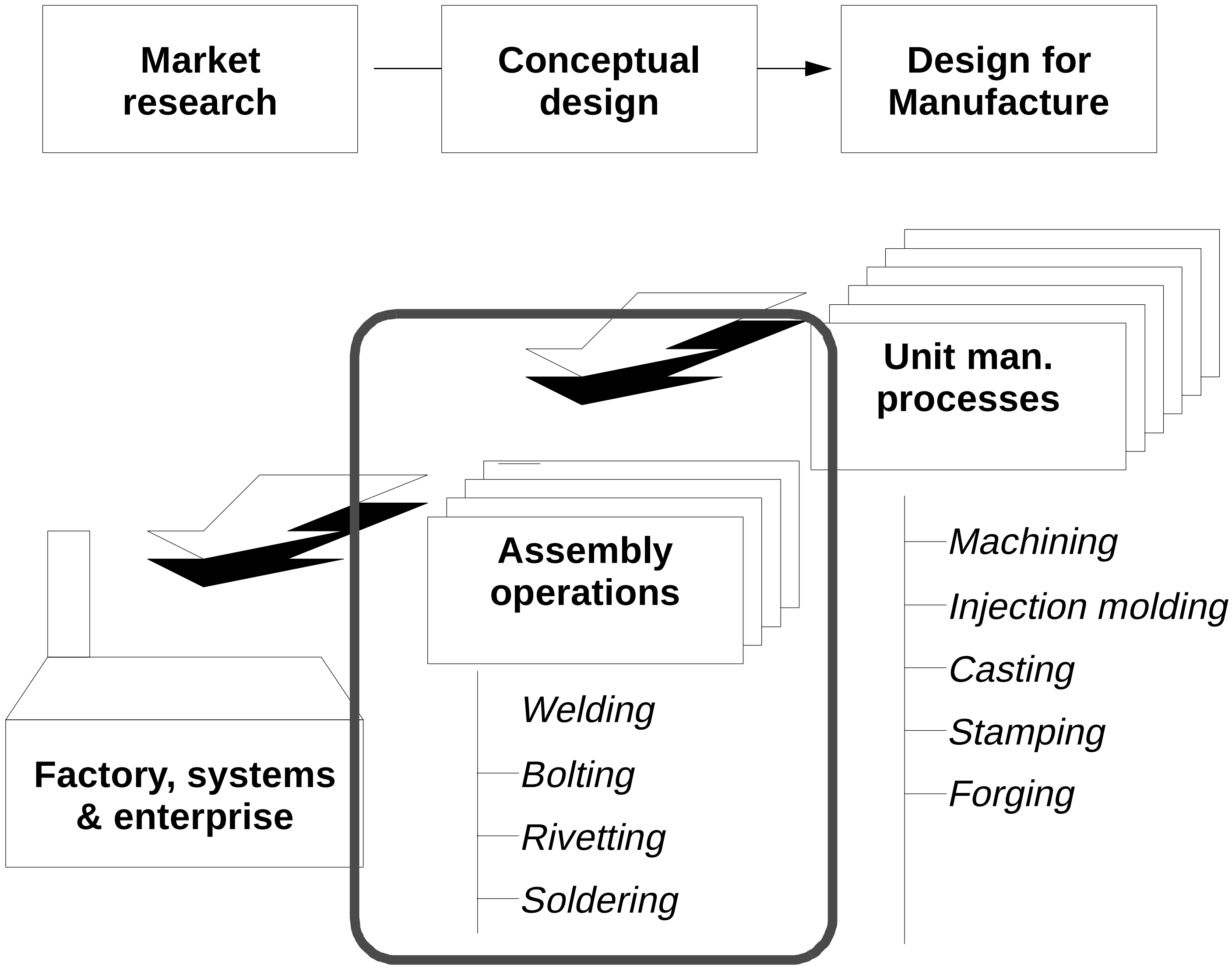
Today & Monday: Joining and Assembly

- Parts handling & Mechanical assembly
- Joining processes:
    - Mechanical joining
    - Soldering & Brazing
    - Gluing
    - **Welding (Several sub areas)**
- Design for Assembly

Manufacture



Joining assembly

- Study the chairs you are sitting on. How many unit components, and how were they joined?
  - geometry
  - material
  - size
  - value of product
  - quality
  - strength
  - size of run
  - Availability

Cost: 👎
Expensive $100.00 — $10,000.00

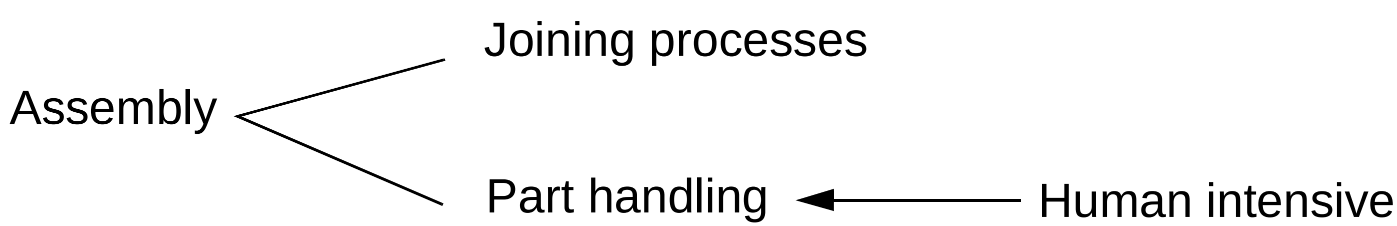
Flexibility: 👍
Any shape under the sun!

Quality: 👍
Very high quality.

Rate: 👎
Slow compared to other production techniques.

Statistics: How important is assembly?

Industry	% Workers in Assembly
Automobile	45.6%
Aircraft	25.6%
Telephone & Telegraph	58.9%
Farm Machinery	20.1%
Home appliances	32.1%
Two-wheel vehicles	26.3%



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:

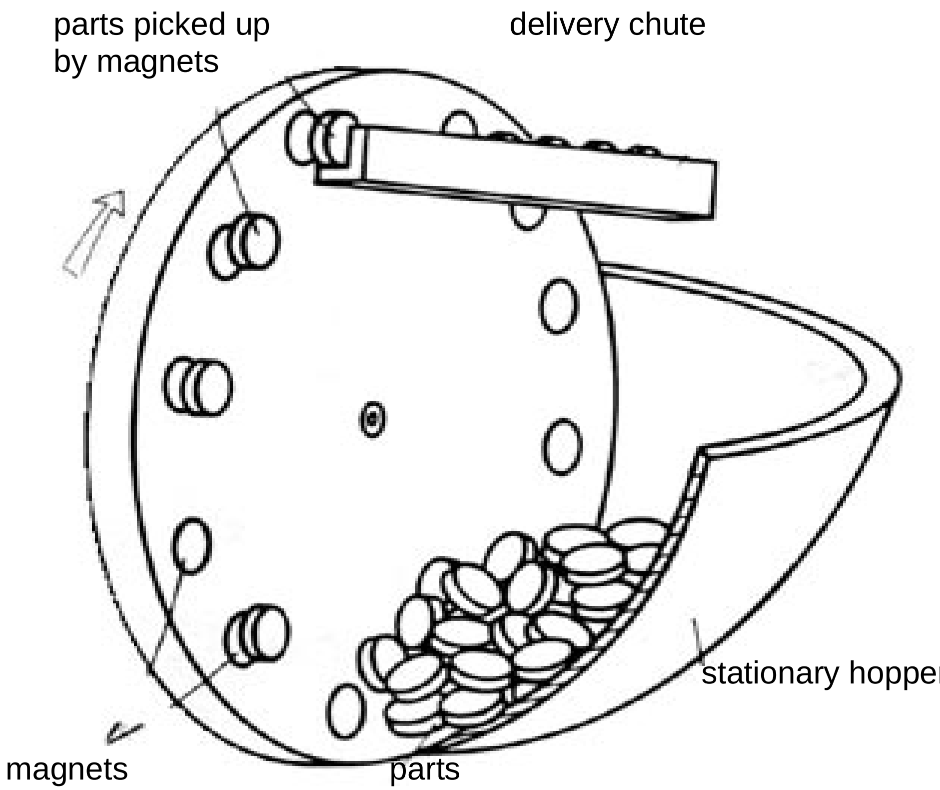
- Spot
- Seam
- Flash

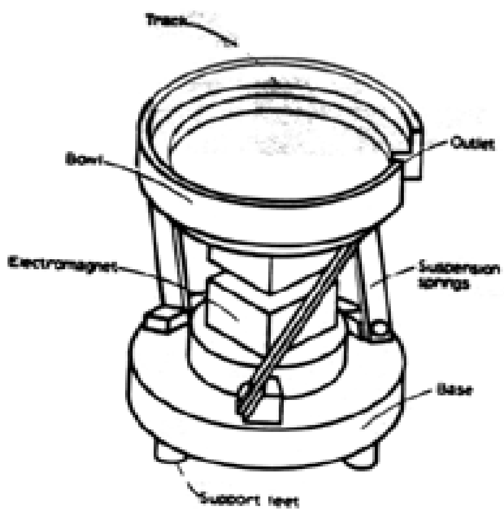
Parts Handling

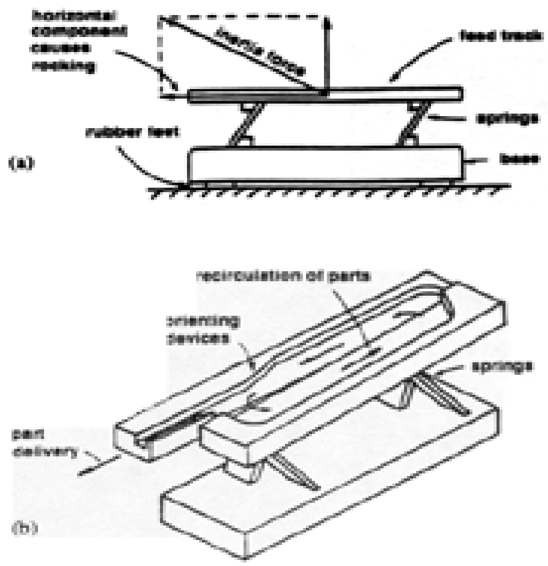
- Part feeding
- Part orienting
- Part transfer

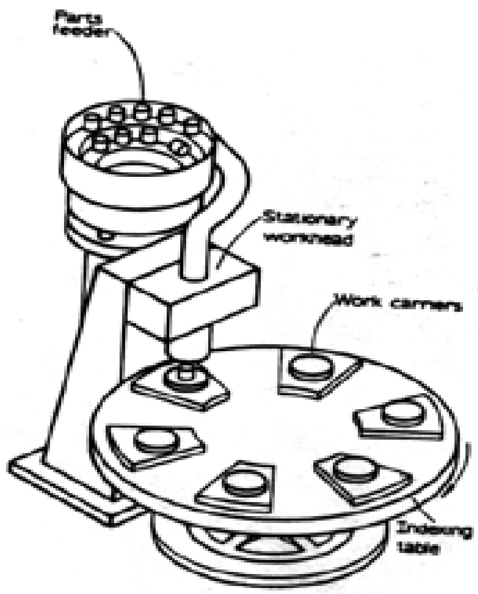
Feeding:

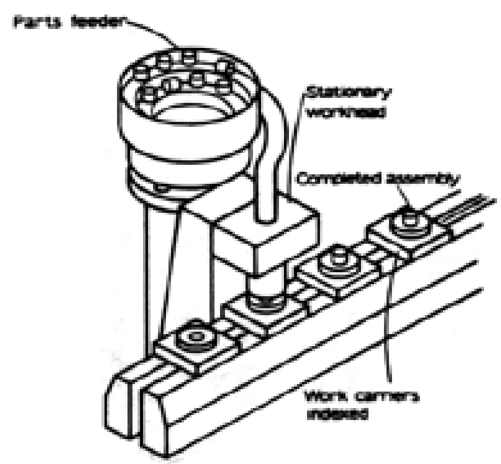
- Spacing and frequency of supply to a machine
- Control of amount or number
- Disentanglement
- Methods:
  - Vibratory Bowl Feeders
  - Magnetic
  - Pneumatic

