Section 1: Theory of Heat

Unit 1: Heat and Pressure

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UNIT OBJECTIVES

After studying this unit, the reader should be able to

- Define temperature.
- Make conversions between Fahrenheit and Celsius scales.
- Describe molecular motion at absolute zero.
- Define the British thermal unit.
- Describe heat flow between substances of different temperatures.
- Explain the transfer of heat by conduction, convection, and radiation.
- Discuss sensible heat, latent heat, and specific heat.
- State atmospheric pressure at sea level and explain why it varies at different elevations.
- Describe two types of barometers.
- Explain psig and psia as they apply to pressure measurements

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TEMPERATURE

- The ***level of heat*** or ***heat intensity***
- Measured with thermometers
- English system – Fahrenheit (°F)
- Metric system – Celsius (°C)
- Fahrenheit Absolute scale – Rankine (°R)
- Celsius Absolute scale - Kelvin (°K)
- Absolute zero – Temperature at which all molecular movement stops (-460°F)

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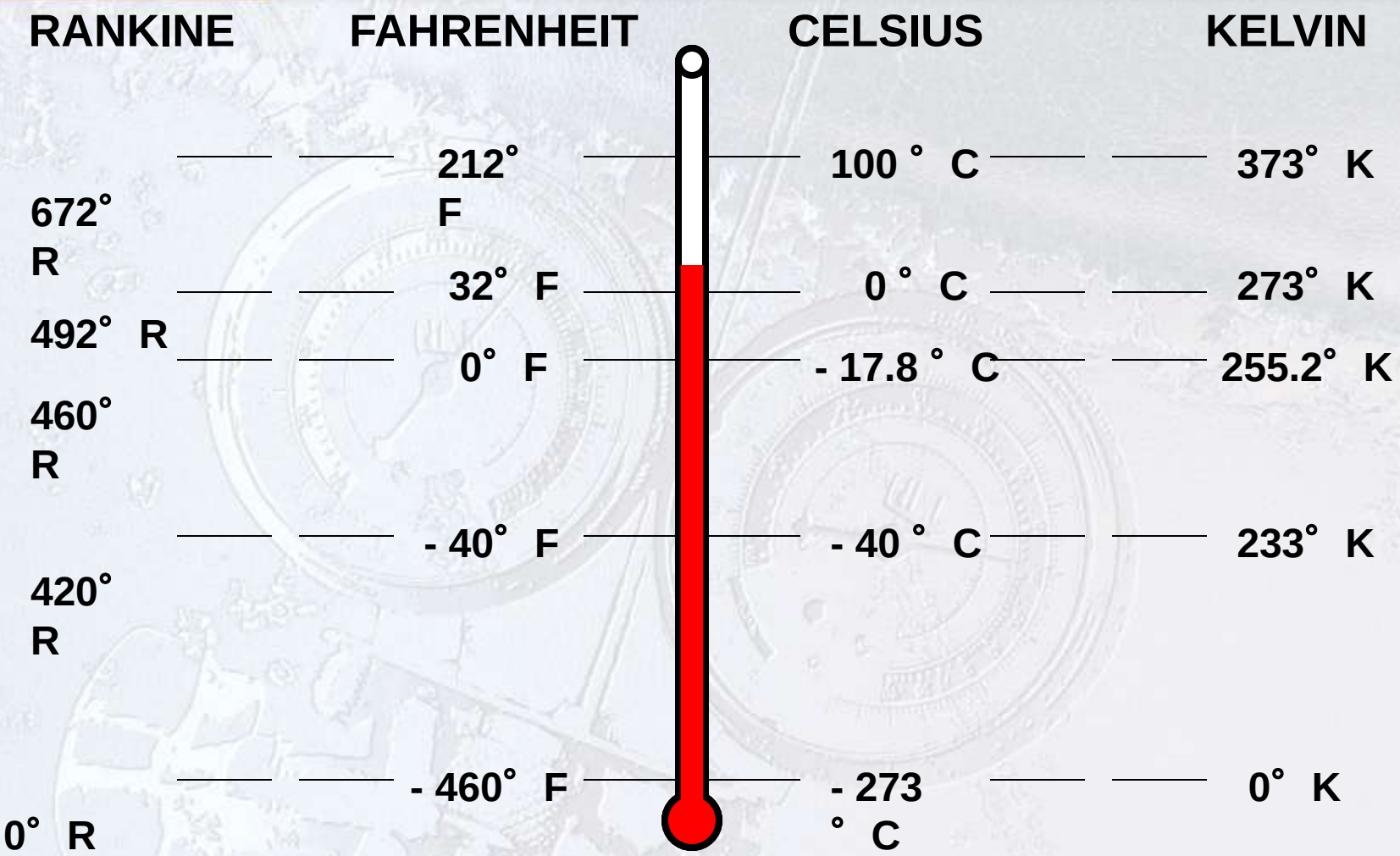

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FAHRENHEIT TO CELSIUS CONVERSIONS

$^{\circ}C = (5/9)\ (^{\circ}F - 32)$

EXAMPLE: CONVERT 212°F TO CELSIUS

$^{\circ}C = (5/9)\ (212 - 32)$

$^{\circ}C = (5/9)\ (180)$

$^{\circ}C = 5 \times 20$

$^{\circ}C = 100$

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CELSIUS TO FAHRENHEIT CONVERSION

$^{\circ}F = (9/5)^{\circ}C + 32$

EXAMPLE: CONVERT $10^{\circ}C$ TO FAHRENHEIT

$^{\circ}F = (9/5)(10) + 32$

$^{\circ}F = (9 \times 2) + 32$

$^{\circ}F = 18 + 32$

$^{\circ}F = 50$

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INTRODUCTION TO HEAT

- Heat is the ***motion of molecules***
- Heat *cannot* be created or destroyed
- Heat *can* be measured and accounted for
- Heat *can* be transferred from one substance to another
- Heat travels from a warmer substance to a cooler substance
- Quantity of heat in a substance is measured in British Thermal Units, BTUs

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THE **BRITISH THERMAL UNIT** IS THE AMOUNT OF HEAT ENERGY THAT IS REQUIRED TO RAISE THE TEMPERATURE OF 1 POUND OF WATER 1 DEGREE FAHRENHEIT

