Phase 2 Mechanical Notes

By Jordan Simon

This document has been reproduced for phase 2 trainees at TTE Training LTD.

The information recorded in this document are some of the many the tips and tricks learned during the second phase at TTE in the core mechanical training area.

Not all tips and tricks have been recorded in this book, however the most useful and important are.

The original document was recorded in a small black notebook. This black book's main purpose was to be used to review notes (as a reminder) while on the job to understand what needs to take place or how a piece of kit is operated if the trainee is in doubt during phase 3.

This small book has a record of all the main areas that engineers will be working on while on site.

The information and images have been extracted from various presentations and collated together. All information in the black book has been replicated in this document. The information may seem brief, however, it is broken down into a basic note format. Some images have been produced digitally whereas others have been scanned and imported into this document directly from the book.

The front of this book has tolerances used for different pieces of equipment used on site.

The main content of this book is how equipment operates, constructed and inspected.

The back of this book is about bolts, servicing and splitting and removing corroded nuts.

Witness mark before disassembly
Store bolts etc. in bags/boxes
Draw sketches
Take pictures if complicated
Keep a record of everything

Pump wear ring
Best to achieve minimal clearance (increases efficiency)
0.50mm max

End Float

- Depends on size/manufacture spec
- General Rule of Thumb

Pumps
} 0.10mm - 0.40mm
Gear box

Alignment tolerance
For Pumps-motors
Radial - 0.1mm 4 thou max
Axial - 0.05mm/2 thou max
± 0.10mm - gear boxes, compressors, turbines

Producing Gaskets/Shims

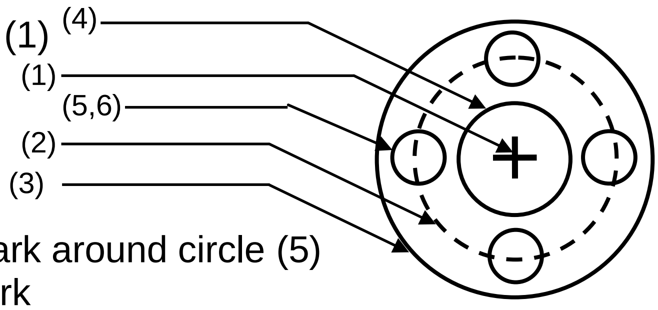
Paper – tap with ball peen hammer around casting

Plastic – use old as template
– use formula

$$x = \frac{360}{\text{no. of holes}}$$

$$\text{PCD} \times \text{Sin}\left({}^{x}/_{2}\right) = \text{Distance between the holes (DBH)}$$

- Pick Center Datum for Circles (1)
- Draw PCD circle (2)
- Draw outer diameter (3)
- Draw inner diameter (4)
- Set dividers to DBH
- Pick any point on PCD and mark around circle (5)
- Reverse direction to check work
- Center pop where arc meets PCD
- Use center pop for dividers, draw bolt diameter (6)
- Wad punch bolt holes and cut out the inner circle and outer material

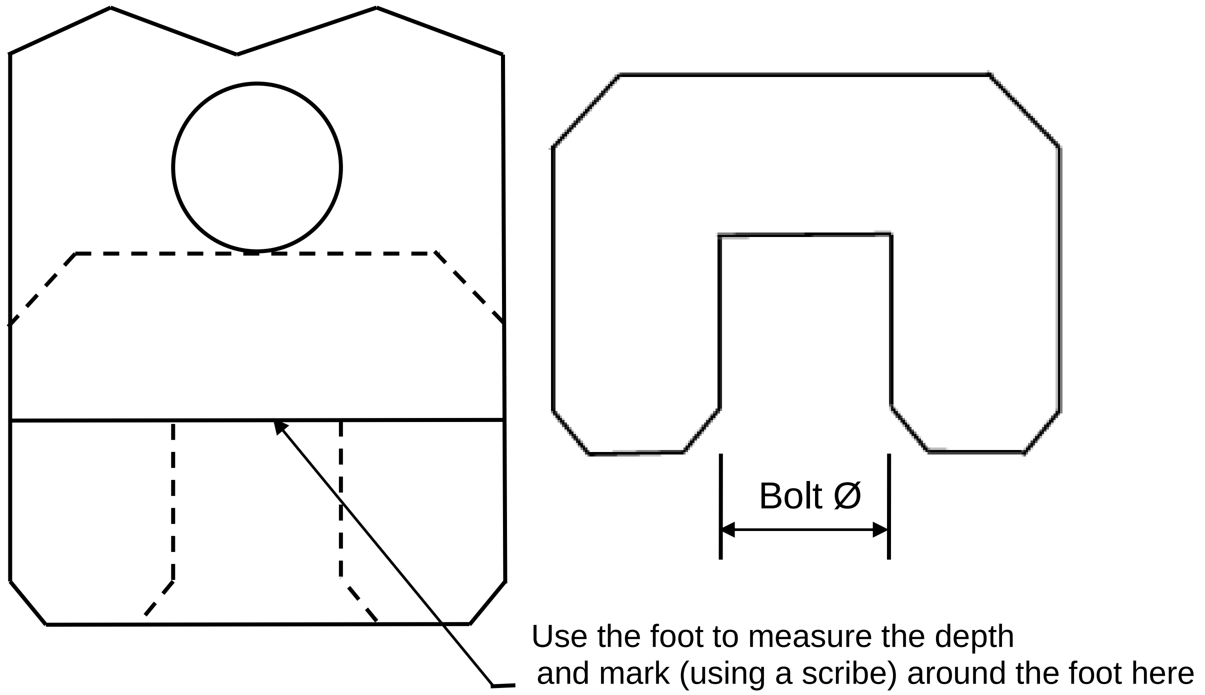


<u>Shims for alignment</u>

Measure the foot and bolt Ø and bolt location

Make sure <u>corners</u> are <u>snipped</u>

Shims inserted from side



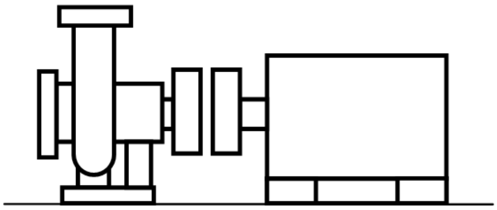
Shaft Alignment - Step by Step Methods
3 methods of alignment:
Straight edge with taper gauge or feeler gauge.
Reverse clock (2DTIs) –graph, mathematical.
Lasers: (recorded in mm/”)

There are different manufacturers. For example
- SKF
- Optiline
- Rotalign

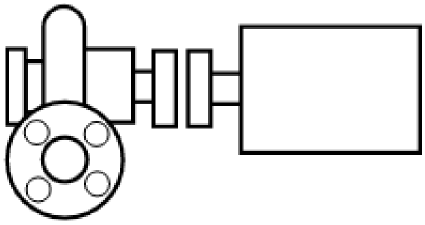
The three types of misalignment:
Axial – centerlines aligned perfect but couplings too close/too far
Angular – shaft centerlines aren’t parallel
Offset (Radial) – shaft centerlines are parallel but offset

These Occur in 2 Planes:
HP – Horizontal Plane – looking from the top
VP – Vertical Plane – looking from the side

Vertical Plane



Horizontal Plane



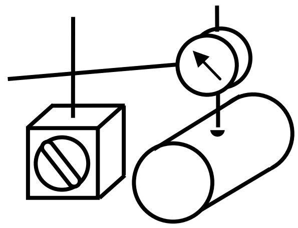
Faults in using the reverse clock method

When using clocks we can have an inaccuracy which will affect our readings. This is called “bar sag”. Bar Sag is a phenomenon where the DTI dips ever so slightly due to the weight of the clamp etc. This can be reduced by fabricating a strong sufficient frame for the DTI. Bar sag can be measured by being fixed to a shaft on a pair of knife edges. Zero the clock on the top, and then rotate the shaft through 180^{O} record this reading and rotate the shaft so the clock is on the top to check the zero. The reading wants to be minimal.

Equipment Failure

Misalignment can cause uneven wear in bearings, causing vibration and reduced lifetime of the machine. As equipment operates at faster speeds, the forces applied are magnified.

Misalignment can cause the shaft to whipround and lose concentricity. Before alignment begins, it is good to check the concentricity of the coupling mating face and the shaft. This can be done by eye (for approximate check) but will be more accurate with use of a DTI.



Soft Foot

Before any alignment takes place, we must check for soft foot. Soft foot is a naturally occuring phenomanon that takes place on the base of the motor. Motor feet are cast and not accurate. They may also be deformed due to incorrect tightening in previous instalation. Also the plinth in which the motor is mounted may be uneven due to wear and tear. Soft foot is removed by nipping diagonal bolts and rocking the motor. This can be corrected by using a feeler gauge and shim. All shims for soft foot are placed under one foot.

Failure to remove soft foot results in inaccurate alignment and vibration causing premature failure.

Adding Shim

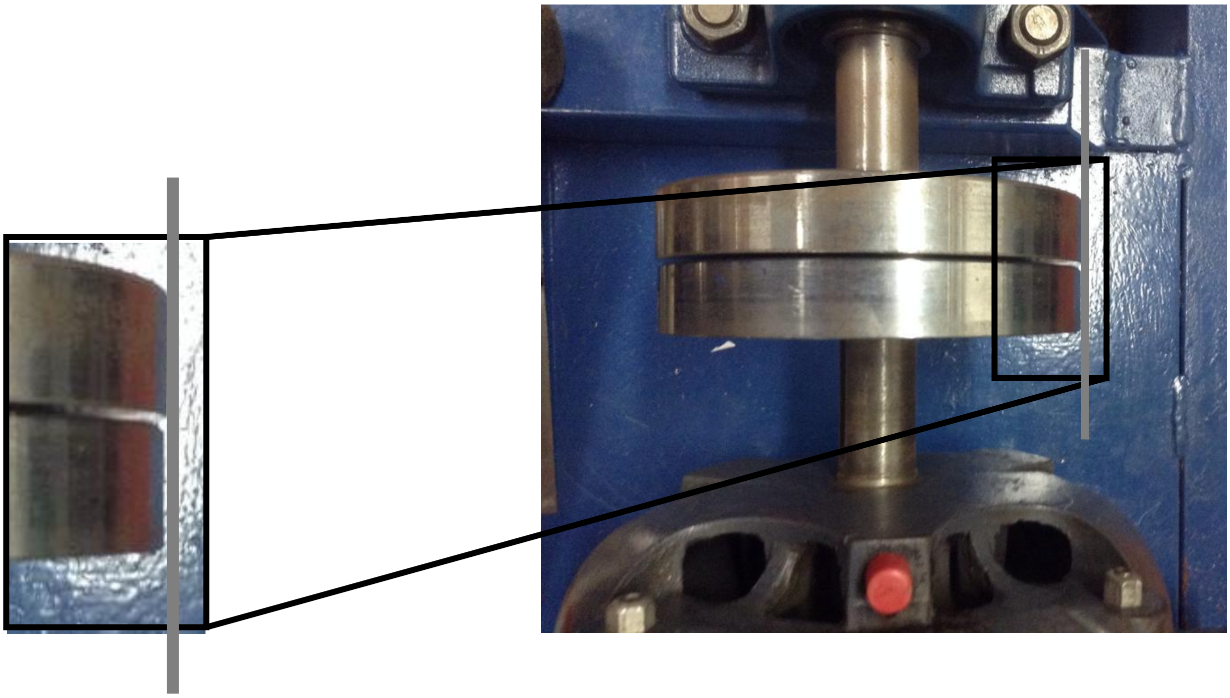
General Rule of Thumb when using shim packs:
Add shim from the side of the motor.

