

### 3.37 (Class 16)

#### Review

- Heat intensity determines heating efficiency, HAZ size, travel speed, automation, equipment cost, depth to width ratio and production volume requirements
  - Pass around: weld in HY80 showing heat affected zone
  - Fourier's 1<sup>st</sup> law of heat conduction  $q$  (in  $\text{w/cm}^2$ ) =  $-k \cdot dT/dx$
  - Heat flows into cold material faster than hot material
- The temperature of flames is controlled by enthalpy of reaction, oxygen/fuel ratio and presence of inerts

#### Today

Combustion Intensity (or Index) = heating value of gas x gas velocity

- $CI = CH \times CV$
- Proportional to temperature squared

Types of burners/torches, three types of flames (diagrams on board)

- Diffuse flame
  - Fireplace
  - Fuel and oxidant comes together in an uncontrolled way
  - Know that it is typically an oxygen-starved flame (add more oxygen to make it burn quicker and hotter, i.e. blacksmith, also can tell from the color of the smoke)
  - World Trade Center, smoke was black, unburned carbon, say 1200-1300degF, steel did not melt, did get hot
  - Cannot melt steel in a diffuse flame, because do not control the inerts
  - Relatively low burning velocities ( $<1\text{m/s}$ , say  $0.1\text{m/s}$ )
- Premixed flame
  - Premix the unburned fuel and oxygen
  - Ignite externally
  - Burning velocity of approx  $1\text{m/s}$
  - Constant pressure process
- Jet burner
  - Mix and ignite
  - Ignition at constant volume
  - Burning velocities at say  $100\text{m/s}$

Premixed flame is of the most interest in welding

- Measure heating rate on surface of plate, 10-50 times less than theoretically calculated value using equation above, flame only about 2-10% efficient

- Due to boundary layer, gas hits surface (see diagram on board), shoots off to the side, gas boundary layer forms, gas doesn't move as fast at the boundary (drops to zero), thermal boundary layer, creates insulating layer
- Flames can be very inefficient due to the gas boundary layer
- Even for the best pre-mixed flames like acetylene with pure oxygen only about 10% efficient, only about 1000W/cm<sup>2</sup> reaches surface
- Pure oxygen vs. air, can get about a 10fold increase of
- Oxyacetylene torch about 10 times the efficiency of an air acetylene torch, inerts drop both CH and CV

#### Demonstration

- Propane: C<sub>3</sub>H<sub>8</sub>
- MAPP Methyl Acetylene Propadiene: two carbons with triple bond, add methyl group to get C<sub>3</sub>H<sub>4</sub>, mixture of this and propadiene, also C<sub>3</sub>H<sub>4</sub>
- To burn a solid, have to vaporize the solid first (ex. candle)
- MAPP has higher carbon ratio than propane, burns hotter
- In notes, temperature plotted against C/H ratio (see diagram on board), with 0 as pure hydrogen, 1 as acetylene, methane, MAPP at approx 0.75
- Piece of steel in the two flames, MAPP heats faster and hotter than the propane, air premixed flame

#### MAPP gas safer than acetylene

- Acetylene has a wide range of flammability limits (concentration for explosion)
- Acetylene self ignites under pressure

#### Discovery of acetylene

- Limestone in arc furnace
  - $\text{CaO} + 2\text{C} \rightarrow \text{CaC}_2 + \text{CO}$
- Threw in brook, brook caught on fire
  - $\text{CaC}_2 + \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2 + \text{C}_2\text{H}_2$
  - Discovered acetylene

#### How to store acetylene

- B-cylinder ("Bus" cylinder)
- Dissolve in acetone
- Very porous ceramic, with small felt filter
- Many sites generate own acetylene w/ CaC<sub>2</sub>, pipe around facility
- Story: with a fire, don't want to use water on CaC<sub>2</sub>
- Water on metal fires same thing, decompose the water, form hydrogen and get secondary (type D extinguisher is for metal fires, an inert powder that coats)