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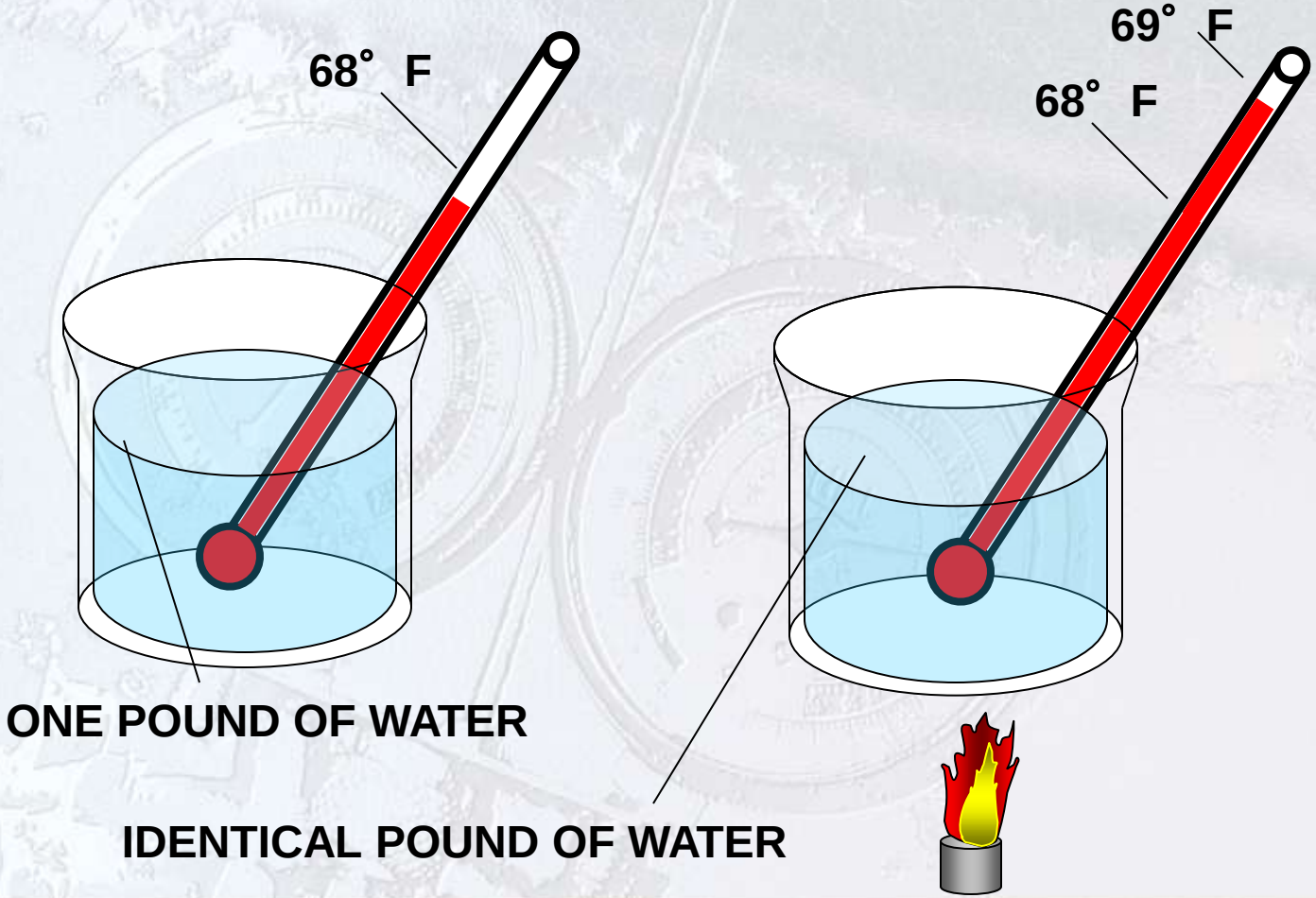
ONE BTU OF HEAT ENERGY HAS BEEN ADDED TO ONE POUND OF WATER



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CONDUCTION

- Heat energy travels from one molecule to molecule within a substance
- Heat energy travels from one substance to another
- Heat does not conduct at the same rate in all materials
- Example of conduction:

Heat will travel through a copper rod when placed near fire

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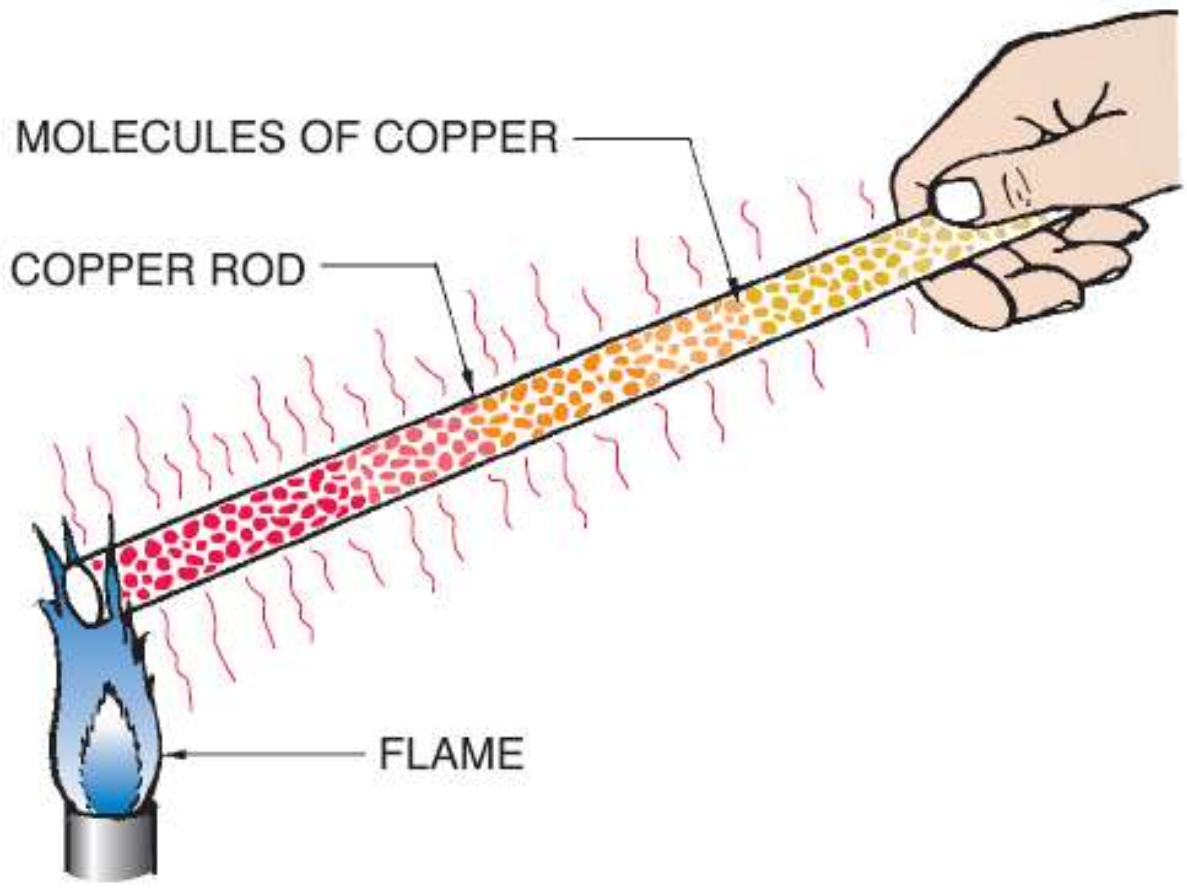