Use as minimum shims as possible (reduces air pockets between shims) this causes cumulative errors in misalignment.

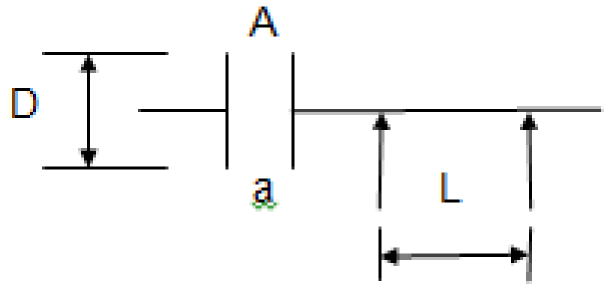
When adding various thicknesses, use thinner shims in the middle.

When adding shims, push all the way to the bolt, but pull back slightly, this prevents the bolt binding on the shim which may cause burrs, this adds to the cumulative error.

<u>Straight edge method</u>
- Remove soft foot
- Gross misalignment
- Nip bolts slightly to prevent motor from skidding (helps reduce movement for fine adjustment)
- HP – Angular – taper gauge (take readings at 9 o'clock and 3o'clock) and adjust the angle of the motor until readings are the same
- HP – Offset – straight edge on outer diameter parallel to the shaft, - adjust motor until gap has been removed (as shown below)
- HP – check angular misalignment and correct
- HP – check offset misalignment



- VP – Angular – measure using taper gauge at A and a

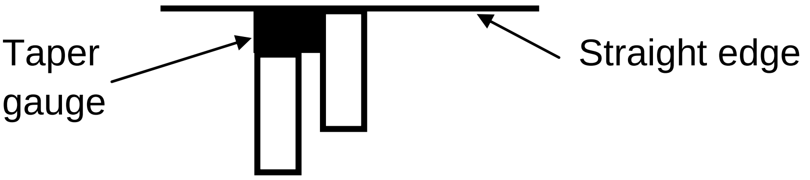


A= Top reading
B= Bottom reading
L= Bolt dimensions (front to rear)
D= Coupling diameter
S= Shim

Formula to calculate shim:

$$S = (A - a)\,{}^{L}/_{D}$$

- Add shim required, ensuring bolts are backed off, pry bar to lift motor, and bolts are nipped as before
- Check HP angular and offset correct any misalignment
- Measure height adjustment



- Add shim to all four feet of the motor
- Check height make adjustments
- Tighten down bolts
- Final check make any adjustments

Reverse Clock Method

- Remove soft foot
- Check for bar sag
- Check shaft and coupling concentricity using DTI

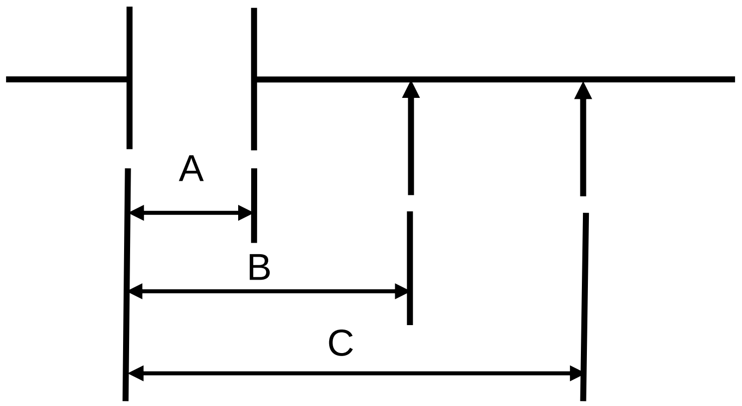
Fixed Machine → Movable Machine = Offset

Movable Machine → Fixed Machine = Angular

- Use jacking bolts to move motor (if present) if present ensure the jacking bolts are backed off on the side the motor is moved to.
- Clamp DTI on Static Machine (SM) (clock on Movable Machine, MM) zero on 3o'clock, rotate to 9o'clock. Alter the position of the motor, check by returning to the two positions. Repeat until the reading is approximately the same. This is removing the gross misalignments
- Reverse the clock, Clamp on MM (clock on SM), zero on 3o'clock, rotate to 9o'clock. Alter the position of the motor, check by returning to the two positions. Repeat until the reading is approximately the same.

This is removing the gross misalignment

- Clamp DTI to the SM zero on 12o'clock on hub
- Take readings left and right 9o'clock and 3o'clock
- Make adjustments until reading is similar (and add up to reading at (6 o'clock).
- Reverse clock and repeat
- Measure the following

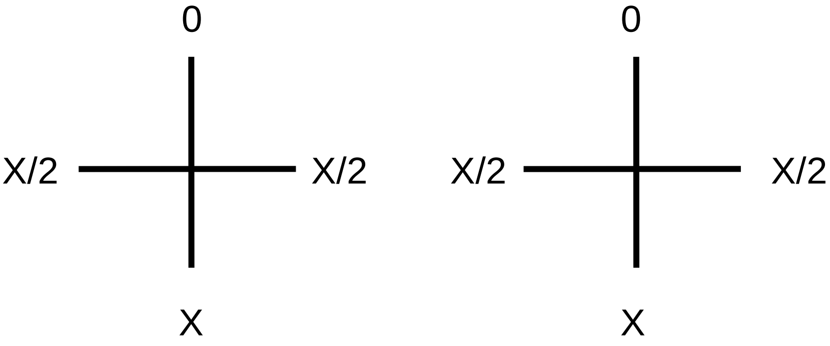


A = Dist. between hubs

B = Dist. from hub to front bolt center

C = Dist. from hub to Rear bolt center

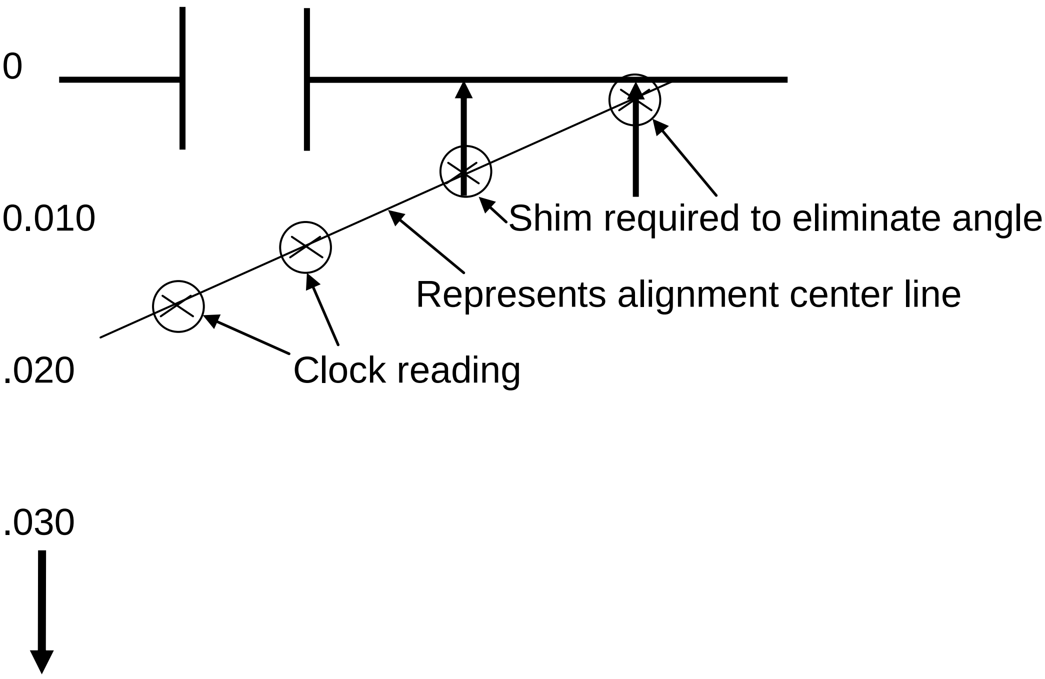
- Take readings on hubs



- Produce graph/equations to calculate shim for motor

There are two methods to eliminate the angular misalignment in the vertical plane. This can be done via a graph, or mathematically using a formula.

<u>Draw Graph to Scale e.g.</u>



A line is drawn using the 2 readings to represent the centerline of the motor shaft. This line is extended to cross with the bolt holes (this is why it must be drawn to scale). The point on the graph where the line crosses the bolt centers is the reading for how much shim is required to eliminate the angular misalignment in the vertical plane. Shim is then fabricated to suit the measurements

Mathematical method

Terminology:

MM – Movable machine
SM – Static Machine
TIR – Test
Indicator
Reading

$$\frac{SM+MM}{A \times 2} = X$$

$$\frac{SM}{2} \times -1 = Y$$

$$X \times B + Y = \text{Front Foot Shim}$$
$$X \times C + Y = \text{Rear Foot Shim}$$

- Add shim required
- Nip down check position (book hubs)
- Make adjustments
- Replace shim (for as few used as possible)
- Final checks
- Make adjustments
- Record final readings

Rotalign lasers

- Check for soft foot
- Remove gross misalignments
- Nip down
- Gag coupling
- Fit magnetic clamp to shaft behind coupling (against the back of the coupling)
- Remember "Lazy Laser", this means the laser is lazy and is mounted on the SM because it doesn't move

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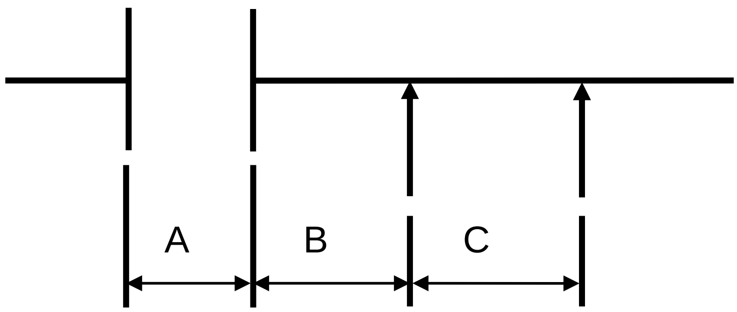
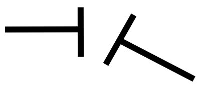
- Press D (dimensions)
- Ø of coupling
- Rpm of motor
- (A) Coupling→ Sensor CTR
- (B) Sensor CTR → FL
- (C) FL → RL
- Fit laser and sensor

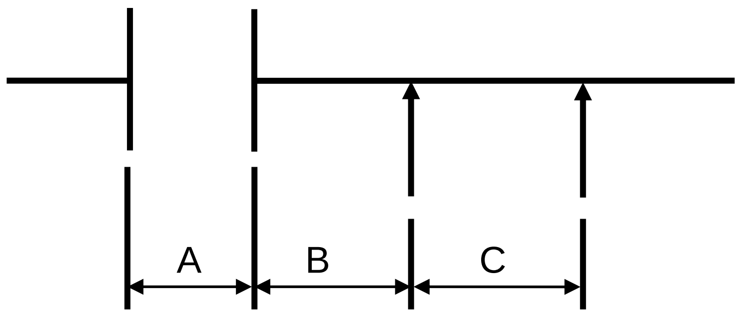


- Laser roughly in middle of sensor on cap, remove cap
- Press 

- CTR laser
- Rotate coupling (ensure no collisions)
- Press 
- The screen will show misalignment in the horizontal and the vertical
- Adjust the motor with the lasers on live mode until well within tolerance (a smiley face will appear) but ensure you are within the correct tolerance as a smiley face isn't a technical measurement
- Sweep (any errors repeat the previous step)
- Replace shims
- Nip down
- Final check
- Record data on company system