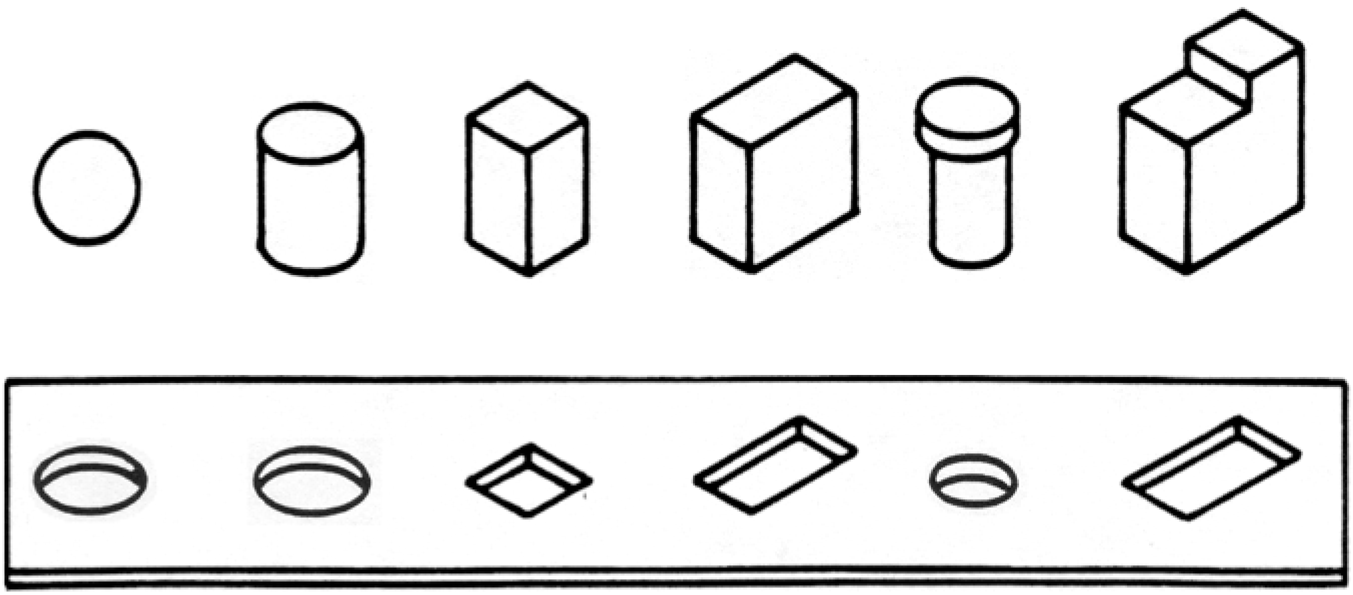

parts picked up
by magnets
delivery chute
stationary hopper
magnets
parts


Track
Bowl
Outlet
Electromagnet
Suspension springs
Base
Support feet


horizontal component causes rocking
inertia force
feed track
springs
rubber feet
base
(a)
recirculation of parts
orienting devices
springs
part delivery
(b)

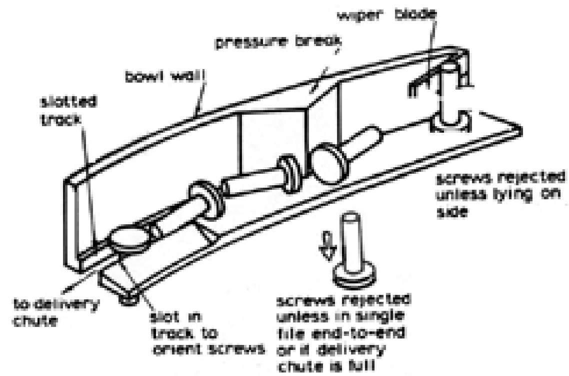

Parts feeder
Stationary workhead
Work carriers
Indexing table

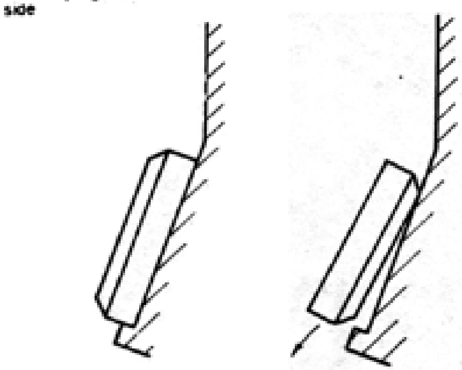

Parts feeder
Stationary workhead
Completed assembly
Work carriers indexed



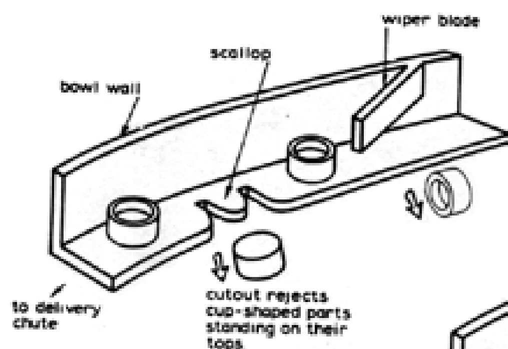
α	0	180	180	90	360	360
β	0	0	90	180	0	360

