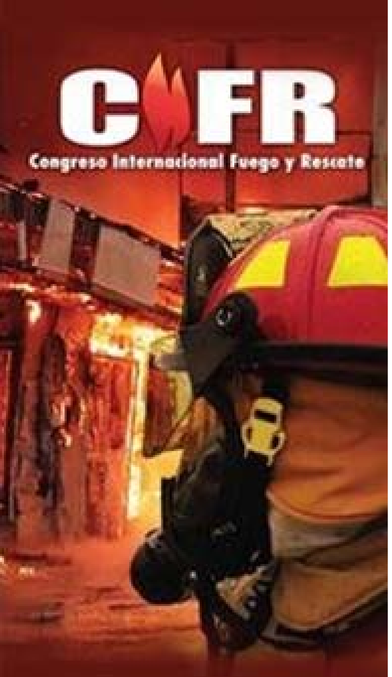

3D Firefighting

Controlling the Environment

Valdivia, Chile
January 2010

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In order to extinguish a fire properly, it is necessary for the firemen to approach it for the purpose of putting the water wherever it is most wanted. Any attempt to extinguish a fire from a distance almost invariably proves a failure.

Fire Protection, 1876
Sir Eyre Massey Shaw
Chief, London Fire Brigade

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Learning Outcomes

- Identify and describe factors influencing effectiveness of extinguishment by cooling
- Describe the application of indirect attack, direct attack, and 3D gas cooling

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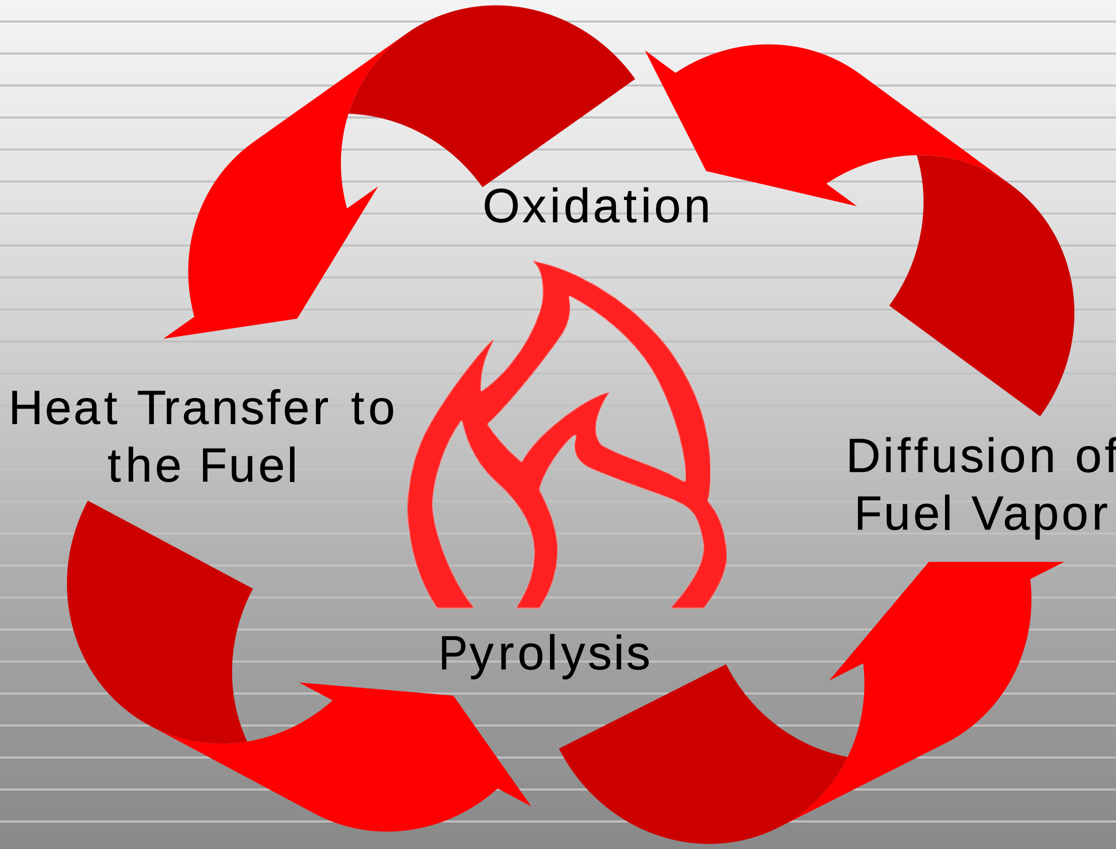
Extinguishment by Cooling



