Today

- Parts handling & Mechanical assembly
- Joining processes:

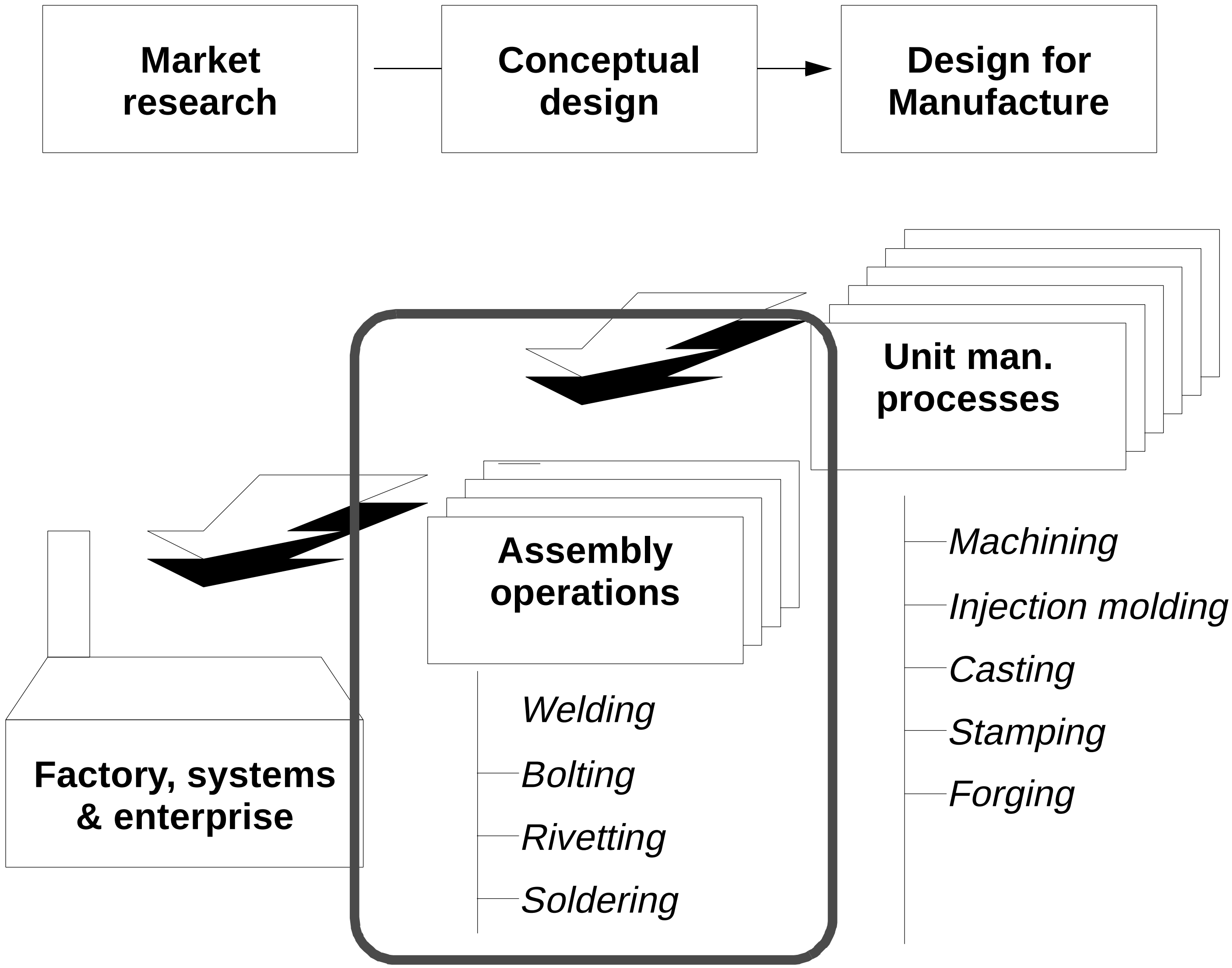
  Mechanical joining

  Soldering & Brazing

  Gluing

  Welding (Several sub areas)
- **Design for Assembly**

Manufacture



Classification of joining processes

Mechanical:

- nuts/bolts
- rivets
- C-clips
- pressure fits

Solid-liquid:

- Adhesives
- Soldering
- Brazing

Solid:

- Friction
- Diffusion
- Explosion
- Ultrasound

Liquid:

Chemical:

- Oxyfuel
- Thermit

Arc Welding

Consumable electrode

- Shielded metal arc
- Submerged arc
- Gas metal arc

Consumable electrode

- Gas Tungsten
- Plasma Arc
- Electron Beam

Resistance:

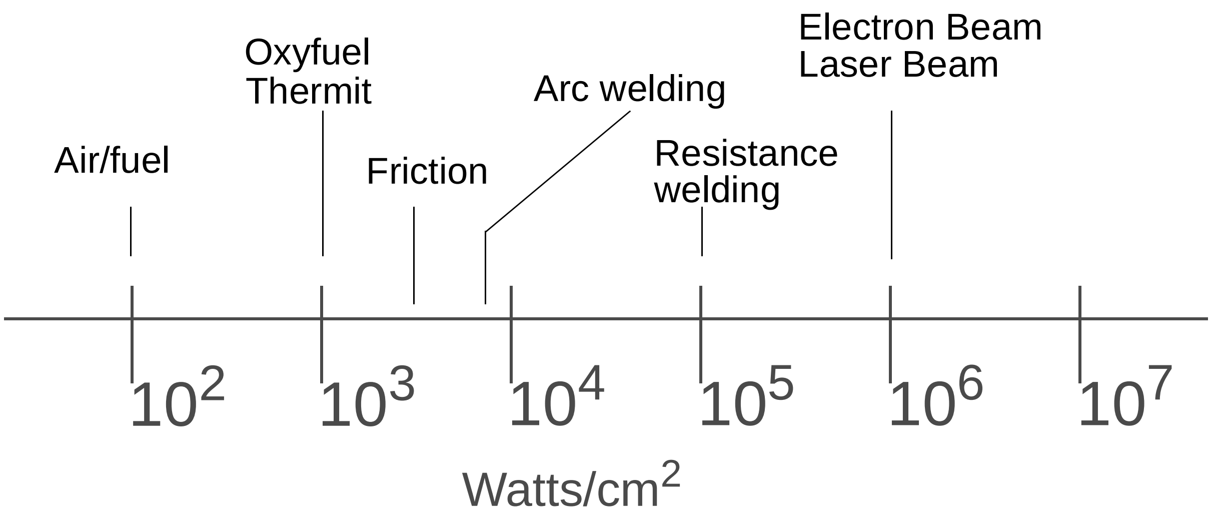
- Spot
- Seam
- Flash

Basic Physics

- Heat flux (what is it?)
- Thermal diffusivity (what is it?)
- $T_{melting}$
- Heat affected zone
- Overmelting and feedrate