<u>SKF lasers</u>

- Remove soft foot
- Check coupling concentricity
- Clamp laser frame to shaft (Remembering Lazy Laser)
- M on movable (receiver)
- S on Stationary (Laser)
- Center the laser on the receiver
- Take dimensions ABC and input on Device



- Ensure laser is at correct height
- Move laser to 9 o'clock
- Check reading (on device) (record it)
- Move laser to 3 o'clock
- Check reading (on device) (record it)
- Return to 12 o'clock
- Check reading (on device) (record it)

 = Angular HP

 = Offset HP

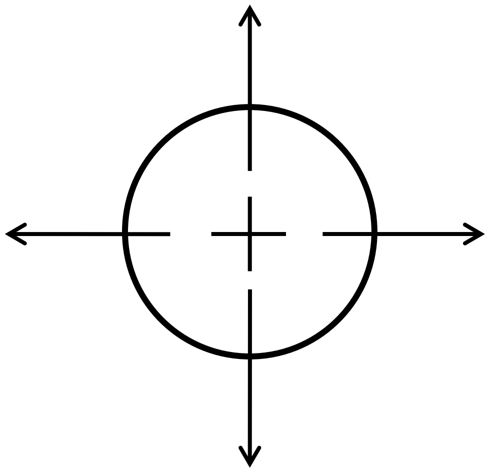
F1= Front Feet
F2= Rear Feet
Motor VP

- Remove angular and offset
- Produce shims (defined by F1 and F2)
- Check
- Make adjustments
- Nip down
- Final check

- Record results on computer

Bearings

Types of load



Radial

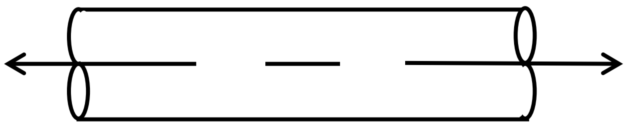
Occurs 90º from shaft center

Usually caused by weight of shaft or belts

Thrust

Occurs along center of shaft

May be caused by impeller or turbine



Types of Bearing Failure (Many more)

Shock loading effects rolling element bearing more than journals.

Flaking
- Material split off from smooth surface
- Rough and course texture

- caused by rolling fatigue, excessive load, misalignment, poor lubrication

Peeling
- Dull or cloudy spots
- Tiny cracks
- Small particles many may fall off

- caused by poor lubrication

Scoring
- Metal to metal contact
- Lines scribed on rule or roller

- Poor lubricants
- Dirty lubricant

Smearing
- Small seizures between bearing components
- Melting and surface roughening

- Over lubrication (slipping)
- Poor lubrication

Fracture
- Small pieces broken off
- Corner of rib or ring

- Impact
- Excessive load

Pitting
- Tiny pits or indents

- Debris
- Moisture
- Poor lube

Brinelling
- Solid Bodies forced together
- Leaves marks of the same shape (rollers or balls)

- High load

False Brinelling
- Wear caused by excess vibration
- Impact

- Poor lubrication
- Vibration
- Too much clearance (bearing worn)

Bearing Removal
From Housing

- Single part bearings
- Slide hammer
- Assemble tool
- Insert all pins into took and insert into bearing
- Slide hammer against handle (hard, avoiding) (fingers)
- Remove bearing
- Disassemble tool

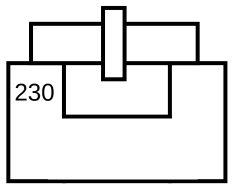
- 2 part bearings
    - Remove inner vale and rolling element assembly
    - Heat outer race (weld MMA, MIG, oxy fuel)
    - Use heat proof gloves (resistant)
    - Or tap out using hammer and center pop
    - Or tap against the shaft against bearing inner race

From Shaft
- Bearing pullers
    - Assemble tool
    - Clamp shaft in vice
    - Set up took on shaft
    - Turn handle/use hydraulic lever
    - Remove bearing
    - Disassemble tool

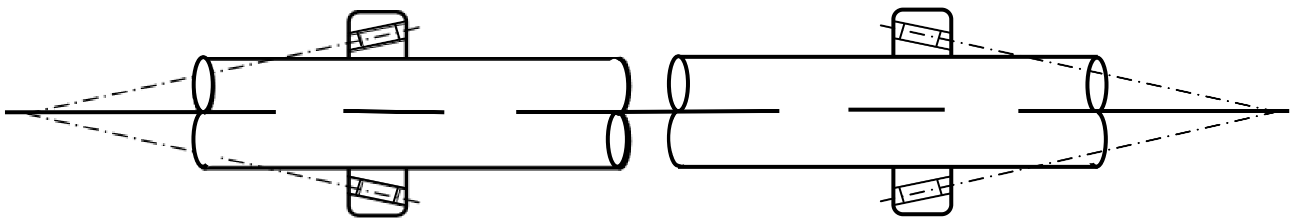
- Hydraulic Press
    -Place bearing on correct size disc with slot
     (or hydraulic pullers)
    -Ensure at the correct height
    -Position jack on shaft
    -Push shaft until bearing falls off and shaft falls through.
    -Ensure shaft isn't damaged by holding it

Bearing Fitting
- Heat bearing to 230^0F using induction heater (cross bar as big as possible) ensure cross bar metal side is down
- Use heat proof gloves (resistant)
- Fit onto shaft square
- Ensure bearing sits evenly

- Outer race evenly tapped into housing (if 2 parts)

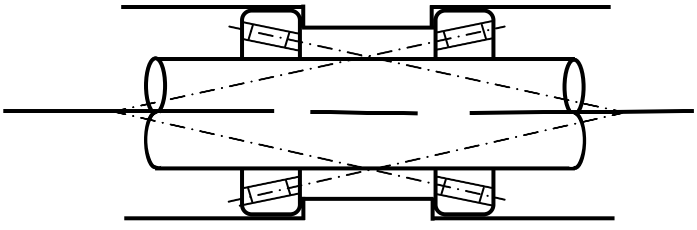


Mounting of tapered bearing direct



- Better rigidity when not closely spaced
- Transmission, speed reducers etc

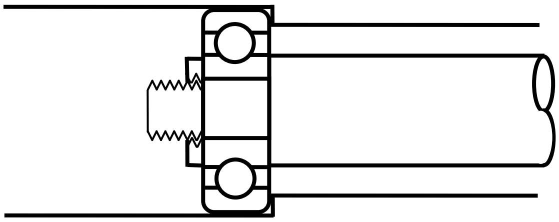
Indirect



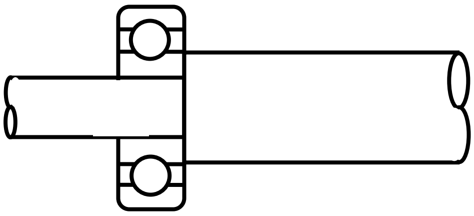
- Better rigidity when closely spaced
- Wheel of a car, drums, sleeves

Mounting Bearings

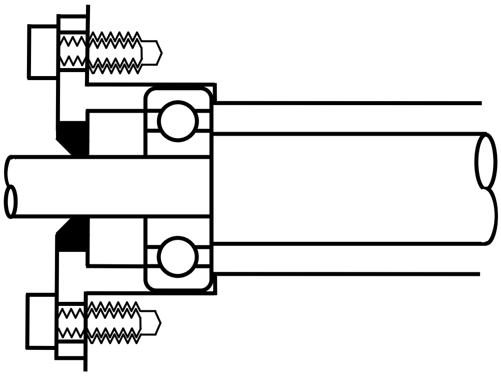
- Commonly held in by shaft nut



- Alternatively pressed onto shaft (heating)



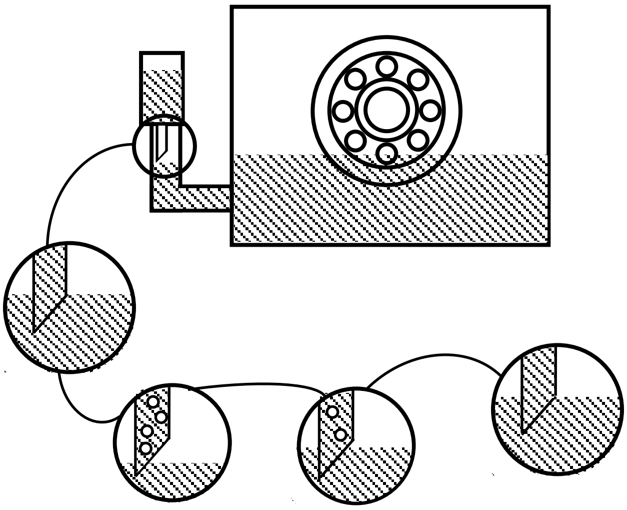
- Cover plate



  - Pushes bearing into housing
  - Used to set end float with shim

Lubricating bearings

-Self leveling bottle oiler

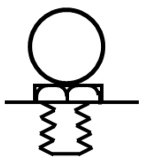


- Once level decreases on angled lube, air rushes into the bottle

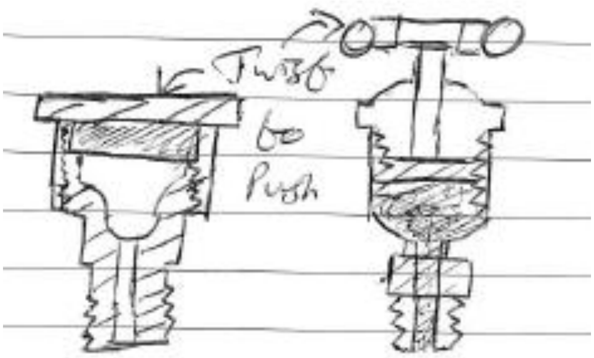
- Air pushes oil out until no air can go in

- Self leveling bottle

Grease Nipples
- Located on outside face of casting
- Threaded in

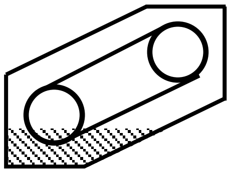


Grease Cups
- Threaded into outside face on casting



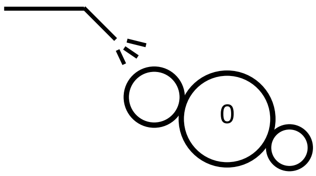
<u>Oil bath lubrication</u>

- Lubricates using chain drive coupling
- Chain passes through oil, lubricates gear and reciprocates, lubricating other gear.



<u>Stream (spray)</u>

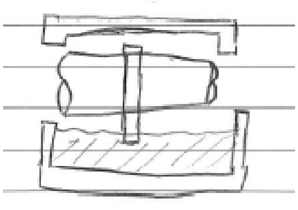
-Carried from one gear to the next using light oil (low viscosity)



<u>Oil Ring</u>

- Picks up lubricant and deposits on the shaft
- Reciprocates with shaft continuously applying oil

- Correct weight required
- Too light – won't cover in oil
- Too heavy – won't turn



Valves

Used to:

Control flow- (regulating or throttling)

Isolate Flow- (starting or stopping)

Prevent backflow- (usually centrifugal pump outlet)

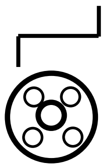
Relieve or regulate pressure- (to equipment or out of vessels)

Valves can be serviced in situe:
- Isolated
- Drained
- Repaired

High priority valves would be isolated and swapped to be repaired in the workshop. This allows the line to operate during maintenance, reducing the downtime of the plant.