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CONVECTION

- Heat transfers through a fluid from one substance to another
- Natural convection utilizes natural fluid flow, such as the rising of warm air and the falling of cooler air
- Forced convection uses fans or pumps to move fluids from one point to another
- Example of convection:

Baseboard Heating

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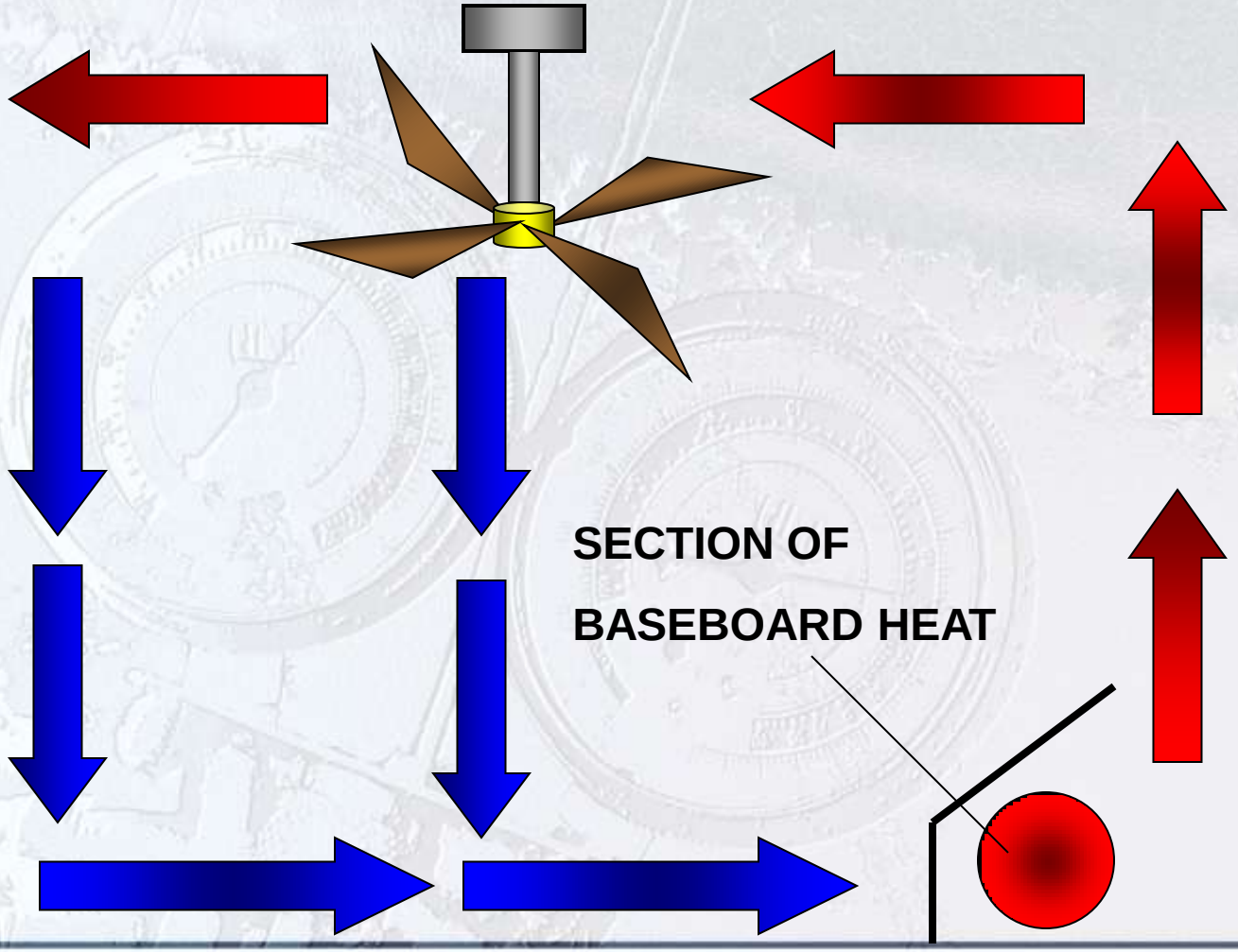

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RADIATION

- Radiant heat passes through air, heating the first solid object the heat comes in contact with
- These heated objects, in turn, heat the surrounding area
- Radiant heat can travel through a vacuum
- Radiant heat can travel through space without heating it
- Example of radiation:

An electric heater that glows red

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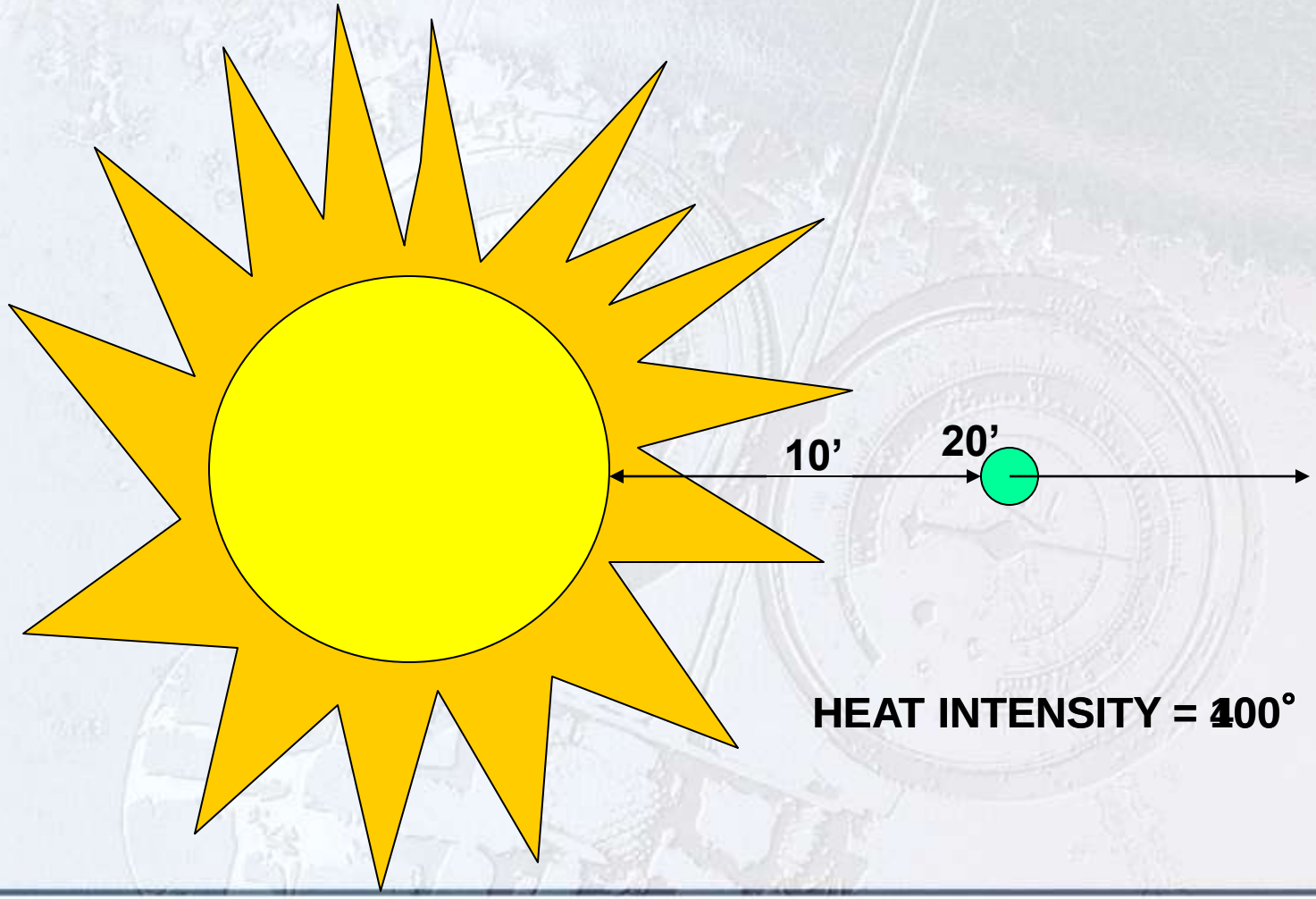

HEAT INTENSITY = 400° F

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SENSIBLE HEAT

- Heat transfer that results in a change in temperature of a substance
- Sensible heat transfers can be measured with a thermometer
- Example of a sensible heat transfer:

  Changing the temperature of a sample of water from 68° F to 69° F

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LATENT HEAT

- Also referred to as ***hidden heat***
- Latent heat transfers result in a change of state of a substance with no change in temperature
- Latent heat transfers cannot be measured with a thermometer
- Example of a latent heat transfer:

Changing 1 pound of ice at 32˚ F to

1 pound of water at 32˚ F

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SPECIFIC HEAT

- Defined as the number of btus required to raise the temperature of 1 pound of a substance 1 degree Fahrenheit
- Specific heat of water is 1.00
- Specific heat of ice is approximately 0.50
- Specific heat of steam is approximately 0.50
- Specific heat of air is approximately 0.24

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SPECIFIC HEAT FORMULA

Q = Weight x Specific Heat x Temperature Difference

Where Q = Quantity of heat needed for the temperature change

Example: 1000 pounds of steel must be heated from 0° F to 70° F.

How much heat is required to accomplish this?

The specific heat of steel is 0.116 btu/lb

Substituting in the above formula gives us

Q = 1000 pounds x 0.116 btu/lb x (70° F - 0° F)