Heat Flux

- A measure of radiation intensity, W/cm^2

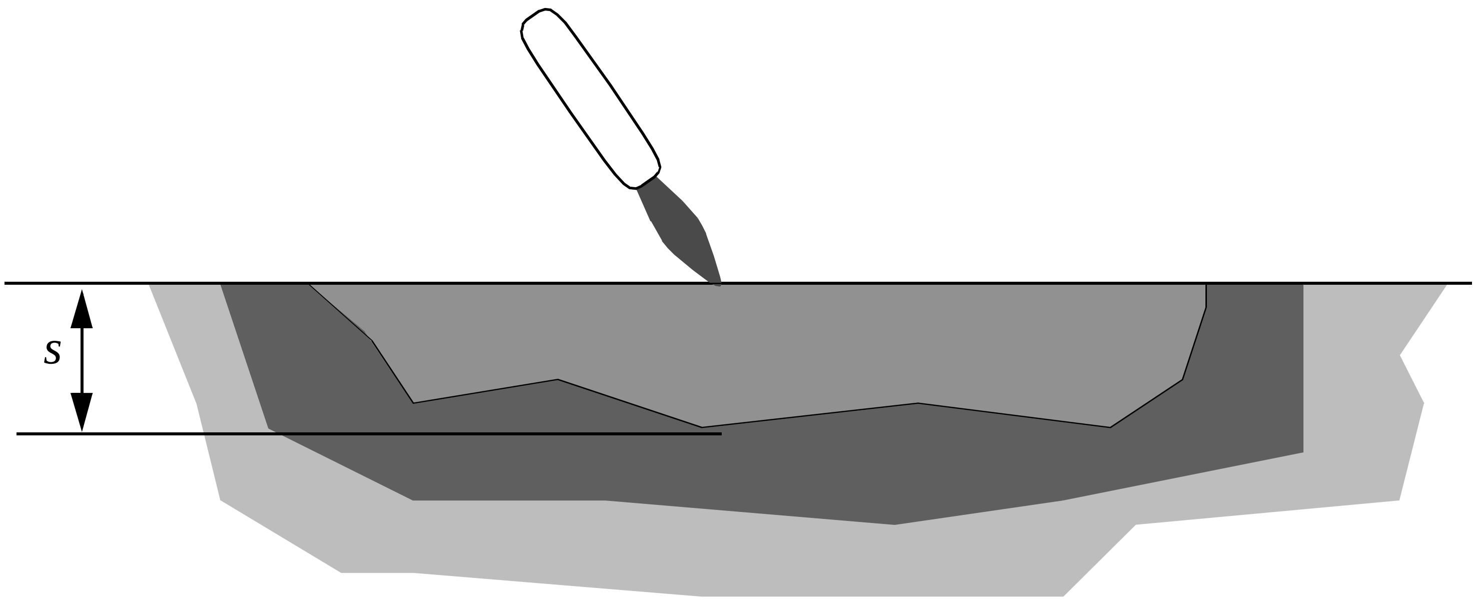


- Obviously, the more intense the source, the faster the melting.
- Very difficult to prevent overmelting; therefore automation!

Solidification front, 2D simplification

The Jacob number, $Ja = c_p \frac{(T_{melt} - T_{initial})}{h_{fs}}$. The thermal diffusivity is given by $\alpha = \frac{k}{\rho C_p}$. The melt front moves as:

$$s = \sqrt{2\alpha \mathrm{Ja} t}$$



Cutting rate

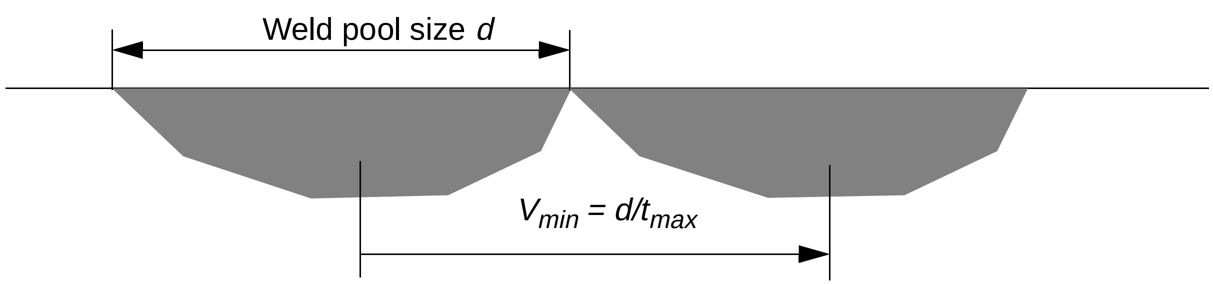
- The rate at which the welding device must be moved is governed by:

The Heat intensity. The greater the intensity, the faster the motion must be to keep the weld pool size, s_{max}, constant.

The product, αJa. The greater it is, the faster the melt front moves.

Cutting rate

- In fact, the time at a spot, t_{max} is given by $\frac{s_{max}^2}{2\alpha Ja}$. Anymore, and you over-melt!



- If the weld pool size is *d* in length, then you *must* feed at a rate that exceeds $\frac{d}{t_{max}}$. Similarly a lower limit.