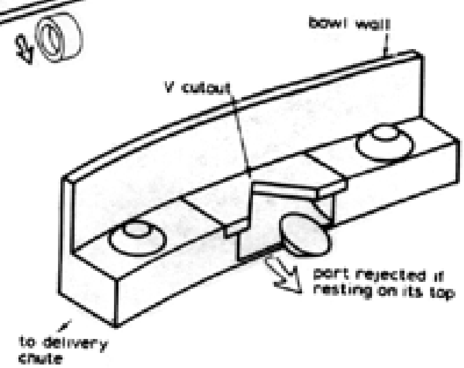
Mechanized Part Orienting





(a) Washer accepted (b) Washer rejected





Mechanized part transfer

- transfer line

- conveyor

- overhead transport

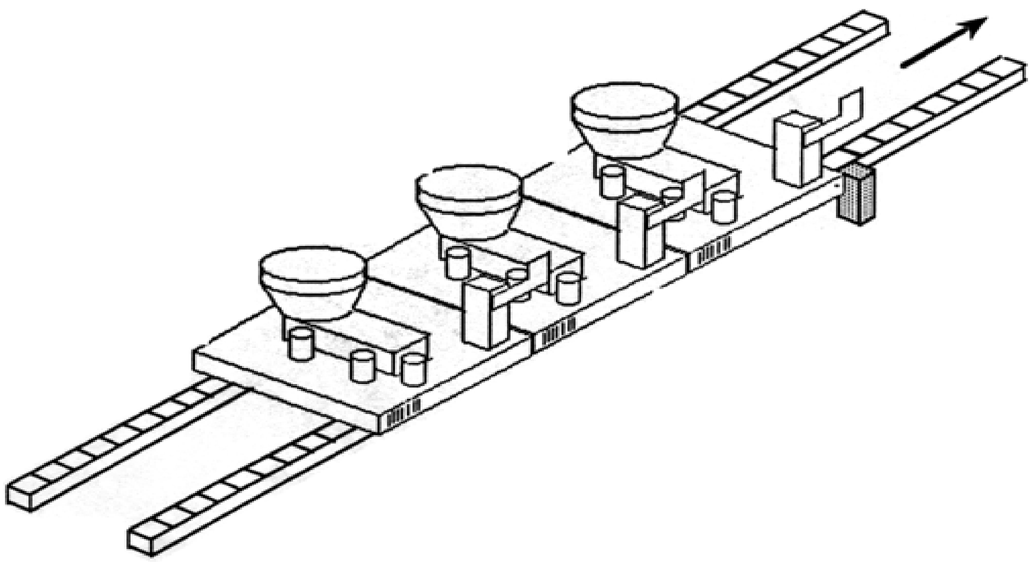
- automated guided vehicle

Conveyors

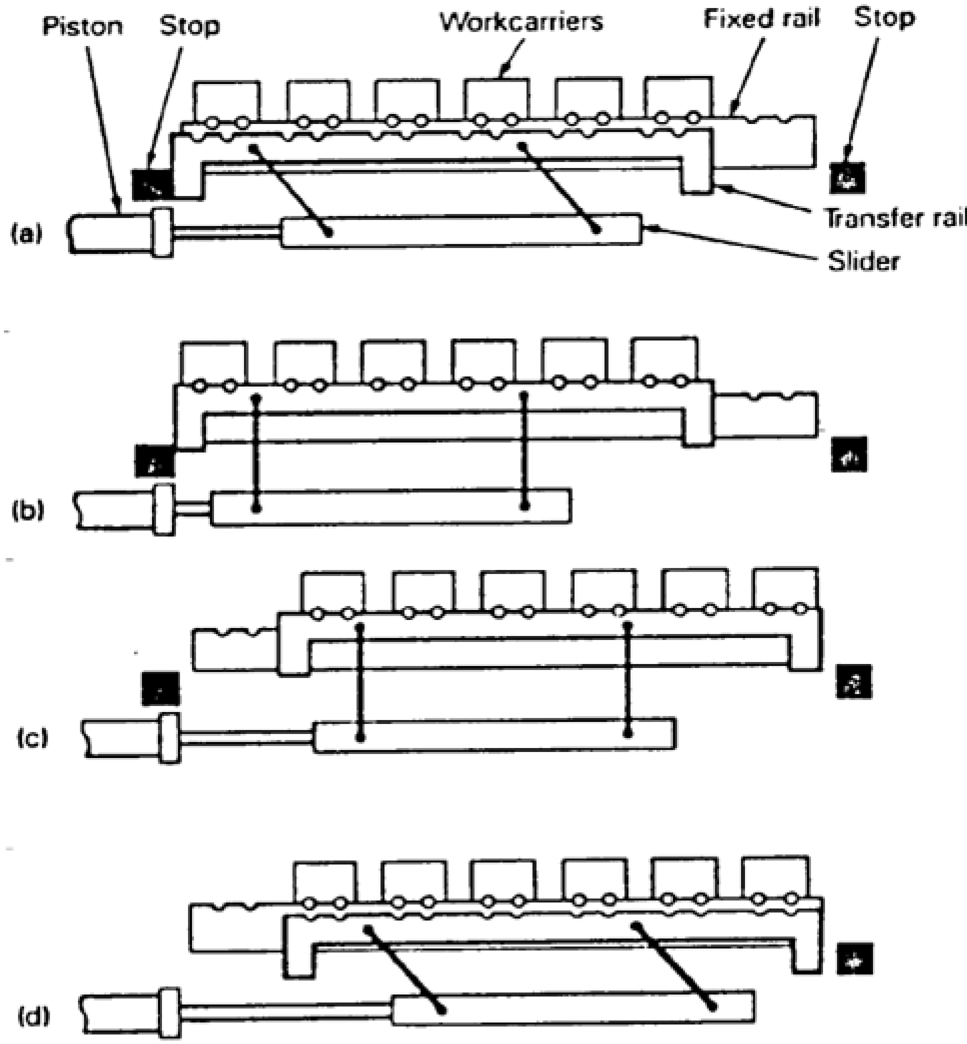
Types:

- belt
- chain
- roller

With conveyors, material is often held in palettes or totes. These serve to organize the parts and allow a given conveyor to transport a wide variety of sizes and shapes, making it more flexible.



Transfer Lines



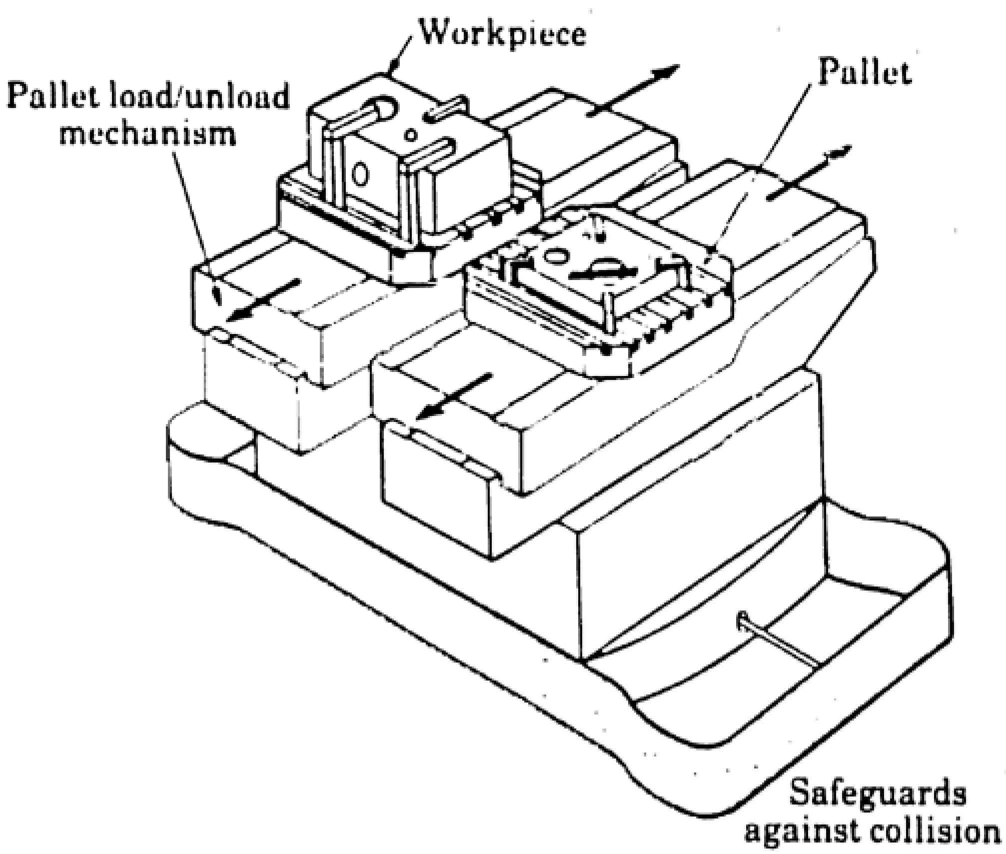
classic example : machining an automotive engine block, 100-200 stations

Hard Automation - not very flexible.