Valve Identification

Valves can be identified by:
- Mainly by the shape of the casing
- The handle
- And unique symbols
- Always 2 holes up on flange



Valve selection
Things to consider:
- Liquid, solid or gas?
- Fluid continues solid particles?
- Will it vaporize?
- Will it condense?
- Will it crystallize?
- Is it corrosive or erosive?
- What is the temp?
- What is the pressure?
- Used for isolation?
- Used to throttle or regulate?
- Will it be used frequently?
- Operation? (Manual/Auto)
- Environment? (E.g. access.)
- How big of a valve is needed?

- How much product?

<u>Most Common Valves</u>

<u>Plug Valves</u> – Isolation valve
– Handle can be removed

Can be – lubricated – not with oxygen in pipe
– none lubricated

Low pressure
High temperature
Gas, liquid and slurries

Can be used as throttle, wears bore and reduces life.

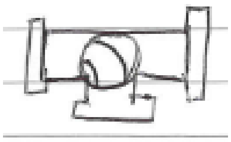
Lugs where the handle goes shows open/close position

Oil forces valve out hydraulically, assists sealing

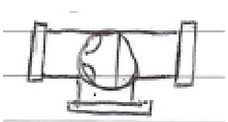
Pressure of inlet pushes plug against outlet wall, helping assists sealing

Plug valves can be:

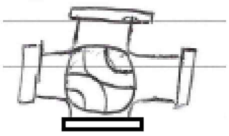
2 port 3 way

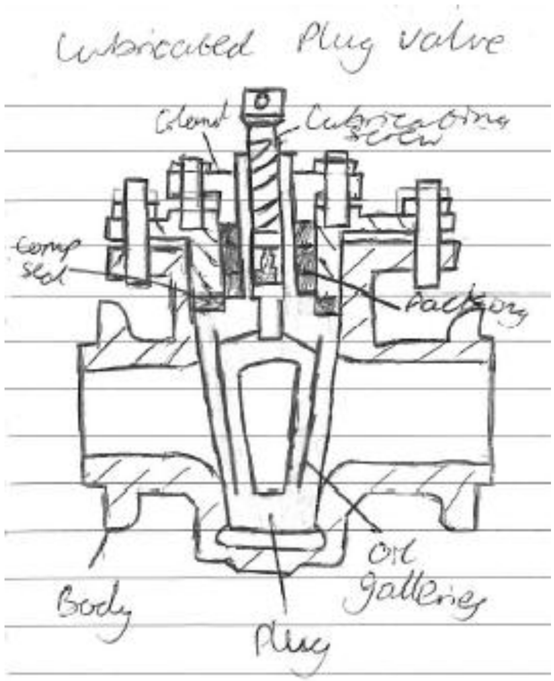


3 way 3 port



4 way 4 port





Lubricated Plug Valve

The various port type is used to redirect the flow e.g. to a pump on standby.

Ball Valve – Isolation Handle can be removed

Can have a split case or colleted

Flange or screwed into pipework.

Used for fast shut off.

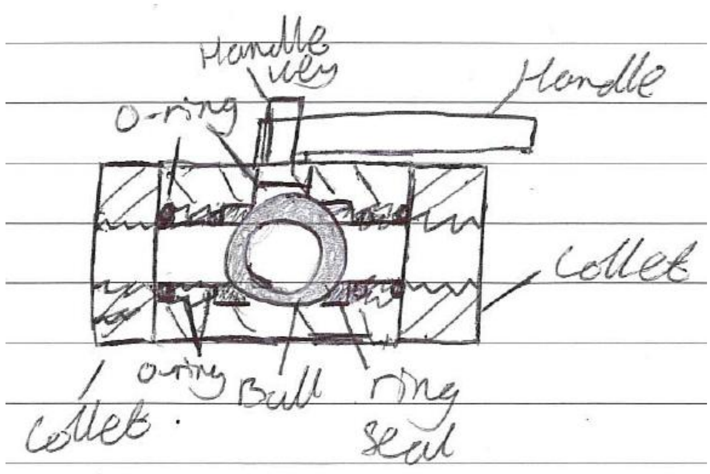
Used to handle gas and liquid.

H Pressure and H temp. (Depends on material of seals).

Handle in line with center of ball hole. (Inline with pipe, valve is open, crosses the valve, valve is closed). Easy way to remember is if the handle crosses, it is blocking the path of flow.

When closed, ball is pushed (via inlet fluid) against rear ring seal acts as a second seal.

O-ring on collect to prevent lean



Knife Valve

Solids or slurries

Flat blade reduces build up

Fast shut off

Cuts through inline material easily

<u>Gate Valve</u> – Shut off valve

Slow open/crossing

Reduces water hammer

Used to regulate, throttle and to fully close.

Rising/ non rising stem

Wedge disc uses tapered seats.

Sliding disc uses spring loaded parallel seats

Build up of residue may cause improper sealing and may weep.

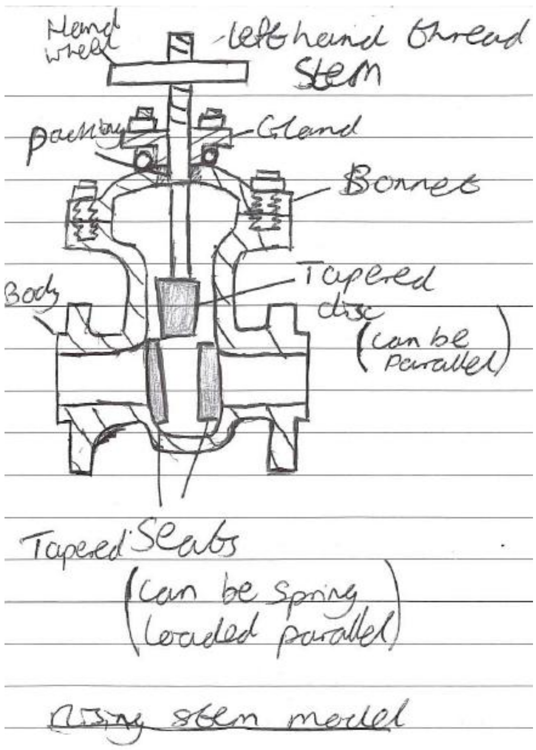
Reassemble ensure stem is open, nip gland last.

This helps to realign bolt holes and disk.

Length of thread shows open/close

Non rising may not have indication method

Tapered seats (can be spring loaded parallel)



<u>Globe Valve- </u>shut off valve

Rising/one rising stem

Have dingle direction of flow – indicated by a symbol- " → " " └─┐ "

Flow travels under to over 

Used for throttling or regulating (more common)

Used for open/closed.

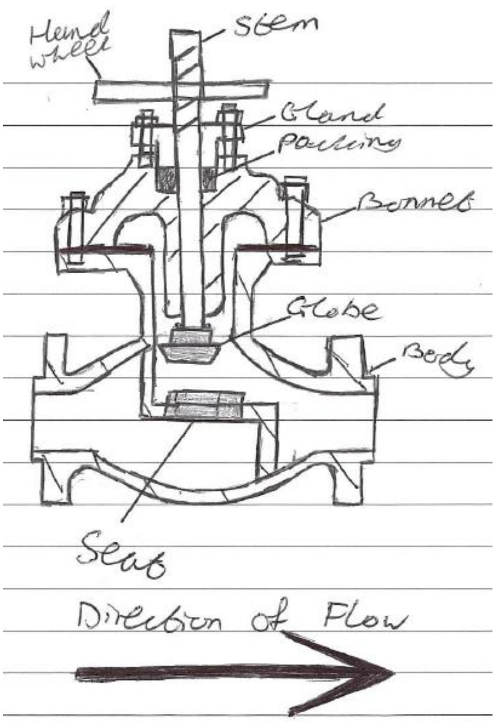
Reduces the effects of water hammer

Slow open/close

Can be blocked by buildup of product

Installation in the wrong direction applied constant load on the working ports causing premature failure.

Wrong direction causes constant contamination against working parts also causing premature failure.



Pipe work + flanges

Pipe work

Pipe work can be made of different materials. This is because of :
- Safety
- Cost
- Environment
- Material handling
- Pressures
- Temperatures
- Strength

4 types of pipe materials are:
- Ferrous- contains iron, magnetic
- Non ferrous- none iron, non rust
- Non Metals- PTFE, plastic
- Composites- Glass fiber concrete

Pipework can be:
- Extruded- (melted and turned in a mould)
- Cold Rolled- (Folded and welded)

Pipe Identification

- Pipe work is identified by the specification and pipeline reference

- Pipeline reference is where it is located on the plant and where it was manufactured

- Pipe line specification refers to the size, material, and nominal bore.

<u>Pipe line specification</u>

Pipe work of different sizes

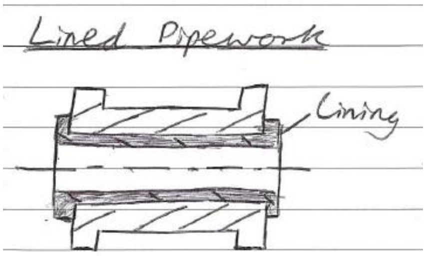
- Nominal bore
    - The area in which the product flows.
    - Nominal meaning average as sizes may be slightly more or less

- Schedule refers to wall thickness

- Outer diameter
    - Made to a standard size
    - To enable standard fittings and flanges

- Material
    - Different materials
    - Different properties
    - Different grades
    - Different cost

Lined Pipe work



Pipework may be lined.
This may be because of the media moving in the pipe. The media may be a harsh chemical.

- Operate at higher temp
- Operate with harsh chemicals
- Cheaper

The pipe around the lining may be carbon steel

This adds strength to the pipe

The materials use be may be:
- Glass
- PTFE
- Rubbers
- Teflon
- Resin

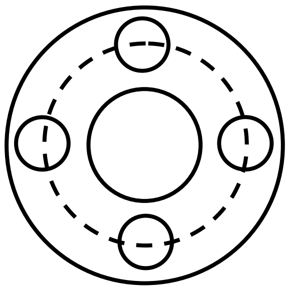
Flanges

Used to connect pipework to pipework, equipment or vessels.

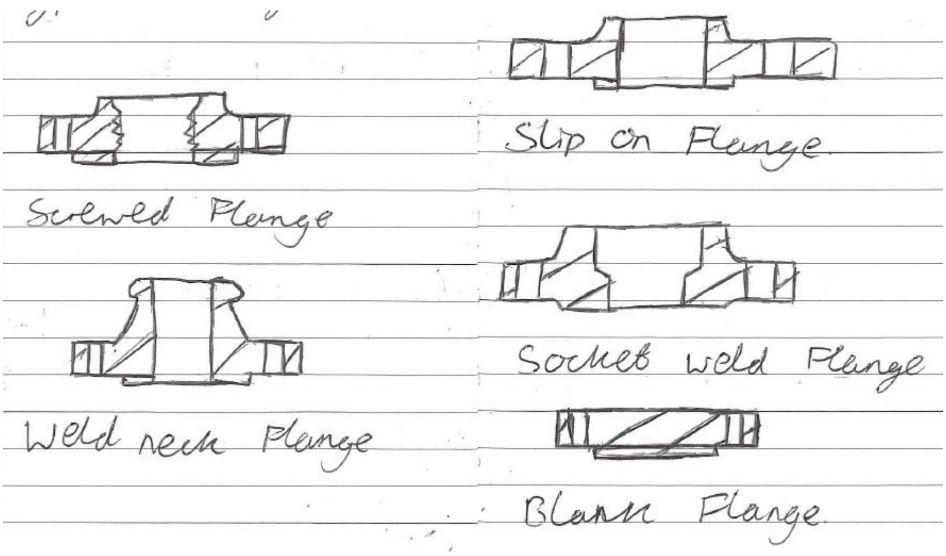
On the periphery of the flange is the flange class and pressure rating with the nominal bore.