Cooling the fuel

Cooling the gases

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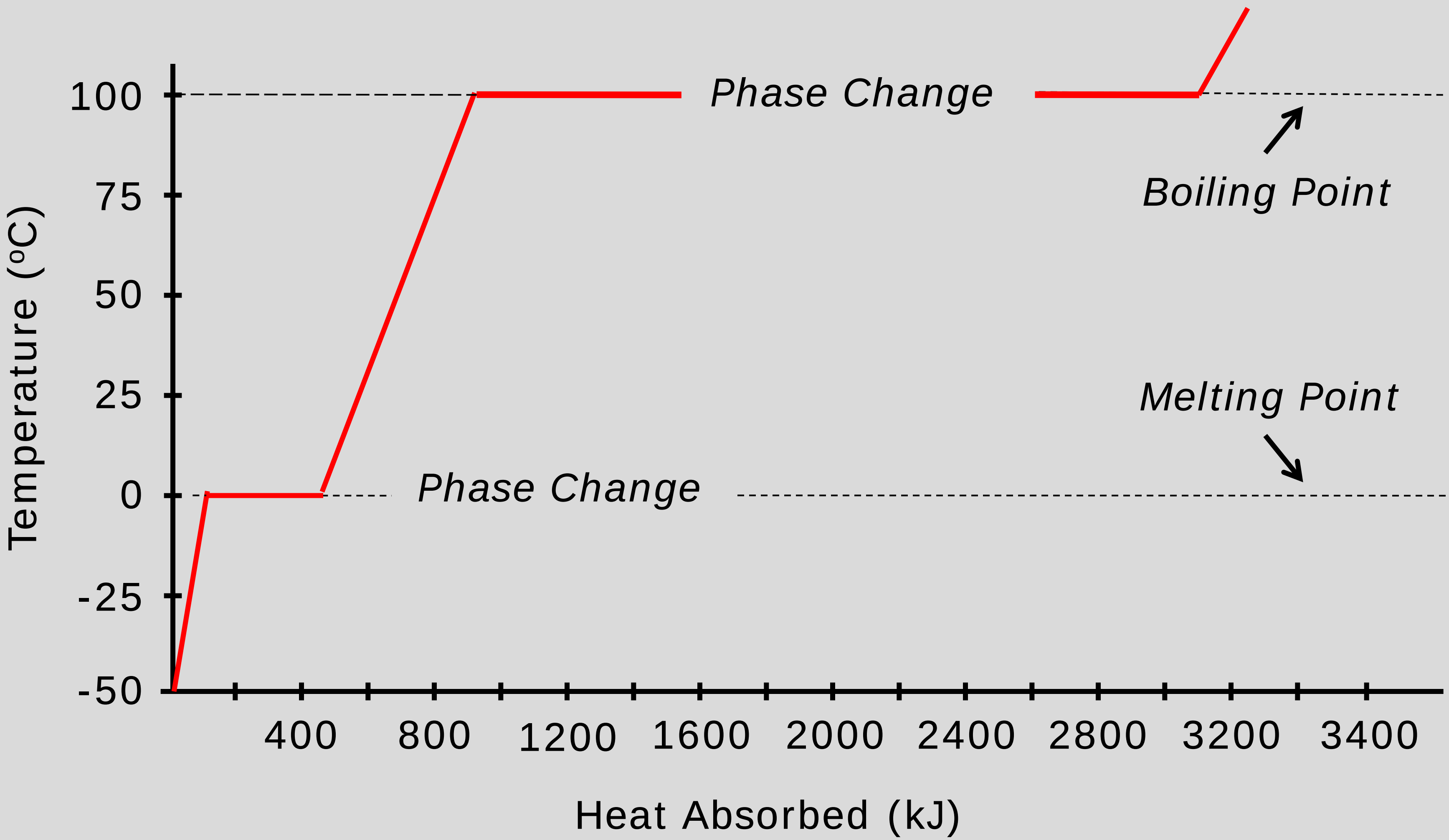
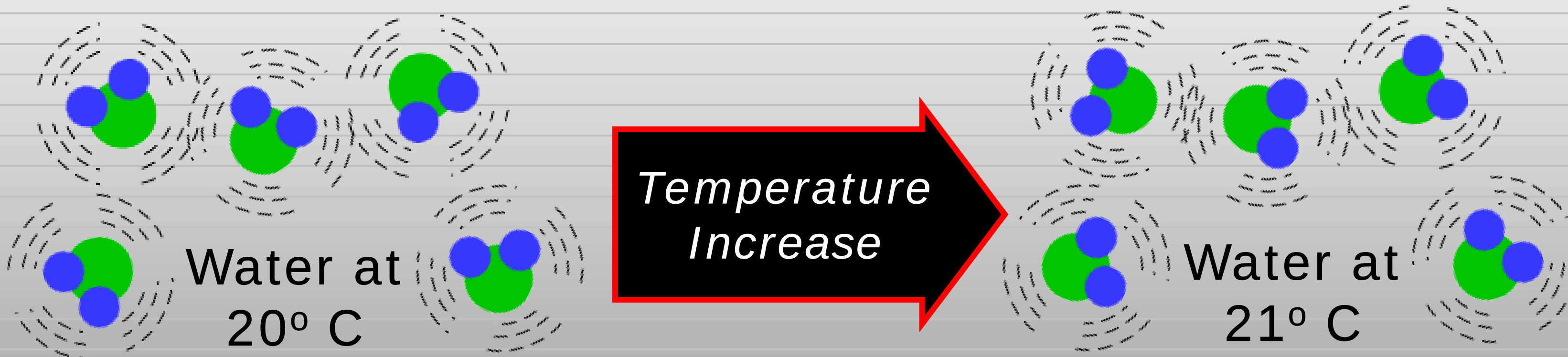
Heating Curve for Water*