A “true” transfer line is shown here:

AGV

Schematic illustration of an automated guided vehicle [AGV], showing two different workpieces on pallets. [source: P. Ranky]



Overhead Transport

- usually runs on " I " beams.
- can be self powered or driven
- Often can be used for large items - auto bodies

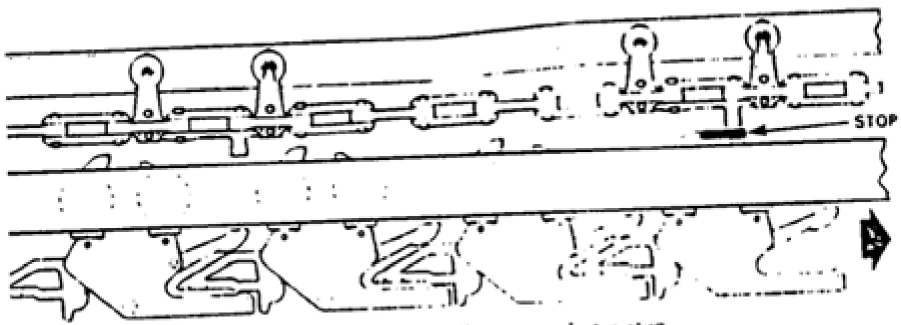


Fig. 9.6.1 Power-and-free trolleys queued at a stop.

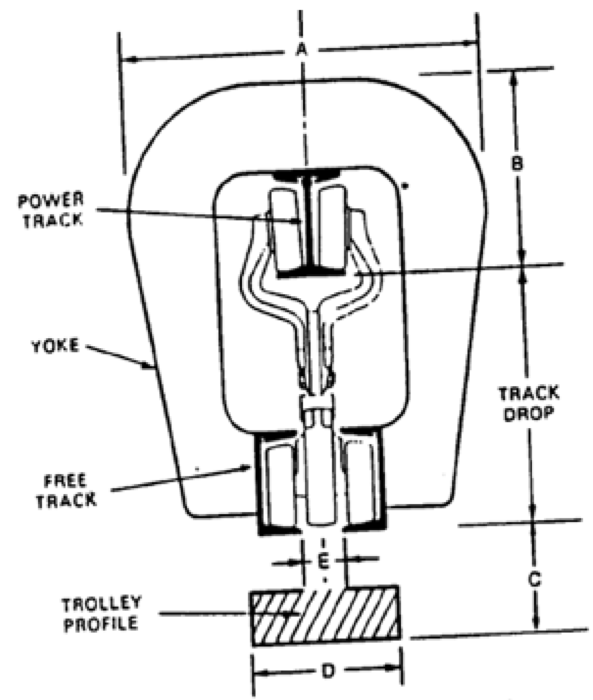
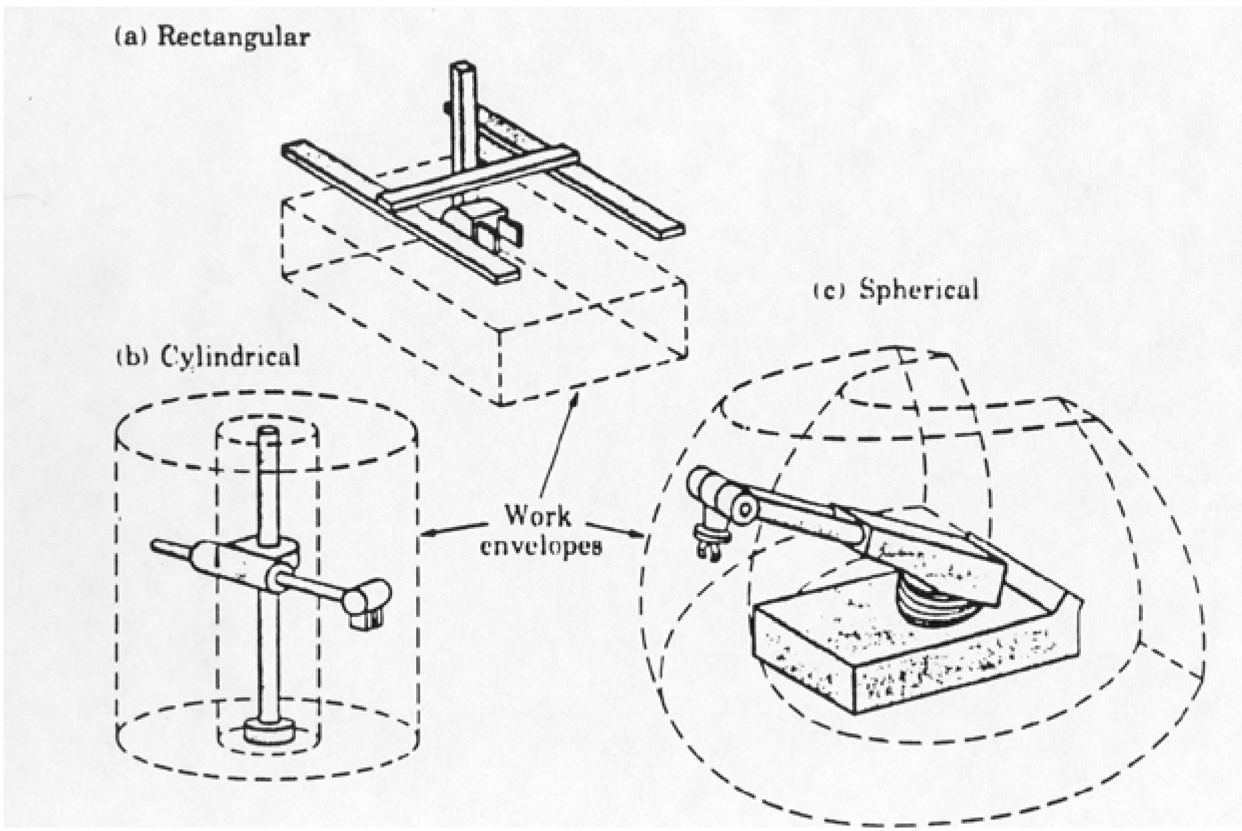


Fig. 9.6.8 Typical power-and-free cross section.

Work Envelopes

for three types of robots. The choice depends on the particular application.



Robots

Definition I : Emulates a human being.