Cutting rate

- For a planar heat source on steel,

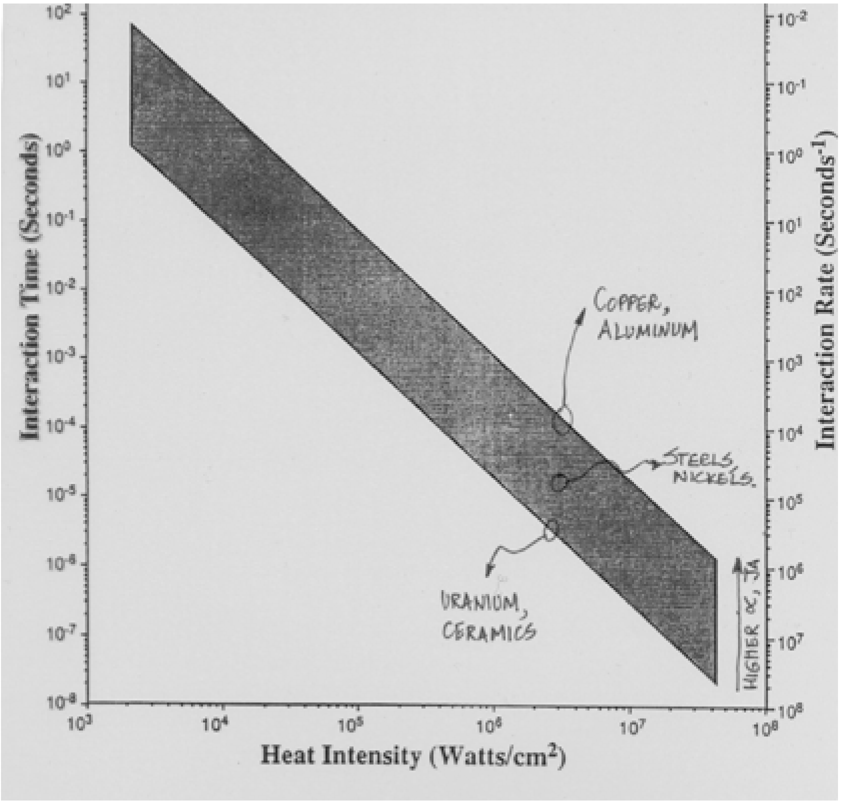
$$t_m = \left[\frac{5000}{\text{H.I.}}\right]^2,$$

where H. I. is the heat intensity in W/cm^2. The number 5000 includes the material constant related terms.

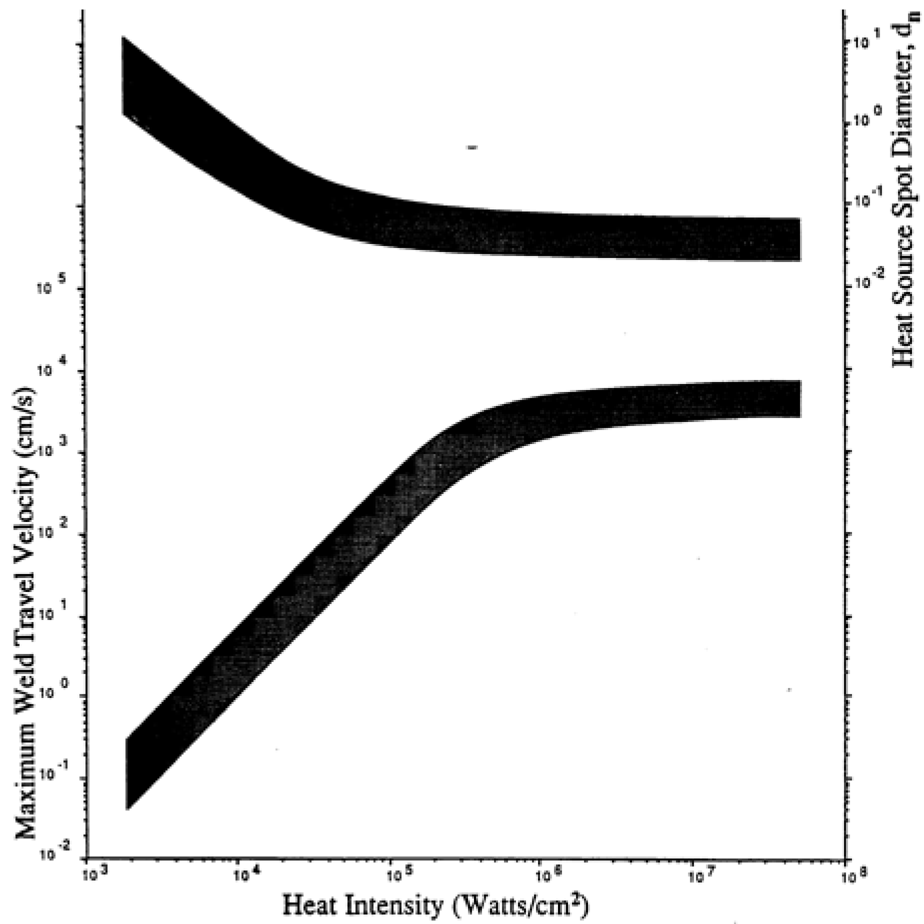
- Clearly, the greater the H. I. the faster the metal melts.

See Interaction time graphs

Typical weld pool-heat source interaction times as a function of source heat intensity. Materials with a high thermal diffusivity, such as copper and aluminum, would lie near the top of this band, while steels, nickel alloys or titanium would lie in the middle, and uranium and ceramics , with very low thermal diffusivities, would lie near the bottom of the band.