* 1 kg (2.2 lbs) of Water from ice at -50º C to Steam over 100º C.

Specific Heat

The amount of heat per unit mass required to raise the temperature by one degree



Specific heat applies to all states of matter

Ice 2.093 kJ/kg

Water 4.186 kJ/kg

Steam 2.009 kJ/kg

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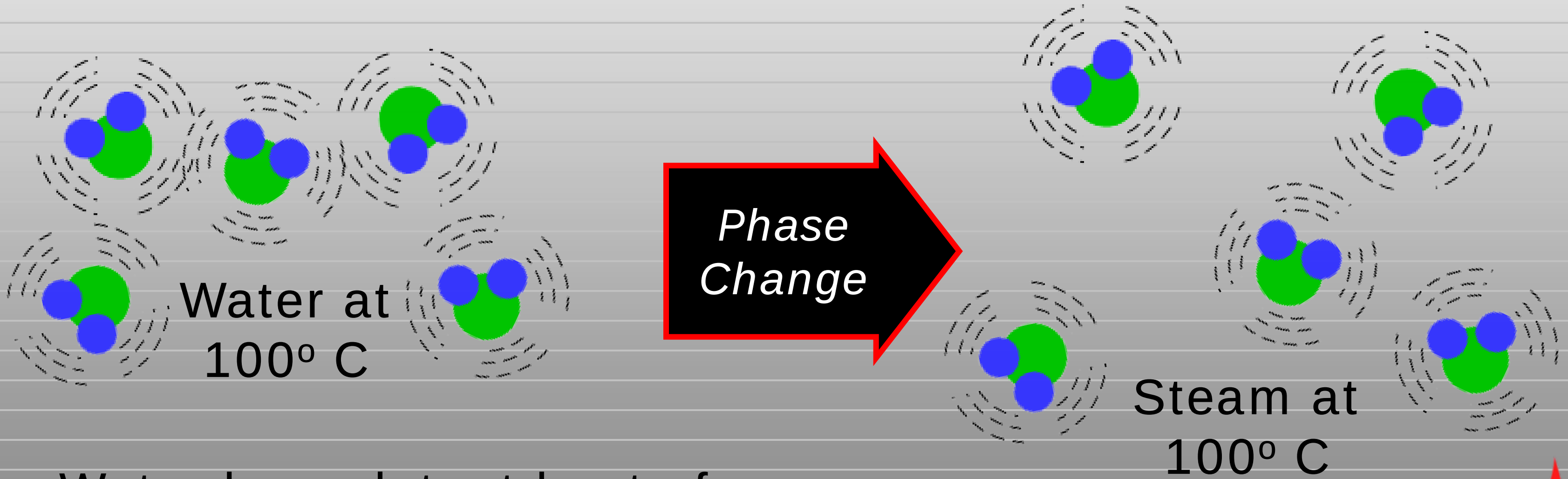
Latent Heat of Vaporization