Q = 1,000 x 0.116 x 70 = 8,120 btu

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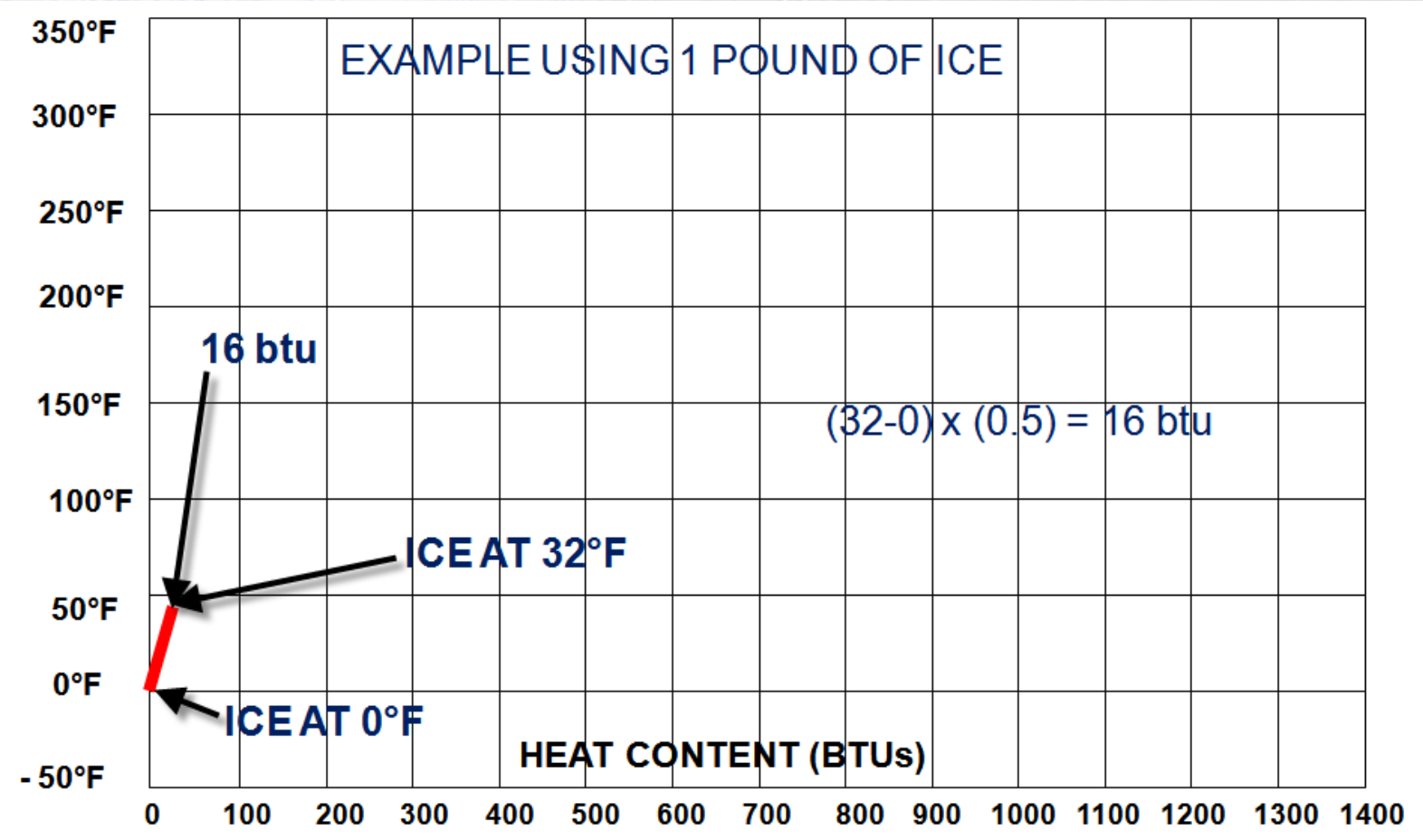

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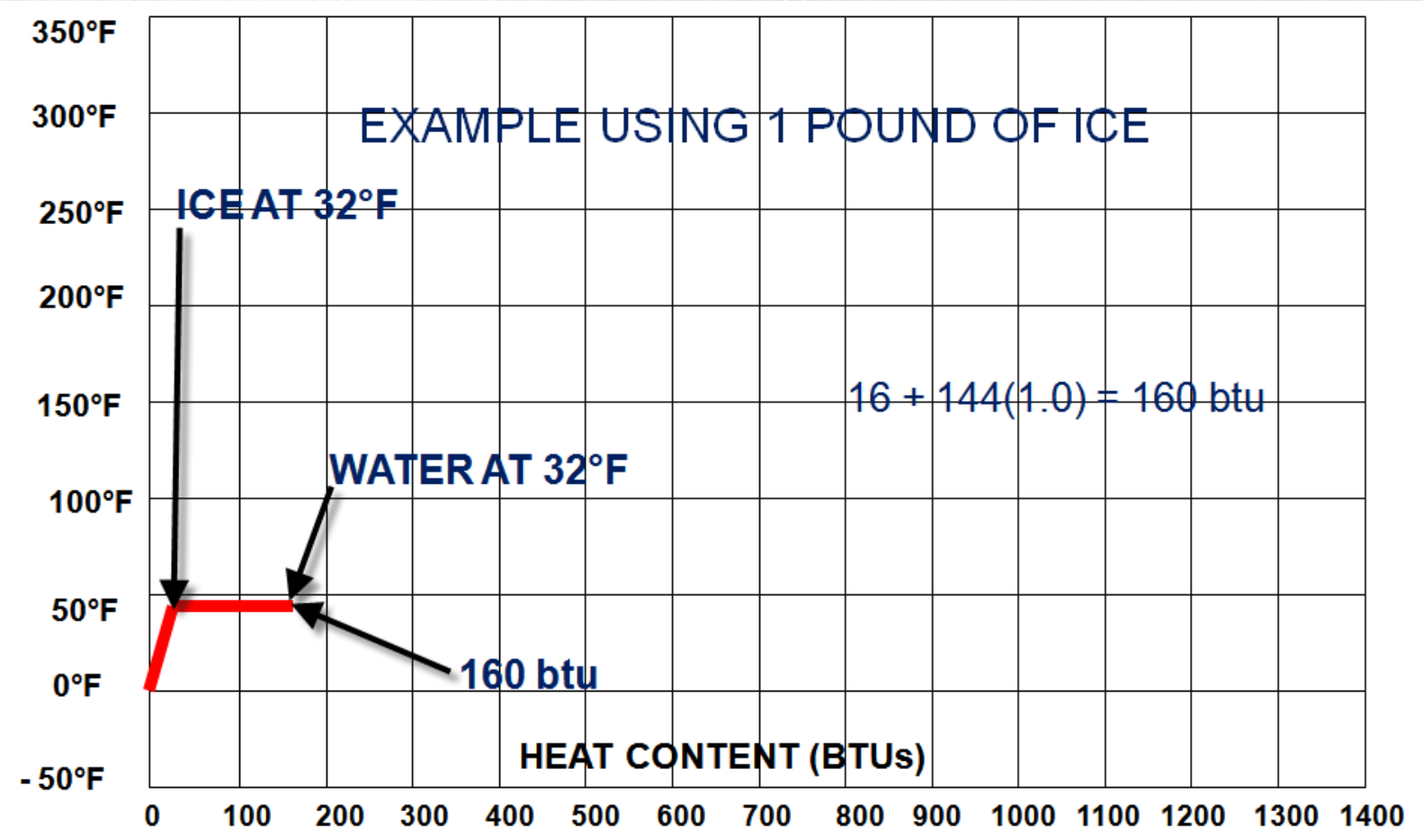