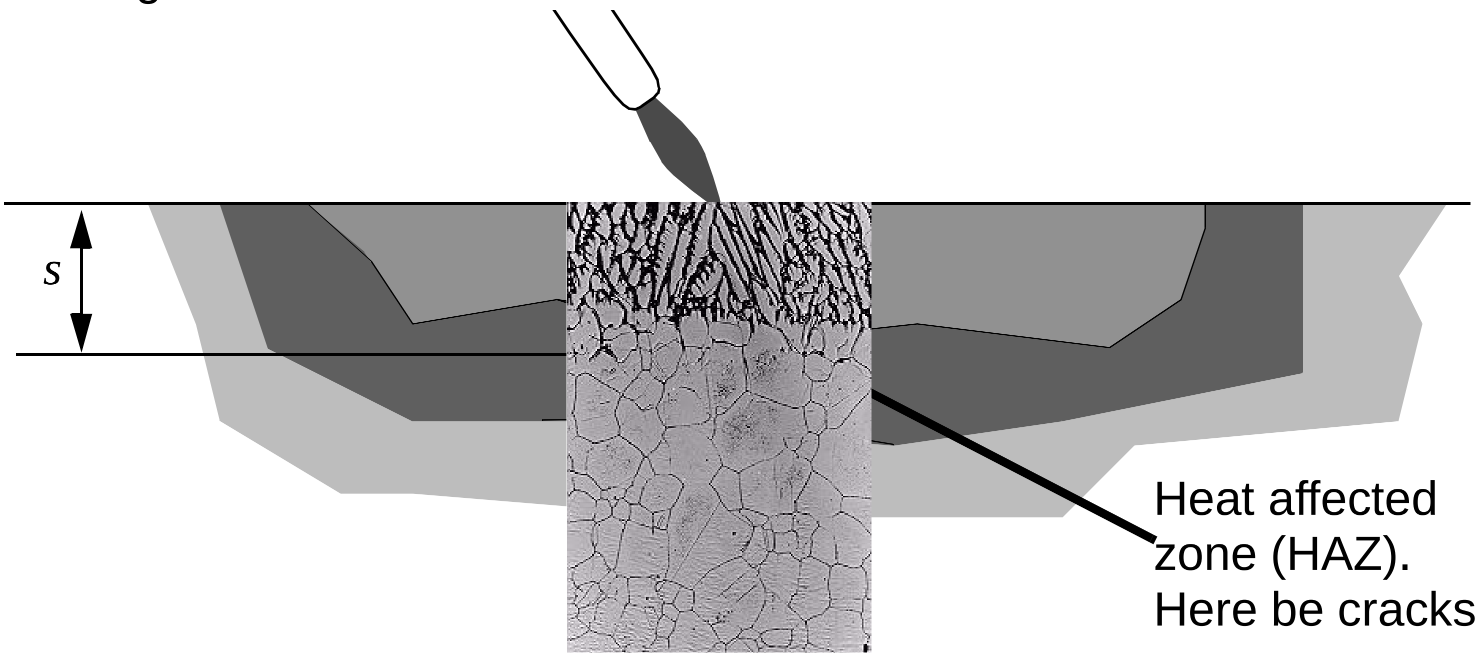


Maximum weld travel velocity as a function of source heat intensity based upon typical heat source spot diameters.



Heat affected zone

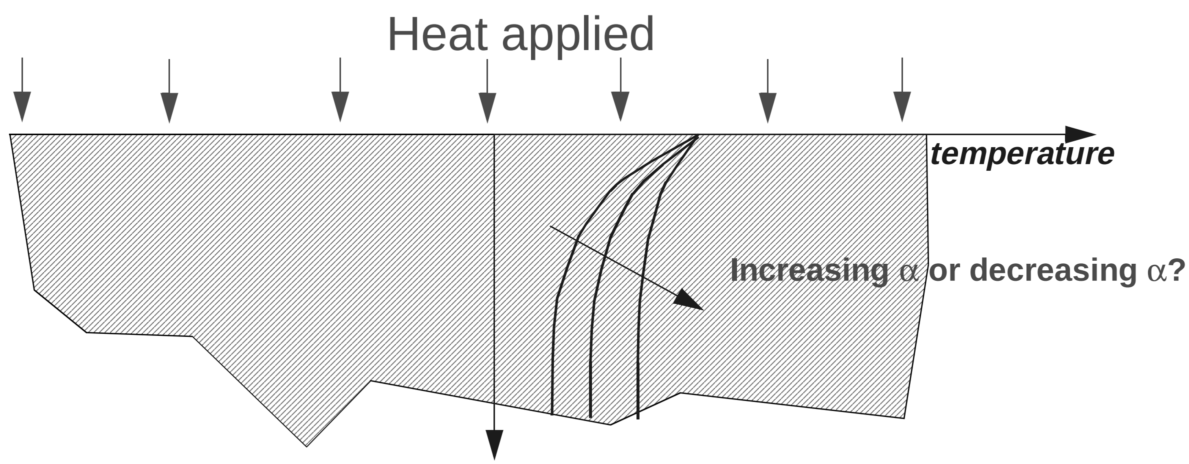
- Region near the weld pool is affected by heat. Microstructure changes.



- The size of the heat affected zone is controlled by the thermal diffusivity, α.