The amount of heat required to convert unit mass of a liquid into the vapor without a temperature change



Water has a latent heat of vaporization of 2260.0 kJ/kg

Cooling Capacity

Heat required to raise the temperature of 1 kg (2.2 lbs) of water from 20º C (68º F) to 100º C (212º F)	**0.3 MJ**
Heat required to vaporize 1 kg (2.2 lbs) of water at 100º C	**2.3 MJ**
Total Heat Required	**2.6 MJ**

What happens after the water is vaporized into steam?

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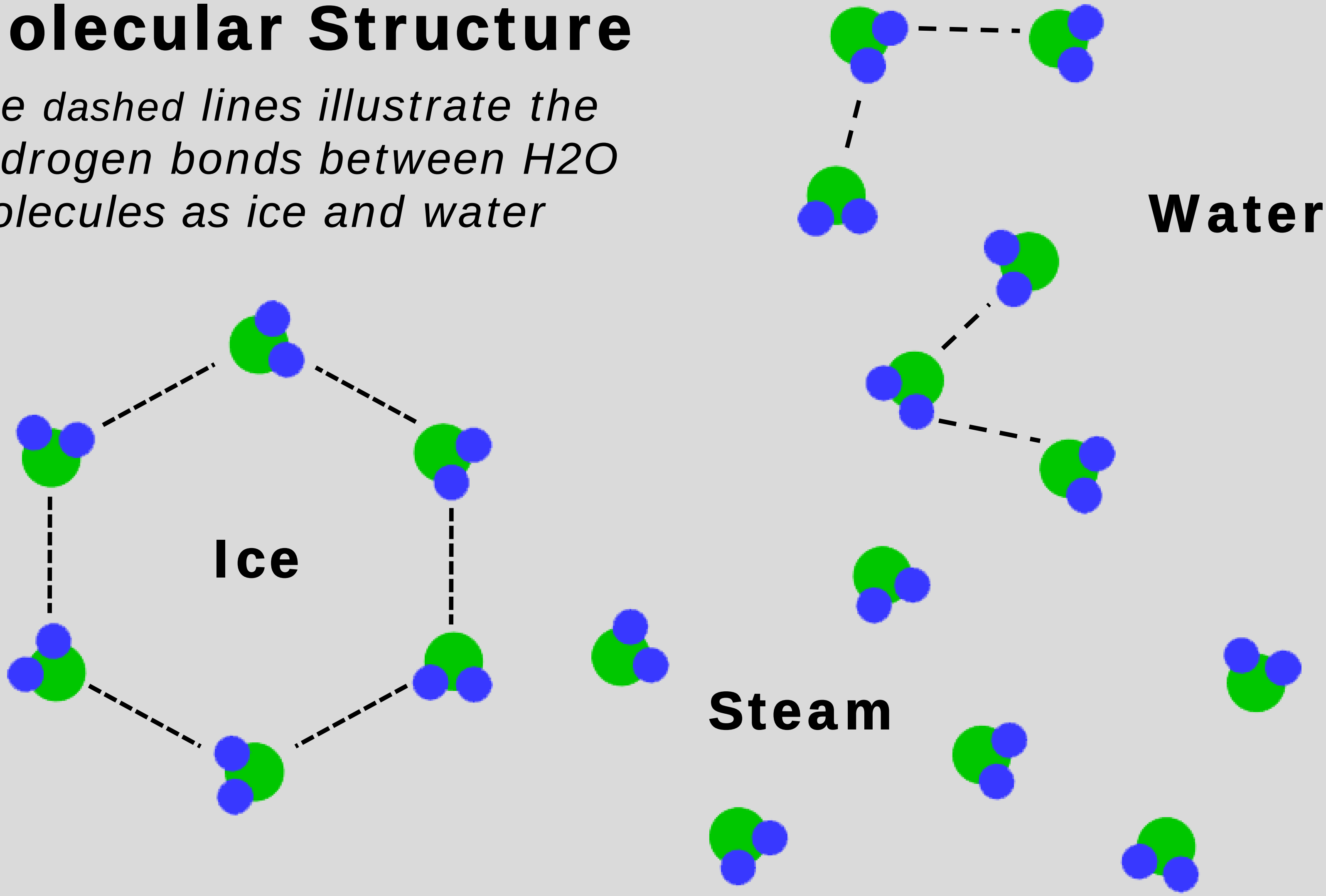
Molecular Structure