- has intelligence
- can manipulate in space

Definition II : Is a mechanical manipulation device

- programmable
- wide range of motion

Components

1. Manipulator

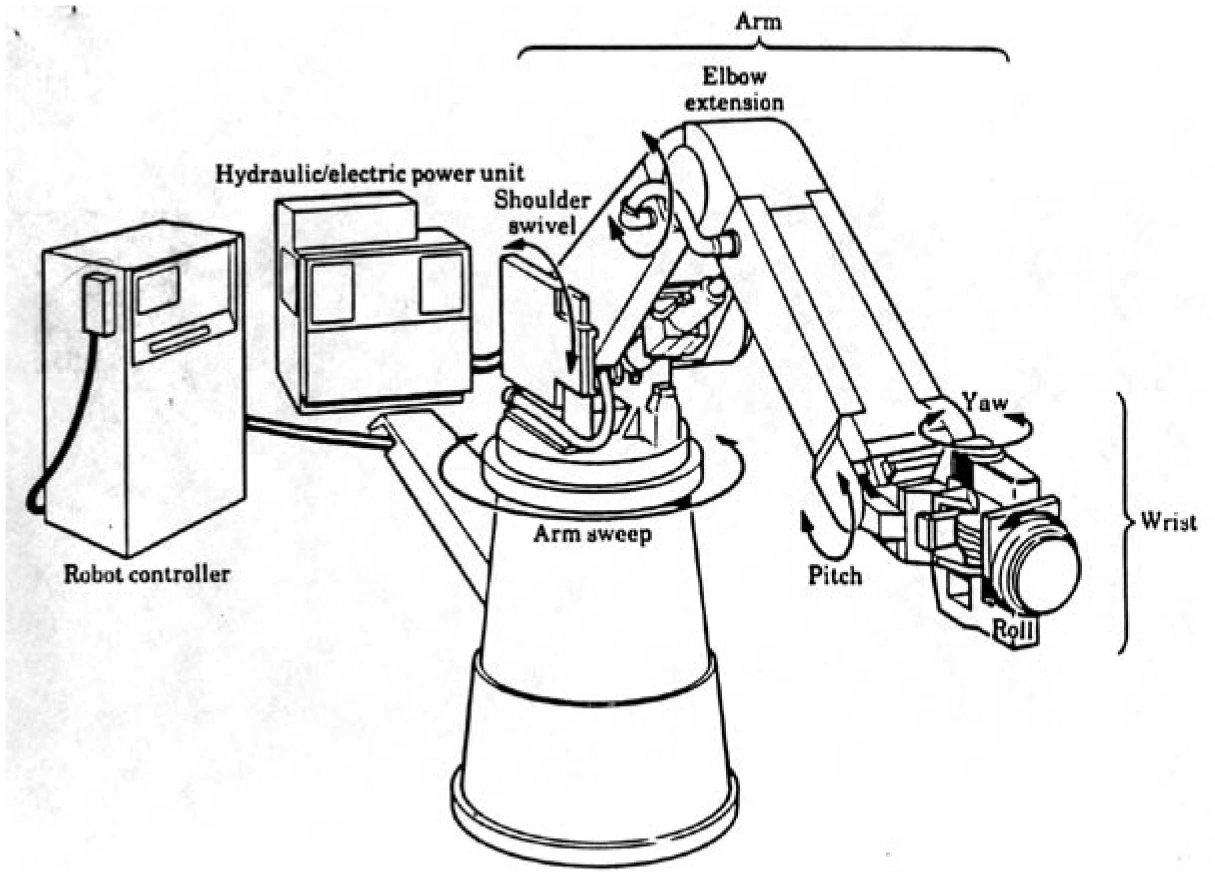
- positioning
- power
- stiffness
- control

2. End Effector

- tooling

Components of a typical industrial robot

[source : Cincinnati Milacron, Inc.]



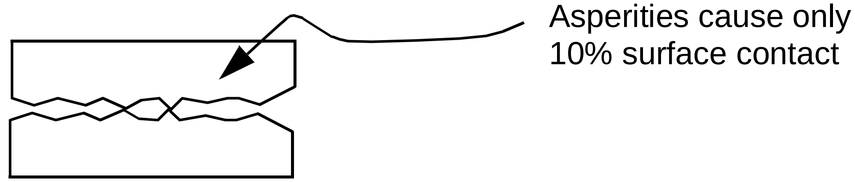
Joining: Mechanical fastening

- Rivets
- Nuts-Bolt
- Screw-Tapping
- Press fits
- Mechanical locks

Solid-Liquid Joining: Adhesives

- Quick, non-invasive, inexpensive
- Quality questionable, rate depends on technology
- Extremely good for home applications and non-critical components such as
- Techhnologies:
  - Water or oil soluble
  - Thermoplastic or thermoset
  - Chemical set (epoxy glues)

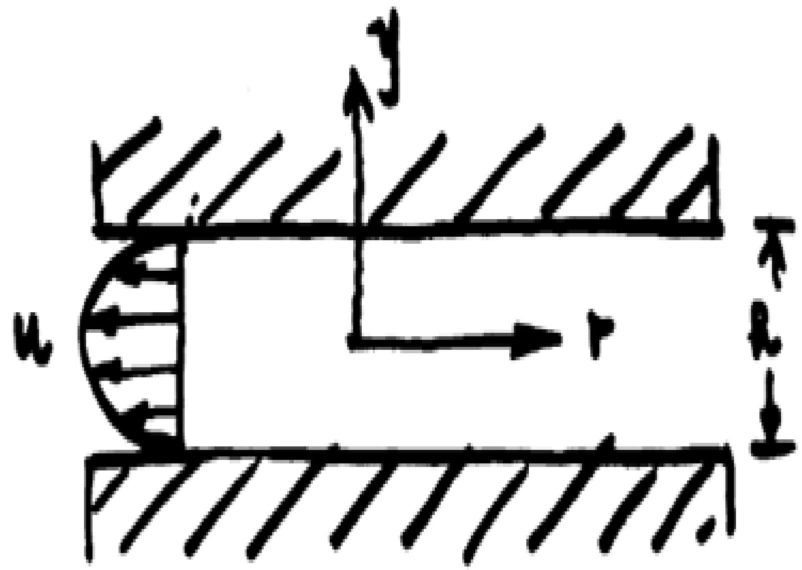
Adhesives: physics



- Bonds created by filling hills and valleys
- Best for components with high surface to volume ratio:

  sheets, fibres, small particles
- Dominant physics:
  - Viscosity $\leftarrow$ Stefan's Law
  - Surface Tension
  - Phase Transformation

How long to squeeze drop?