Heat localization

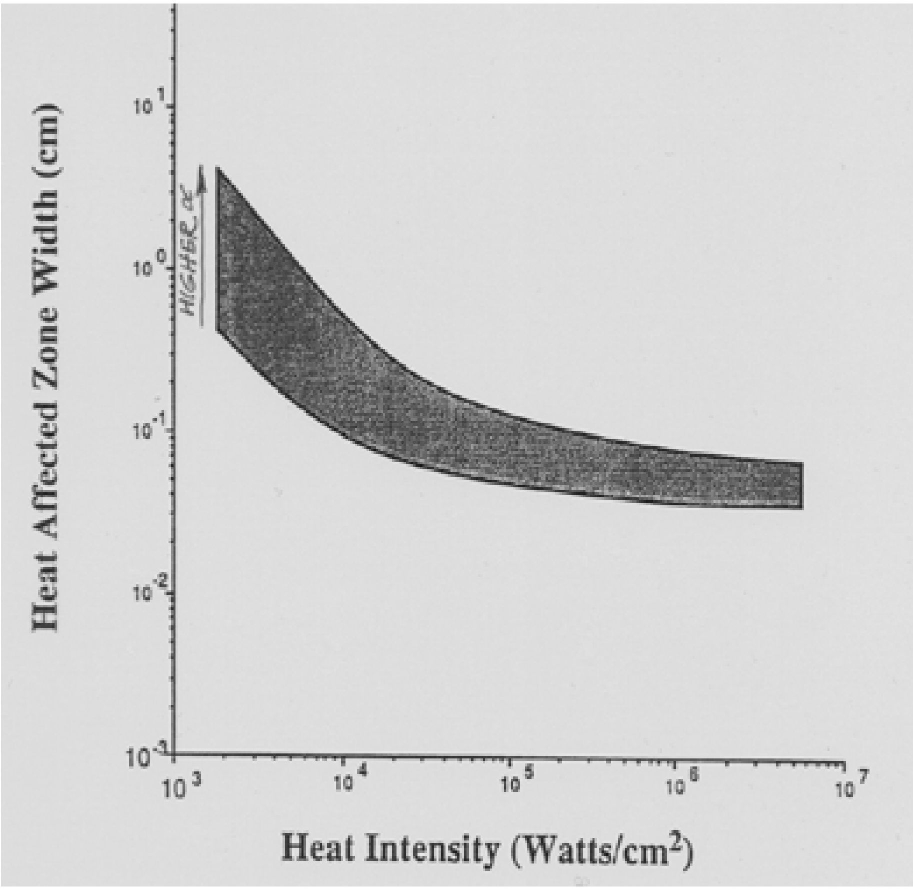
- Why does α affect the size of the HAZ?



- Lower values of α more localized heating, which is better for welding.
- Have you tried taking a soldering iron to plastic? You get small weld pool. But on metal, you heat the whole piece!

See HAZ Graph

Range of weld affected zone widths as a function of source heat intensity.



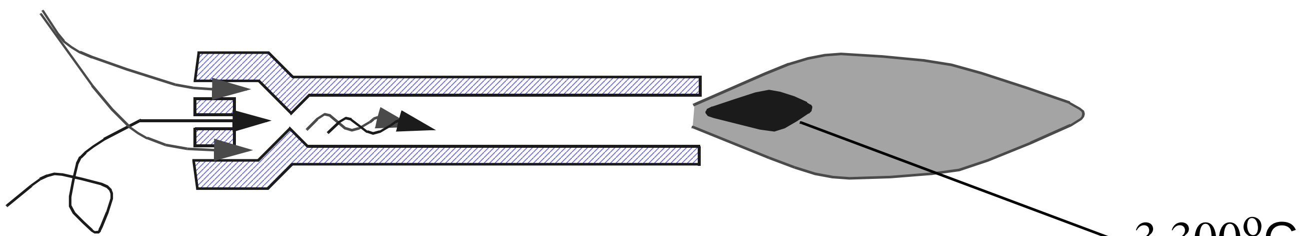
Welding processes: Chemical

- Oxyfuel: Oxygen + Fuel (Acetylene, methyacetylene-propediene, etc)

Stoichiometry:

$$C_2H_2 + O_2 \rightarrow 2CO + H_2 + \text{Heat}\uparrow$$

$$2CO + H_2 + 1.5O_2 \rightarrow 2CO_2 + H_2O + \text{Heat}\uparrow$$

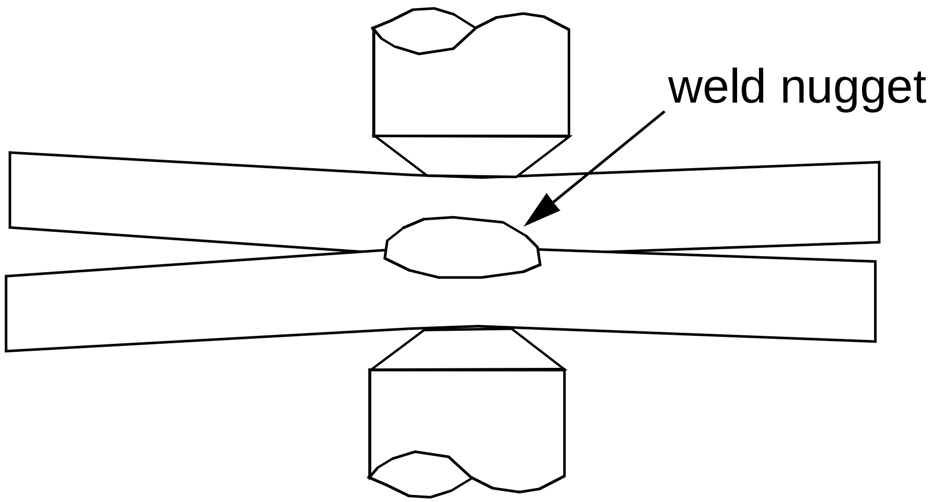


- More oxygen will cause oxidization (bad)

- More fuel will cause carburization (reducing but lower temp :-( )

Welding processes: Resistance

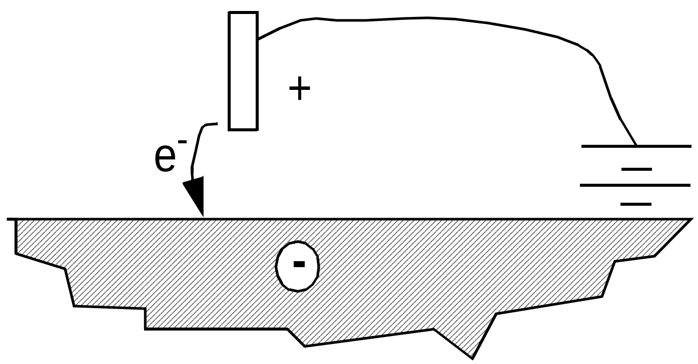
- High current through the weld area, 3,000A - 40,000A.



- Extremely high heat flux (10^5 W/cm^2)
- Energy input: $E_{input} = i^2Rt$
- Energy needed ideally: $E_{ideal} = \rho V C_p$. Efficiency = ?