The dashed lines illustrate the hydrogen bonds between H2O molecules as ice and water



Phase Change Requires Energy to Break the Bonds

Heat Release & Flow Rate

- Heat Release Rate
  - *Kilowatts (kW)*
  - *Megawatts (MW)*
- Flow Rate
  - *Gallons/Minute (gpm)*
  - *Liters/Minute (lpm)*

The higher the heat release rate,
the higher the required flow rate!

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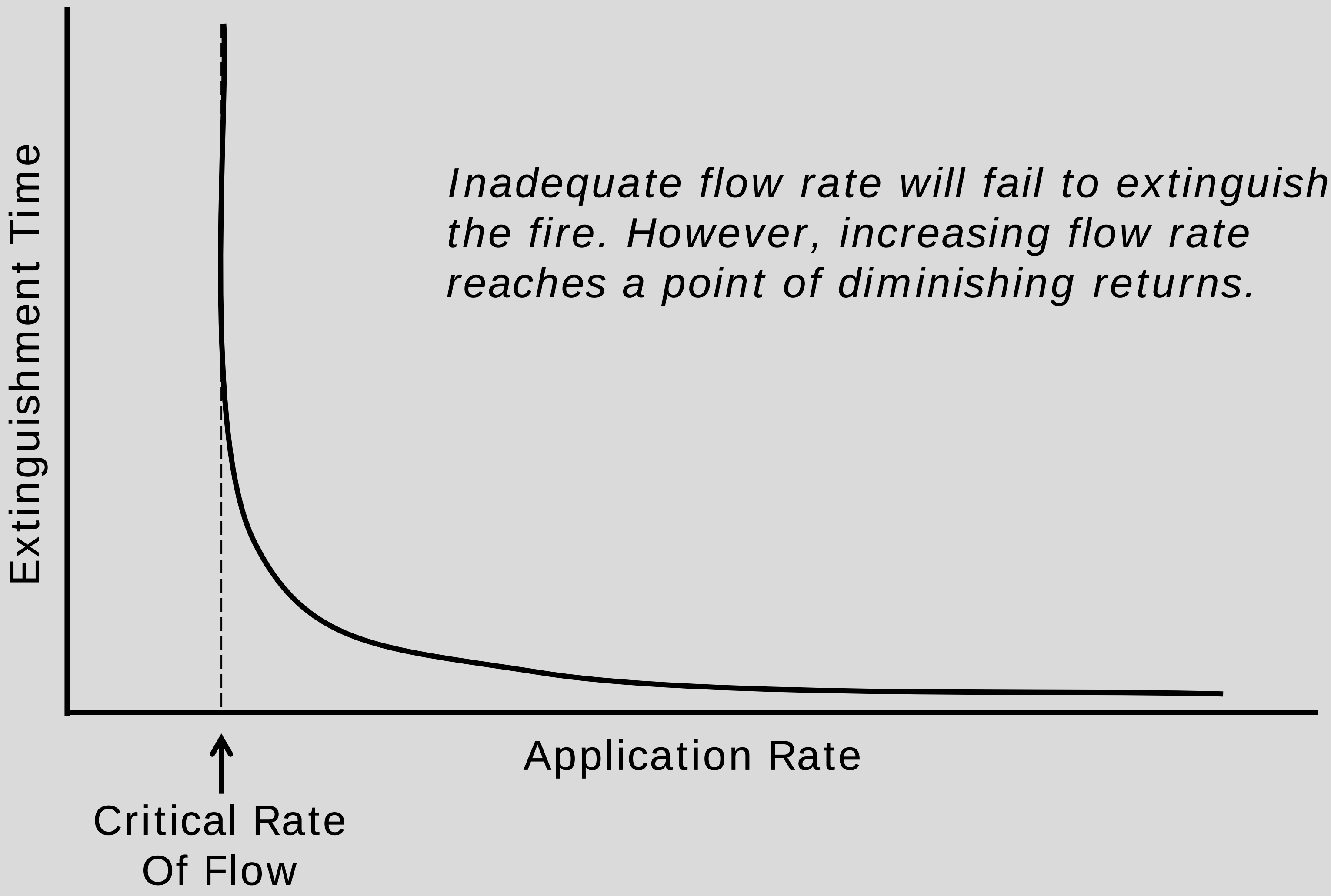
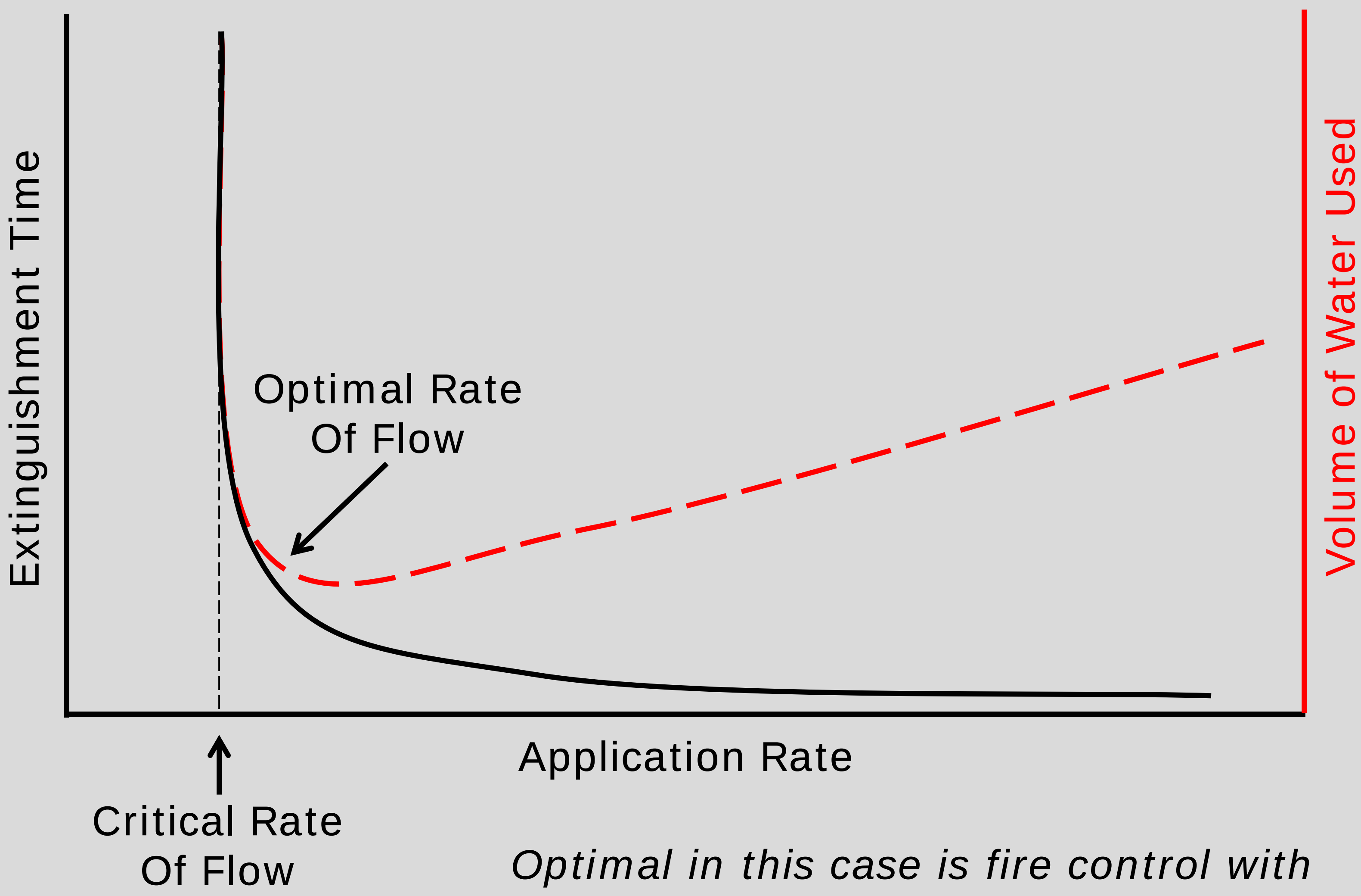
Critical Rate of Flow



Optimum Rate of Flow



Optimal in this case is fire control with the minimum volume of water used.

