Properties of Steam: Thermodynamics 101

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Introduction

- Why Do We Care?
  - This forms the basis for how a steam engine operates, without a basic understanding of the “why” it's very hard (impossible?) to be a safe and competent engineer.

Intro (continued)

- Steam Engine = Heat Engine
- Able to turn stored mechanical energy in fuel to mechanical energy via a heat transfer medium (water)

Terminology

- Heat-Measurement of ENERGY
  - BTU in imperial measurements, calories or kJ in metric

Terminology

- Temperature-Measurement of hot or cold, expressed on a scale (Celsius & Kelvin in SI, Fahrenheit & Rankine in Imperial). Temperature is not a measurement of heat ENERGY
- Consider a coffee cup vs a swimming pool!

Terminology

- BTU= British Thermal Unit
  - Amount of HEAT ENERGY required to raise 1 lb of water 1 degree F

Water

- Water is a compound- H20, 2 hydrogen atoms combined with 1 oxygen atom forms a water molecule.
- Has a large amount of intermolecular bonds (4), which means that it takes energy (in the form of heat) to “break up” it's natural tendency to bond together
- Exists in 3 phases: solid, liquid, vapor

Teeny Little Bit of Thermodynamics

- Sensible Heat: Heat Energy that results in a change in Temperature. Expressed in BTU/lb
- Latent Heat: Heat Energy that is absorbed by a substance, not resulting in a change of temperature but usually a change of state. Expressed in BTU/lb
- **1st law of Thermodynamics, Energy can neither be created nor destroyed, merely change from one form to another.

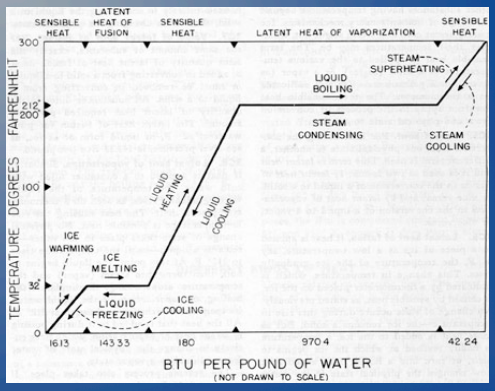
Less-Teeny Bit of Thermodynamics

- Specific Heat: Also know as heat capacity, amount of energy a substance can absorb before a temperature change is noted.
- Specific Heat of Water= 1BTU/LB
- Specific Heat Calculation
  - Q=MC(T2-T1)

Slightly More Thermodynamics

- Latent Heat of Fusion: Amount of energy required to change a substance from solid to liquid, water= 144 BTU/lb
- Latent Heat of Vaporization: Amount of energy required to change a liquid to a vapor/gas, water = 970 BTU/lb

Heat Diagram



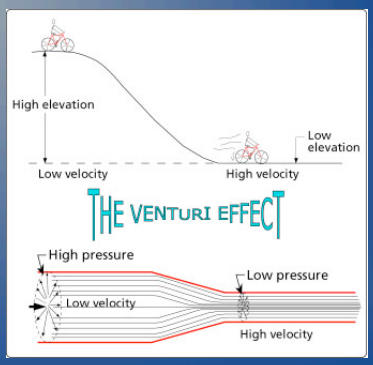
Why Did I Bother With That?

- Consider the VASTLY GREATER amount of energy required to make steam, vs just raising the temperature
- There's a reason a watched pot seems to never boil!

Pressure

- Measurement of force over area
- In imperial system, Pounds per Square Inch (PSI)
- Atmospheric pressure at sea level 14.7 PSI (A)
- PSIA vs PSIG
- Pressure is different than velocity (static force vs movement)
- Pressure can be changed to velocity using a venturi (2 cones), and back again

Venturi



Pressure/Temperature relationships

- Once vaporization has been achieved, temperature will increase with pressure.
- Steam Tables provide a convenient reference (see included table)
- Note: Vaporization can occur at lower temperatures, with less heat energy, at less than atmospheric pressure (14.7 PSIA)

Properties of Steam

- Water that has changed to steam expands approximately 1650 times.
- For example:
  - A boiler contains 200 gallons of water at 365 F, if suddenly released from the pressure keeping it liquid, will expand to approx 44000 cubic feet of steam.

Flashover/BLEVE

- With sudden reduction in Pressure, a liquid that has been heated above the (new) boiling point will expansively “flash” to steam.
- This can be caused by a sudden increase in boiler load, oversized pressure relief valve, etc
- BLEVE= Boiling Liquid Expanding Vapour Explosion. A sudden and catastrophic release of liquid above atmospheric boiling point resulting in an explosion

Types of Steam

- Saturated: Steam that is in contact with the water. This steam has a saturation temperature.
- Wet vs Dry: description of the amount of liquid entrained in the steam, expressed in dryness fraction. 100% dry would be perfectly dry saturated steam, but this is a theoretical impossibility.

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- Consider the amount of energy contained in steam vs liquid water. We always want to aim for the driest steam possible, as it contains the most energy and can do the most work.
- Excessively wet steam can result in engine problems such as pounding, cylinder breakage, lubrication loss, etc

Types of Steam

- Superheated Steam: Steam which has been removed from contact with the liquid water and had additional heat energy added to it, raising it above the saturation temperature.
- Not common in traction engine use, but extensively used in railway and power generation practices.
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