Arc Welding

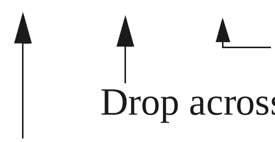
- Voltage difference between work and electrode 100-500 V
- Current: 50 - 300V
- Heat travels with the electrons!



Arrangement for consumable electrodes

Heat generated at anode is about 15% of the heat generated at cathode.

$E_{electron}$ at cathode is given by three components:



$I(\phi + V_a + V_{Thomson})$

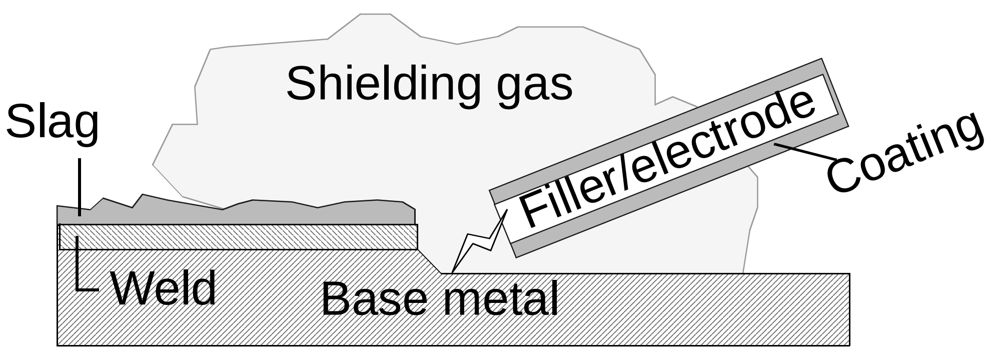
Consumable electrode processes:

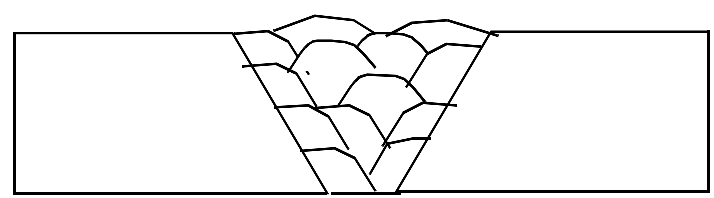
- Sheilded metal arc welding

Cheapest and most basic process ($1,500.00)

50A-300A, < 50KW

Workpiece thickness 3-20 mm





Consumable electrodes: continued

- Oxidation is the most important problem. Solutions:

    Coated electrodes to outgas shielding layer

    Slag/flux submersion

    Inert gas from external source

    Mix-and-match: Gas metal-arc welding, Submerged arc-welding, Flux-cored arc welding, etc.

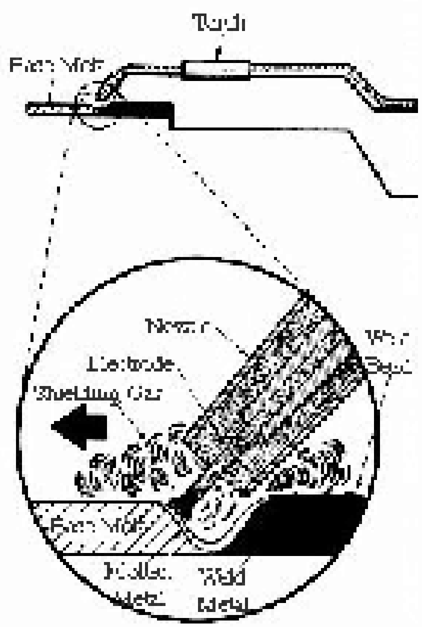
- Electrodes: different materials such as mild steel. Mild steel

  Designations on page 870 of Kalpakjian.

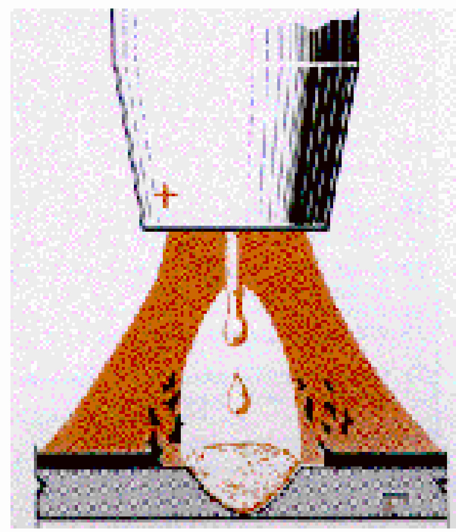
- Coatings: fluorides, silicate binders (clay), cellulose, carbonates.

Gas Metal Arc Welding

Gas Metal Arc Welding



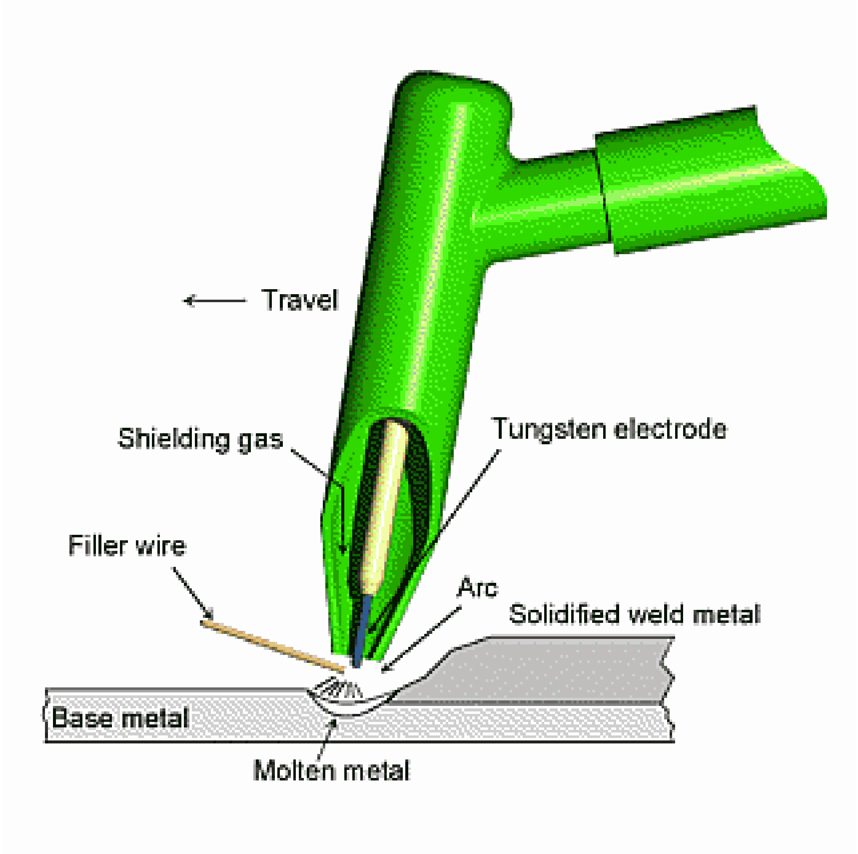
Gas Metal Arc Welding is a special variation on arc welding in which the electrode filler metal is fed directly through the torch tip. As arcing occurs the electrode instantly melts, forming molten droplets that fall into the weld pool. Shielding gas is supplied through the torch tip to prevent chemical interactions with the surrounding atmosphere.



