper, cloth	Type A Type A-B
B Flammable liquids	Gasoline, paints, oils, grease	Type A-B Type B-C Type A-B-C
C Live electrical equipment	Electrical wiring, fuse box	Type B-C Type A-B-C
D Combustible metal	Metals	*Bucket of sand
K Commercial cooking equipment	Commercial cooking oil appliances	*Wet chemical

Fire extinguishers have specific ratings that identify the type or class of fires where they should be used:

- **Numbers** on extinguishers indicate the volume of content (agent).
- **Letters** indicate the class of fire for which the agent can be used.

***Do not extinguish Class D or K fires. These types of fires carry risks that typical fire extinguisher training does not cover.**

EXTINGUISHING FIRE

Suppression agents

Suppression agents are what make up contents inside fire extinguishers. These are the most common:

DRY CHEMICAL	The most common fire extinguishers, often used for Class A, B and C fires. Discharge a blanket of fine powder designed to coat fuel and smother the fire, breaking the chemical chain reaction between fuel and oxygen.
CLASS B FOAM	Discharge a solution of water and a synthetic or protein foam. They may also be effective for Class A fires.
Carbon Dioxide (CO2)	Uses pressurized CO2 for Class B and C fires. CO2 smothers the fuel and interrupts the chemical reaction by removing oxygen.
WATER	Used for Class A fires to cool the fuel source and/or remove heat.

Other kinds of fire extinguishers include:

- Water-mist extinguishers that contain distilled or de-ionized water that conducts less electricity.
- Wetting-agent extinguishers contain a solution to reduce surface tension so water spreads over the fire and penetrates more efficiently into Class A or B fuels.
- Halogen-agent extinguishers use liquefied gases (halogens: fluorine, bromine, iodine, and chlorine) that do not leave residue on electronics.

Fire departments typically store fire extinguishers in strategic locations:

- Fire Trucks
- Fire Stations
- Training Areas
- Utility Rooms

EXTINGUISHING FIRE

Fire extinguisher components

Locking mechanism: Stiff pin to lock against accidental discharge, designed for quick release

Trigger: Lever squeezed to discharge agent

Carrying handle: To hold while in use or being moved

Pressure indicator: Usually needle gauge that monitors for sufficient pressure. Ensure the needle is in the green zone, indicating the extinguisher is fully charged and ready for use

Cylinder: Holds the extinguishing agent (water, CO2 or dry chemical)

Nozzle or horn: Where extinguishing agent is released

Care and maintenance

Ensure your fire department has procedures for the care and maintenance of the types of fire extinguishers you carry. Procedures should also follow the manufacturer's care and maintenance recommendations.

- Proper training is required before use
- Keep records of scheduled inspection and maintenance
- Use service tag with date of the last inspection, inspector's initials, and maintenance performed

SKILL DRILLS

SKILL DRILLS

Scenario

You arrive at a small fire at the town dump. It is burning cardboard and wood, but other materials might be involved. The flames are small with minimal smoke, and there are no apparent hazardous materials within 20 feet. The fire truck arrives with a 5-pound multi-purpose dry chemical fire extinguisher.

Is a multipurpose dry-chemical fire extinguisher safe and effective for this fire?

☐ YES ☐ NO

Is the fire extinguisher large enough to be safe and effective?

☐ YES ☐ NO

Are you wearing the required PPE?

☐ YES ☐ NO

Determine an exit route from the fire using this map:

SKILL DRILL 5-1: Extinguish a Class A or B fire with a multipurpose dry-chemical fire extinguisher