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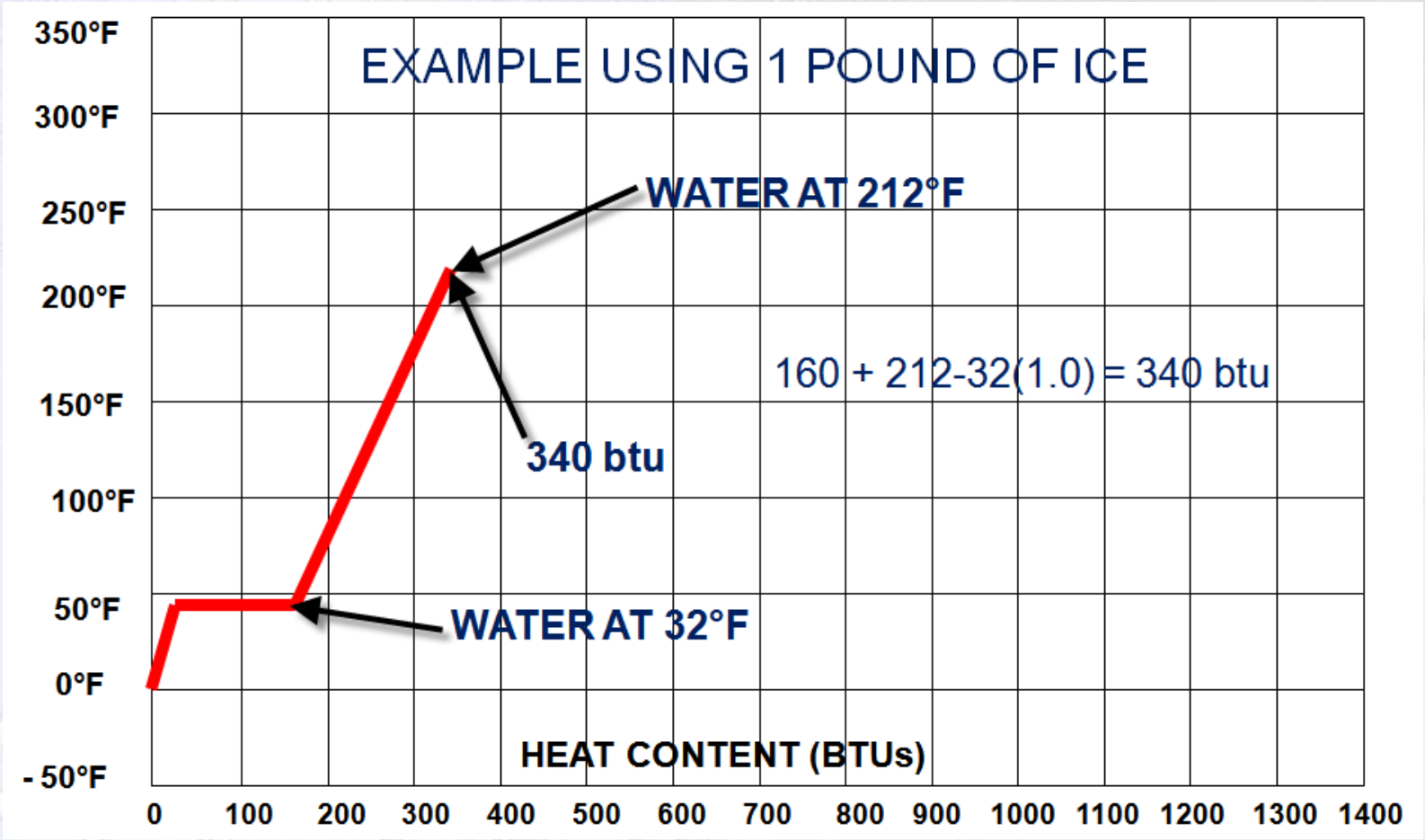