Non-consumable electrodes: GTAW

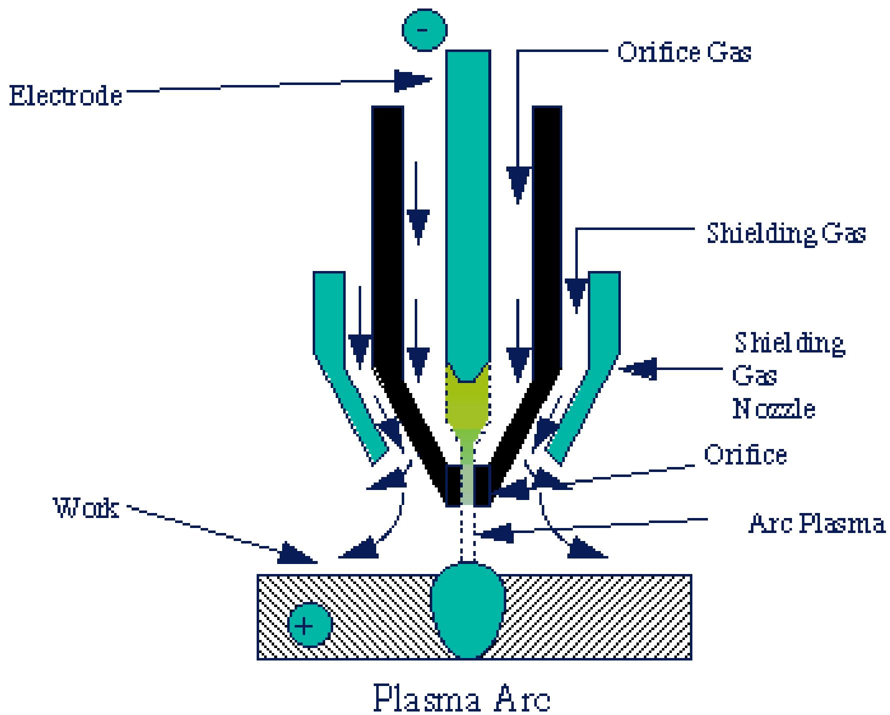
- Gas tungsten-arc welding, formerly known as TIG welding
- Tungsten electrode + filler. Goiod for thin materials, better control, Al, Ti, etc.

  200A-500A, 8kW-50kW.

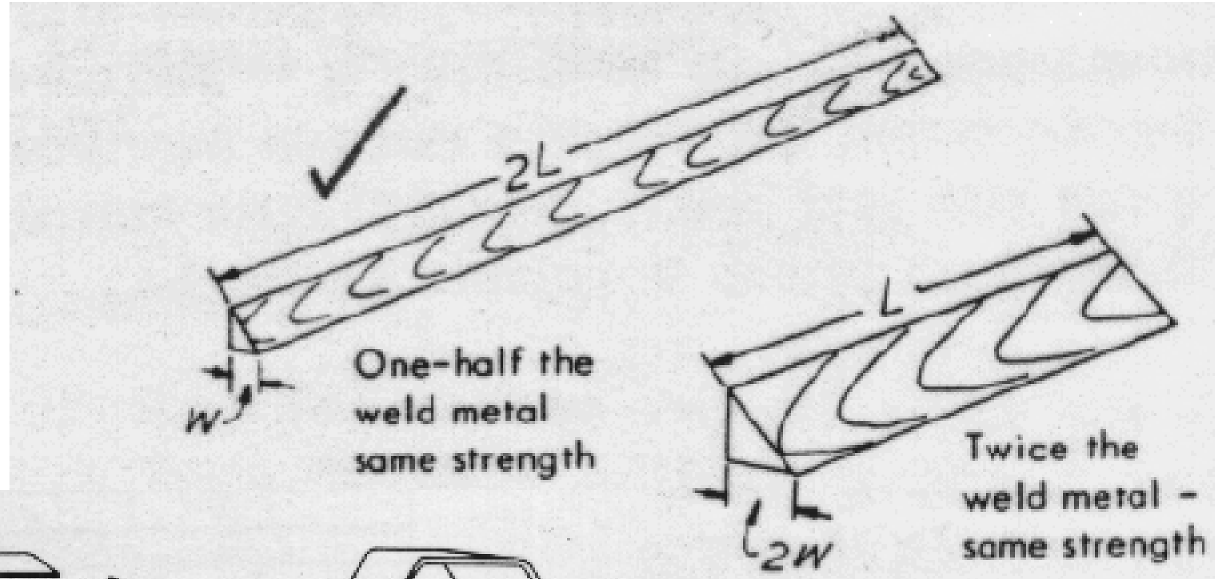


Other non-consumable electrode processes

- Plasma-Arc Welding: Very high heat flux, feed rate required is 120-1000 mm/min. Stable, less thermal distortion, narrow welds.
- Laser Beam Welding, Electron-Beam Welding, etc.