Theory and Application

- Only a small fraction of theoretical cooling capacity can be achieved on the fireground.
- Actual cooling is dependent on the efficiency of the fire stream (and its use).
- Water is applied to cool one of four things:
  - *Hot gases*
  - *Surface of burning fuel*
  - *Surface of unignited, but pyrolizing fuel*
  - *Surface of unignited fuel (exposure protection)*

Cooling Hot Gases

- Hot gas layer temperature can be 600º C (1112º F) at the point of flashover.
- The temperature of flames burning in the hot gas layer may be even higher
- Even pre-flashover, growth stage fires can result in extremely high hot gas layer temperatures
- Application of water fog into the hot gas layer cools and extinguishes these flames and cools the hot gases.

Cooling Fuel

Burning Fuel

- Application of water onto burning fuel reduces the pyrolysis rate
- Reduction of fuel vapor production results in extinguishment.

Unignited Fuel

- Unignited, but pyrolyzing fuel is contributing fuel to the hot gas layer.
- This fuel may also be ready to ignite!

Activity

Fire Stream Efficiency

- The efficiency of a fire stream is dependent the total amount of thermal energy absorbed.
- What factors influence this process?
  - *Think about the difference between cooling hot gases and fuel surfaces.*
  - *Is there a difference in the amount of heat that can be absorbed from application of water to hot gases as compared to hot surfaces?*

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Fire Stream Efficiency

- Small droplets have greater surface area and absorb heat more effectively than large ones.
- A thin film of water will have a greater surface area and absorbs heat more readily.
- Hot surfaces will heat water to 100º C (212º F)
- Steam in the hot gas layer continues to absorb heat as vapor temperature increases.

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Effective Fire Streams

- Put the water where it is needed (hot gases or fuel surface).
- Have an adequate flow rate to absorb heat faster than it is being generated by the fire
- An effective flow rate is dependent on actual flow rate and the efficiency of the stream

Water on the floor or running out the door did not do significant work!

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Fire Control Methods

- Direct Attack
- Indirect Attack
- Gas Cooling

No method is appropriate under all circumstances!

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Direct Attack

Application

Final extinguishing process for burning fuel

Effect

- Extinguishes the fire
- Cools hot surfaces
- Stops pyrolysis

Technique

Straight stream applied directly to burning or pyrolyzing fuel.

Smoke is fuel. Direct attack alone does not address this hazard.

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Indirect Attack

Application

Fully developed fire or potential backdraft conditions within a compartment

Technique

Medium fog pattern applied from outside the compartment using long pulses to generate a large volume of steam

Effect

- Cools hot gases
- Steam displaces air, smothering the fire
- Lowers the neutral plane, worsening conditions for casualties and firefighters

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3D Gas Cooling

Application

Cooling of hot gases to provide a buffer zone in the immediate work area

Technique

Pulses of water fog applied into the hot gas layer.

Effect

- Cools hot gases
- Adds thermal ballast
- Slows pyrolysis
- May raise the hot gas layer

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3D Gas Cooling

Application of the correct amount of water to the hot gas layer results in the following:

- Water is converted to steam and expands
- The volume of hot gas is reduced as it cools
- If the correct volume of water is applied the hot gas layer contracts and the bottom of the gas layer rises.

Nozzle Techniques

- Fog Stream
  - *Short Pulse*
  - *Longer Pulse*
- Straight (or Solid) Stream
  - *Penciling*
  - *Painting*

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Pulsing

Short

Long

- Angle of the Fog Cone

  Maximize the volume of droplets in the hot gas layer

- Position of the Fog Cone

  As with angle, maximize the volume of droplets in the hot gas layer

- Duration of the Pulses

  Sufficient to cool the gases

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Nozzle Pressure

150 gpm at 50 psi
(567.81 lpm at 3.44 bar)

150 gpm at 100 psi
(567.81 lpm at 6.89 bar)

Droplet size is significant!
0.3 mm is optimal
Size may be estimated using “hang time”, smaller droplets “hang” longer

Surface Cooling

- Pattern

  Straight stream or very narrow fog cone

- Force

  Sufficient to reach the target fuel and place water where it is needed

- Duration of application

  Sufficient to cool the surfaces, achieve extinguishment and stop pyrolysis

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Key Points

No one technique is appropriate under all circumstances

- 3D gas cooling most important when the fire is shielded and hot gases are overhead.
- 3D gas cooling is a control technique and does not completely extinguish the fire
- Extinguishing fires involving solid fuel generally requires a direct attack

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