1	Scene size-up: • *Determine whether a multipurpose dry-chemical fire extinguisher is safe and effective for this fire* • *Ensure the fire extinguisher is large enough to be safe and effective* • *Ensure your safety: Wear the appropriate PPE; have an exit route from the fire; do not turn your back on a fire*
2	Remove fire extinguisher hose and nozzle
3	Quickly check pressure gauge to verify that the fire extinguisher is adequately charged
4	Position yourself • *Depending on the size of the fire and fire extinguisher, you must be within 5 to 45 ft (2 to 14 m) away from the fire to be effective*
5	Implement the PASS techniqe: • *P-Pull the pin to release the fire extinguisher control valve* • *A-Aim the nozzle at the base of the fire* • *S-Squeeze the handle to discharge the agent* • *S-Sweep the nozzle from side to side at the base of the fire*
6	Overhaul the fire • *Take steps to prevent rekindling: break apart tightly packed fuel*

LEARNING DEBRIEF

REMEMBER

- Developing proper work habits during training in this course helps ensure safety later
- Do not attempt anything you feel is beyond your ability or knowledge
- Tell someone if you see something that you feel is an unsafe practice
- Continue to learn teamwork and practice working as a team
- A firefighter injured during training should not return until medically cleared for duty

Reflect on the following questions. Jot down notes or sketches in the spaces provided.

How does knowing about fire properties and how they ignite help you as a firefighter? Reflect on the fire triangle and what happens if one property is removed.	
Why does it matter how a fire behaves on the inside of a structure if you are working as a defensive firefighter? Consider how stages of fire may play a role.	
How do different fire extinguisher agents affect fire properties and the chain reaction that keeps fire going?	

APPENDICES

GLOSSARY OF TERMS

Communications

- **ABC Button:** Customizable preset button on radios
- **Channel Selector:** Dial or button to change radio channels
- **Communication Feedback Loop:** Confirming messages by repeating them back
- **Decoding:** Interpreting the received message
- **Emergency Button:** Sends alert for immediate help
- **Emergency Line:** Dedicated line for urgent calls
- **Emergency Traffic:** High-priority message overrides others
- **Encoding:** Turning thoughts into a message
- **Feedback:** Receiver's response to a message
- **Message:** Information being communicated
- **Monitor/Scan Buttons:** Used to listen to multiple radio channels
- **Noise:** Anything that disrupts communication
- **Portable Radio:** Handheld radio for communication
- **Push-to-Talk (PTT) Button:** Press to talk on a radio
- **Receiver:** Person who gets the message
- **Sender:** Person who sends the message
- **Transmission:** Sending a message over radio

Equipment

- **Apparatus:** Firefighting vehicle
- **Deck Gun:** Fixed, high-volume water device on fire trucks
- **Dry Barrel Hydrant:** A hydrant that drains to prevent freezing
- **Handline:** Hose operated by hand
- **Hose Appliance:** Tools used with fire hoses to control flow
- **Hose Couplings:** Connect hoses to each other or a water source
- **Hose Lays:** How hoses are arranged from source to scene
- **Hose Loads:** Hose stacking methods for easy deployment
- **Nozzle:** Controls water stream from a hose
- **Pumper Truck/Attack Engine:** Vehicle with pump, hose, and water for fire attack
- **SCBA** (Self-Contained Breathing Apparatus): Air tank and mask for breathing in smoke-filled areas
- **Standpipe:** Built-in pipe system for supplying water inside buildings
- **Storz-Type Coupling:** Quick-connect hose ends without threads
- **Suction Hose:** Pulls water from static sources
- **Supply Hose:** Delivers water from source to pump
- **Threaded Couplings:** Screw-type hose connections
- **Turnout Gear:** Protective clothing worn during responses

Education and Training

- **Codes and Standards:** Laws and guidelines for fire safety
- **Exit Drills In The Home (EDITH):** Practice home fire escape plans
- **Home Safety Surveys:** Checking homes for fire safety issues
- **NFPA (National Fire Protection Association):** Sets fire safety standards