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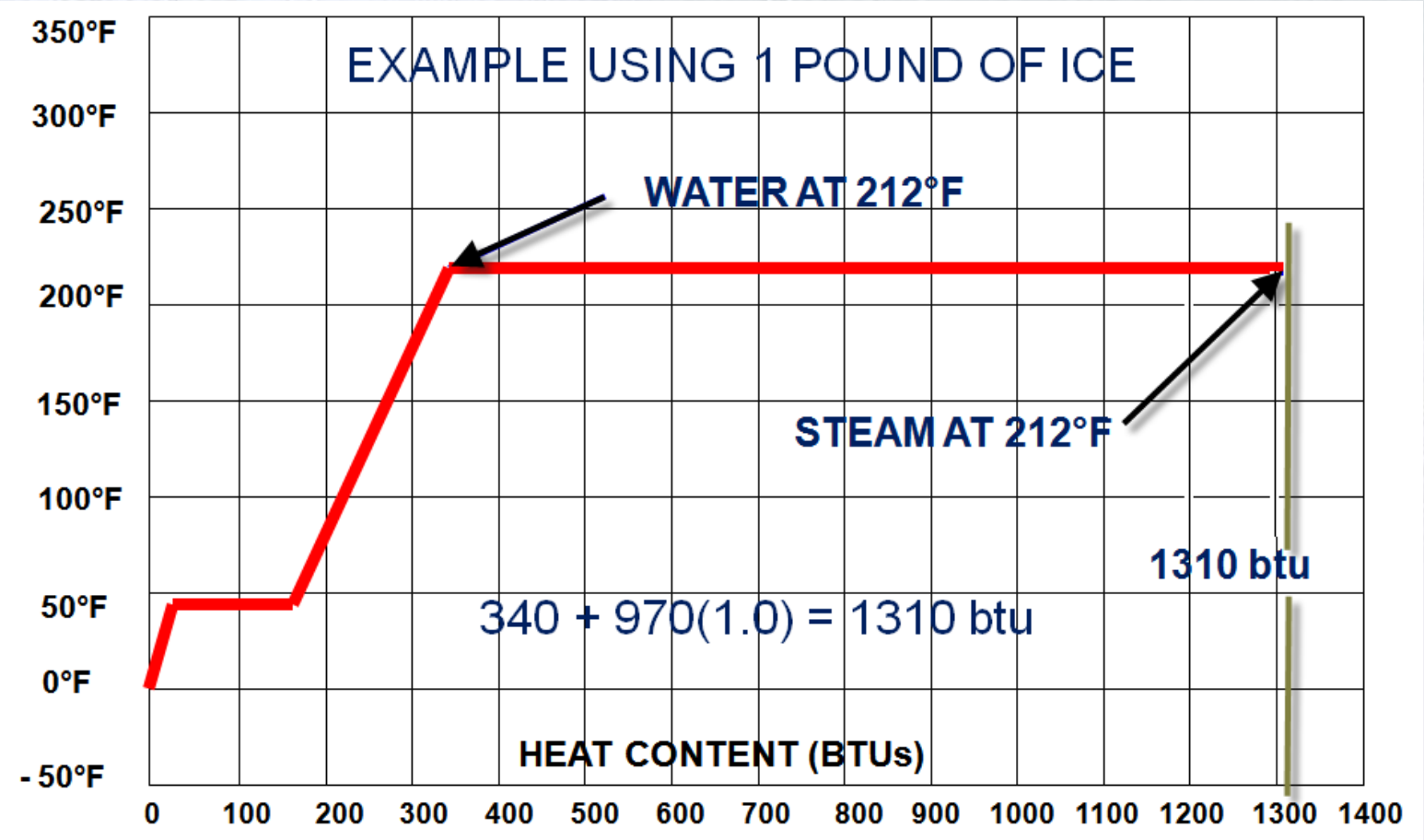

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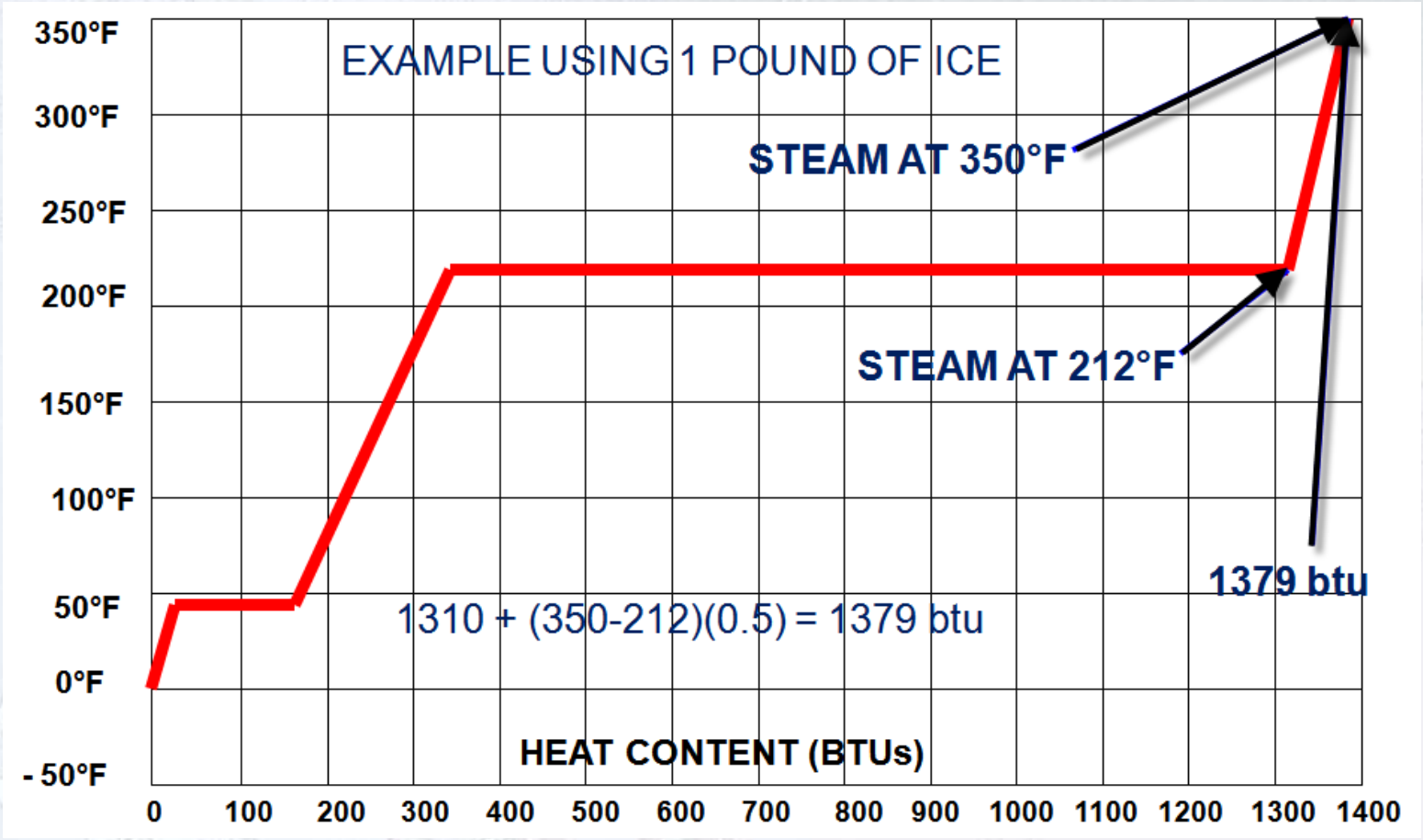