Welding, DFM



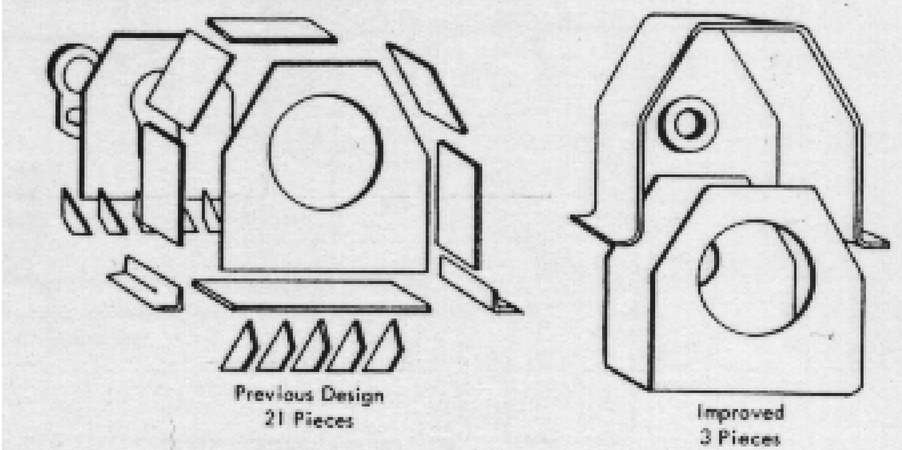
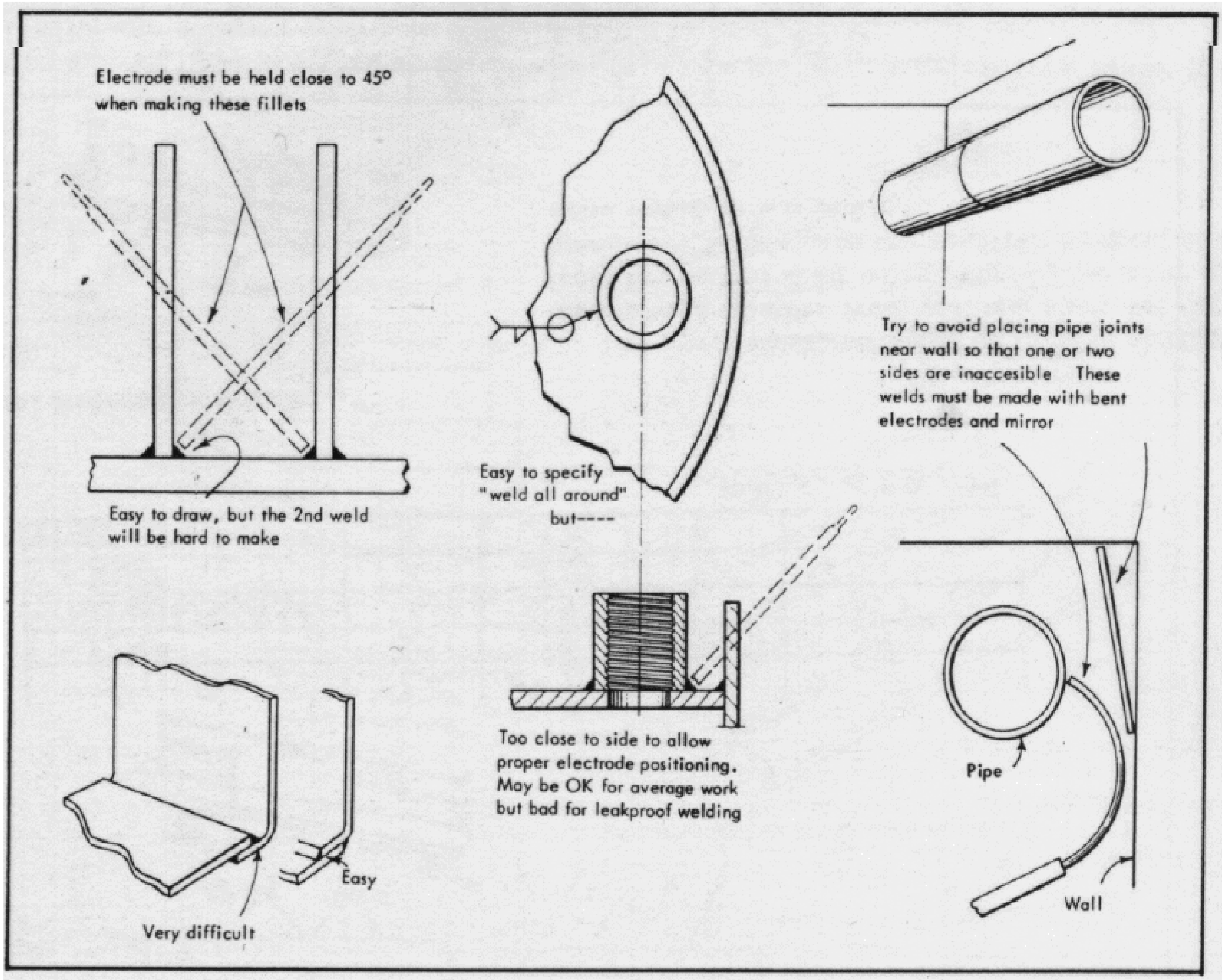


Fig. 8 Design simplicity can save much welding and assembly time.

Credit:

http://www.ecs.umass.edu/mie/labs/mda/dlib/machine/weld/weld.html



Electrode must be held close to 45°
when making these fillets
Easy to draw, but the 2nd weld
will be hard to make
Easy to specify
"weld all around"
but----
Try to avoid placing pipe joints
near wall so that one or two
sides are inaccesible These
welds must be made with bent
electrodes and mirror
Too close to side to allow
proper electrode positioning.
May be OK for average work
but bad for leakproof welding
Pipe
Wall
Very difficult
Easy