Fire Science

- **Backdraft:** Explosive ignition when oxygen re-enters a smoldering fire
- **Combustion:** Chemical process of burning
- **Conduction:** Heat transfer through contact
- **Convection:** Heat movement through air or gas
- **Decay Stage:** Fire slows as fuel runs out
- **Fire Tetrahedron:** Fire needs heat, fuel, oxygen, and a chemical reaction to burn
- **Fire Triangle:** Fire needs heat, fuel, and oxygen to start
- **Flashover:** Sudden full-room ignition
- **Fully-Developed Stage:** Maximum burning
- **Growth Stage:** Fire starts spreading and intensifying
- **Heat Transfer:** Movement of heat via conduction, convection, or radiation
- **Incipient Stage:** Fire just igniting
- **Light (Thermal) Energy:** Heat and light given off by fire
- **Mechanical Energy:** Energy from movement, sometimes causes sparks
- **Oxidation:** Reaction of fuel with oxygen
- **Pyrolysis:** Breakdown of material from heat before ignition
- **Radiation:** Heat traveling in waves
- **Smoke Colour:** Helps indicate type of material burning
- **Smoke Explosion:** Ignition of trapped fire gases

Incident Command Structure

- **Chain of Command:** Order of authority
- **Division:** Personnel and resources assigned to a geographic location
- **Emergency Management Organization (EMO):** Coordinates emergency responses
- **Group:** Personnel and resources assigned to a specific task
- **Incident Action Plan (IAP):** Plan for managing an incident
- **Incident Command System (ICS):** Structured approach to managing emergencies
- **Incident Commander (IC):** Person in charge of an incident
- **Operations Function:** Part of ICS that manages tactical operations
- **Span of Control:** Number of people a leader can manage (usually 3–7)
- **Single Resource:** One unit (e.g., one engine or person)
- **Unity of Command:** Each person reports to only one boss

Operations and Tactics

- **Advancing Hose:** Moving hose toward the fire
- **Attack Hose:** Used directly on the fire
- **Charged Hose:** Filled with water, ready to use
- **Defensive Operations:** Fighting fire from a distance
- **Establishing Command:** Identifying who's in charge
- **Evolution:** Planned firefighting tasks or maneuvers
- **Exposure:** Nearby object at risk of catching fire
- **Freelancing:** Acting without direction during an incident
- **Initiating Response:** Units are en route
- **Overhaul:** Checking for and putting out hidden fire
- **PAR (Personnel Accountability Report):** Roll call for safety
- **Rehabilitation:** Rest and recovery for firefighters
- **Salvage:** Protecting property during/after firefighting
- **Scene Size-Up:** Assessing what's happening at the scene
- **Size-Up:** First look and judgment of the fire scene
- **Staging Area:** Place where people/equipment wait near the scene

PPE and Safety

- **Accountability Tag:** Tracks firefighter location and status
- **Bunker Gear:** Full protective firefighting gear
- **Carcinogens:** Cancer-causing substances from fire/smoke
- **Critical Incident Stress Management (CISM):** Mental health support after tough calls
- **Freelancing:** Acting without direction during an incident
- **PPE (Defensive):** Gear for indirect fire attack
- **PPE (Structural):** Gear for entering burning buildings
- **Rehab Officer:** Person monitoring health in rehab area
- **Safety Culture:** Shared values and actions for safety
- **Unacceptable Risk:** Danger too high to allow action

Radio Language and Protocols

- **Arrival on Scene:** Unit has reached the incident
- **Cancelling Response:** Units not needed anymore
- **Clearing the Scene:** Leaving the scene, ready for next call
- **Incident Type:** Describes the emergency
- **Location Indicators:** Help identify where something is
- **Phonetic Alphabet:** A set of code words used to clearly communicate letters over radio
- **Priorities:** Life safety, property protection, incident control
- **Resource Request:** Ask for more units/equipment
- **Situation Report:** Update on the current status

Water Supply

- **Dry Hydrant:** Pipe for pulling water from lakes or ponds
- **Portable Pump:** Moveable water pump
- **Portable Tank:** Temporary water holding tank at the scene
- **Pumper Truck/Attack Engine:** Vehicle with pump, hose, and water for fire attack
- **Static Water Supply:** Water from non-pressurized sources like ponds
- **Water Fill Station:** Spot for refilling water trucks
- **Water Shuttling:** Moving water from water source to scene