Velocity profile: $u = \frac{1}{2\mu} \frac{dP}{dr} \left\{ y^2 - \frac{h^2}{4} \right\}$ — I

Volume flowrate at r:

$$\int_{-h/2}^{h/2} u \cdot 2\pi r \cdot dy = -\pi r^2 \frac{dh}{dt} \qquad \text{— II}$$

Rearranging: $\frac{dP}{dr} = \frac{6\mu}{h^3} \cdot \frac{dh}{dt} \cdot r$

$\Rightarrow P = \frac{6\mu}{h^3} \frac{dh}{dt} \frac{r^2}{2} + C$

B.C: $P = 0$ @ $r = a$

$\rightarrow C = -\frac{3\mu a^2}{h^3} \frac{dh}{dt}$

$\therefore$

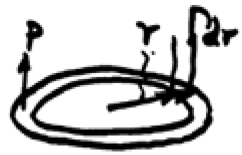
$$P = \frac{3\mu}{h^3} \cdot \frac{dh}{dt} (r^2 - a^2)$$

How long to squeeze a drop?

$$P = \frac{3\mu}{h^3}\frac{dh}{dt}(r^2 - a^2)$$

Force balance:

$$F = \int_0^a P \cdot 2\pi r \cdot dr$$



$$dF = P \cdot 2\pi r \cdot dr$$

$$\therefore \quad F = -\frac{3\mu\pi a^4}{2h^3} \cdot \frac{dh}{dt}$$

Integrating from $t: 0$ to t, $h: h_i$ to h_f.

$$\int_0^t F \cdot dt = \int_{h_i}^{h_f} -\frac{3\mu\pi a^4}{2}\frac{dh}{h^3}$$

$$\therefore \quad Ft = \frac{3\mu\pi a^4}{4}\left[\frac{1}{h_f^2} - \cancel{\frac{1}{h_i^2}}^{\,0}\right]$$

STEFAN'S EQUATION

$$Ft = \frac{3\mu\pi a^4}{4} \cdot \frac{1}{h_f^2}$$

Stefan's Equation

What's the point?

- valid for separation

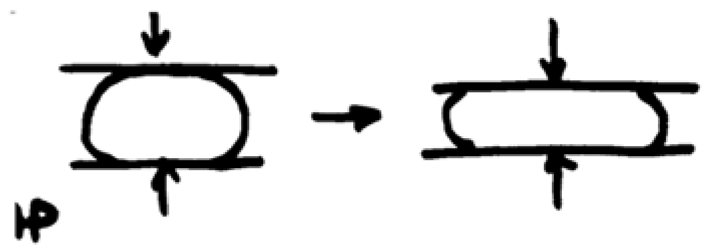
$$F t = \frac{3 \mu \pi a^4}{4} \cdot \frac{1}{h_f^2}$$

for constant time: $h_f \downarrow \rightarrow F \uparrow$

$\mu \uparrow \rightarrow F \uparrow$

Basic Idea in Adhesion:

- start with low viscosity



- reduce gap

- increase viscosity

Adhesion complete.

Solid-Liquid Joining: Soldering & Brazing

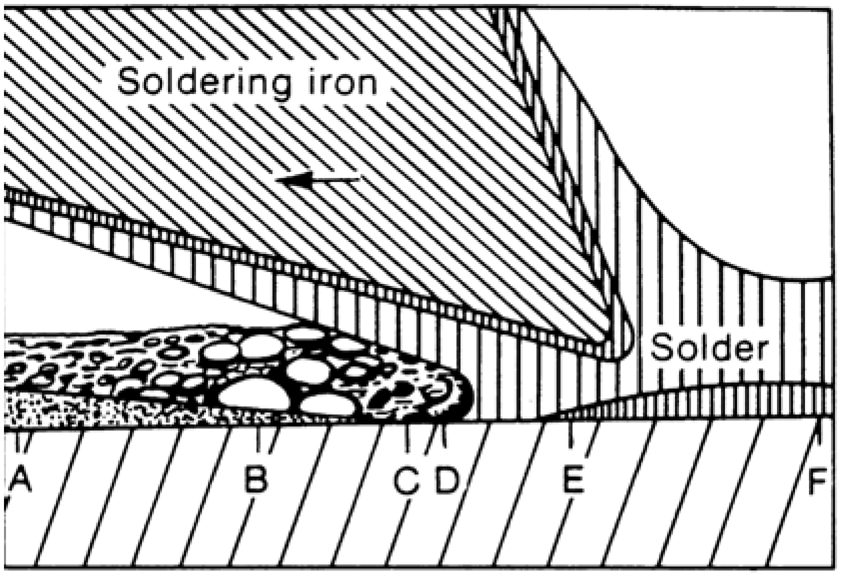
- Substrate phase stays **solid!** Can be used on dissimilar metals.
- Filler phase is melted, less than $700^{o}C$
- Soldering: <$425^{o}C$: Lead, Tin, Bismuth, Cadmium
- Brazing: >$425^{o}C$: Silver, Brass, Bronze
- Used in electronics, plumbing, jewelry, and recently, as a structural joining technique.

Physics:

- Phase change of solder or braze
- Surface tension, low viscosity = capillary action, improved wetting
- Intermetallic compounds may be formed. They are brittle.
- Problems:
  - Oxides prevent good diffusion and cohesion

    (1-3 oxide monolayers in 10^{-14} s with 1 atm pressure)
  - CTE mismatch can cause problems
  - Fracture, fatique, creep problems, porosity