2-150
InchNB- PSI

PCD - Pitch circle diameter bolt to bolt.



Types of Flanges

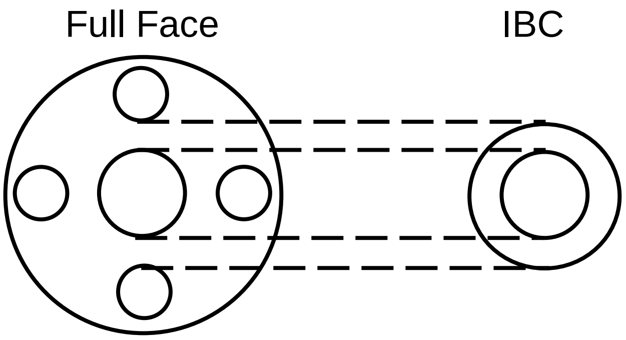


Sealing Flanges

To seal flanges different gaskets can be used.

A full face flange uses a full faced gasket. This gasket has holes for bolts and is the same size as the flanges.

IBC is more common



The type of gasket depends on the application
- Temp
- Pressure
- Materials
- Type of flange

Flange ratings

ASA 150
300
600

Refers to pressure rating

Selection of flange and gasket

- Strength
- Cost
- Materials handled
- Pressures
- Temperatures
- Size
- Safety

<u>Holding a Joint</u>

To hold 2 flanges together fasteners are required.

- Bolts

- Studs

Bolts are made from medium carbon steel

Studs are a carbon steel alloy denoted as B7

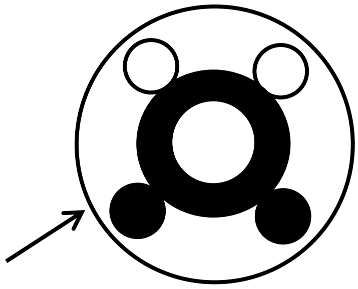
Bolts "neck" and fracture where the shoulder is.

Studs are high tensile, which is much stronger and can be torqued.

<u>Making a joint</u>

Take into account:
- May be old spec (table A,B etc)
- Bolt holes may not line up
- Different diameters
- Materials
- Clean flange faces

<u>Method of joint assembly</u>



- Clean faces
- Insert bolts on underside
- Insert gasket (sit on bolts)
- Insert remaining bolts
- Finger tighten bolts
- Align flanges to remove stress/strain
- Tighten bolts in opposing sequence to share the load over the gasket

PPE required for making/removing joint

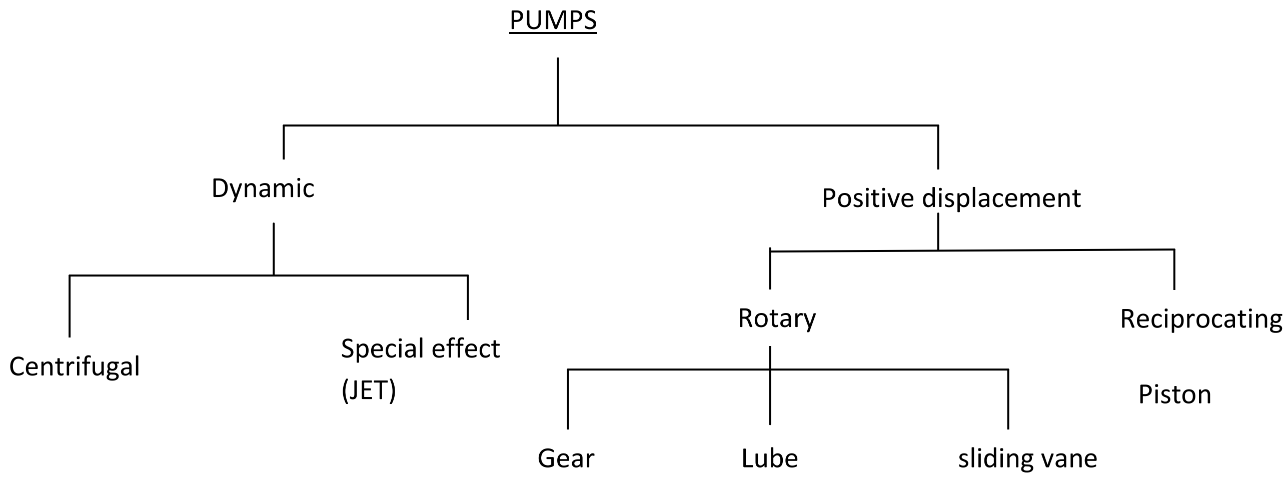
- Gloves
- LEP
- Boots
- Overalls
- Hard hat

Misc
- Breathing app
- Ear defenders
- Goggles

Safely breaking a joint
- Always assume live
- Ensure wind is behind you
- Place drip tray under joint (ensuring empty)
- Ensure not below pipe, always be above
- Open bolts lowest and away from you
- Remove product in pipeline
- Be aware it may be pressurized
- Slacken bolts away to towards you
- Remove bolts
- Remove gasket

Testing pipe work
- Hydraulic (water)
- Pneumatic (soap and water)
- In situe (safe e.g. water)

Pumps



Never close valve on delivery line- suction line. Pressure increases causing the pump to fail.

- Transfer fluid from source to destination
- Circulation

Dynamic Pumps

- Rotating impeller converts kinetic energy into pressure or velocity

Centrifugal - 75% of pumps used in industry

Special effect – specialized conditions

Closing discharge over heats pump as it churns liquid

Centrifugal pumps

Use an impeller
- Main rotating part
- Provides centrifugal force

No. of impellers = no. of stages

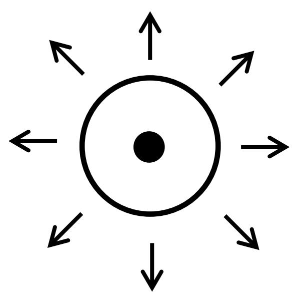
(Like compressor)

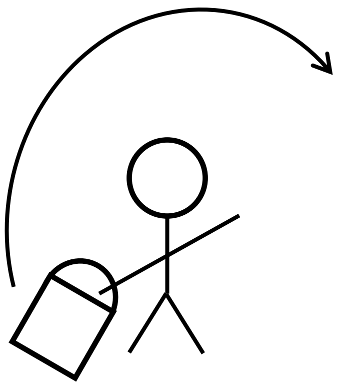
Classification – DOF, suction type, shape

Shafts transfer torque from the motor to impeller.

Motors rotate at
- 1400rpm
- 2800rpm

Centrifugal force





Water doesn't spill out of bucket

Centrifugal pump basic components

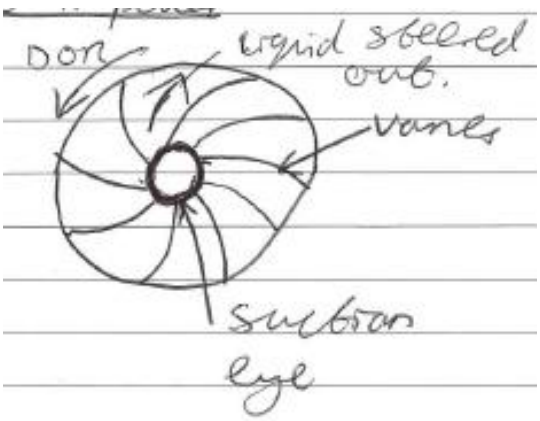
Volute (snail shell casing)

Impellers

Diver (motors)

How do the work?
- Liquid pulled into impeller
- Vanes transfer kinetic energy
- Liquid rotates and leaves
- Volume converts kinetic into pressure

The impeller



Impel – bring towards
Propel – push away

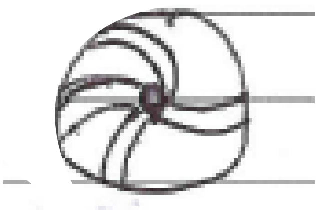
Vanes steer fluid in forward direction
If installed with vanes in opposite direction
Fluid would be thrown out rather than steered causes inefficiency

Water wheel turns by using water.
Like water wheel, wheel turns and moves water.

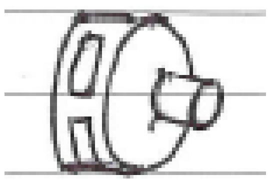
Wear ring should have minimal clearance

Impeller types

- Open (slurries, high viscosity)
- Semi open



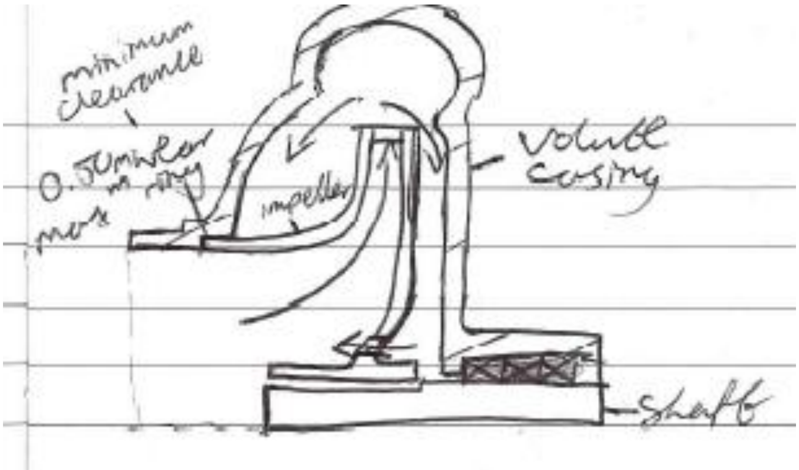
- Closed (low viscosity)
    - Single suction
    - Double suction



- Non clogging

- Axial flow

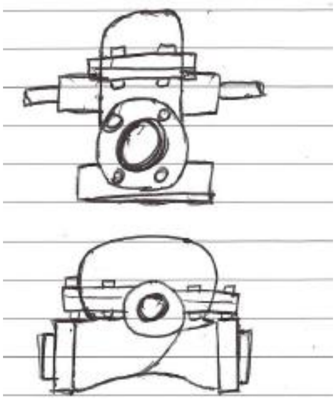
- Mixed flow



Flow of liquid around a closed impeller to help balance the forward thrust of the rotating element.

Without separated wear ring, system is very inefficient.
(Leaks back to suction eye, should be minimal)

Double Suction Pump



- Perfectly symmetrical

- Remove top cover to inspect without removing pump

- Radially and axially balanced

- Long life

- Greater volume pumped

<u>Multistage Pump</u>

- Multi impellers
- Increases pressure
- Overcome pressures in the boiling point

- Used for boiler water feed

<u>Pump failure</u>

- Cavitation
- Lack of fluid
- Reverse rotation
- Cycling
- Coupling misalignment
- Imbalance
- Closed head operations

<u>Cavitation</u>

- Pump sounds like its pumping rocks
- High vacuum reading on suction line
- Low discharge pressure/ high flow
- Power draw doesn't match manufacture curve

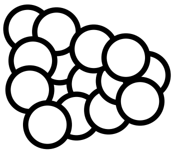
- Hear – Vibration
  – Collision
- Feel – Vibrations

<u>Causes of cavitation</u>

- Air in the system
- Clogged suction line
- Suction line too long
- Suction line Ø too small
- Suction lift too high
- Valve on suction partially open
- Discharge pressure too low (same problem as clogged)

Cavitation occurs when vapor bubbles are formed and collapse as they move in the pump - (changes in pressure).

Strainers are designed specifically to remove vortex on suction filter.
Looks like scoring on impeller and bubbles on volute.

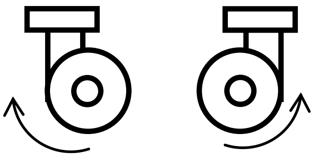


Cavitation remedies

- Remove debris from suction line
- Move pump closer to source tank/sump
- Increase suction line diameter
- Decrease suction lift requirement
- Install larger pump running slower to decrease net positive suction head required (NPSHR)
- Increase discharge pressure
- Fully open suction line valve

Commissioning CPs

1- Bearings are oiled
2- Check aux feeds are working (seals, oil supply)
3- Fully open suction valve making sure filters are clear
4- Flood volute casing vent gas
5- Discharge valve throttled – no more ¼ open
6- Start pump check DOR – less efficiency if wrong



7- Slowly open discharge to fully open (discharge pressure increases)
8- Check – leaks, vibration, noise, temp

<u>Positive Displacement</u>

- Each revolution transfers fixed amount from inlet and positively discharges it at other end.

- If pipe work is blocked it causes higher pressure which damages the pump.

- Used on a variety of fluids

- <u>Can't close discharge</u> - hydraulic pressure

- Reciprocating pumps are displaced by reciprocation of piston

- Viscous fluids

- Precise metering capacity

- Vary delivering rate
    - Speed of driver
    - Length of crank arm

<u>Volumetric Pumps</u>

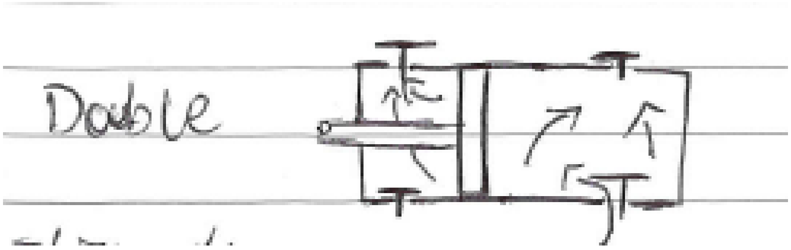
- Piston
- Plunger
- Diaphragm

- Piston reciprocating pumps may be single/double action

<u>Alternating Volumetric Pumps</u>

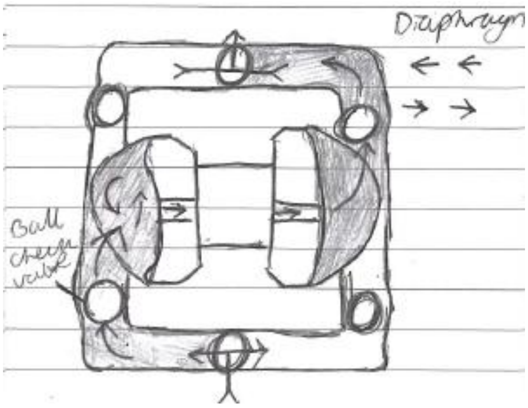
Pulls in
Pushes out
(like water gun)

- Liquids
- High viscosity
- High Pressure
- Bigger then CPs



Fills dead space behind piston

Diaphragm Pump



One draws in while other discharges
Moves valves like valves on piston

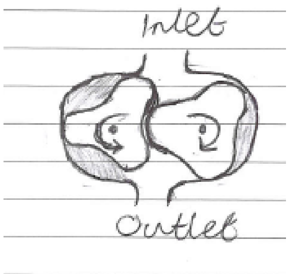
Ball moves to open/closed from pressure and flow of fluid

Rotary PD pump

- Displacement by rotary action of
    - Gear
    - Lobe
    - Pump

Lobe Pumps

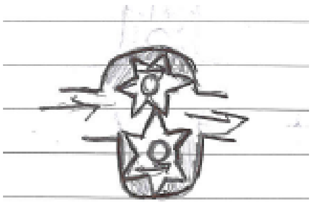
- Require external gear boxes to drive components



- Contact causes wear and seepage

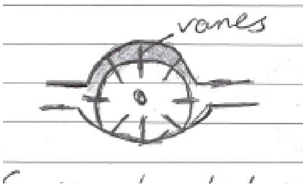
- Lubricates contact faces but still wears

Gear Pumps



- Operate same as lobe pump
- Wear on teeth

Sliding Vane Pump



- Spring loaded vanes
- Works like water wheel
- Wear on graphite vanes

Heat Exchangers

Primary Purpose:
-Transfer energy between 2 fluids, use conduction and forced convection

Types of Heat Exchangers

- Shell and tube
- Kettle boiler
- Double pipe exchanger
- Carbon block
- Plate Heat exchanger
- Spiral heat exchanger
- Air cooled exchanger

Shell and Tube

TEMA standards
Tube
Exchanger
Manufactures
Association

- Wide range of temp/press
- Many materials
- Many suppliers
- Repair- non specialist
- Design methods and mech codes from years of experience.

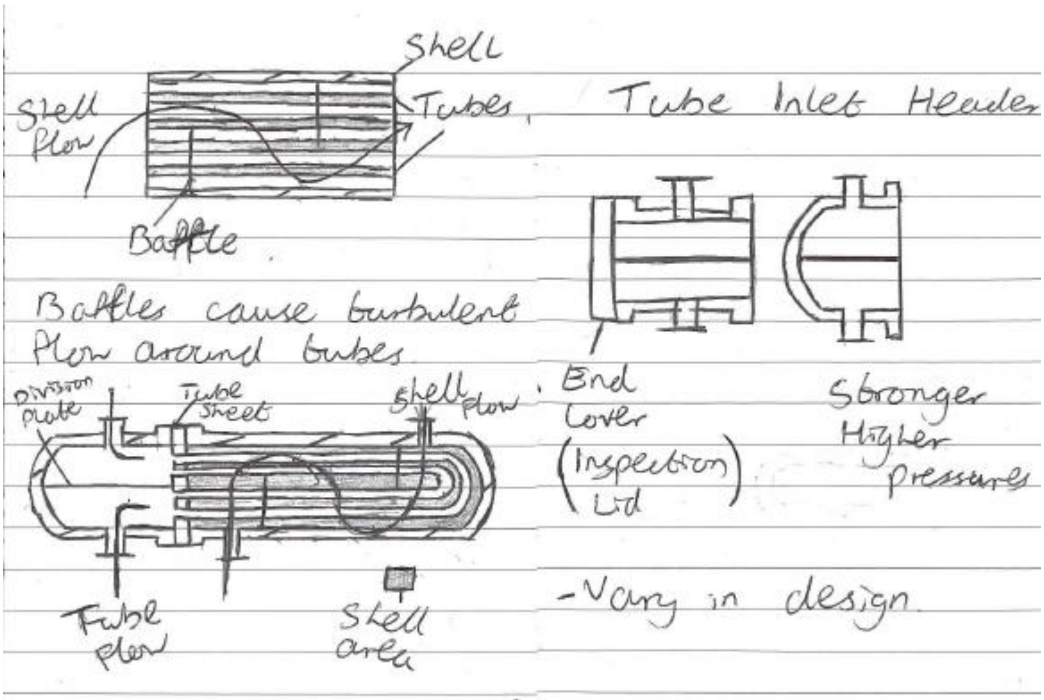
Max pressure:
Tube - 1400 bar
Shell - 300 bar

Temp range:
600 or 650 (ºC)
-100(ºC)

Fluids:
Subject to materials
Available in a wide range of materials

100 -10,000 ft^2
Can be extended with different designs/materials

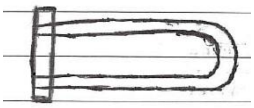
Construction
- Bundle of tubes in large cylindrical shell
- Baffles support tubes and direct flow
- Gaps or clearances must be left between the baffles and the shell must be kept to ease assembly
- Backing plate to attach nozzles – indication of high pressure



Floating head and U tube
- The U tube is an easy and cheap method

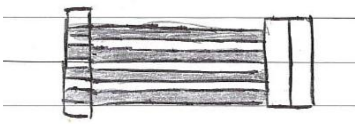
- Difficult to maintain tube internal

- Used to compensate for thermal expansion



- The floating head has inspection lid to inspect the tubes straight through

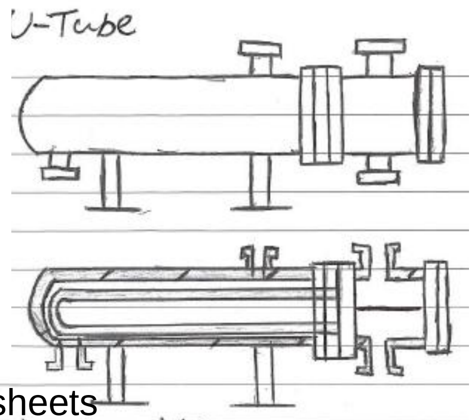
- Easier to maintain



<u>Inspection</u>

Things to look for:

- Necking on tubes (where medium meets tubes from shell nozzle)
- Flashing off – medium vaporizes instantaneously (different colour)
- Deposits -
    - Tube side
    - Sell side
    - Inlet header
    - Return header
    - Baffles
- Secure baffles
- Erosion
    - Division plate
    - Baffles
    - Tubes
- Impinchment/ necking on tubes
- Shell inlet nozzle
- Condition of guard on tubes
- Condition of raised face on flange (gramophone finish)
- Condition of flat flange
- Bellows
- Tubes
- Tube sheet
- Leakage – Tubes
    – Tube sheet
    – Bellows
    – blank o/p nozzle and drop tests - pressurize and leave then check back plate weep hole.



- Corrosion
    - Shell
    - Tubes
    - Tubes internal
    - Tube sheets
    - Bolts
- Condition of bolts

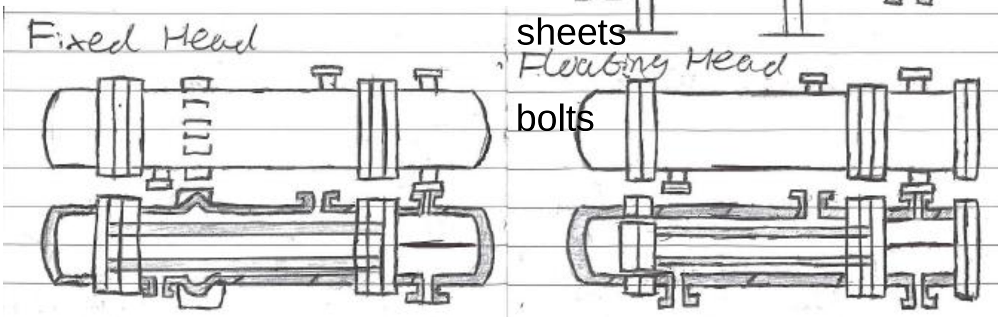
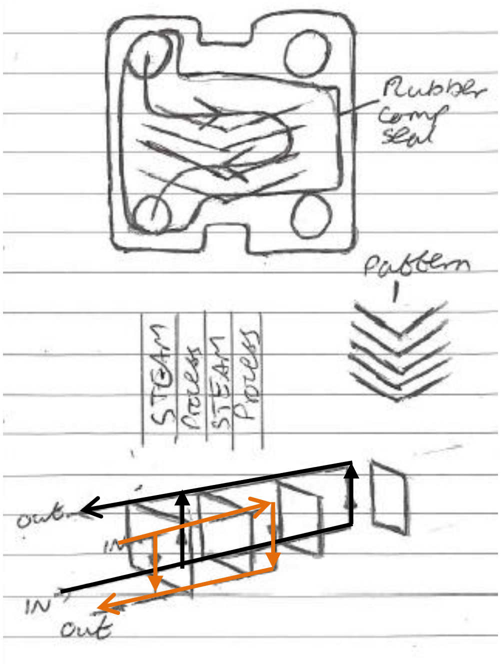


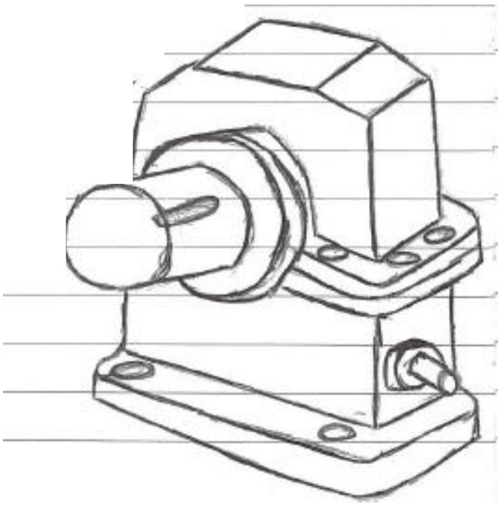
Plate Heat Exchange
- Smaller
- More efficient
- Large surface area
- Susceptible to - mechanical damage
  - build up

- In event of leakage, passive side is lower pressure (process is HP)
  - Process leaks out instead of contaminating process
- Seals using rubber compression



Radicon Gearbox

- Massive speed reduction
- Massive torque
- Various sizes
- Standard design
- Can be 2 together for massive reduction



- Worm and wheel arrangement
- Crown wheel made of phosphor bronze – designed to wear (more material than worm)
- Crown wheel is biased to one side over worm to produce oil wedge to maintain film and prevent metal to metal contact

- Contact mark
- Drain oil
- Allen key grub screw

<u>Inspection</u>

- Teeth condition
    - Wear
    - Seizing
    - Pitting
    - Backlash
- Worm condition
    - Wear
    - Pitting
    - Back lash
    - Seizing

- Oil - Level
    - Condition

- Bearing fault

- Key way and keys

- Correctly sealed

- End float (bump clearance, 0.10-0.40mm)

- Auxiliary Fan

- Contact mark (80%, 2/3rds)

- Condition of breathe vents

- Lack of lubrication
  (Scraper not fitted correctly, installed on wrong side)

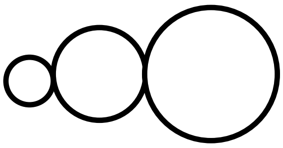
- Equipment rotating in wrong direction

- Condition of the wheel always worse than worm

Pitting is caused by oil particles, long operation, and high load.

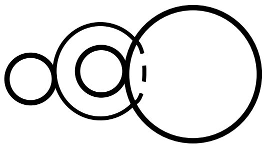
Gear Train

Simple



Single axis

compound

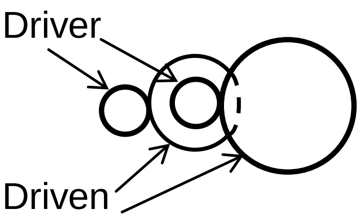


2 or more on single Axis

Gear ratio

$$\frac{\text{Driven}}{\text{Driver}} = \text{ratio}$$

$$\frac{\text{Driver}}{\text{Driven}} \times \text{RPM driver} = \text{RPM driven}$$



Compound is driver <u>and</u> driven

Torque

$$\frac{RPM_{Driver}}{RPM_{Driven}} \times Force_{Driver} = Force_{Driven}$$

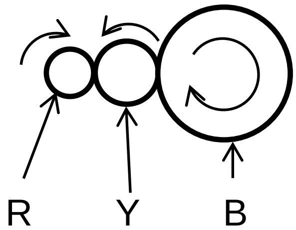
$$\frac{900\ \text{RPM}}{300\ \text{RPM}} \times 50 = 150\text{Nm}$$

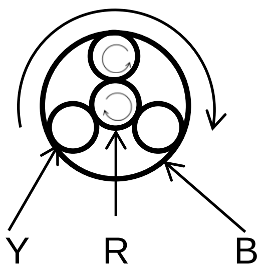
Gear ratio (3:1)   3X bigger

Planetary Gear Train

B = 6 x ØR

Y → Changes DOR



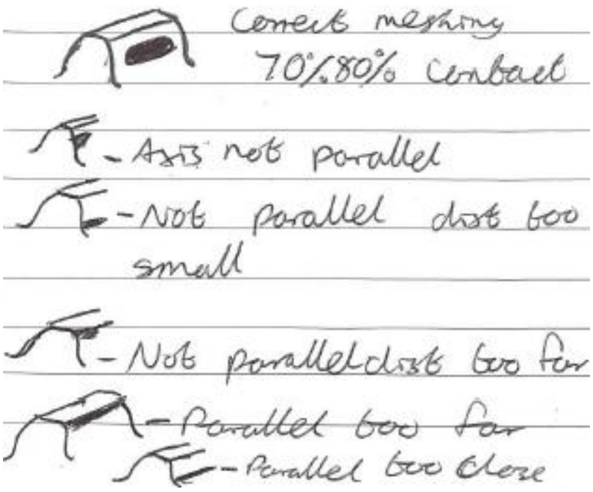


Planetary gears are

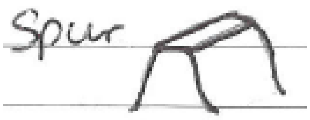
- Compact
- Strong
- Slightly more expensive
- Higher gear ratios

Gearboxes need EP oil (Extreme Pressure)
High Pressure – Low Viscosity

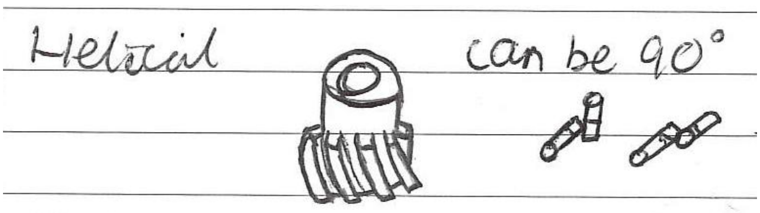
Magnet may be fitted to drain pipe of sump to remove fine particles from circulating oil.



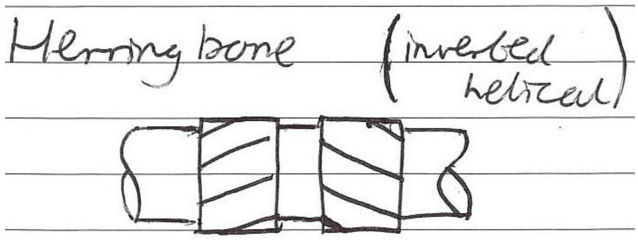
Gear Teeth



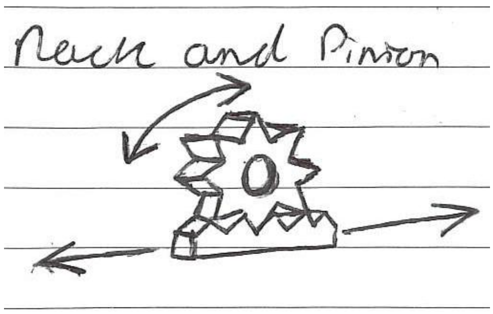
- Vibrations/noise
- Fast speeds
- Internal/external



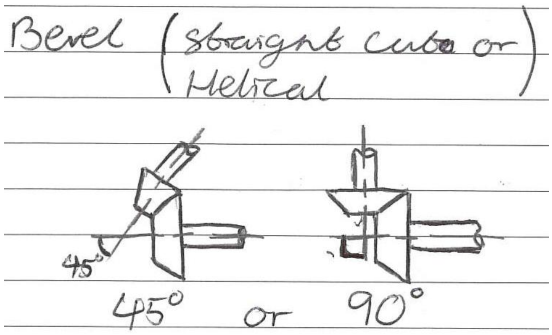
- 3 teeth mesh – shared load
- Less vibration/noise
- Axial load



- No axial load
- Oppose each other
- High speed reduction



- Rotary to linear and vice versa



- Allows angled alignment

Pressure relief

Protect the plant from:
+ pressure
- pressure

Relief stream is a relief device with associated pipe work.

- Self-contained
- No external power } Fail safe
- Automatic }
- Achieve (safe) reasonable pressure
- The capacity should be for “worst case” scenario

E.g. - Large bore pipe for greater volume of flow.

Increase/ Decrease in pressure
Explode / Implode vessels.

Common causes for Relief events

- External fire
- High pressure source
- Heat from equipment
- Pumps / compressions failure
- Heat transfer
- Liquid expansion – Vapor/ Hydraulic
- Logic failure
- Closed / blocked valves

Safety Valve – used for Gas
Relief Valve – used for Liquids
(Often safety relief valve, pressure relief valve etc.)

Valve snaps open / shut

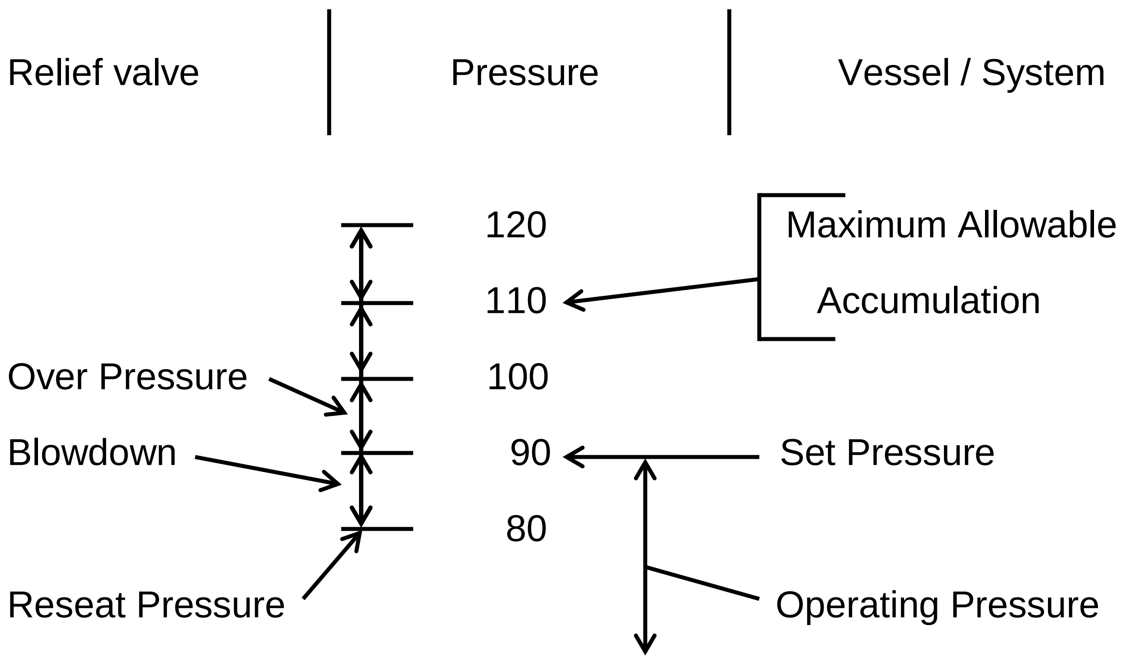
Snap open
↓
Blow down
↓
Snap shut

} Spring operated
Weight operated

<u>Order of Process Safety</u>

- Basic process control system
- Alarm system
- Safety interlock (shuts down part of process)
- Relief system

Seriousness of Event



Relief types

- Spring, weights or pilot operated
- Rupture device

Direct Acting

- Spring
- Weight

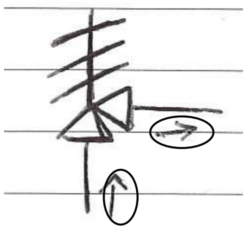
Oldest
Most common
Closed via spring / weight

Pilot Operated

- Closed via process pressure

Spring relief valve

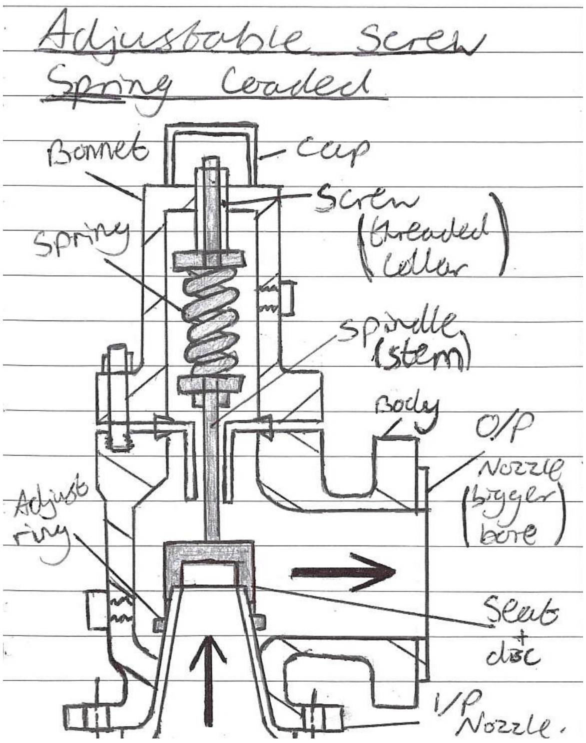
Symbol



Labelled arrows show direction of flow, not shown on actual drawing.

Spring acting directly against disc

- Screw is adjusted to alter operating pressure. (Increase spring tension, increase operating pressure)



- Inlet pressure exceeds spring force, causing disc to lift opening the valve.

- The outlet nozzle is bigger (nominal bore) to allow greater volume to discharge. - Also causes rapid pressure drop (like expansion valve)

- Bellows can be fitted if in dangerous atmospheres or handling dangerous materials – tell tale hole shows bellows worn / damaged.

- Once seat is lifted this is called the blow down period. Determined by the height of the adjusting ring. Blow down until safe pressure is reached. Big "Bang" occurs when opened.

- Spring – Operating pressure – Tight = increased pressure

- Adjusting ring – Blow down period

  – Higher = increased period

- Reset and close after blow down

  - Weeps (never close properly)

  - Big "Bang" (snap shut)

- Jacking handle is to test valve lifts – ensure fitted correctly

- Discharge has lower rating – steam to atmosphere

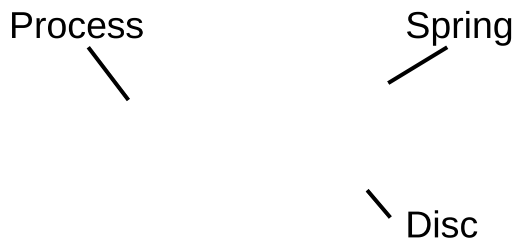
- Dangerous materials go down relief stream

- Relief stream has drain valve to remove condensate

Order relief events:

- Pressure exceeds spring tension
- Lift disc (snaps open)
- Relieves pressure
- Blow down
- Spring tension exceeds pressure (snaps shut)

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$



Inspection

- Chatter in operation (vibration)

- Initial pressure

- Seating pressure

- Before disassembled (tested in w/shop)

- Build up of material

- Corrosion – Inlet from process

  – Outlet from discharge

- Brinelling on disc

- Seals working (no leaks)

- Condition of bolts

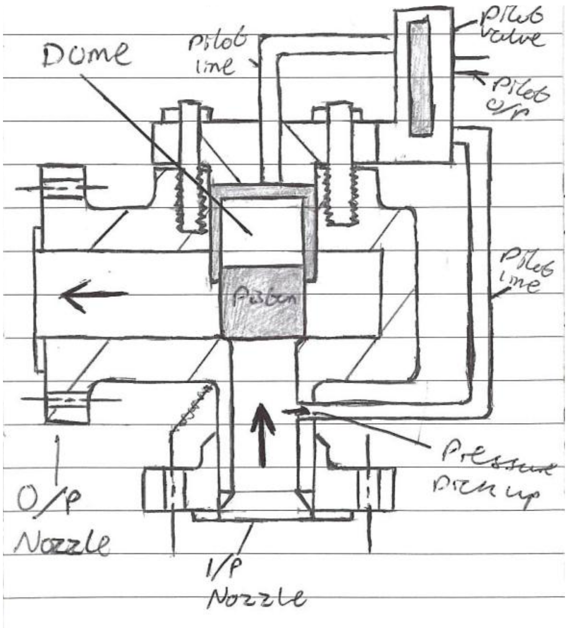
- Erosion

- Condition of flanges

- Back pressure (hydraulic) from discharge preventing/reducing operation

- Chattering is caused by – misalignment
  – Over sized valve
  – Operating at different rates – flow / pressure
  – Back pressure
  – Excessive inlet pressure drop

Pilot Operated Piston



- More expensive
- Easier to overhaul
- Operate at higher pressure
- Controlled by process pressure
- Less susceptible to chatter
- Limited chemical / temp due to O ring seal
- Condensation in dome
- Potential back flow

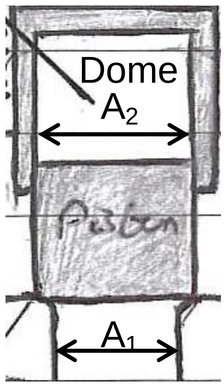
Principle of Operation

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

Pressure is the same on both sides.

Area is different

$A_2 > A_1$



I/p Nozzle

Constant   Variable

Pressure x Area = Force

By changing the area, the force changes meaning there is greater force applied keeping the dome closed.

Therefore the more force in the dome closes piston against nozzle.

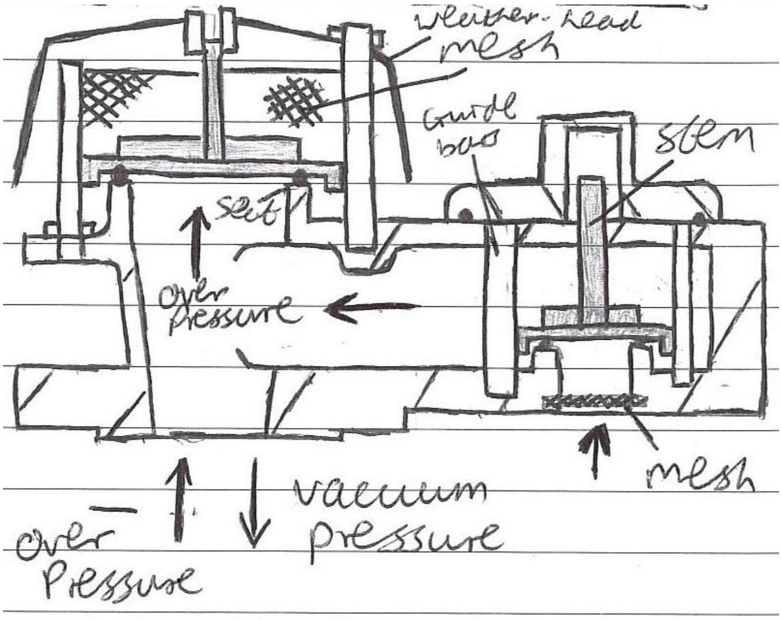
Pilot operates (at predetermined setting) relieving dome pressure. I/P pressure pushes piston open.

Pressure decreases, pilot closes, dome is filled with process, piston closes.

Inspection

- Leakage – Piston/ O- Ring
- Pilot operates – correct pressure
- Clogged
- Chatter – Back pressure
- Corrosion – Condition of bolts
- Condition of flanges

Vacuum Relief Valve



Used to relieve + and – pressures

- Vents off to atmosphere in over pressure conditions
- Pulls in air to vessel under pressure conditions
- Spring or weight

Over pressure

- Opens higher seat
- Safe pressure – closes

Under pressure

- Air overcomes force of seat
- Safe pressure – closes

Inspection

- Erosion
- Corrosion
- Leakage
- Build up – on vacuum part of valve
- Correct operating pressure
- Chattering
- Condition of flange
- Condition of bolts
- Spring tension / weight

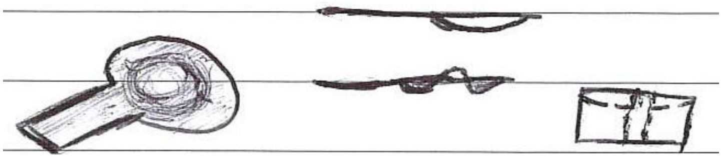
Rupture devices

- Shut down plant to replace

Bursting disc

Rupture pin

Bursting disc



Different designs

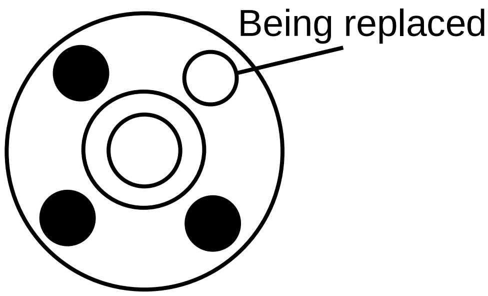
- Bursts at designed pressure
- Ensure correct orientation
- Have blades to help shear disc

Rupture pins

Plug with a pin

- Pin is designed to shear at set pressure
- O-Ring limits temperature
- Cheap and easy to replace
- Replace in situe

<u>Servicing Bolts</u>



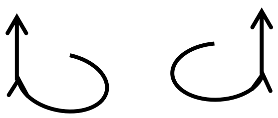
- Can be live
- Replace <u>1 bolt</u> at a time
- Reduces down time
- (Bolts may be seized solid)

<u>Splitting a Nut</u>

- Hitting nut causes shock, breaking debris on the thread, allows ease of fit
- Chisel from the side to produce line down nut
- Chisel from the top to the bottom
- Use chisel to tighten nut
- Nut removed

<u>Removing Corroded Nuts</u>

- Will it shear
- Remove as much rust as possible (wire brush)
- Use tool slightly smaller (better fit, less slip)
- Turn right way (look at hands fingers show direction thumb shows movement)



- Soak in paraffin,WD40, AC90 etc.
- Leverage
- Heat treatment (expanding nut cracks corrosion, and more clearance on thread)
- Last resort – Impact gun (may shear thread)