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SUMMARY OF ICE EXAMPLE

Ice at 0° F to Ice at 32° F	(32 – 0) (0.5)	= 16 btu
Ice at 32° F to Water at 32° F		= 144 btu
Water at 32° F to Water at 212° F	(212 – 32) (1.0)	= 180 btu
Water at 212° F to Steam at 212° F		= 970 btu
Steam at 212° F to Steam at 350° F	(350-212)(0.5)	= 69 btu
TOTAL HEAT TRANSFER		= 1,379 btu

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PRESSURE

- Defined as the force per unit area
- Often expressed in pounds per square inch
- Example: If a 100-pound weight rests on a surface of 1 square inch, the pressure is 100 psi
- Example: If a 100-pound weight rests on a surface of 100 square inches, the pressure is only 1 psi

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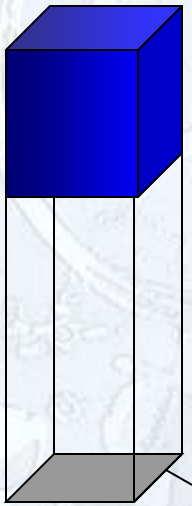
100 pound block

1 cubic inch block with a weight of 1 pound



100 square inches

1 square inch

Pressure = 1 psi

1 square inch

Pressure = 100 psi

Pressure = 1 psi

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ATMOSPHERIC PRESSURE

- The atmosphere we live in has weight
- The atmosphere exerts a pressure of 14.696 psi at sea level (often rounded off to 15 psi)
- 14.696 psi at sea level is known as the **standard condition**
- Measured with a barometer

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THE BAROMETER

- Used to measure atmospheric pressure
- Constructed as a 36” glass tube
- Tube is sealed at one end and filled with mercury
- The tube is inverted and placed mercury
- As atmospheric pressure drops, so does the level of mercury in the tube
- At atmospheric pressure, the height of the mercury will be 29.92”

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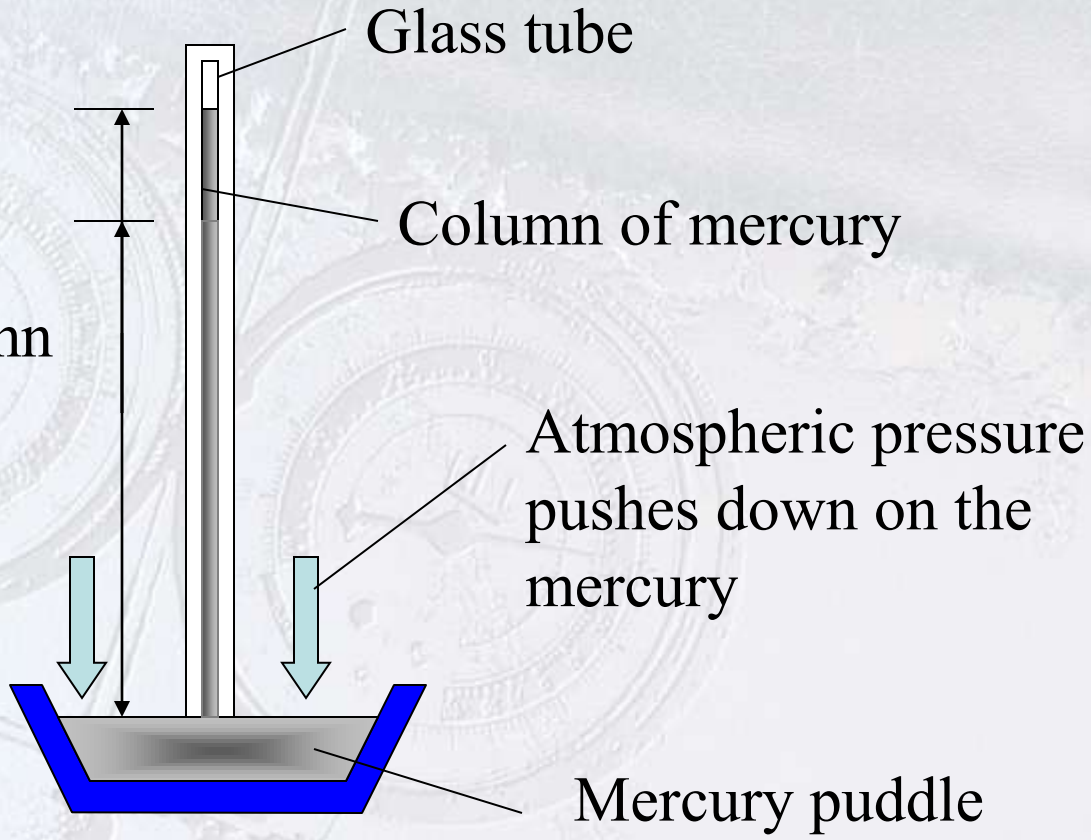
As atmospheric pressure drops, so does the level of mercury in the tube

Height of mercury column is 29.92” at standard condition



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INCHES OF MERCURY AND PSI

- The column of mercury is 29.2” at atmospheric condition of 14.696 psi
- One psi is equal to approximately 2” Hg
- Example: If the barometer reads 20”Hg, then the atmospheric pressure is approximately equal to 10 psi
- Absolute pressures are measured in pounds per square inch absolute, psia

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PRESSURE GAGES

- Bourden tube – measures pressure in a closed system
- Used to measure the pressures in an air conditioning or refrigeration system
- Gages read 0 psi when opened to the atmosphere
- Gage pressures are measured in pounds per square inch gage, psig

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PRESSURE CONVERSIONS

- To convert gage pressure to absolute pressure, we add 15 (14.696) psi to the gage reading
- To convert absolute pressure to gage pressure, we subtract 15 (14.696) from the absolute pressure
- Example: 0 psig = 15 psia
- Example: 70 psig = 85 psia

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UNIT SUMMARY

- Thermometers measure temperature
- The higher the temperature, the faster the molecular movement
- One BTU raises the temperature of one pound of water one degree Fahrenheit
- Heat can be transferred by conduction, convection or radiation
- Sensible heat transfers change the temperature of a substance
- Latent heat transfers result in a change of state with no change in temperature
- Pressure is the force per unit area
- Barometers measure atmospheric pressure in “Hg
- Gauges measure pressures in enclosed systems

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