Mechanism of flux shielded soldering or brazing



A. flux over oxidized metal

B. boiling flux removes oxide

C. base metal in contact with molten flux

D. molten solder displaces molten flux

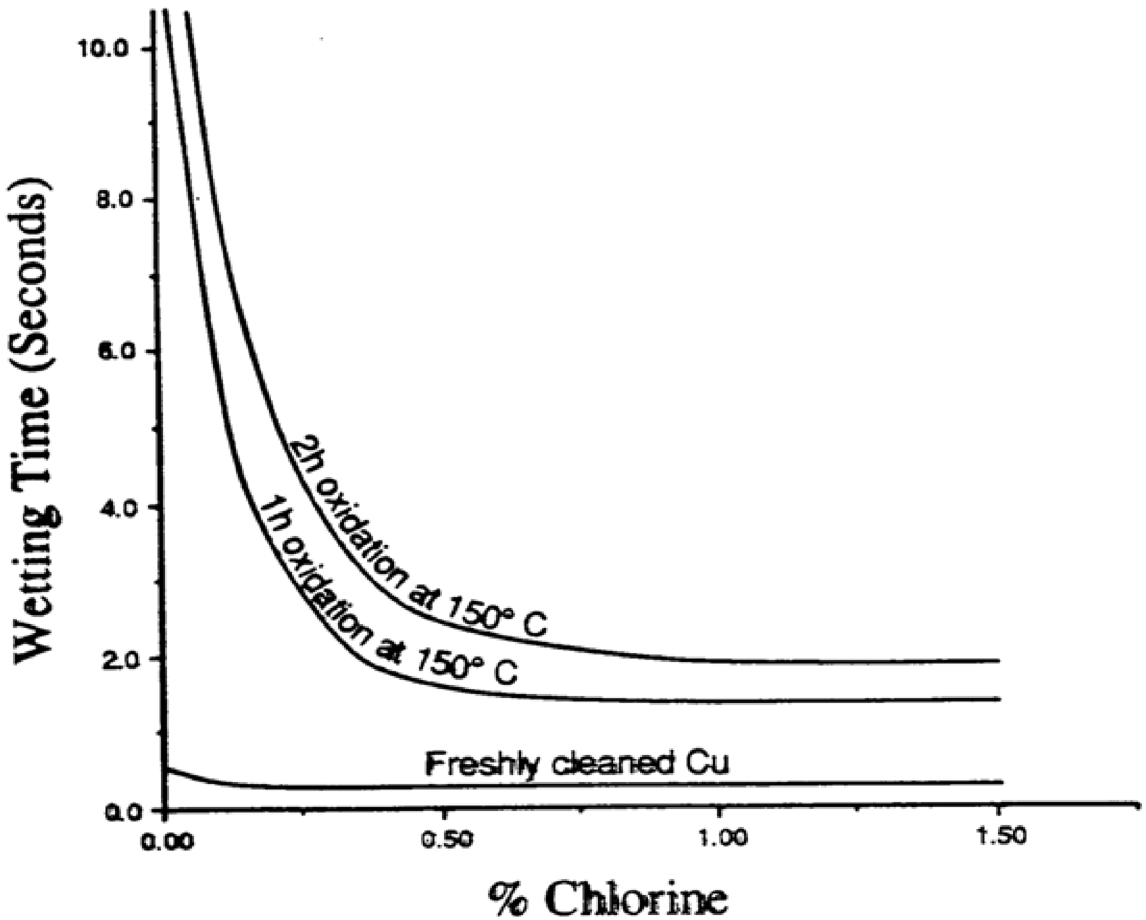
E. solder alloys with base metal

F. solder solidifies

<--- direction of movement of soldering iron

Influence of halide content

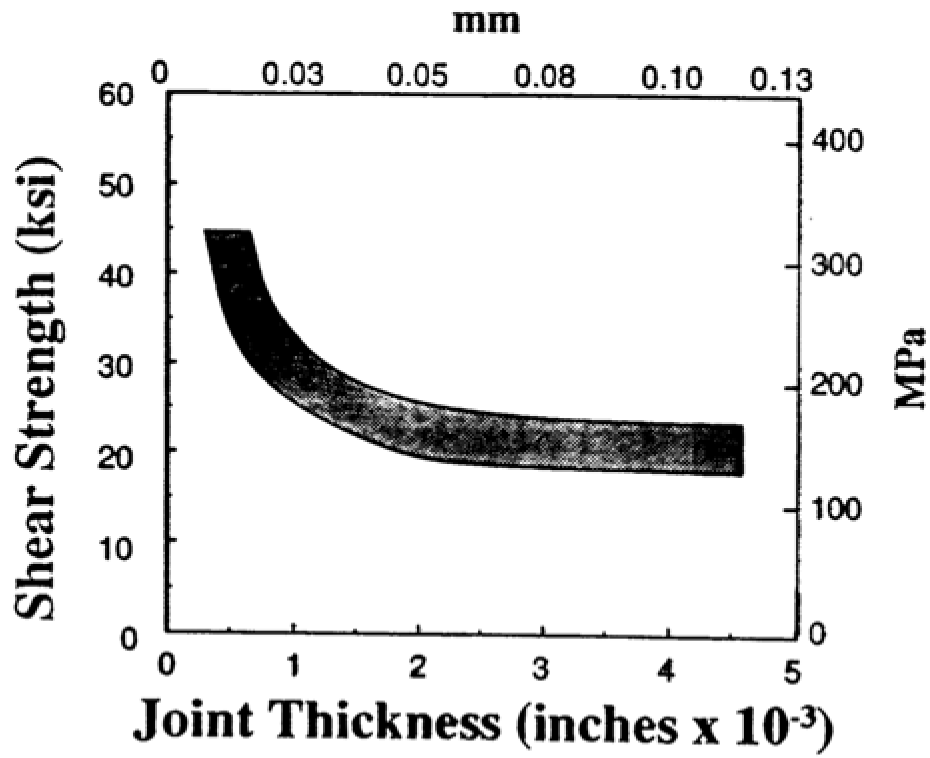
[measured as chlorine] of rosin base activated fluxes on solderability of clean and oxidised copper using 60% tin 40% lead solder at 250 deg. C.



Shear strength vs brazed joint thickness

for pure silver joints in 12.7 mm [0.5 in] diameter steel drill rod.

Creep: > 1000 psi @ 0.75 Tm. make joints thin.



Fluxes

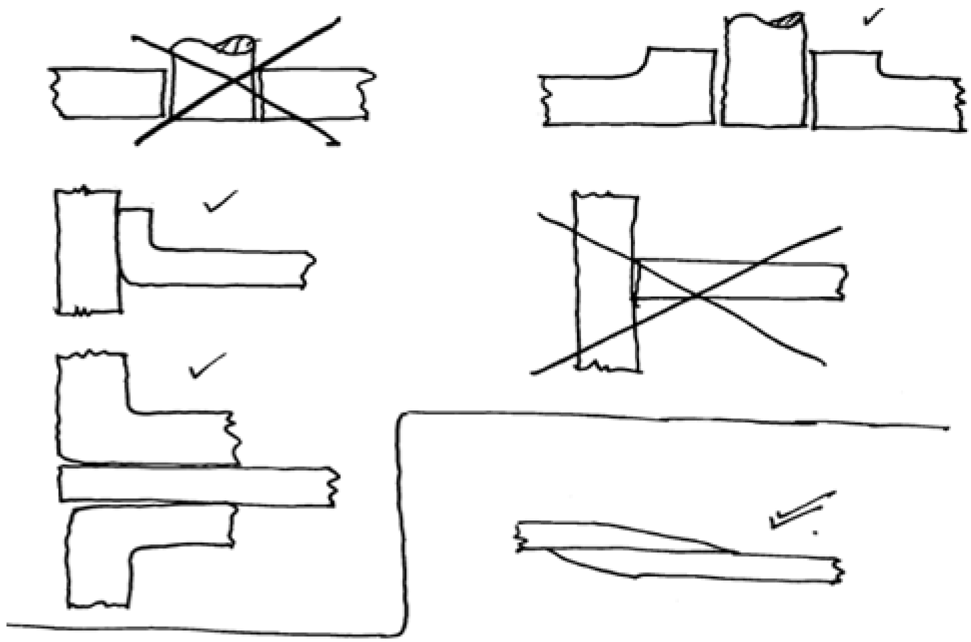
- Essential in soldering, lower temperatures
    - Rosen is an organic material, most common.
      Sometimes contains chlorine for reducing quality.
- Fluxes have three functions:
    - Oxide removal (not required in brazing)
    - Coating to prevent further oxidation
    - Improved surface wetting
- Fluxes usually come in a delivery agent: waxy, oil, grease.

System Performance of Soldering and Brazing

- Very cheap.
- Automatable, hence reasonable rates. Wave soldering machines.
- Reasonable strength, but no surface damage. So Quality OK. Highly conductive.
- Machinery not very flexible.

DFA

solder and braze:



Adhesives: