ME3393- MANUFACTURING PROCESSES

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UNIT – I METAL CASTING PROCESSES

Casting Procedure

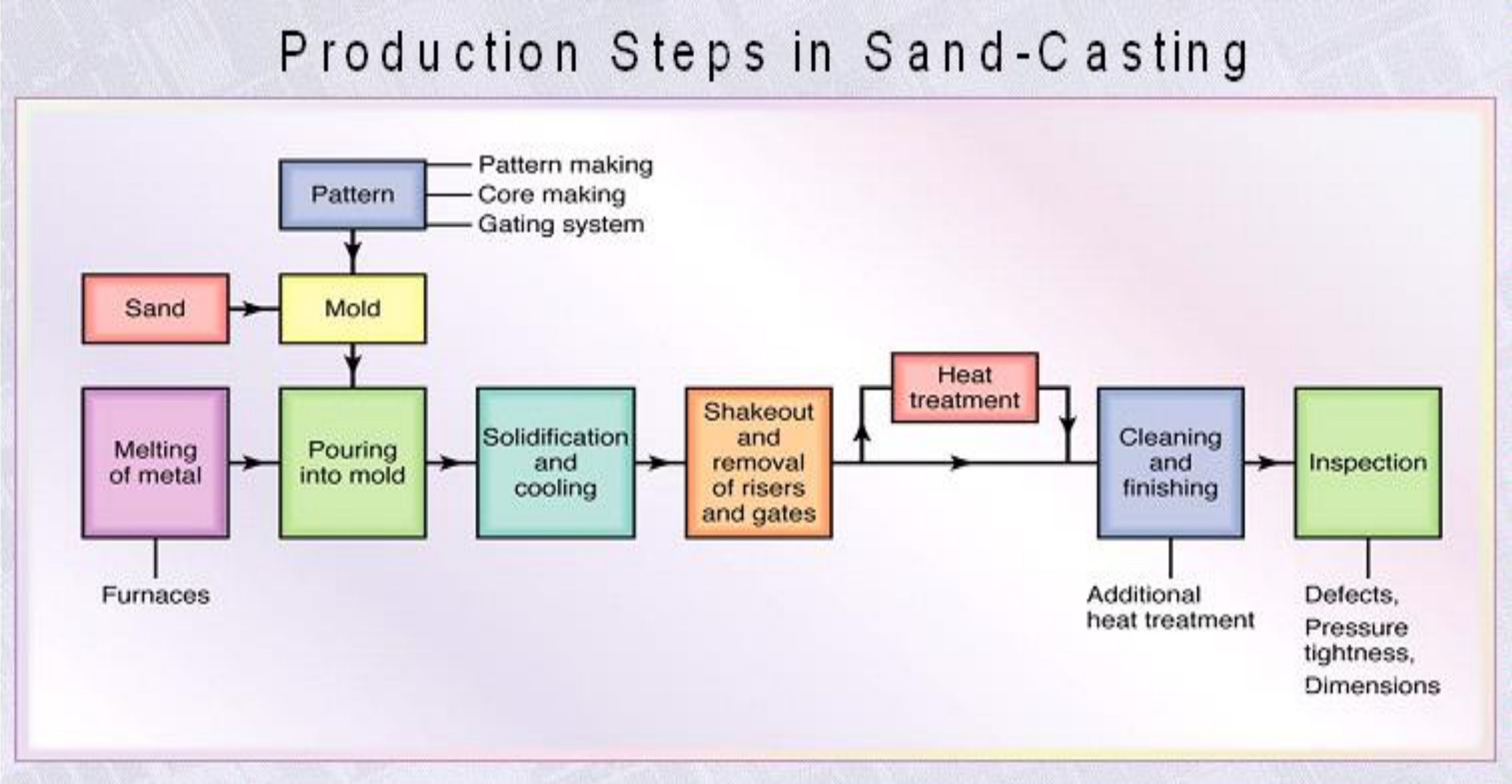

Figure 11.2 Outline of production steps in a typical sand-casting operation.

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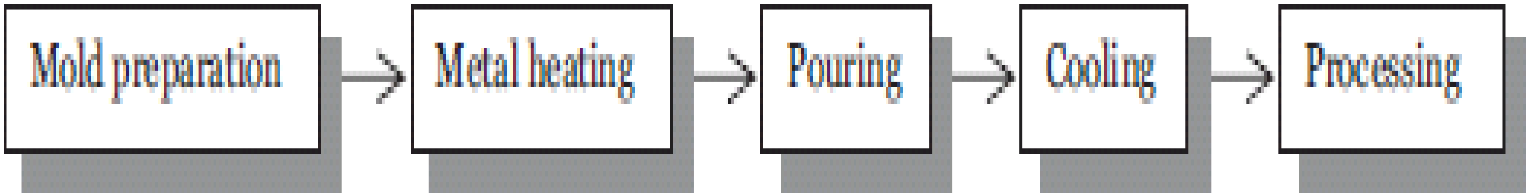
What is Casting?

- Casting is a process in which molten metal flows by gravity or other force into a mold and solidifies in the shape of the mold cavity. The part produced is called *casting*.
- Casting Procedure



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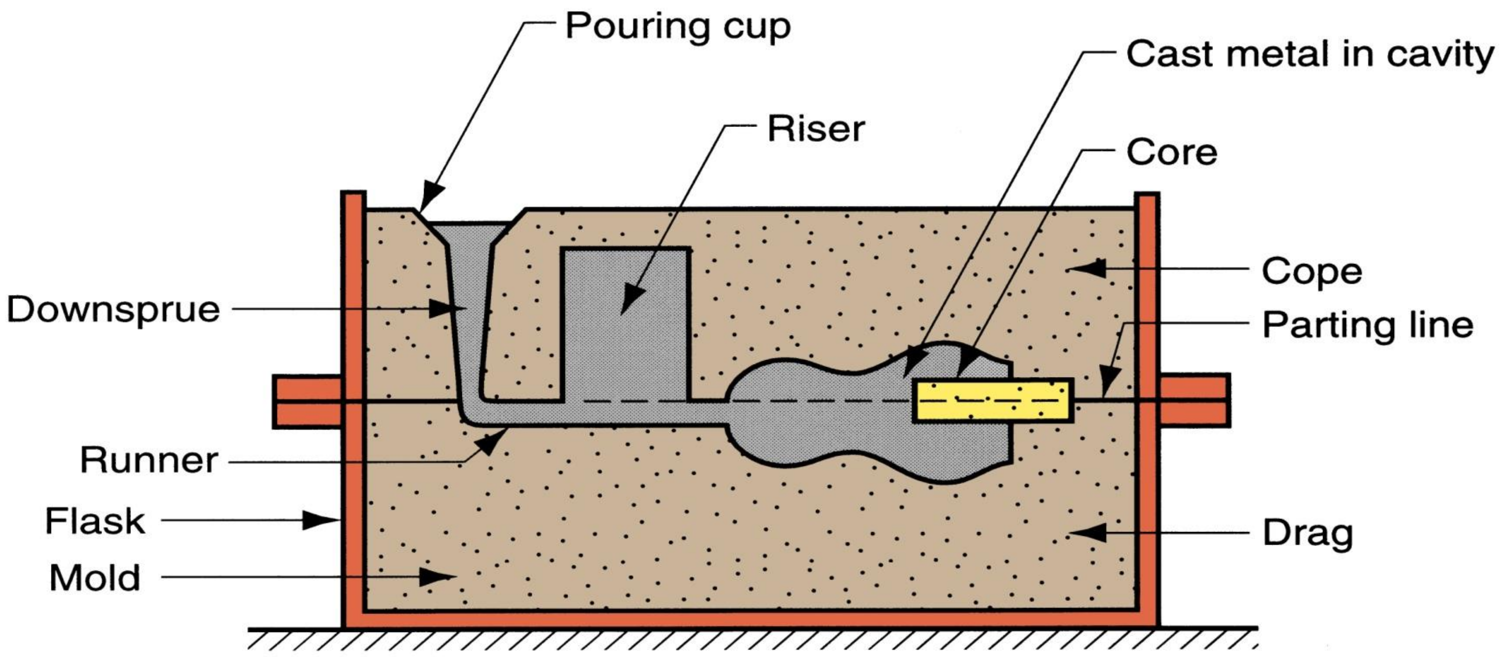
Casting nomenclature



(b)

The pouring cup, down sprue, runners, etc., are known as the *mold gating system*, which serves to deliver the molten metal to all sections of the mold cavity.

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Casting Terms

- Flask: A metal or wooden frame, without fixed top or bottom, in which the mold is formed. Depending upon the position of the flask in the molding structure, it is referred to by various names such as drag - lower molding flask, cope - upper molding flask, cheek - intermediate molding flask used in three piece molding.
- Pattern: It is the replica of the final object to be made. The mold cavity is made with the help of pattern.

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- **Parting line:** This is the dividing line between the two molding flasks that makes up the mold.
- **Molding sand:** Sand, which binds strongly without losing its permeability to air or gases. It is a mixture of silica sand, clay, and moisture in appropriate proportions.
- **Facing sand:** The small amount of carbonaceous material sprinkled on the inner surface of the mold cavity to give a better surface finish to the castings.

- Core: A separate part of the mold, made of sand and generally baked, which is used to create openings and various shaped cavities in the castings.
- Pouring basin: A small funnel shaped cavity at the top of the mold into which the molten metal is poured.
- Sprue: The passage through which the molten metal, from the pouring basin, reaches the mold cavity. In many cases it controls the flow of metal into the mold.
- Gate: A channel through which the molten metal enters the mold cavity.

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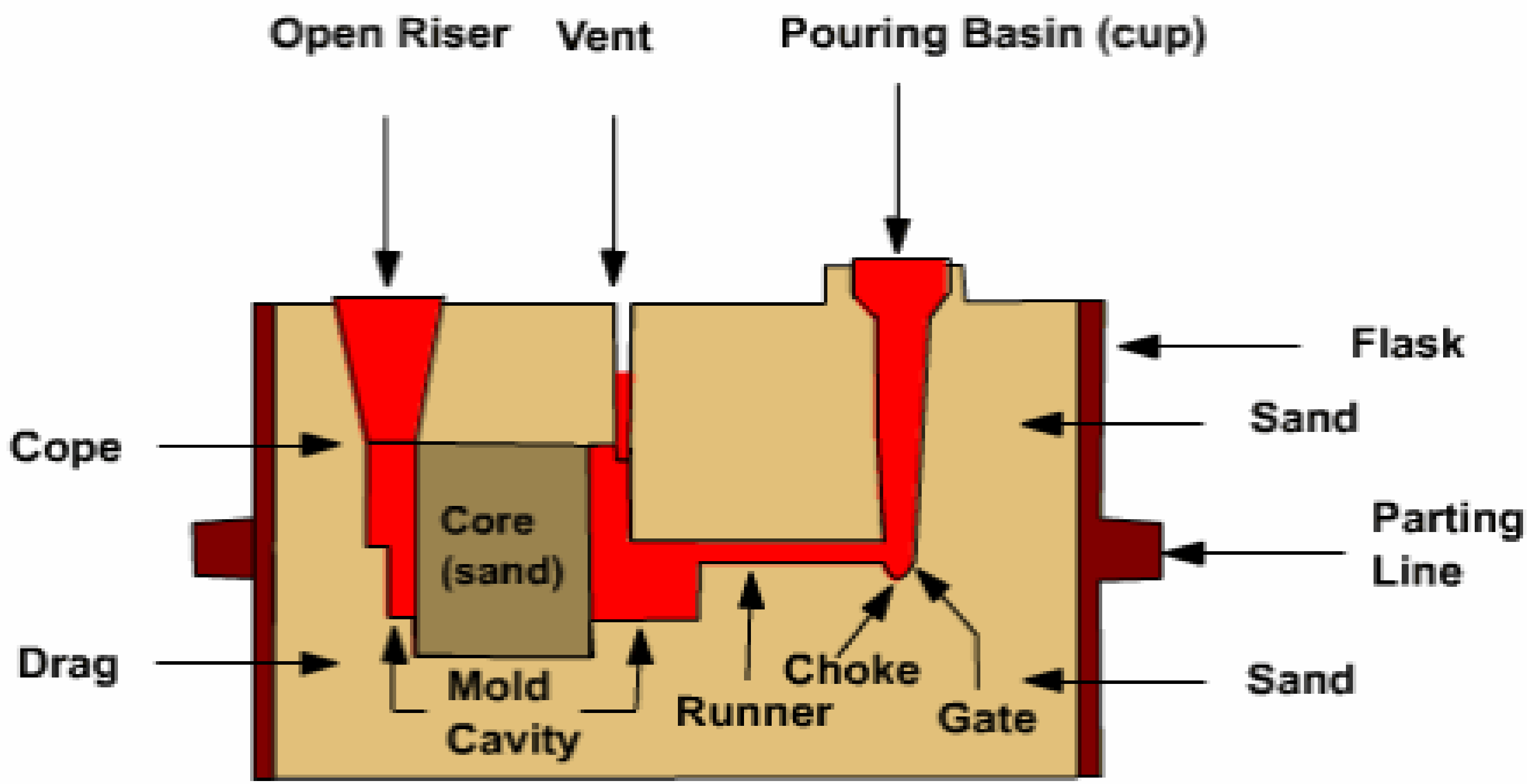
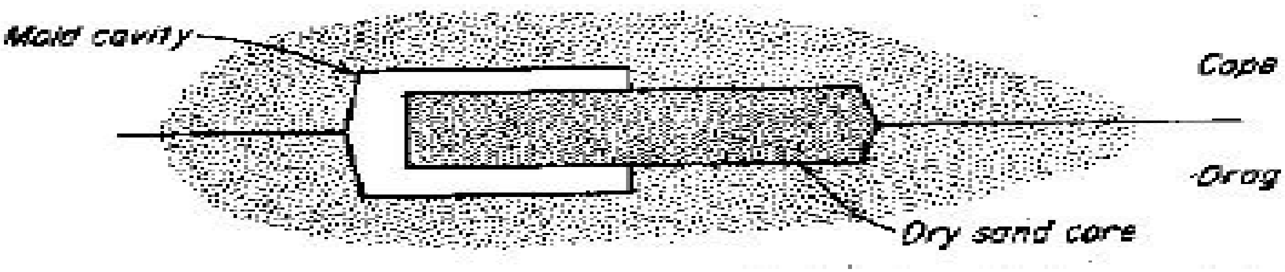
- Runner: The channel through which the molten metal is carried from the sprue to the gate.
- Chaplets: Chaplets are used to support the cores inside the mold cavity to take care of its own weight and overcome the metallostatic force.
- Riser: A column of molten metal placed in the mold to feed the castings as it shrinks and solidifies. Also known as "feed head".
- Vent: Small opening in the mold to facilitate escape of air and gases.

Mold Section showing some casting terms



Core and core print



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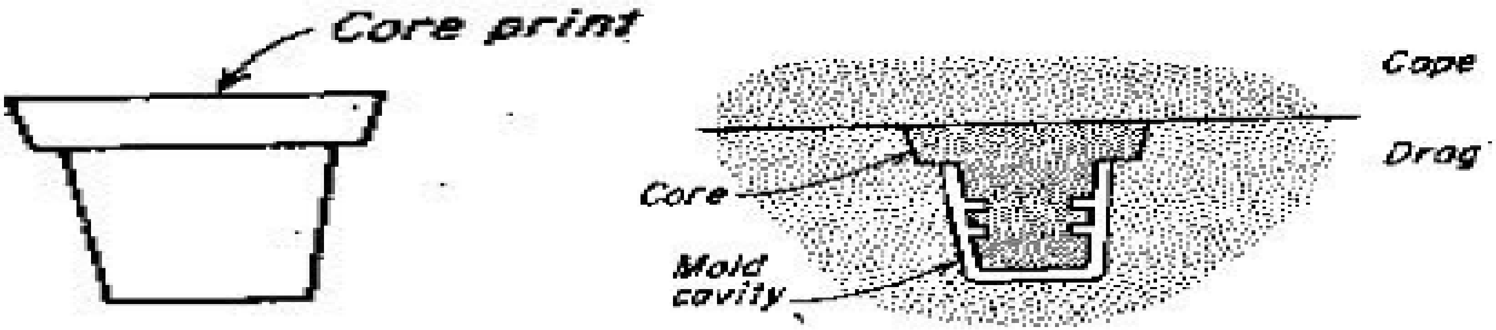
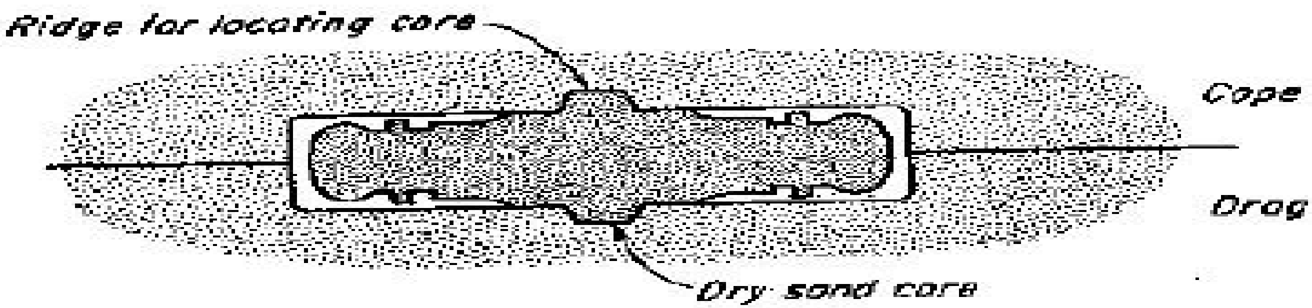
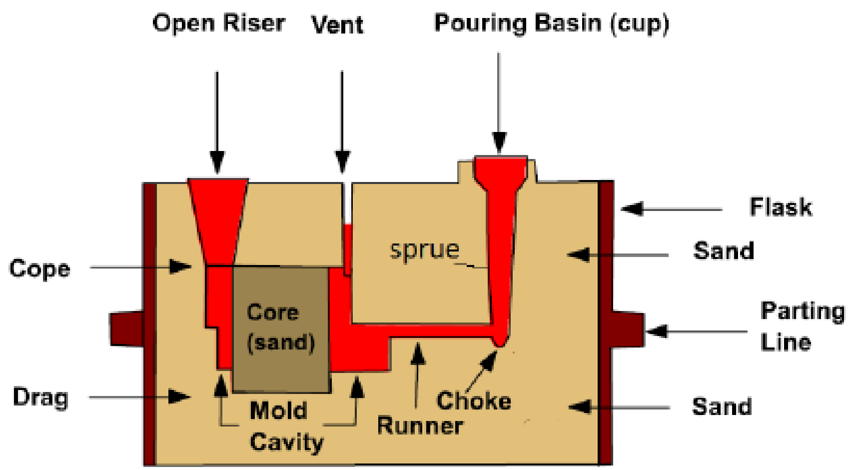
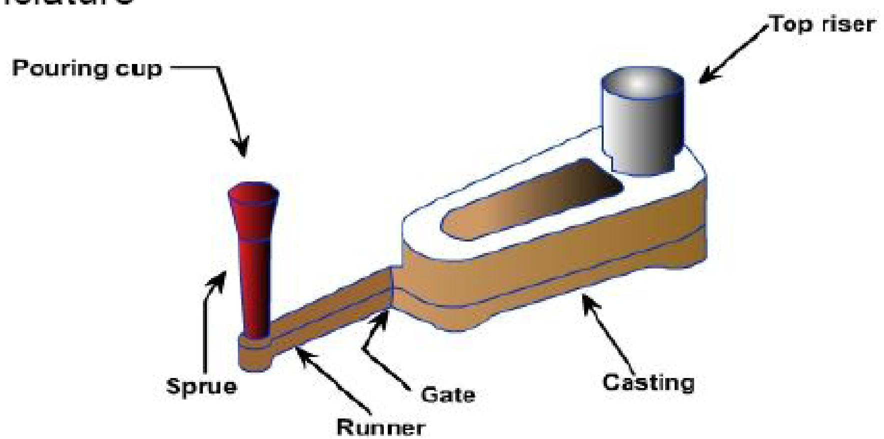




Typical sand mould



Mould Section and casting nomenclature



Pattern Types

- Solid or single piece pattern
- Split pattern
- Loose piece pattern
- Match plate pattern
- Sweep pattern
- Skeleton pattern
- Cope and drag pattern
- Shell pattern

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Solid or single piece pattern

- These types of patterns are made of single solid piece without joints
- It is made exactly into the desire casting shape to be produced with some allowance
- Removal of pattern from the sand is easy

single piece patterns

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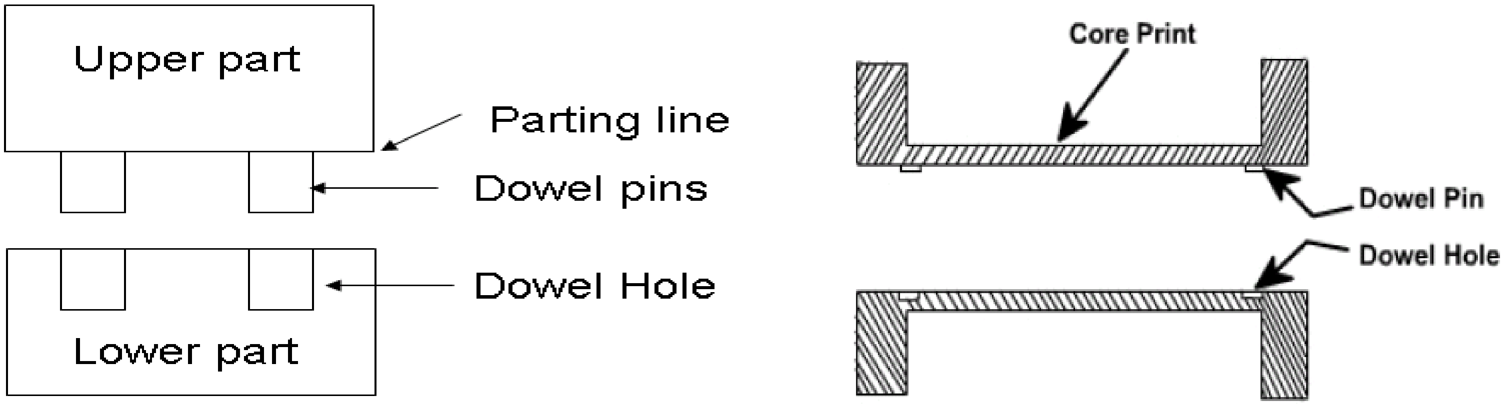
Split pattern

- These types of patterns are made up of two parts. One part is used to produce the lower half of the mould, where us the other part is used to produce the upper half of the mould
- The two parts are assembled together in correct position by pins called dowel pins. The line separating two parts is called parting line
- Split or two piece pattern is most widely used type of pattern for intricate castings



Split patterns

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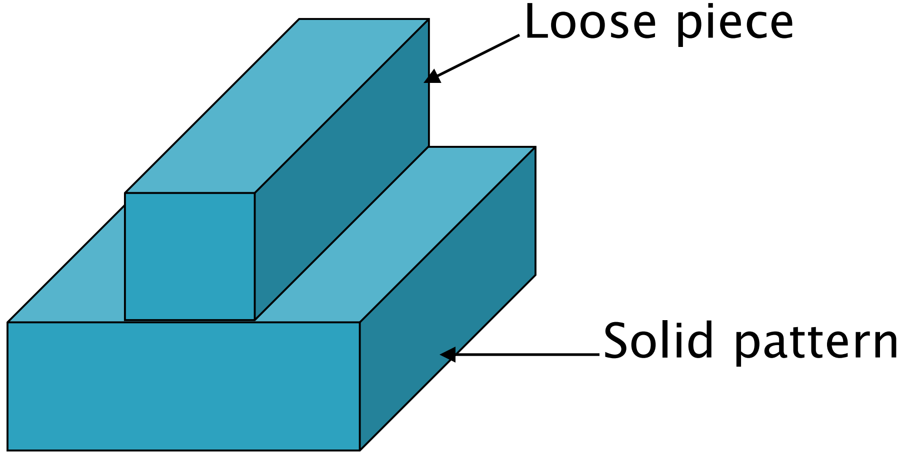
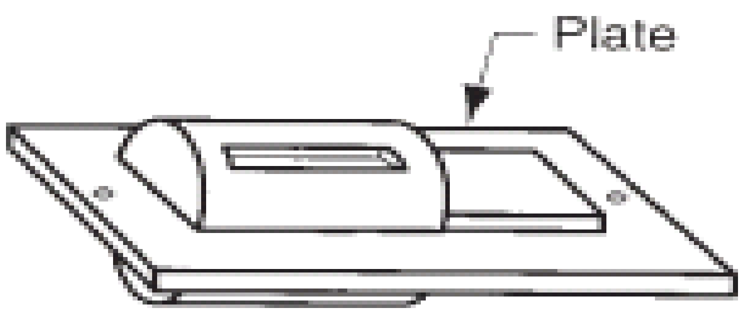
Loose piece pattern

- A pattern which has loose pieces above or below the solid pattern
- Loose patterns are attached to the main body of the pattern by pins



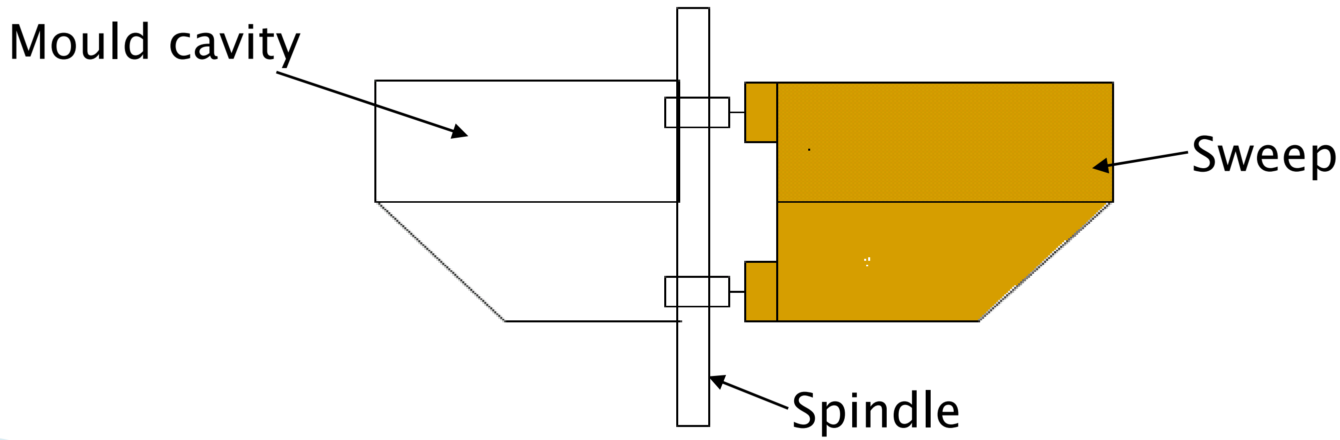
Match plate pattern

- A pattern is made into two halves mounted on both sides of the plate called match plate (wood or Al)
- Mainly used for machine components moulding



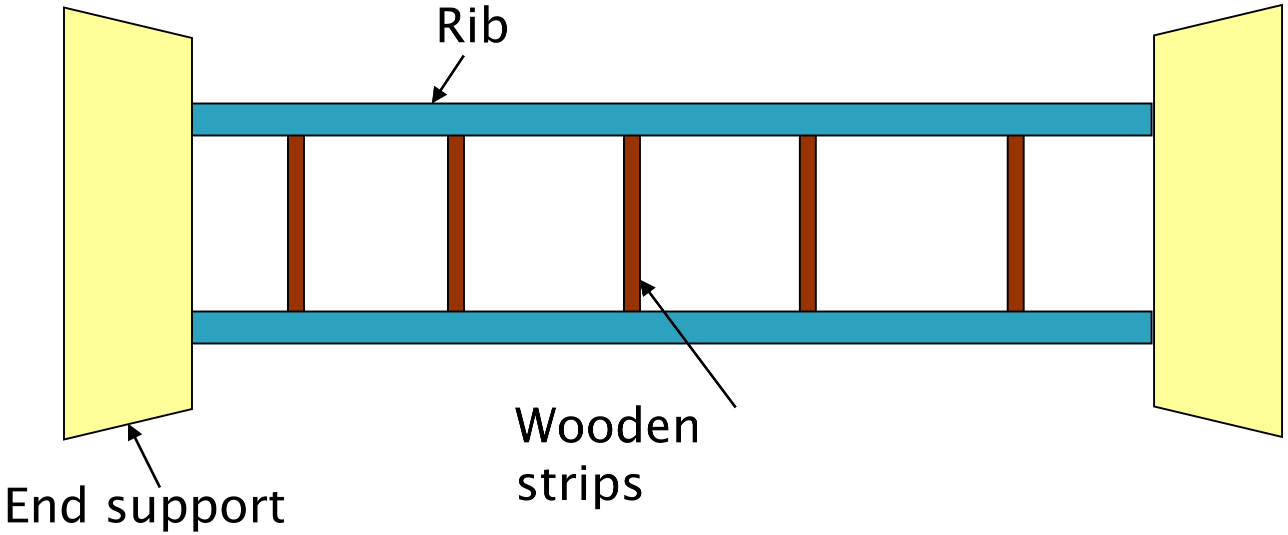
Sweep pattern

- A sweep is a section or board made of wood or metal to the required cross section that is rotated about one edge to shape mould cavities having shapes of rotational symmetry.
- Sweep patterns are mainly used to generate surface of revolution like cylinder, cone, sphere in large castings



Skeleton pattern

- A skeleton pattern in which large no of portioning is made using wooden strips.
- Mainly used to generate large size castings having simple shapes



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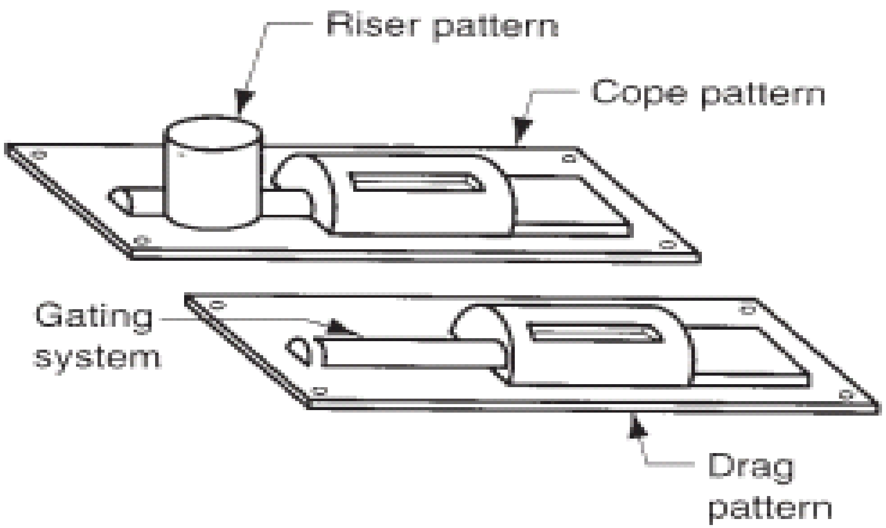
Cope and drag pattern

- A split pattern which has cope, riser and gating arrangement.
- Mainly used for producing complex shapes



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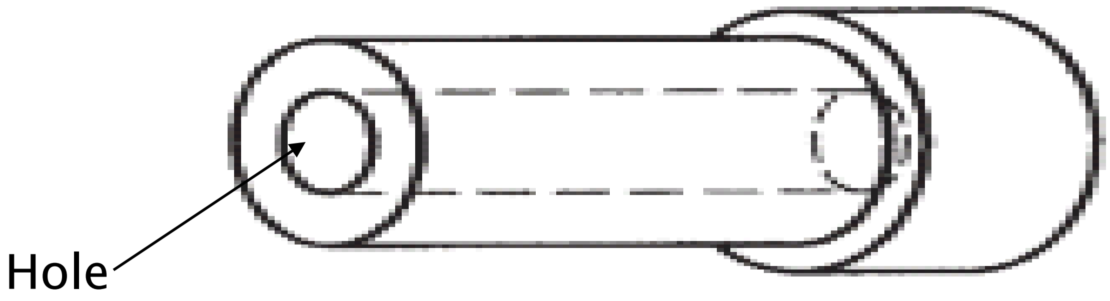
Shell pattern

- A pattern which has Hollow hole in it. only the outer shape is used for making the mould
- The core is prepared inner surface of the pattern itself



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Pattern Material

- Patterns may be constructed from the following materials. Each material has its own advantages, limitations, and field of application. Some materials used for making patterns are: wood, metals and alloys, plastic, plaster of Paris, plastic and rubbers, wax, and resins.

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To be suitable for use, the pattern material should be:

- Easily worked, shaped and joined
- Light in weight
- Strong, hard and durable
- Resistant to wear and abrasion
- Resistant to corrosion, and to chemical reactions
- Dimensionally stable and unaffected by variations in temperature and humidity
- Available at low cost

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Pattern Allowances

- Shrinkage allowance
- Machining or finishing allowance
- Draft or Taper allowance
- Distortion or Camber allowance
- Rapping or shake allowance

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Shrinkage Allowance

- Almost all cast metals shrink or contract volumetrically on cooling. The metal shrinkage is of two types:
- **Liquid Shrinkage**: it refers to the reduction in volume when the metal changes from liquid state to solid state at the solidus temperature. To account for this shrinkage; riser, which feed the liquid metal to the casting, are provided in the mold.
- **Solid Shrinkage:** it refers to the reduction in volume caused when metal loses temperature in solid state. To account for this, shrinkage allowance is provided on the patterns.

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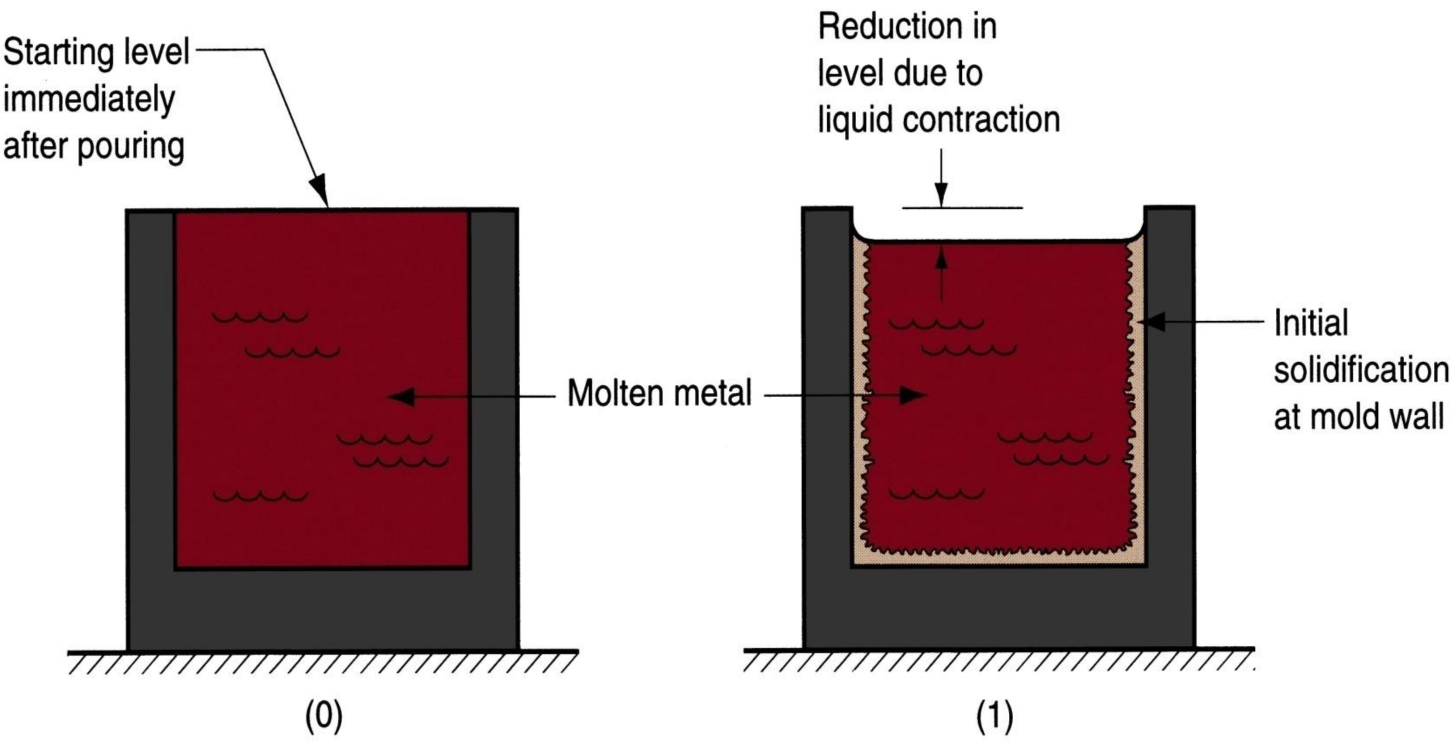
Shrinkage Allowance

- **Liquid Shrinkage**:



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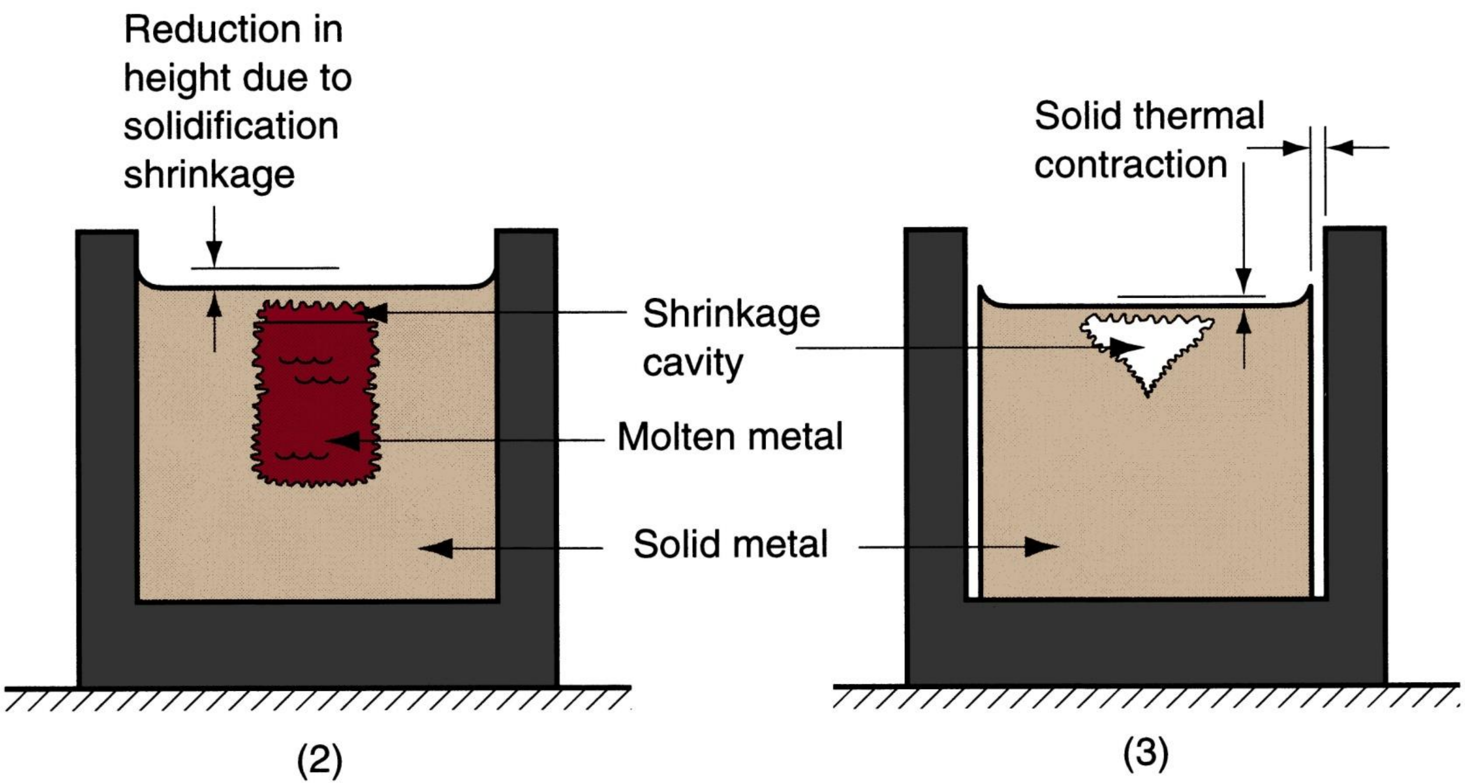
Shrinkage Allowance

- **Solid Shrinkage**:



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Shrinkage Allowance Various Metals

Material	Dimension	Shrinkage allowance (inch/ft)
Grey Cast Iron	Up to 2 feet 2 feet to 4 feet over 4 feet	0.125 0.105 0.083
Cast Steel	Up to 2 feet 2 feet to 6 feet over 6 feet	0.251 0.191 0.155
Aluminum	Up to 4 feet 4 feet to 6 feet over 6 feet	0.155 0.143 0.125
Magnesium	Up to 4 feet Over 4 feet	0.173 0.155

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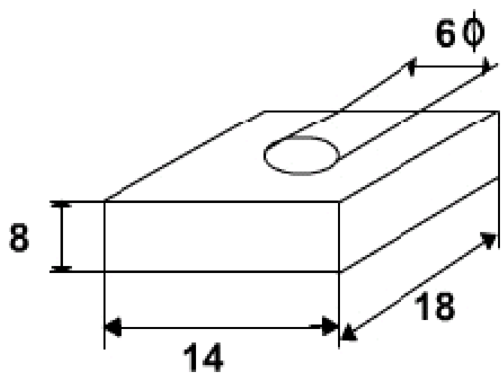
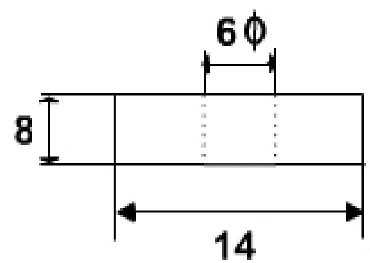
Exercise

- The casting shown is to be made in cast iron using a wooden pattern. Assuming only shrinkage allowance, calculate the dimension of the pattern. All Dimensions are in Inches

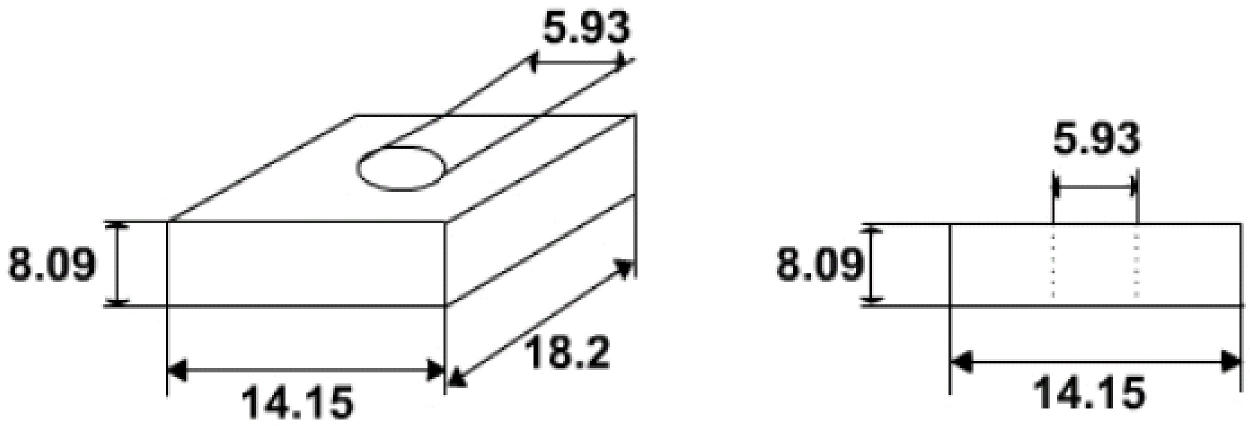




Solution

- The shrinkage allowance for cast iron for size up to 2 feet is o.125 inch per feet (as per Table)
- For dimension 18 inch, allowance = 18 *X* 0.125 / 12 = 0.1875 inch » 0.2 inch
- For dimension 14 inch, allowance = 14 *X* 0.125 / 12 = 0.146 inch » 0.15 inch
- For dimension 8 inch, allowance = 8 X 0.125 / 12 = 0.0833 inch » 0. 09 inch
- For dimension 6 inch, allowance = 6 X 0.125 / 12 = 0.0625 inch » 0. 07

The pattern drawing with required dimension is shown below:



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Machining or Finish Allowance

- The finish and accuracy achieved in sand casting are generally poor and therefore when the casting is functionally required to be of good surface finish or dimensionally accurate, it is generally achieved by subsequent machining. Machining or finish allowances are therefore added in the pattern dimension. The amount of machining allowance to be provided is affected by the method of molding and casting

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Machining or Finish Allowance

- The amount of machining allowance is also affected by the size and shape of the casting; the casting orientation; the metal; and the degree of accuracy and finish required.

Machining Allowances of Various Metals

Metal	Dimension (inch)	Allowance (inch)
Cast iron	Up to 12	0.12
	12 to 20	0.20
	20 to 40	0.25
Cast steel	Up to 6	0.12
	6 to 20	0.25
	20 to 40	0.30
Non ferrous	Up to 8	0.09
	8 to 12	0.12
	12 to 40	0.16

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Draft or Taper Allowance

- By draft is meant the taper provided by the pattern maker on all vertical surfaces of the pattern so that it can be removed from the sand without tearing away the sides of the sand mold and without excessive rapping by the molder

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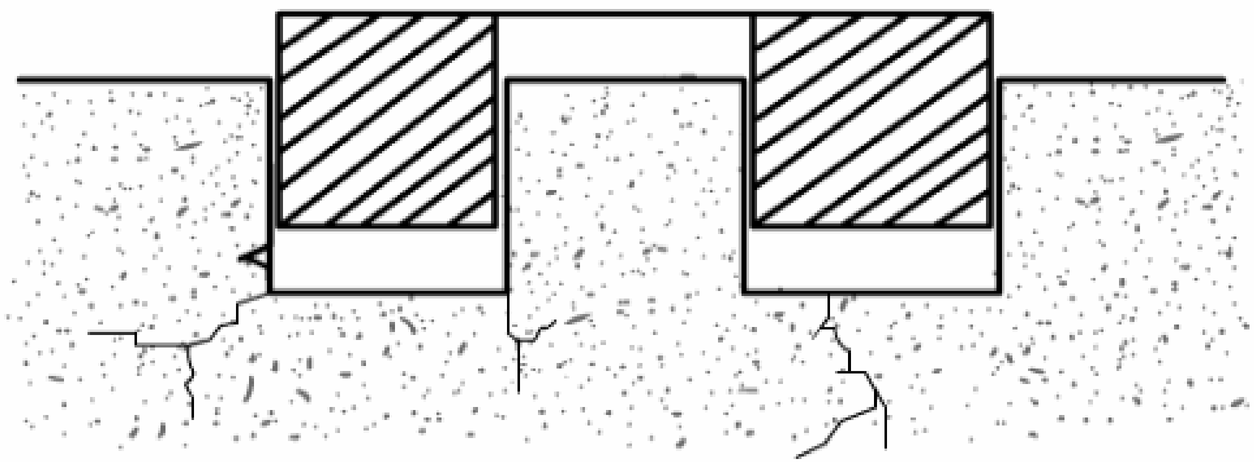
- Figure shows a pattern having no draft allowance being removed from the pattern. In this case, till the pattern is completely lifted out, its sides will remain in contact with the walls of the mold, thus tending to break it.



Pattern Having No Draft on Vertical Edges

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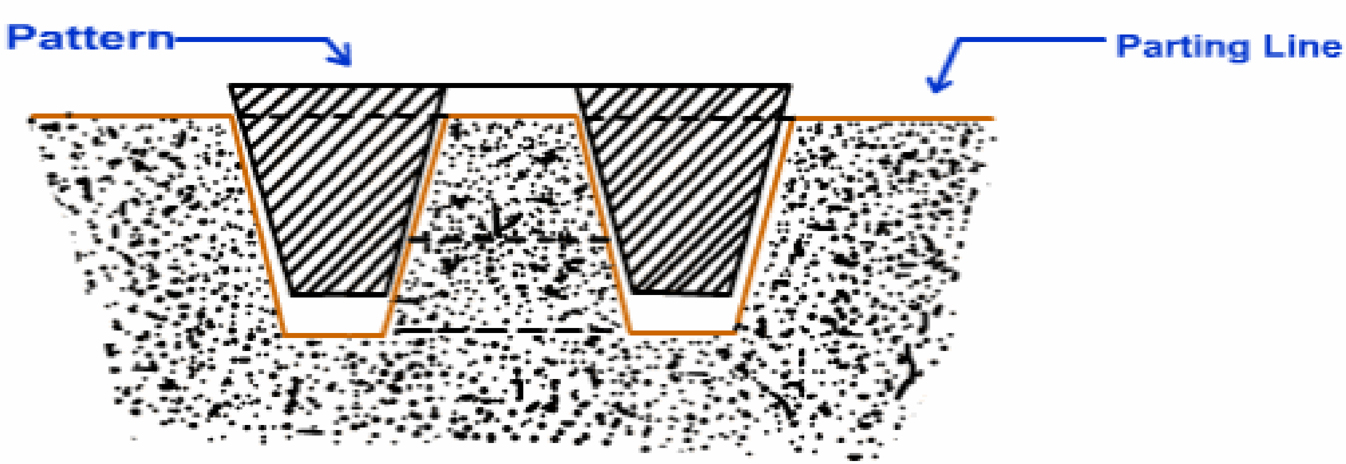
- The given figure is an illustration of a pattern having proper draft allowance. Here, the moment the pattern lifting commences, all of its surfaces are well away from the sand surface. Thus the pattern can be removed without damaging the mold cavity.



Pattern Having Draft on Vertical Edges

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Draft Allowances of Various Metals

Pattern material	Height of the given surface (inch)	Draft angle (External surface)	Draft angle (Internal surface)
Wood	1	3.00	3.00
	1 to 2	1.50	2.50
	2 to 4	1.00	1.50
	4 to 8	0.75	1.00
	8 to 32	0.50	1.00
Metal and plastic	1	1.50	3.00
	1 to 2	1.00	2.00
	2 to 4	0.75	1.00
	4 to 8	0.50	1.00
	8 to 32	0.50	0.75

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Distortion or Camber Allowance

- Sometimes castings get distorted, during solidification, due to their typical shape. For example, if the casting has the form of the letter U, V, T, or L etc. it will tend to contract at the closed end causing the vertical legs to look slightly inclined.
- This can be prevented by making the legs of the U, V, T, or L shaped pattern converge slightly (inward) so that the casting after distortion will have its sides vertical

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- The distortion in casting may occur due to internal stresses. These internal stresses are caused on account of unequal cooling of different section o f the casting and hindered contraction.

Measure taken to prevent the distortion in casting include:

- Modification of casting design
- Providing sufficient machining allowance to cover the distortion affect
- Providing suitable allowance on the pattern, called camber or distortion allowance (inverse reflection)

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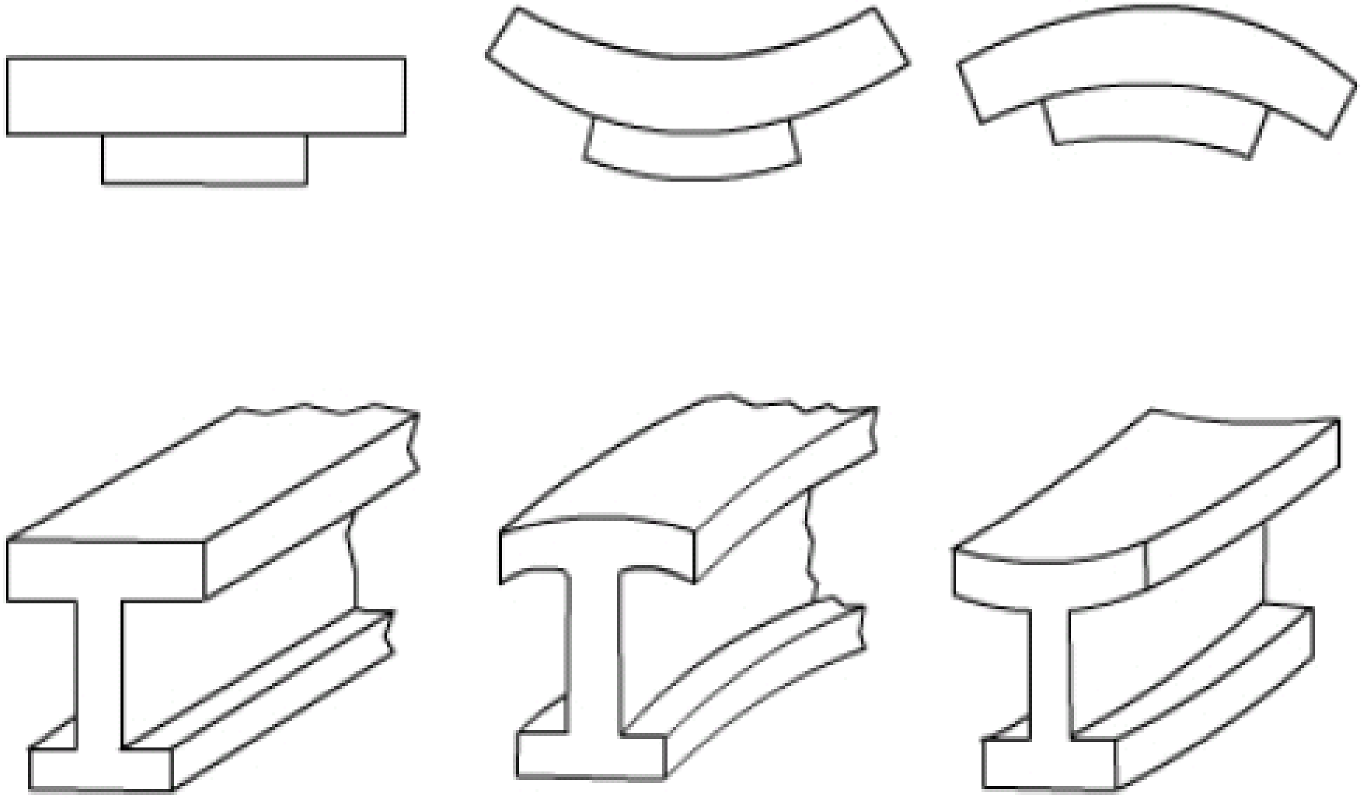
Distortions in Casting



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Rapping or shake allowance

- Before the withdrawal from the sand mold, the pattern is rapped all around the vertical faces to enlarge the mold cavity slightly, which facilitate its removal. Since it enlarges the final casting made, it is desirable that the original pattern dimension should be reduced to account for this increase.
- There is no sure way of quantifying this allowance, since it is highly dependent on the foundry personnel practice involved. It is a negative allowance and is to be applied only to those dimensions that are parallel to the parting plane.

Core and Core Prints

- Castings are often required to have holes, recesses, etc. of various sizes and shapes. These impressions can be obtained by using cores. So where coring is required, provision should be made to support the core inside the mold cavity. Core prints are used to serve this purpose.
- The core print is an added projection on the pattern and it forms a seat in the mold on which the sand core rests during pouring of the mold.
- The core print must be of adequate size and shape so that it can support the weight of the core during the casting operation.
- Depending upon the requirement, a core can be placed horizontal, vertical and can be hanged inside the mold cavity.

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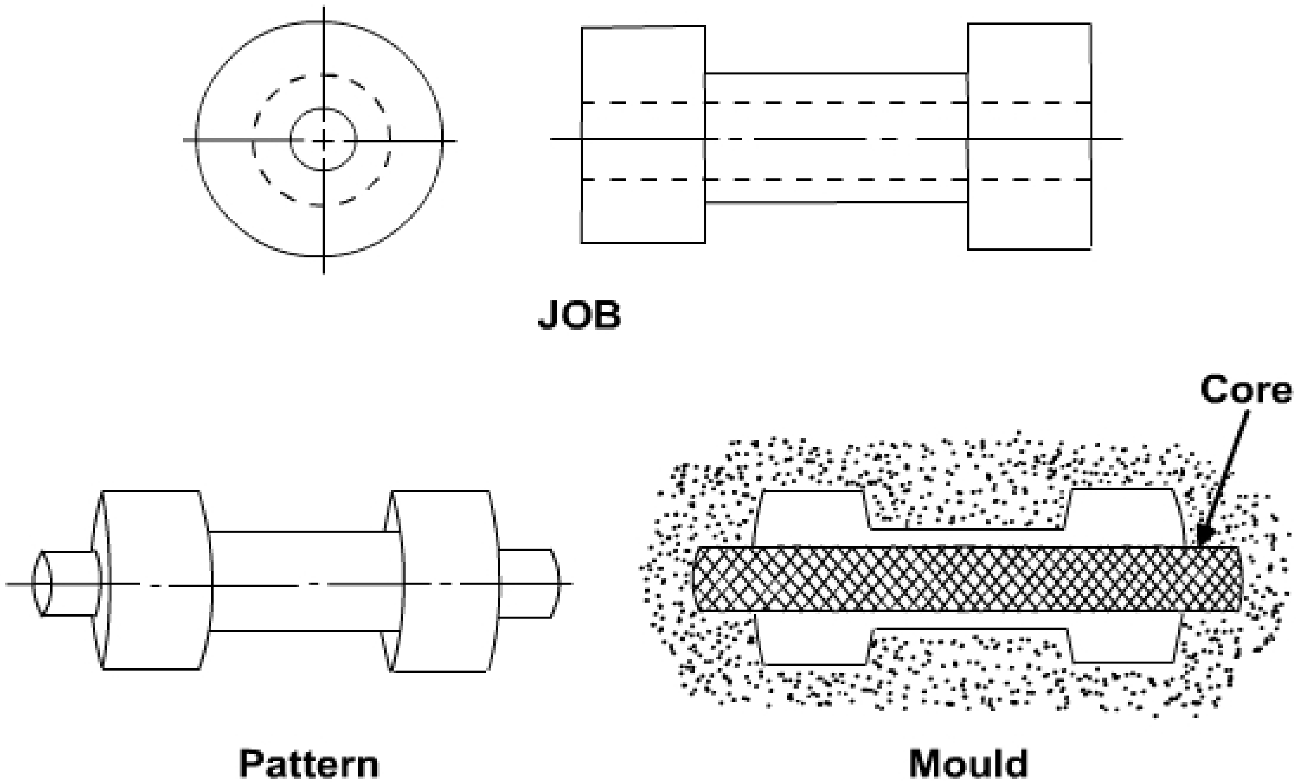
Core and Core Prints



A job & its pattern and the mold cavity with core and core print is shown in Figure

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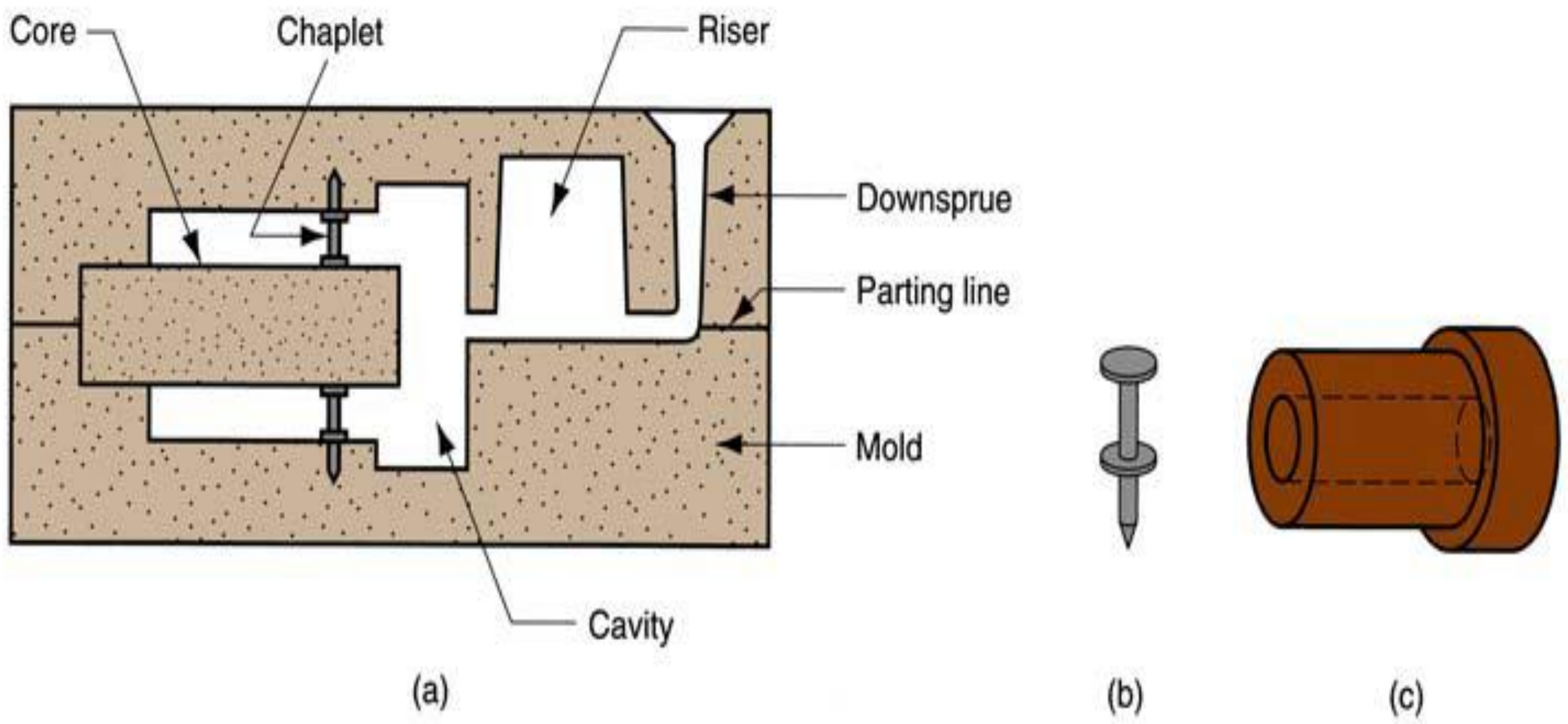
Core and Core Prints



A job & its pattern and the mold cavity with core and core print is shown in Figure

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Moulding

- Moulding is the process of making a mould cavity by packing prepared moulding sand around the pattern and removing the pattern from the mould to form the mould cavity.

Types

- Green sand moulding
- Dry sand moulding
- Loam moulding

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Moulding Sand

- Special type of sand used for making mould is called moulding sand

Constituents of moulding sand

- Sand
- Binder
- Additive

Types of Moulding sand

- Green sand
- Dry sand
- Facing sand
- Loam sand
- Backing sand
- Parting sand

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Green sand

- 8% water, 16 to 30% clay, soft, light and porous ,High damping capacity

Dry sand

- Dry in nature, High strength and rigidity

Facing sand

- Mixture of silica and dry sand
- Normally used to cover the surface of the pattern (fine finish)

Loam sand

- Fine silica, fine refractories, clay, graphite, fiber and water
- It becomes very hard when it is dried

Backing sand

- Old sand, can be used repeatedly

Parting sand

- Mixture Silica and brick powder, used to avoid the sticking of patterns while removing (split pattern)

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Binder

- Organic binder – cereal, resins, drying oils, molasses etc.
- Inorganic binder – clay (fire clay, bentonite, kaolinite)

Additives

- Sea coal, sawdust, pitch, cereals, silica flour, fuel oil

Properties of moulding sand

- Porosity or permeability
- Plasticity or flowability
- Adhesiveness
- Strength or cohesiveness
- Refractoriness
- collapsibility

Manufacturing Technology

Gating and Risering

- GATE -A channel through which the molten metal enters the mold cavity.

The goals for the gating system are;

- To minimize turbulence to avoid trapping gases and breaking up the sand mold.
- To get enough metal into the mold cavity before the metal starts to solidify.
- To avoid shrinkage

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Gating and Risering

- Riser -A column of molten metal placed in the mold to feed the castings as it shrinks and solidifies. Also known as "feed head".

The Purpose of Riser system is;

- To provide that extra molten metal. Basically a riser is a vertical portion of the gating system, similar to a straight sprue, that stores the molten metal until it is needed by the casting. This means the metal in the riser must stay liquid longer than the metal in the part being cast. .
- To avoid shrinkage

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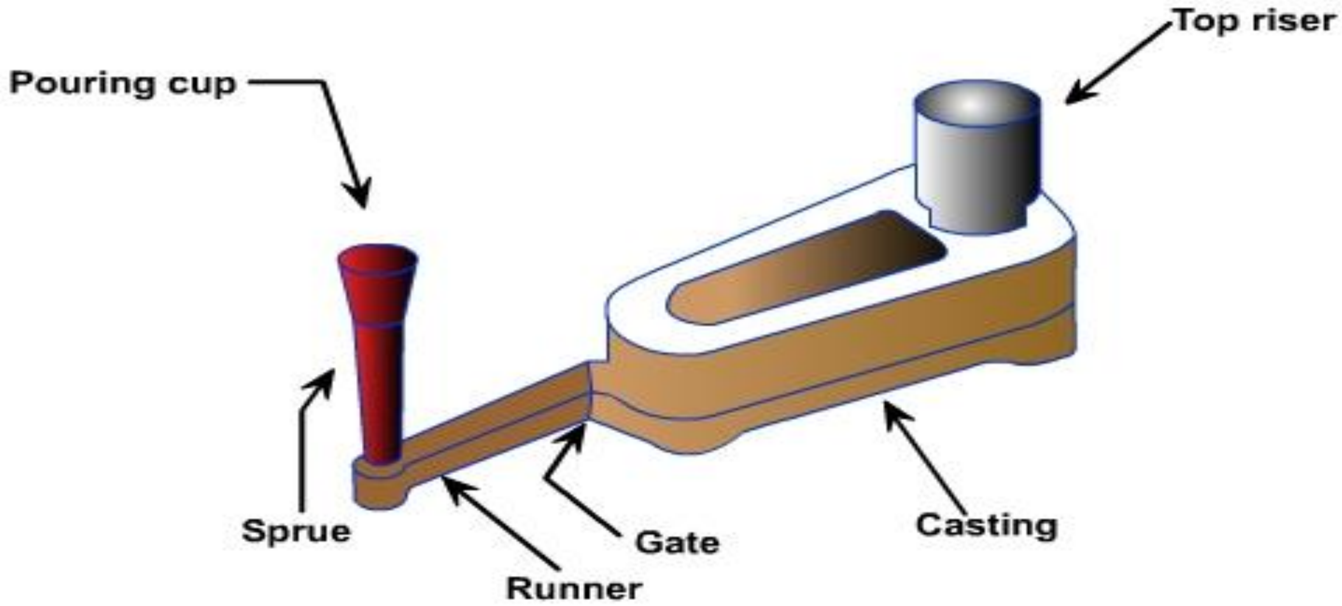
Gating and Risering



A typical pattern attached with gating and Risering system

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Cores & Core Making

- Core: A separate part of the mold, made of sand and generally baked, which is used to create openings and various shaped cavities in the castings.
- Core Making: The process of making cores using core sand, binder and additives with the help of core boxes.

Types of Cores

- Horizontal core – supported Horizontally in the mould
- Vertical core - supported Vertically in the mould
- Balancing core – supported at the ends of the mould
- Hanging core – supported at the top and hung into the mould
- Drop core – supported top or bottom of the parting line

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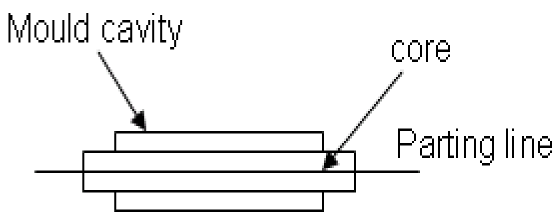
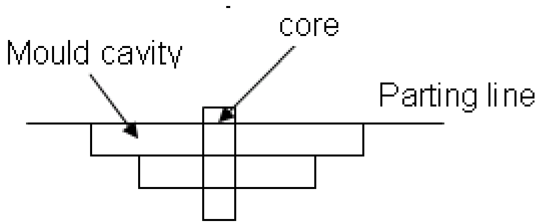
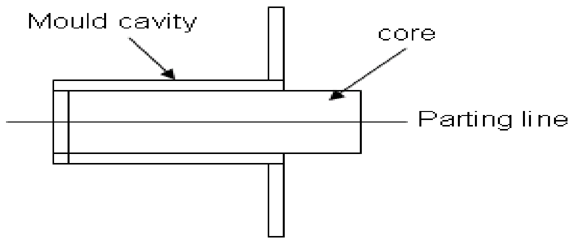


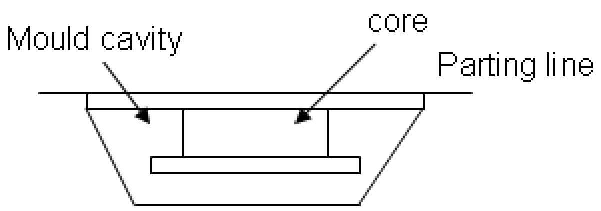
Horizontal core



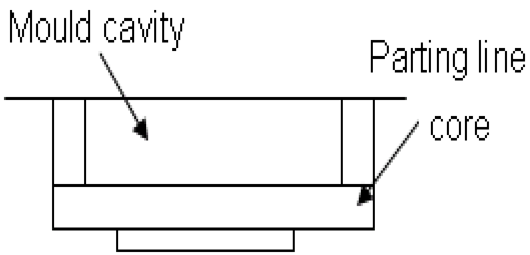
Vertical core



Balancing core



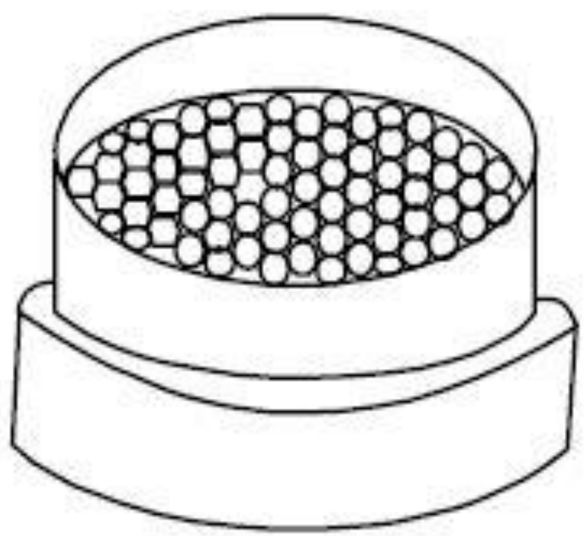
Hanging core



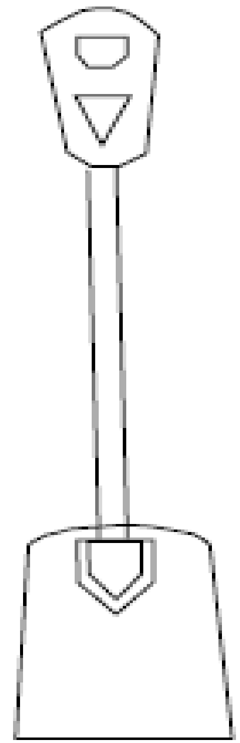
Drop core

Foundry Tools

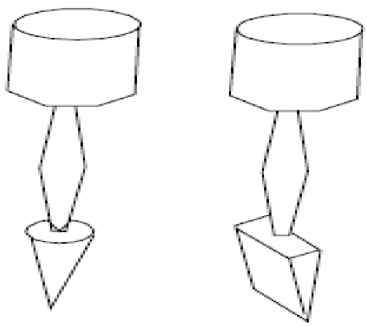
- Hand Riddle
  - Consist of standard circular wire mesh equipped with circular wooden frame.
  - Generally used for cleaning the sand for removing foreign material such as nails, shot metal, splinters of wood etc. from it

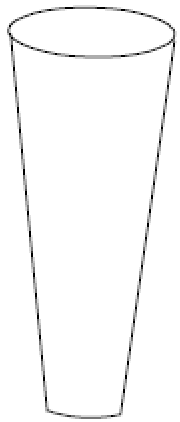


- Shovel
  - It consists of an steel pan fitted with a long wooden handle.
  - It is used in mixing, tempering and conditioning the foundry sand by hand



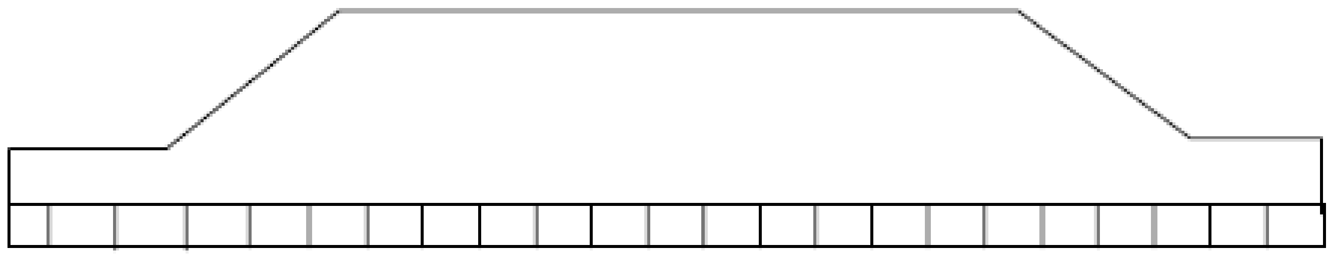
- Rammers
  - These are required for striking the moulding sand mass in the moulding box to pack or compact it uniformly all around the pattern



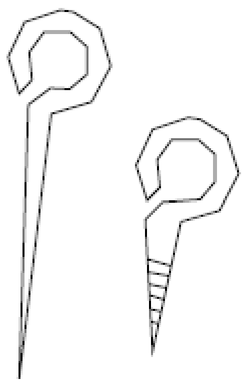


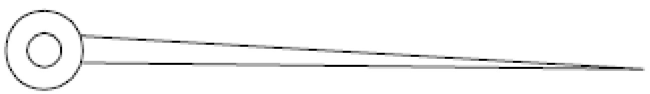
- Sprue Pin
  - It is a tapered rod of wood or iron which is placed or pushed in cope to join mould cavity while the moulding sand in the cope is being rammed

- Strike Off Bar
  - It is used to strike off or remove the excess sand from the top of a moulding box after completion of ramming thereby making its surface plane and smooth.
- Mallet
  - Mallet is similar to a wooden hammer and it is used for driving the draw spike into the pattern and then rapping it for separation from the mould surfaces.



- Draw Spike
  - It is a tapered steel rod having a loop or ring at its one end and a sharp point at the other.
  - It may have screw threads on the end to engage metal pattern for it withdrawal from the mould.





- Vent Rod
  - After ramming and striking off the excess sand it is utilized to pierce series of small holes in the moulding sand in the cope portion

- Lifters
  - They are also known as cleaners or finishing tool which are made of thin sections of steel of various length and width with one end bent at right angle.

Fig. 11.1 (h)

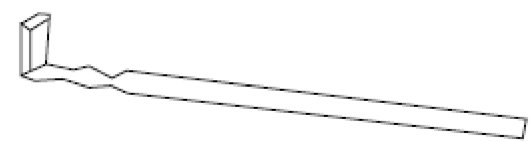


Fig. 11.1 (j)

- Trowel
  - Utilized for finishing flat surfaces and joints and partings lines of the mould.
- Slicks
  - Generally used for repairing and finishing the mould surfaces and their edges after withdrawal of the pattern

Fig. 11.1 (l)

Fig. 11.1 (m)

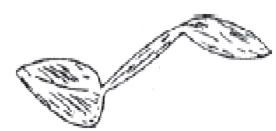


Fig. 11.1 (o)

Fig. 11.1 (p)

Fig. 11.1 (n)

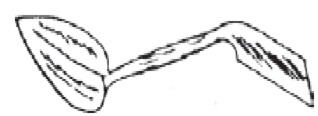


Fig. 11.1 (q)

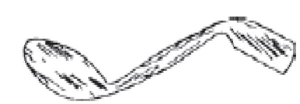
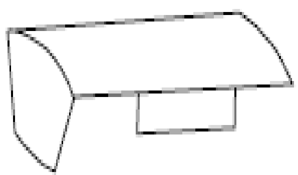
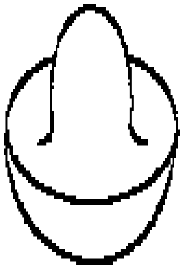
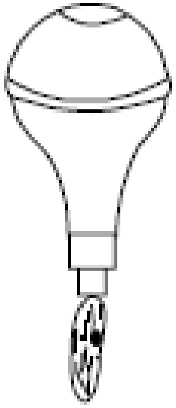


Fig. 11.1 (r)

- Smoothers
  - Finishing tools which are commonly used for repairing and finishing flat and round Surfaces, round or square corners and edges of moulds
- Swab
  - It is a small hemp fibre brush used for moistening the edges of sand mould, which are in contact with the pattern surface before withdrawing the pattern



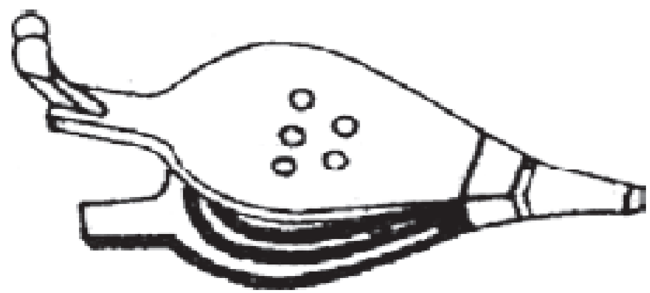




- Spirit Level
  - Spirit level is used by moulder to check whether the sand bed or moulding box is horizontal or not.
- Gate Cutter
  - It is a small shaped piece of sheet metal commonly used to cut runners and feeding gates for connecting Sprue hole with the mould cavity.

- Gaggers
  - Gaggers are pieces of wires or rods bent at one or both ends which are used for reinforcing the downward projecting sand mass in the cope
- Spray Gun
  - Spray gun is mainly used to spray coating of facing materials etc. on a mould or core surface
- Nail and Wire Pieces
  - They are basically used to reinforce thin projections of sand in the mould or cores.
- Wire Piece, Spring and Nails
  - It is used to fasten cores in moulds and reinforce sand in front of an in-gate.

- Bellows
  - It is hand operated leather made device equipped with compressed air jet to blow or pump air when operated.
  - It is used to blow away the loose or unwanted sand from the surfaces of mould cavities.



- Clamps, Wedge and Cotters
  - They are made of steel and are used for clamping the moulding boxes firmly together during pouring.

Moisture Content Test

- Moisture Content Test $= \frac{W_1 - W_2}{W_1} \times 100\%$

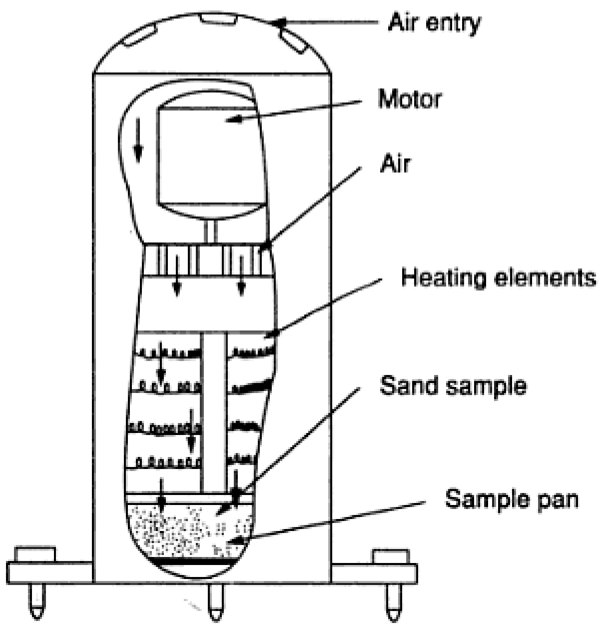


Fig 1.42 Sand moisture drying device.

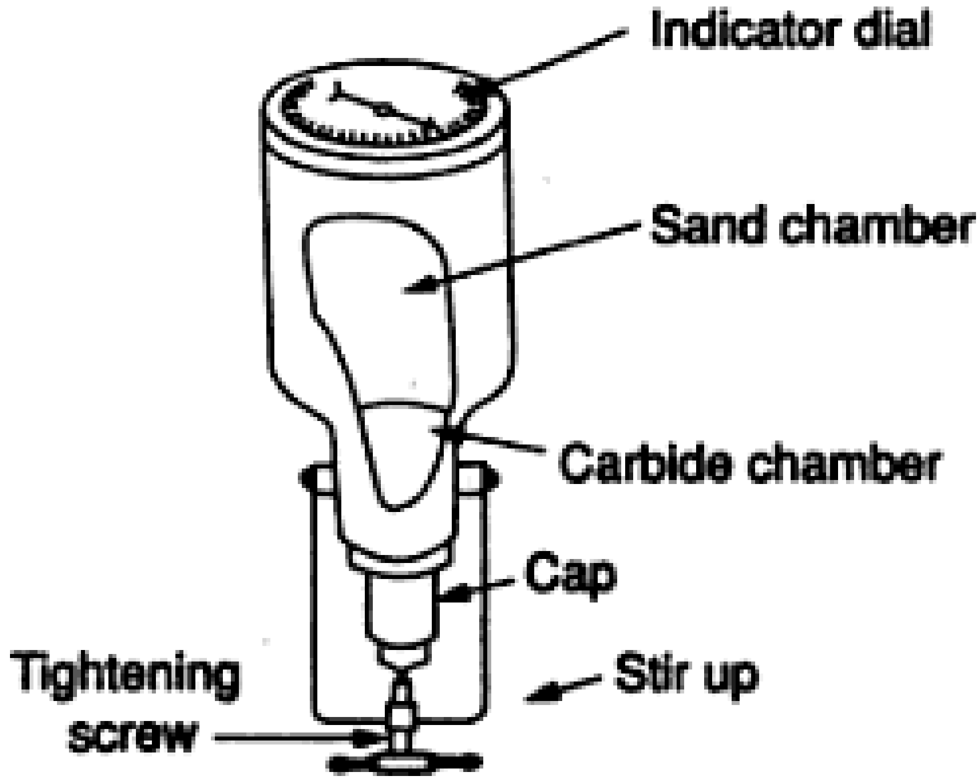


Fig 1.43 Moisture teller.

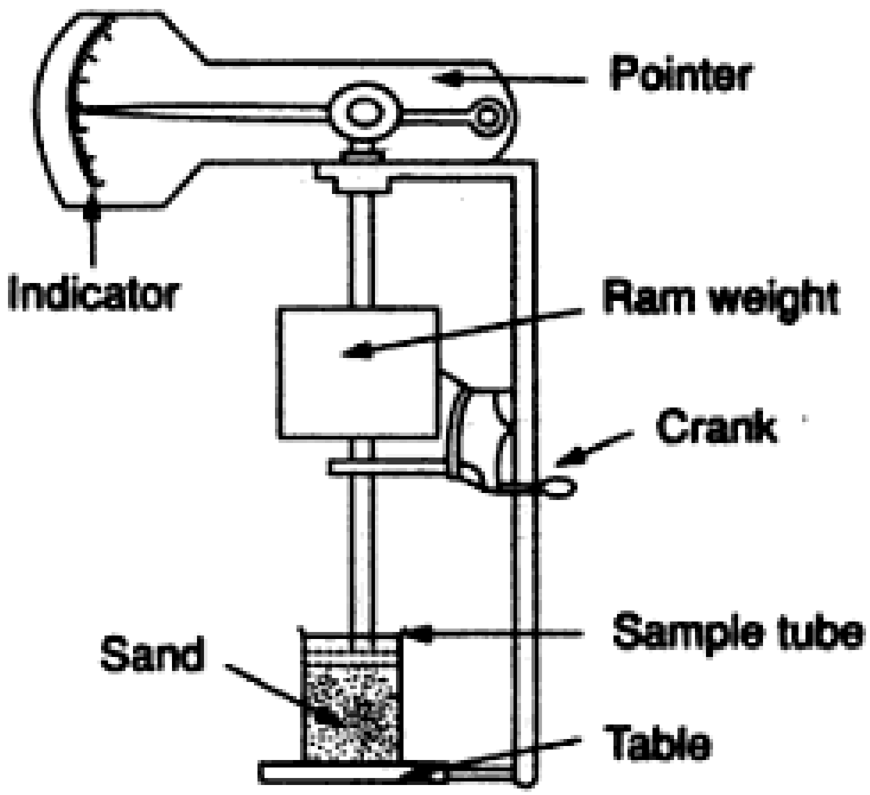
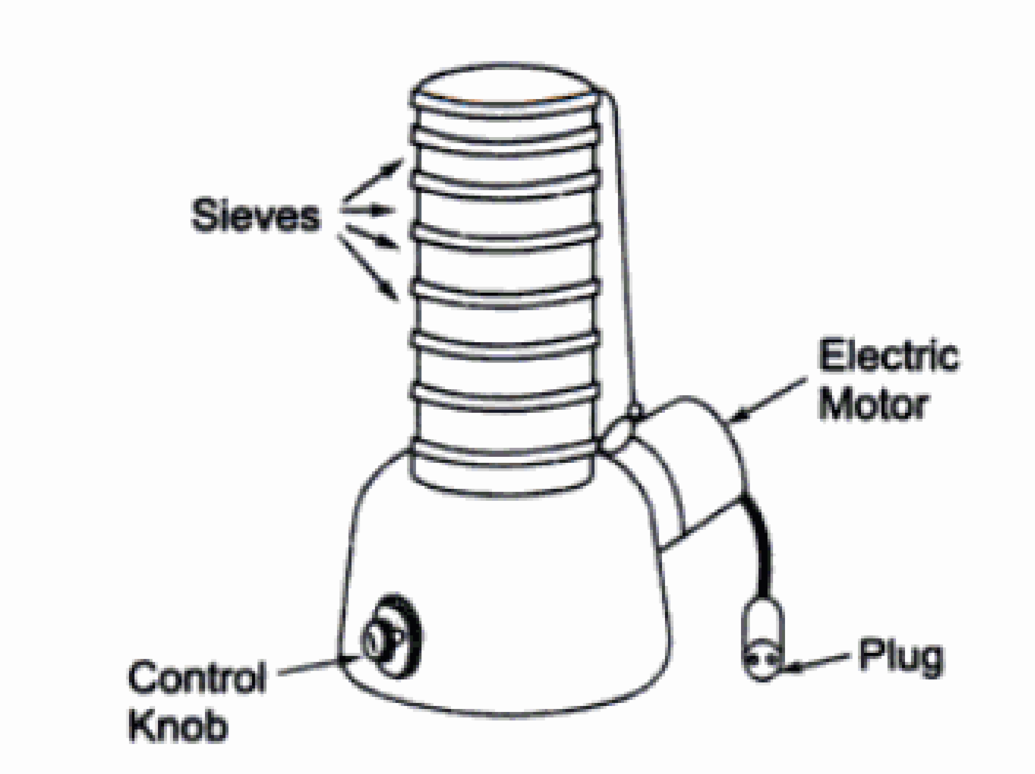
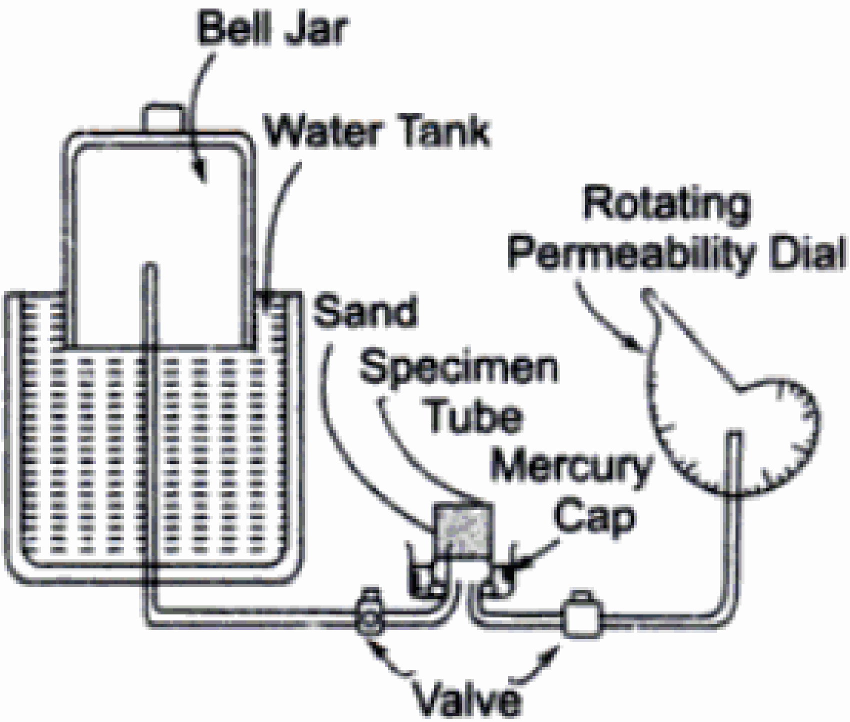


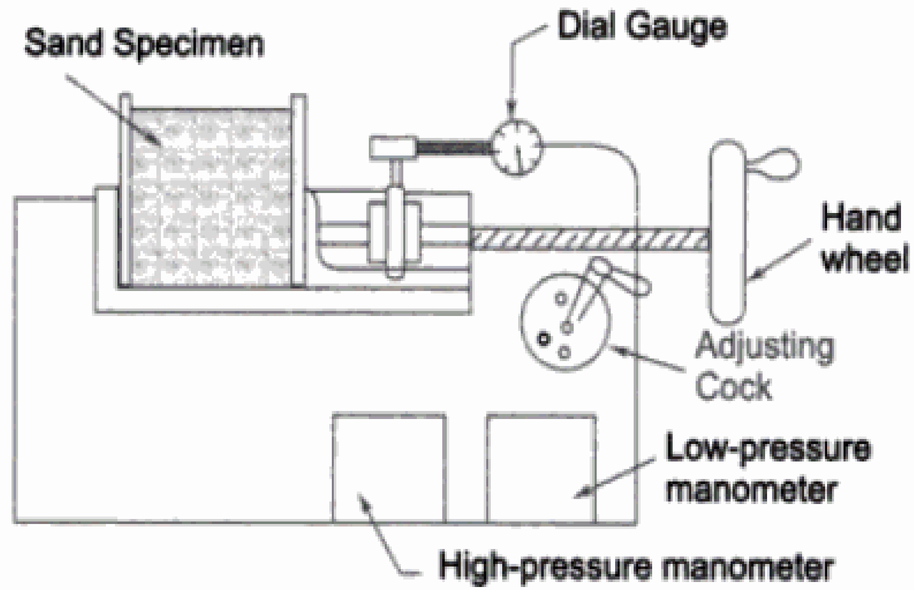
Fig 1.44 Direct reading moisture indicator.

Grain Fineness Test

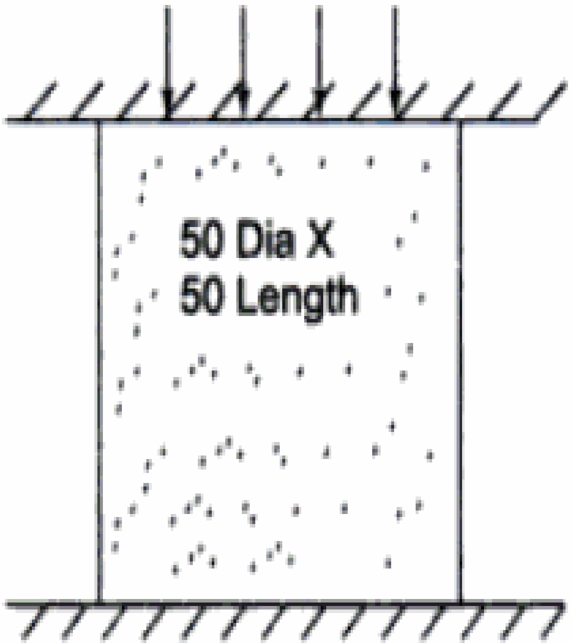


Permeability Test





(a)



. 2.22 *Specimen for compressive test*

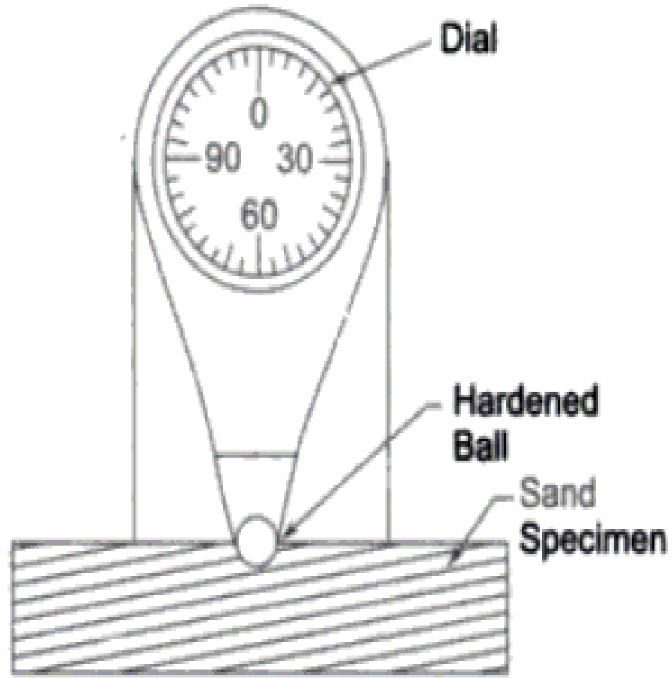


Fig. 2.23 *Hardness tester*

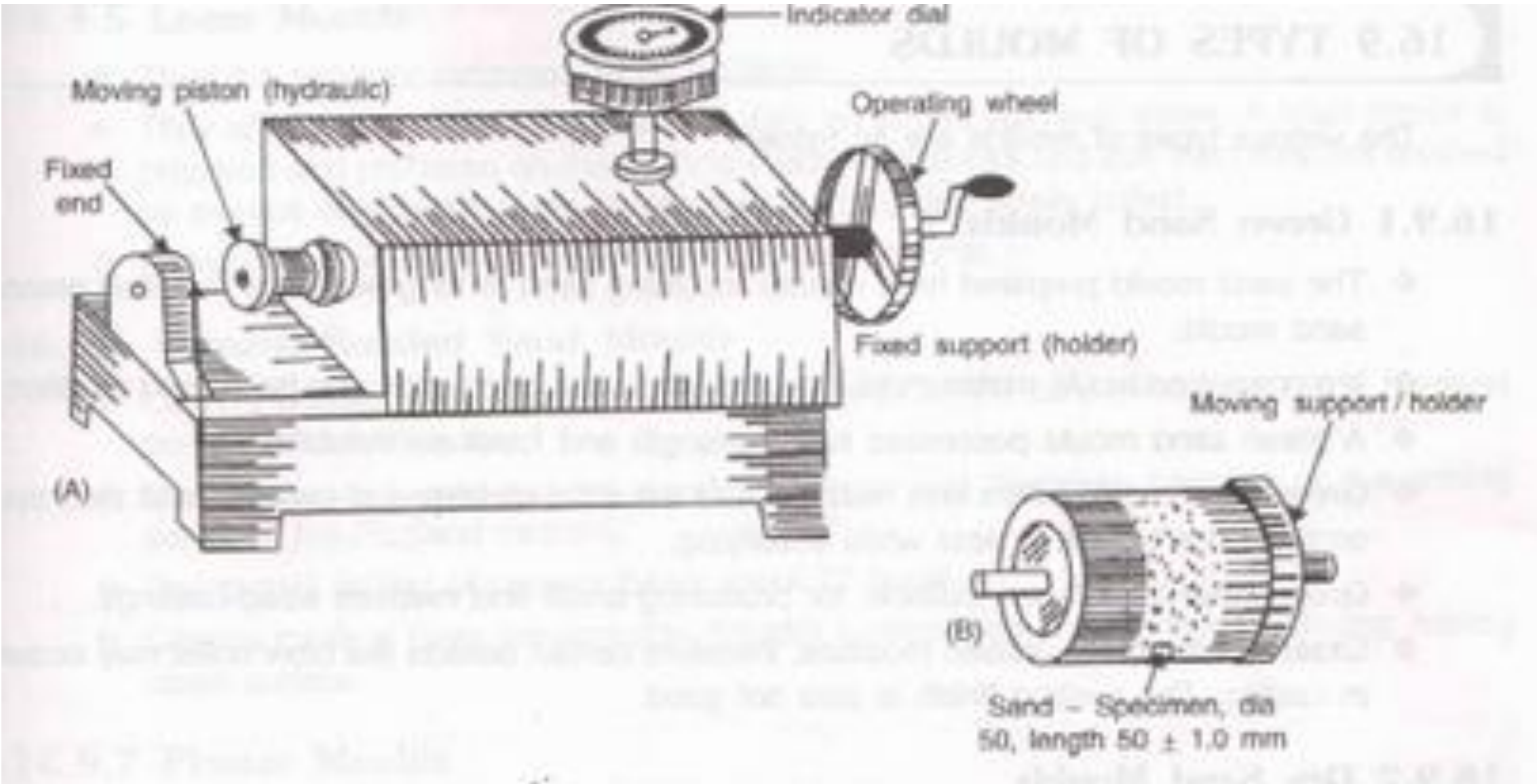


Figure 1.4.4: Sand strength testing set up

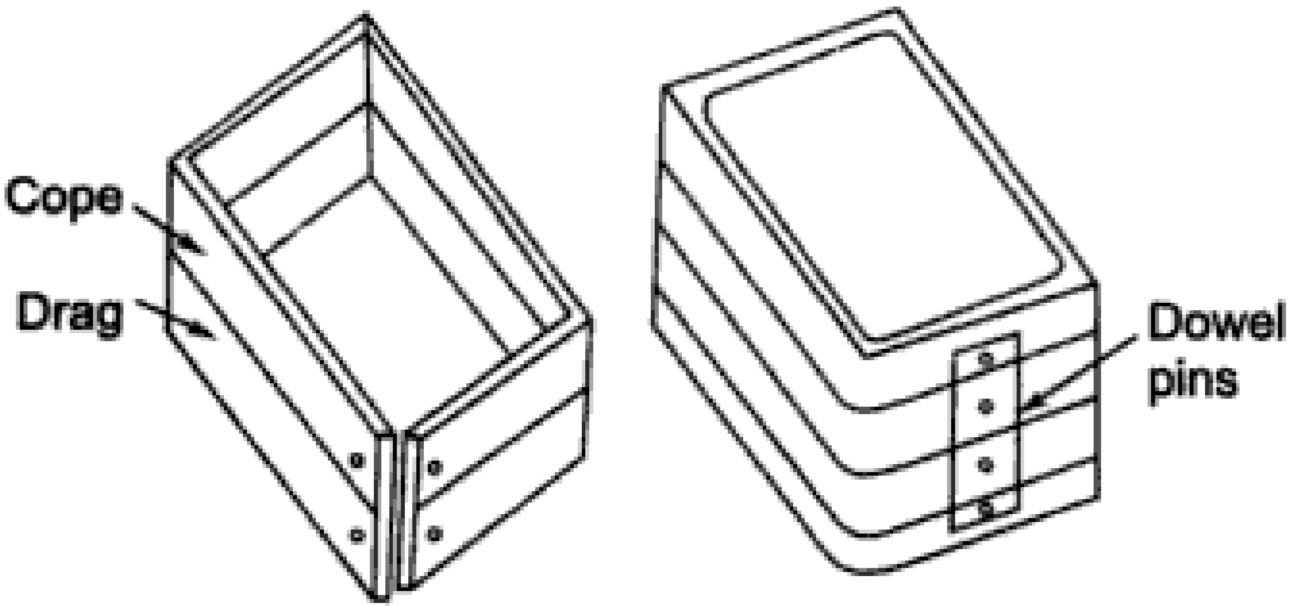
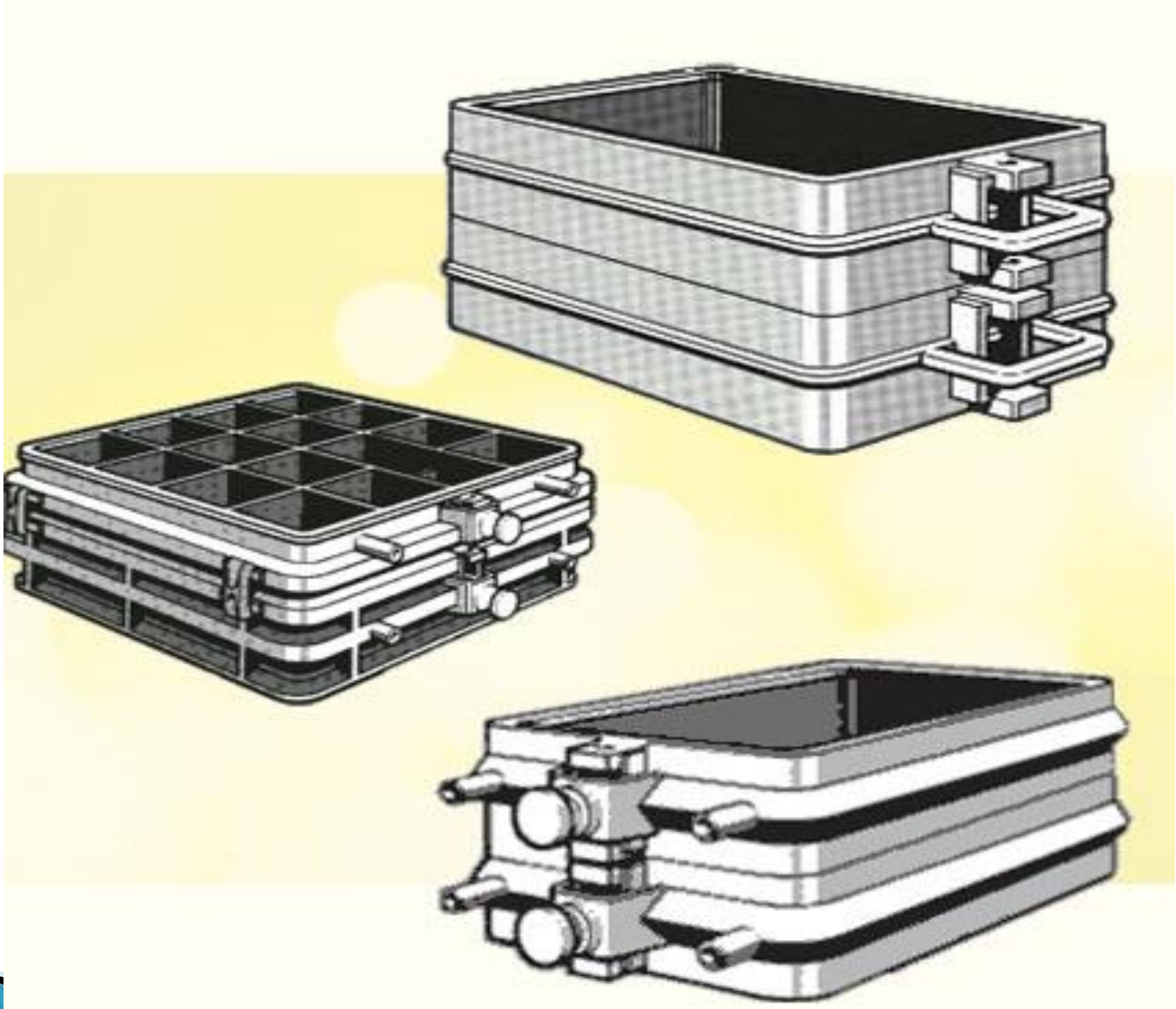


Fig. 2.12 *Moulding flasks*



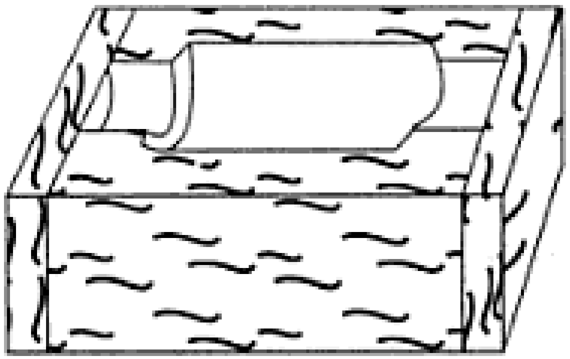


Fig 1.58 Half core box.

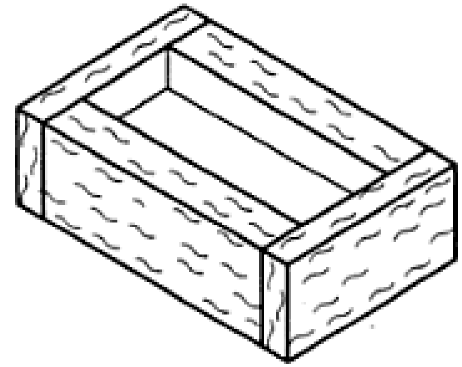


Fig 1.59 Dump core box.

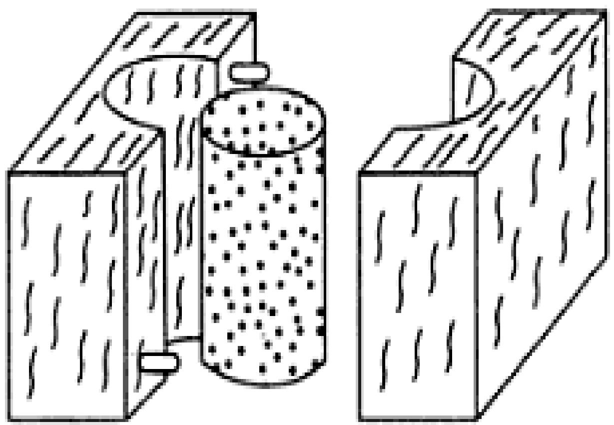


Fig 1.60 Split core box.

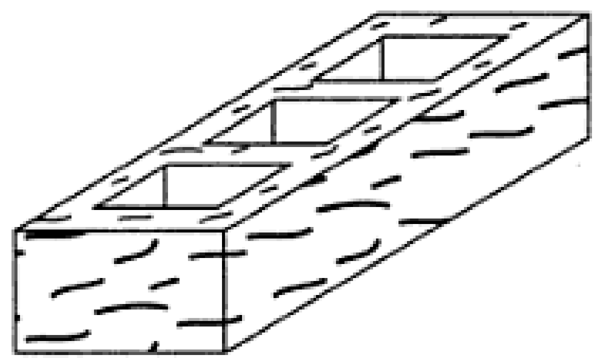


Fig 1.61 Gang core box.

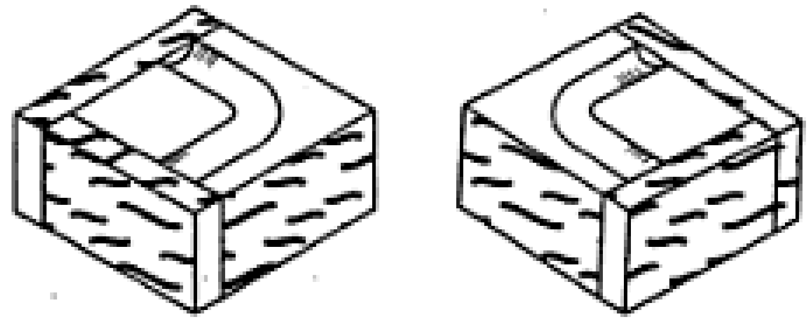


Fig 1.62
Left hand core box and right hand core box.

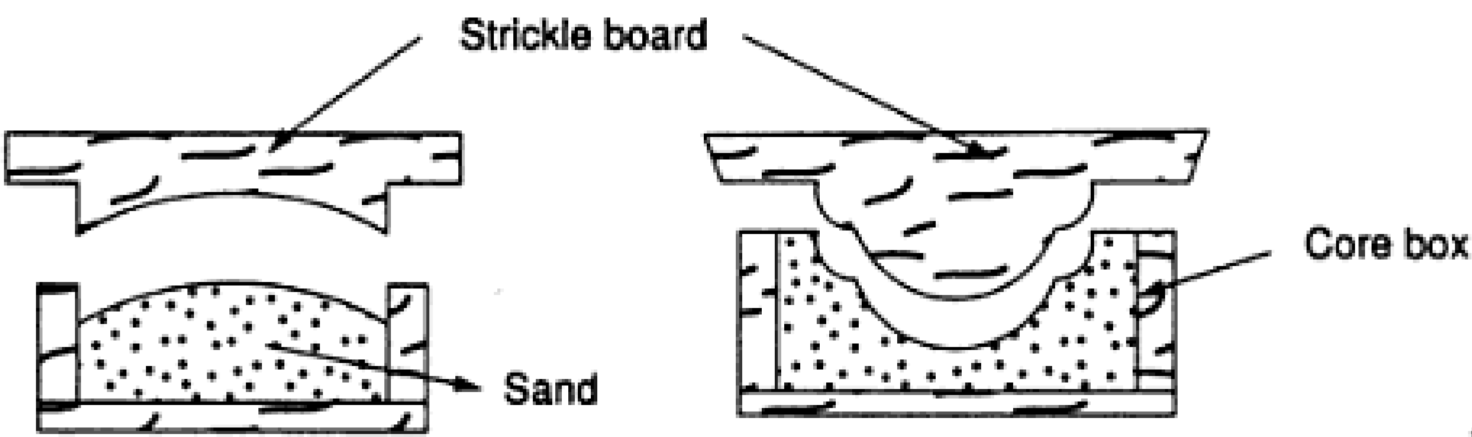


Fig 1.63 Strickle core box.

Core Ovens

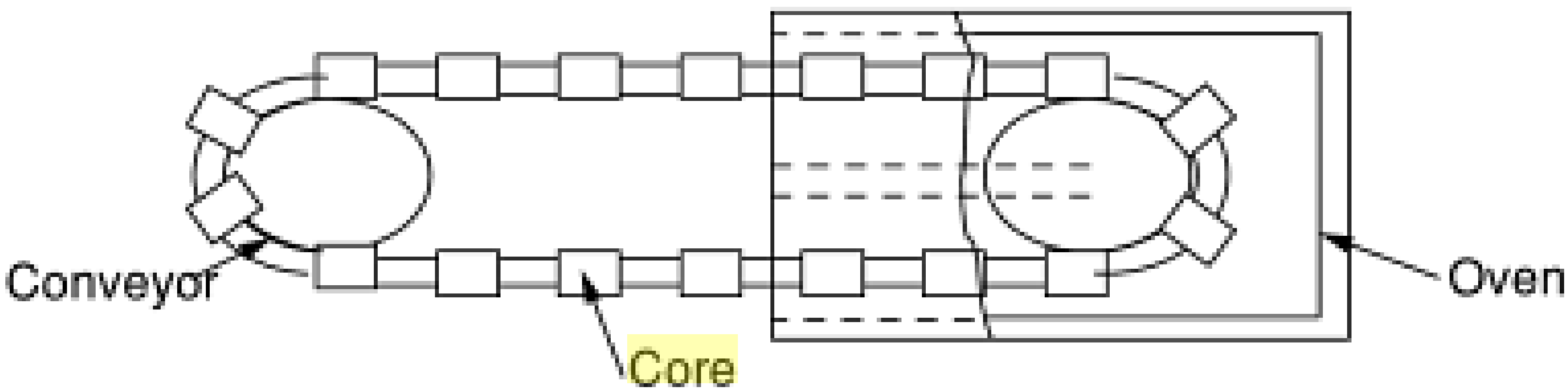


Fig 1.66 Continuous type oven.

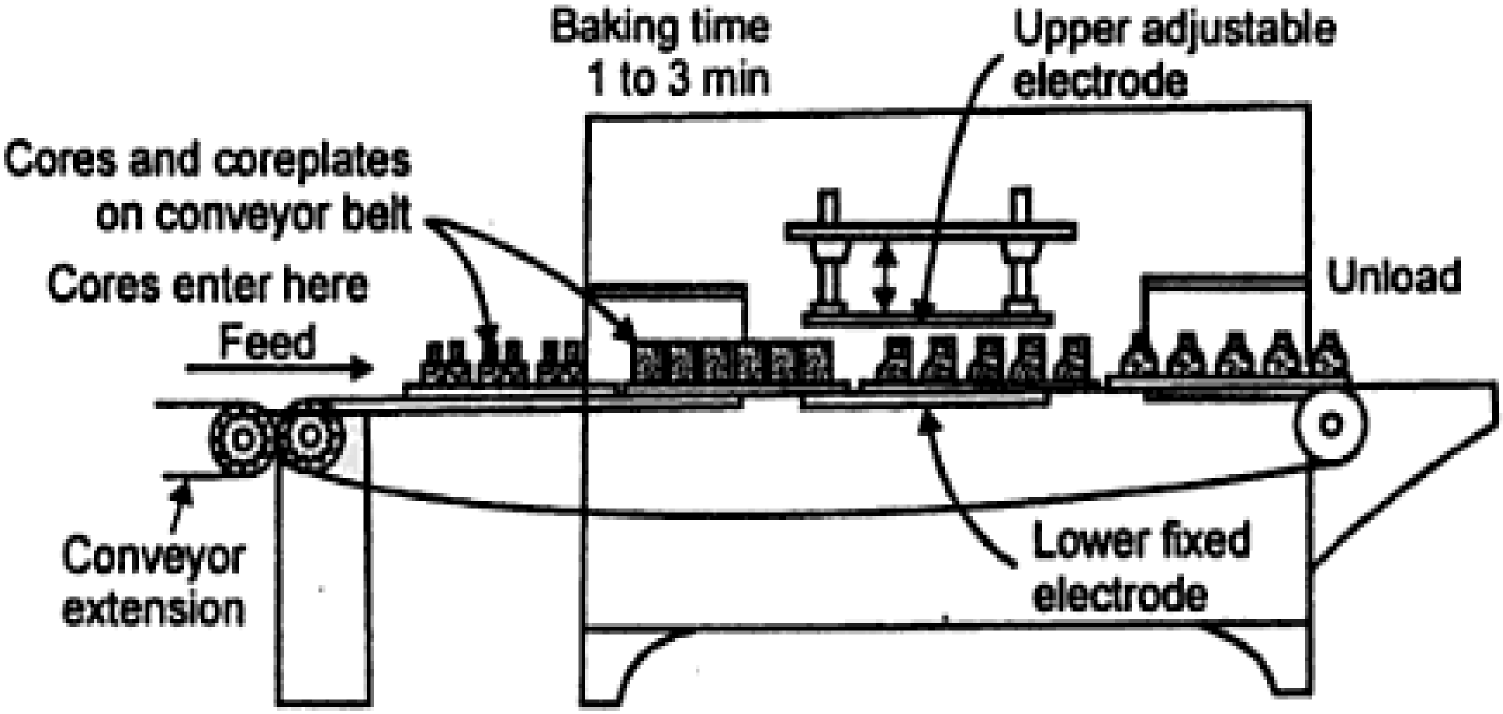
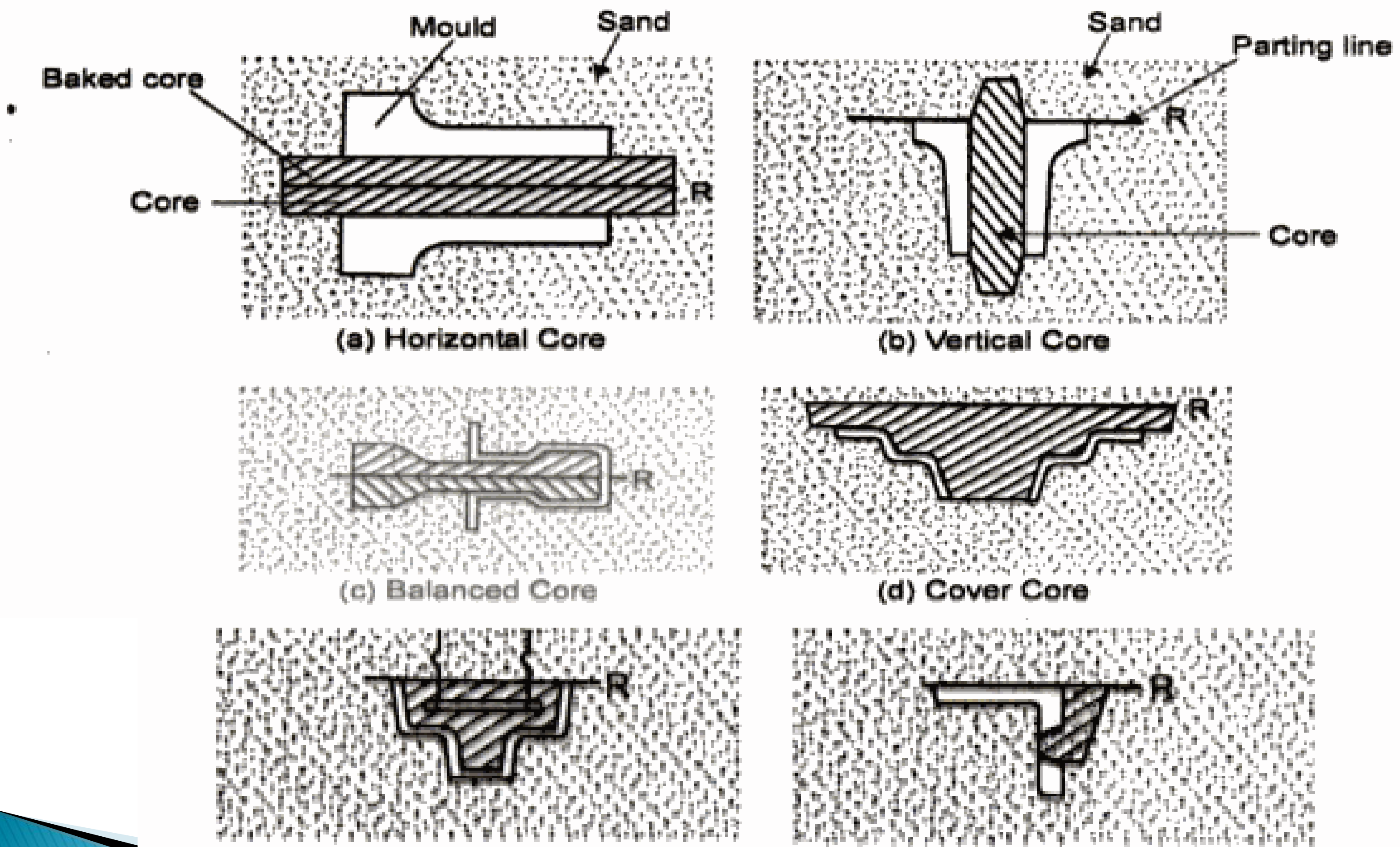


Figure 1.26 Dielectric Core-Baking Oven

Types of cores



(a) Horizontal Core
(b) Vertical Core
(c) Balanced Core
(d) Cover Core
(e) Hanging Core
(f) Drop Core

Types of Mould

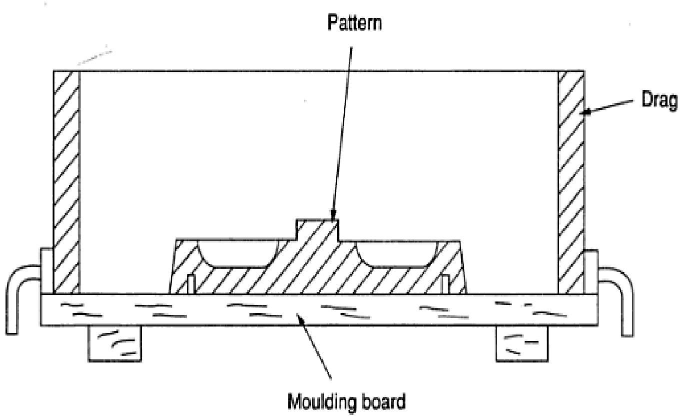


Fig 1.68 Green sand moulding (step 1).

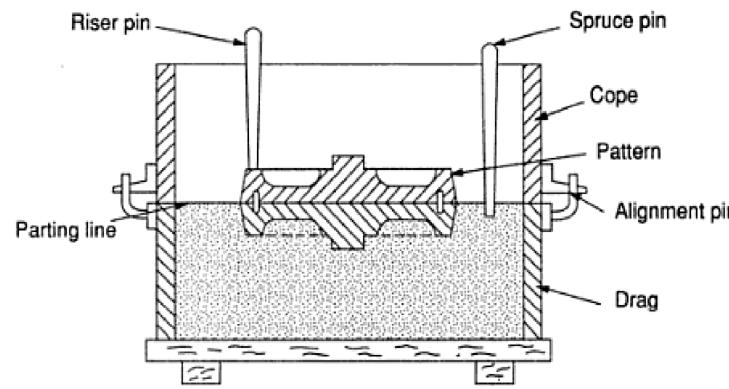


Fig 1.69 Green sand moulding (step 2).

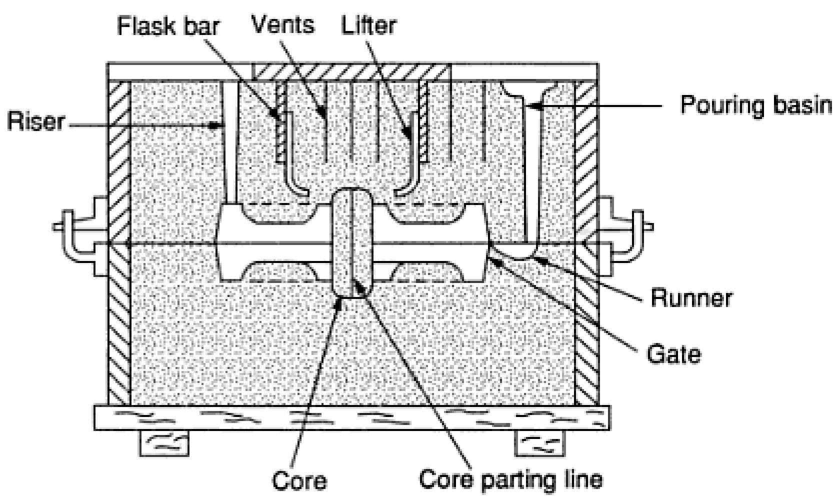
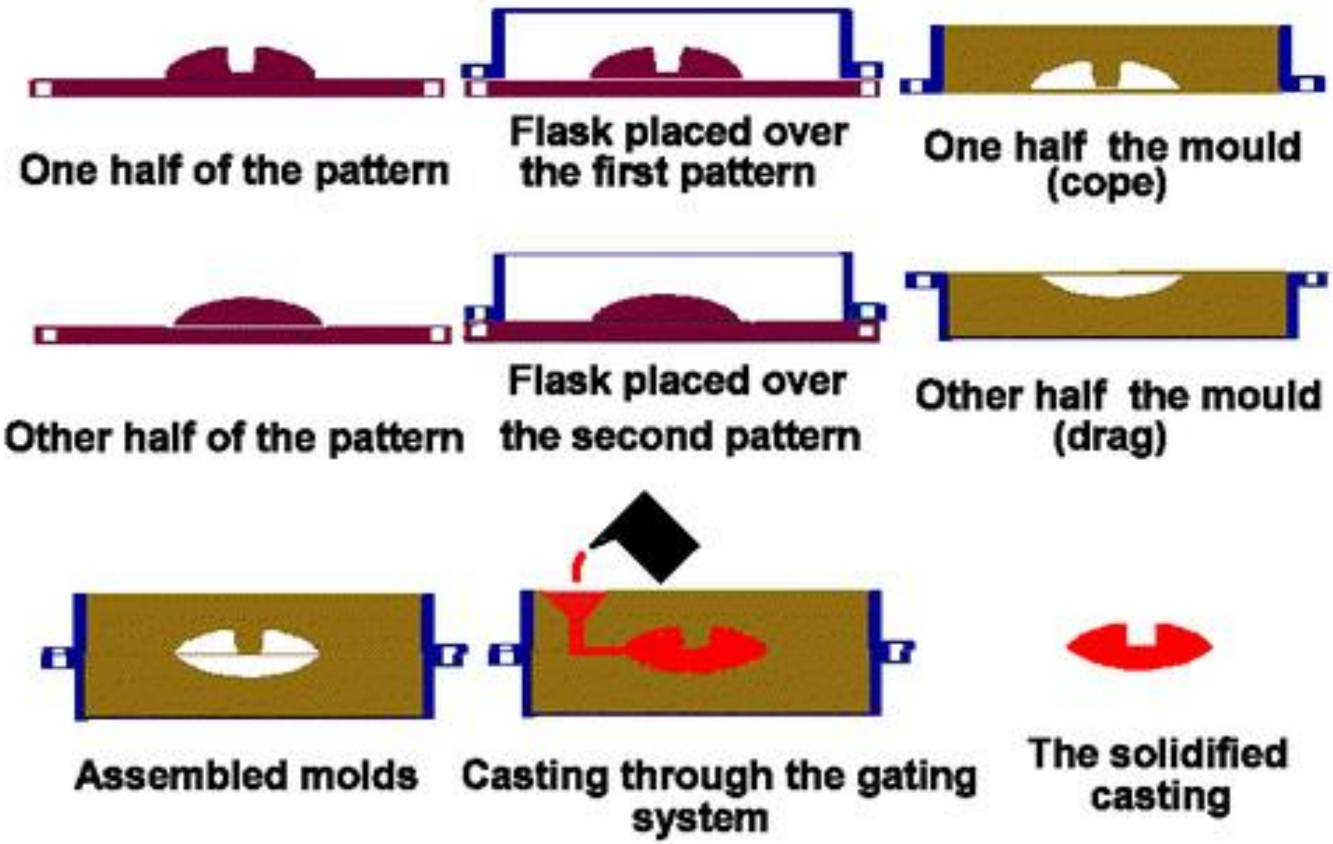
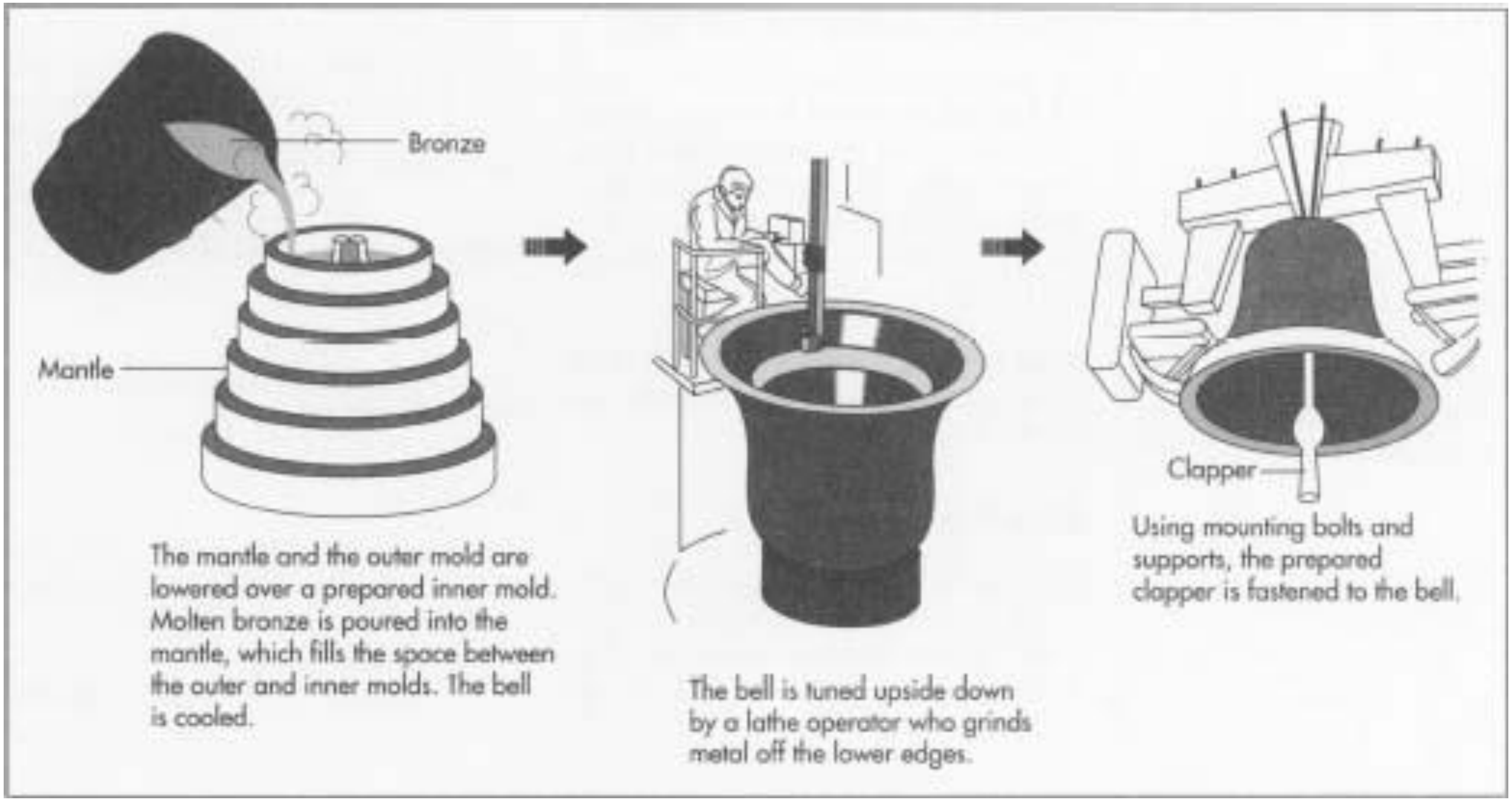


Fig 1.70 Green sand moulding (step 3).

Dry Sand Mould



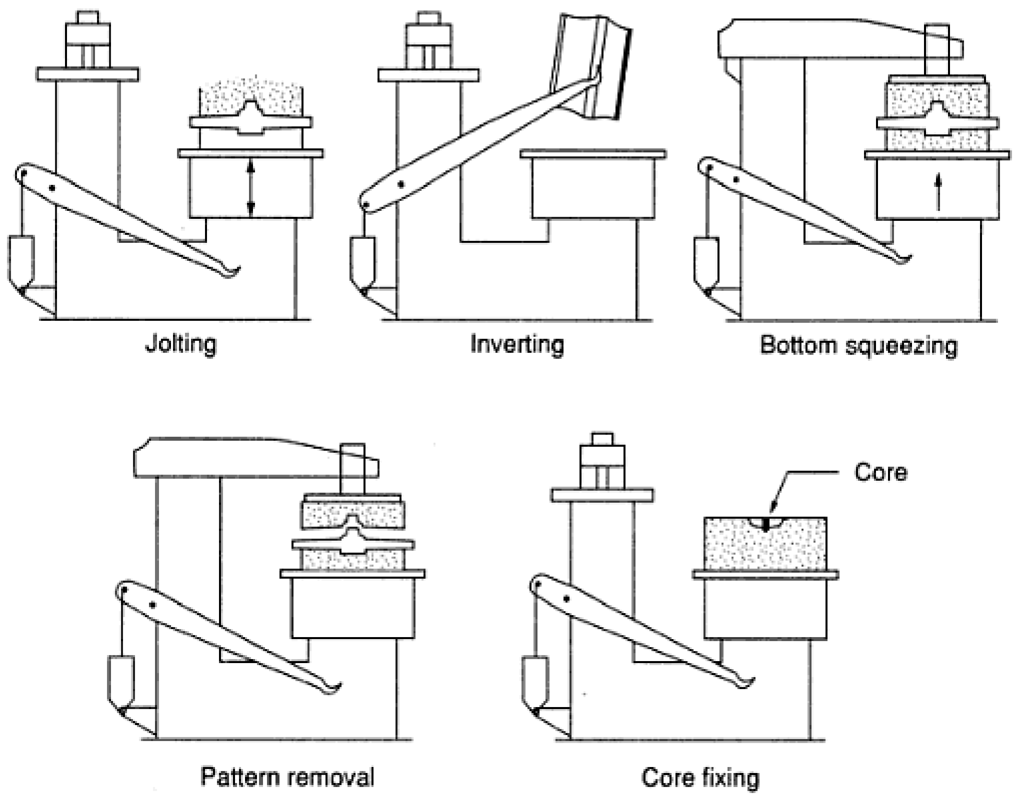


The mantle and the outer mold are lowered over a prepared inner mold. Molten bronze is poured into the mantle, which fills the space between the outer and inner molds. The bell is cooled.

The bell is tuned upside down by a lathe operator who grinds metal off the lower edges.

Using mounting bolts and supports, the prepared clapper is fastened to the bell.

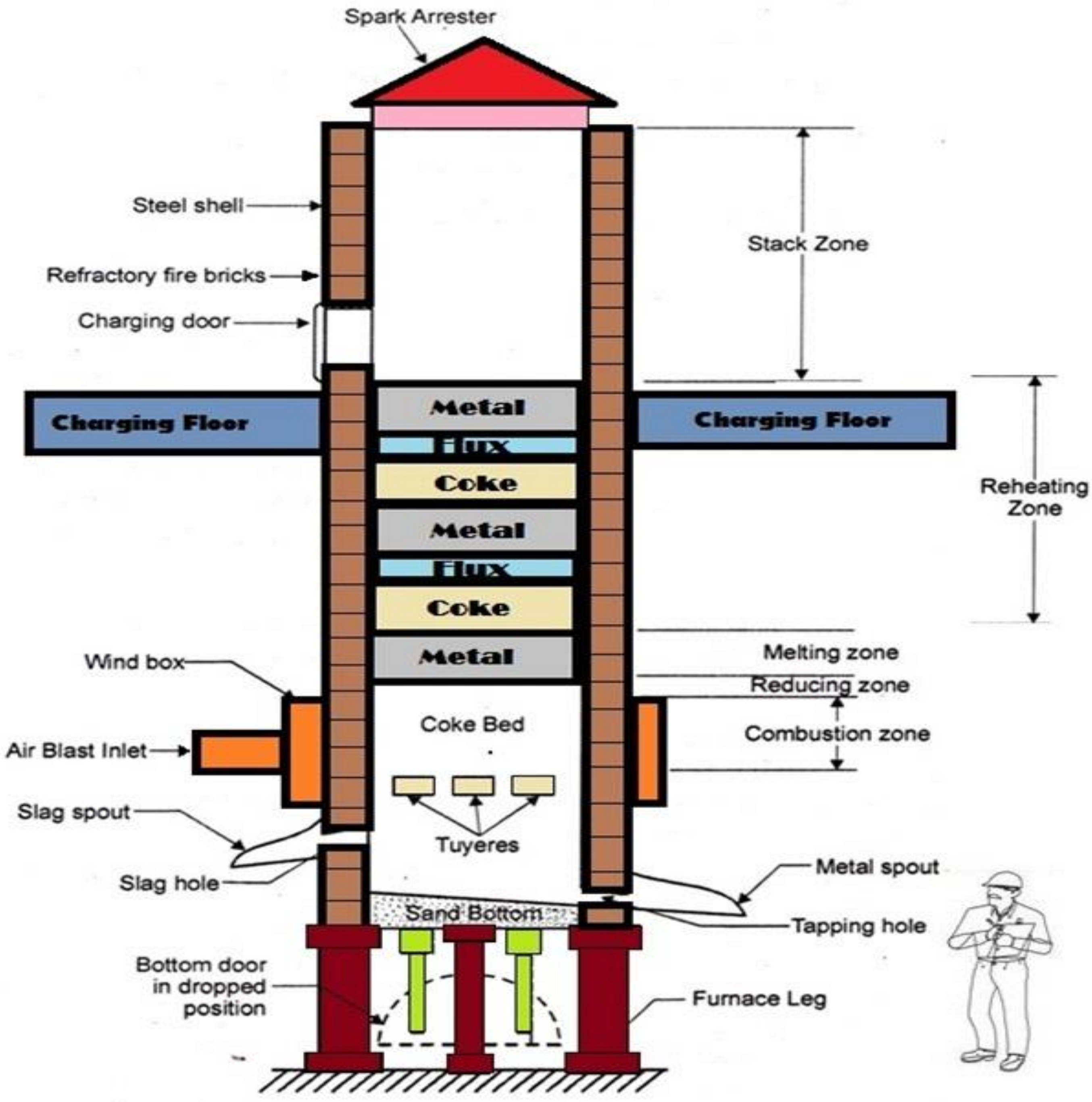
Jolt Squeezing Moulding Machine



Cupola Furnace

- Used for Melting Scrap metals or pig iron for productions of various cast iron.
- Used for Nodular and Malleable cast iron
- Can also used for Copper Alloy

- Construction
  - Bottom door used for contents to left out of the cupola
  - Air enters from blowers through the blast pipes
  - Tuyeres used as refractory chamber for combustion



Cupola furnace

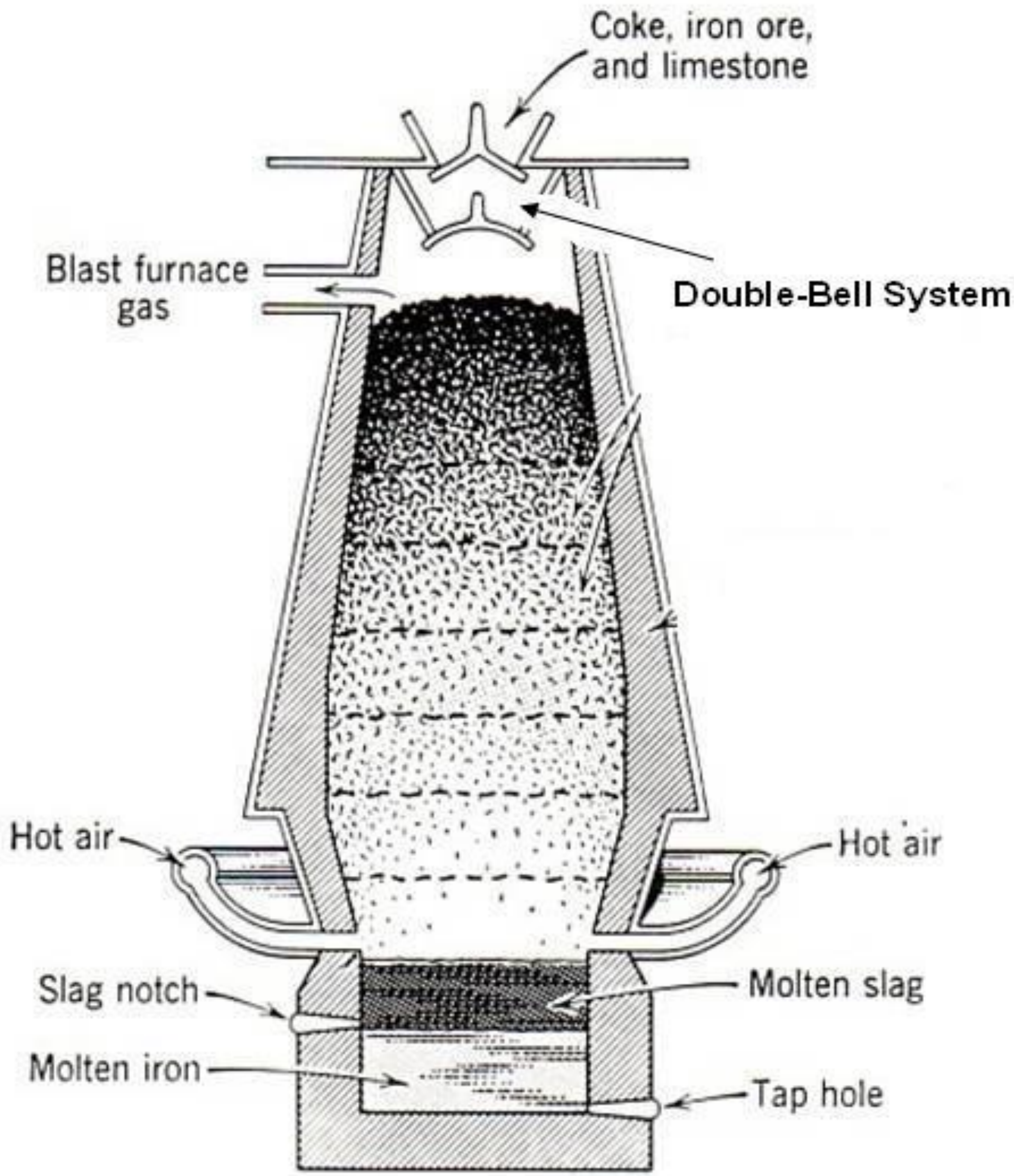
- Tap hole – Through which molten metal is poured out
- Slag hole – Used for removing the slag which is present 250 mm above the Tuyeres
- Cupola is provided with Charging platform with varying height to feed the charge.
- Cupola usually weighs 1 to 15 tons and 6m in height , diameter 750mm to 2.5 m

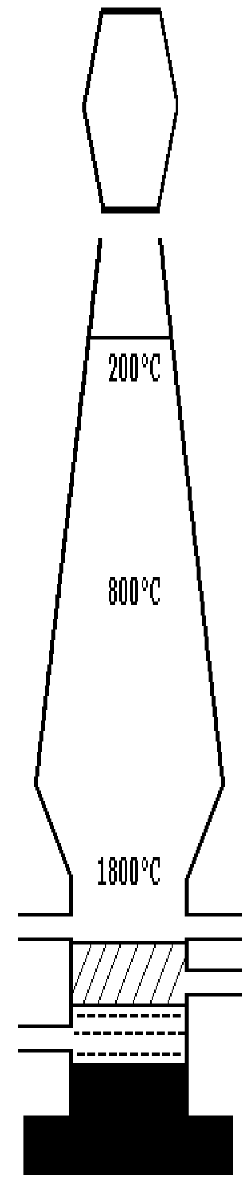
Working

- Cupola is fired for 3-4 hrs before molten metal is poured
- Soft, dry wood is placed above the rammed sand.
- Coke is placed above the wooden pieces
- After coke bed is ignited, then it has to ignited properly.

- Charging of cupola involves addition of limestone(flux), metal(iron), and fuel (coke) up to the door of charging level.
- Soak period of 30-60 minutes is given for pre heating
- Then the blast is turned on
- The molten metal is collect for every five minutes

Blast Furnace





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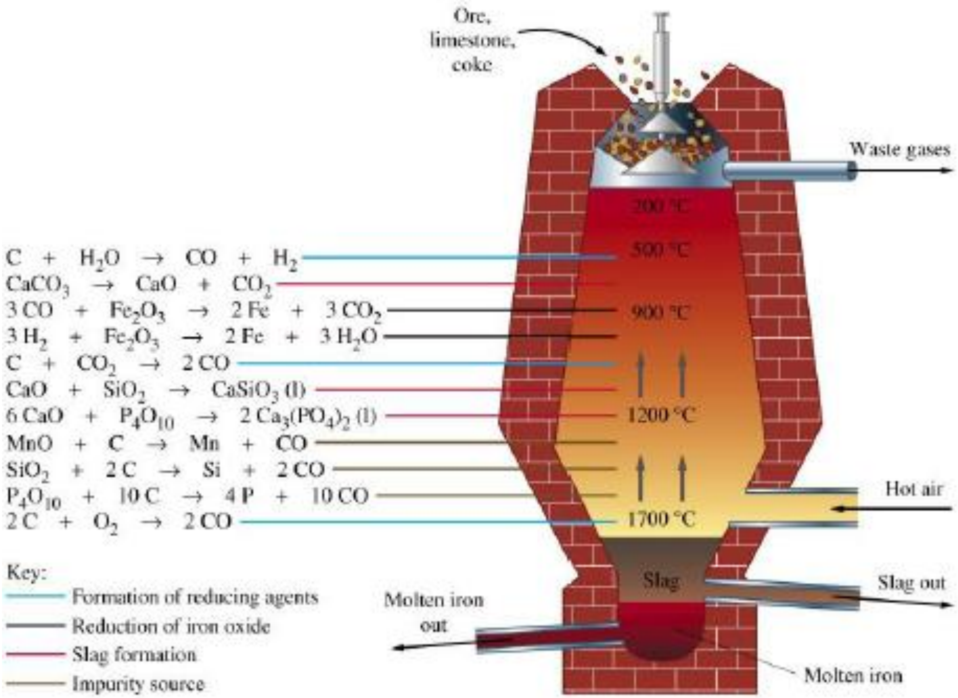
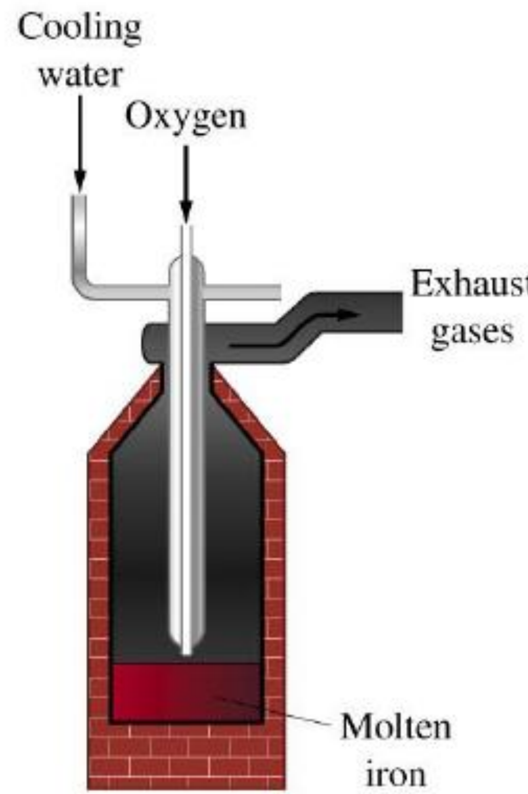
Furnaces



Blast furnace

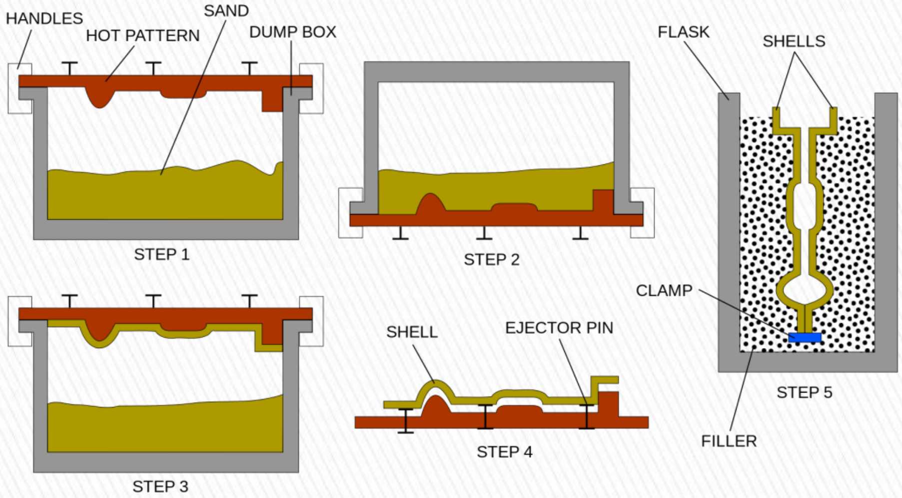


Basic Oxygen Furnace

Special Casting process

- Shell Moulding Process
- Investment Casting Process
- Permanent Mould Process
- Pressure Die casting Process
  - Hot Chamber
  - Cold Chamber
- Centrifugal Casting
- Squeeze casting
- Stir Casting

Shell Metal Casting

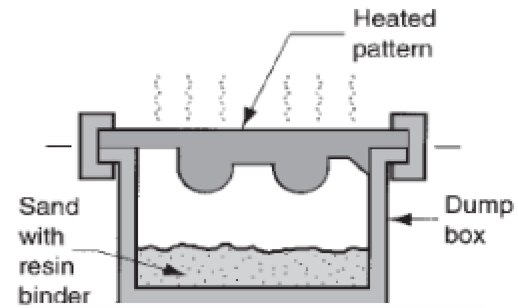


- Match plate pattern is used
- Pattern is heated for 230–600 ℃
- Mould is heated in oven at 300℃
- Used for making brake drums, fan blades Cams, Cam shaft and piston rings

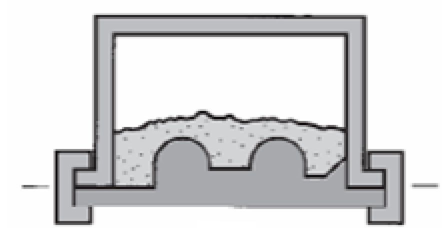
Shell moulding

The shell moulding is a casting process in which the mould is a thin shell of 9 mm thick. This is made of sand held together by thermosetting resin binder.

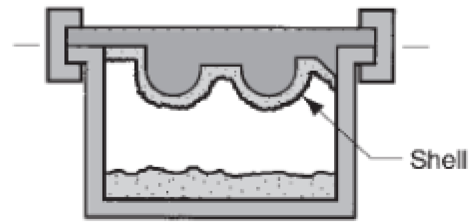
A metal pattern is heated and placed over a box containing sand mixed with thermosetting resin



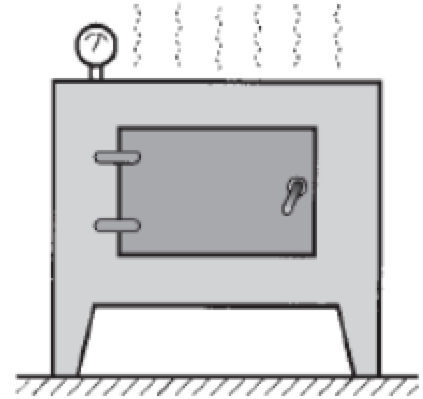
The dump box is inverted so that sand and resin mixture fall on the hot pattern, causing a layer of the mixture to partially cure on the pattern surface to form a hard shell



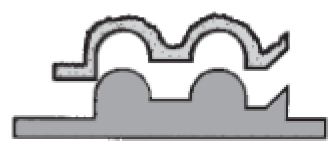
The box is positioned to the previous stage, so that loose, uncured particles drop away

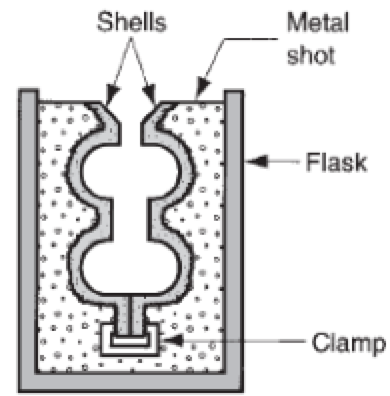


sand shell is heated in oven for several minutes to complete curing

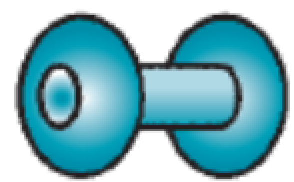


The shell mold is removed from the pattern and two halves of the shell mold are assembled, supported by sand or metal shot in a box, and pouring is completed





The part made by this method is shown here



Advantages of shell moulding process

• The surface of the shell mould is smoother than conventional green sand mould. This permits easier flow of molten metal during pouring and better surface finish on the final casting.

• Surface finish of the order of 2.5 μm can be obtained. Good dimensional tolerances of the order of ± 0.25 mm can be reached in a small to medium sized parts.

• Machining operations are reduced because of good surface finish.

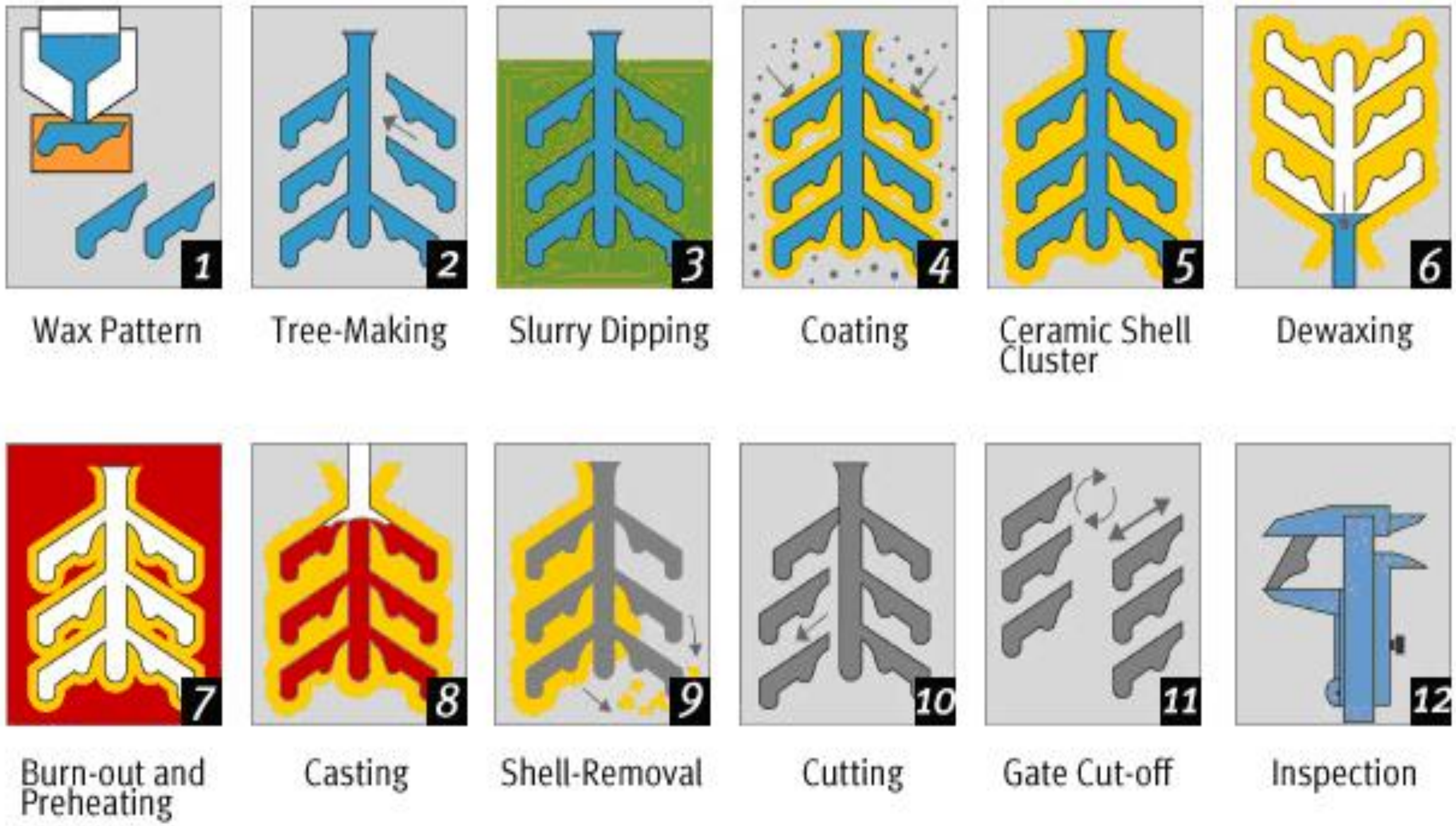
Disadvantages

• expensive metal pattern is required, and hence not suitable for small quantities.

• can be mechanized for mass production and will be economical too.

Examples of parts made using shell molding include gears, valve bodies, bushings, and camshafts.

Investment Casting

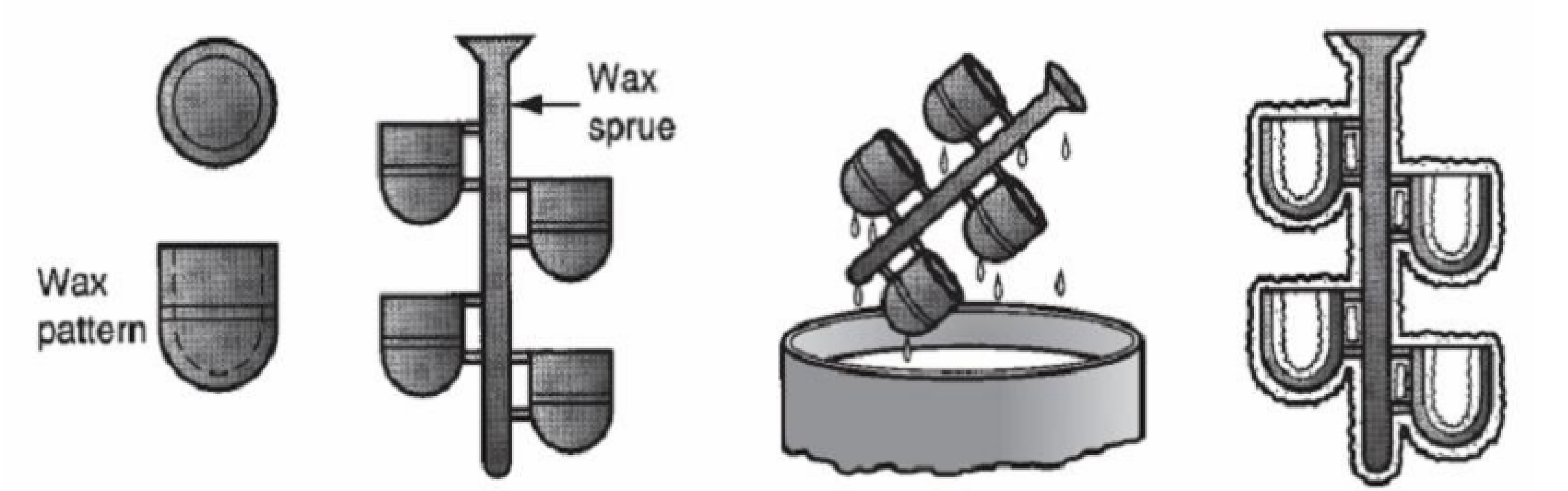


Investment casting

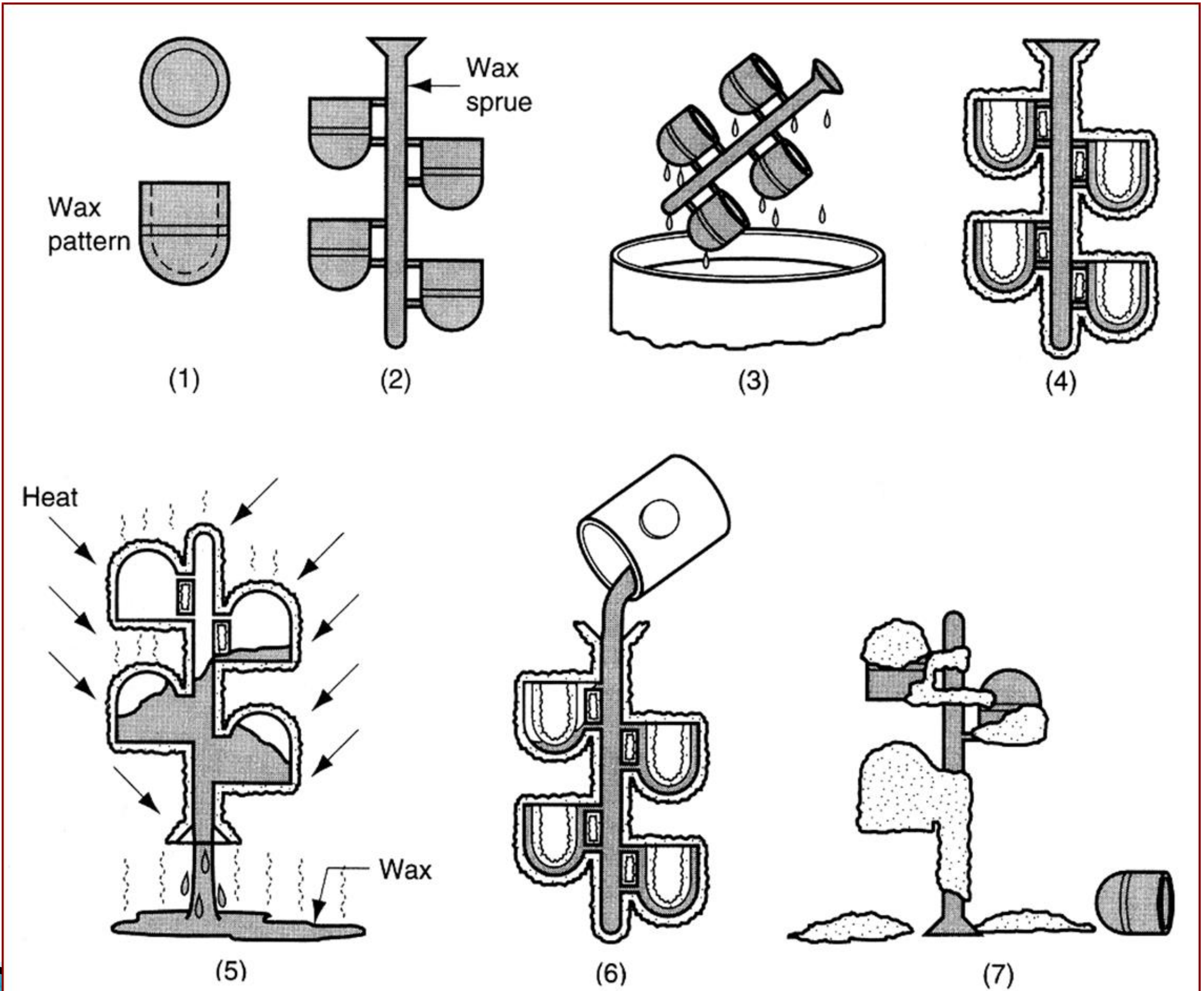
In this casting process, a pattern made of wax is coated with a refractory material to make the mold surface, after which the wax is melted away while pouring the molten metal.

"Investment" means "to cover completely" which refers to the coating of the refractory material around the wax pattern.

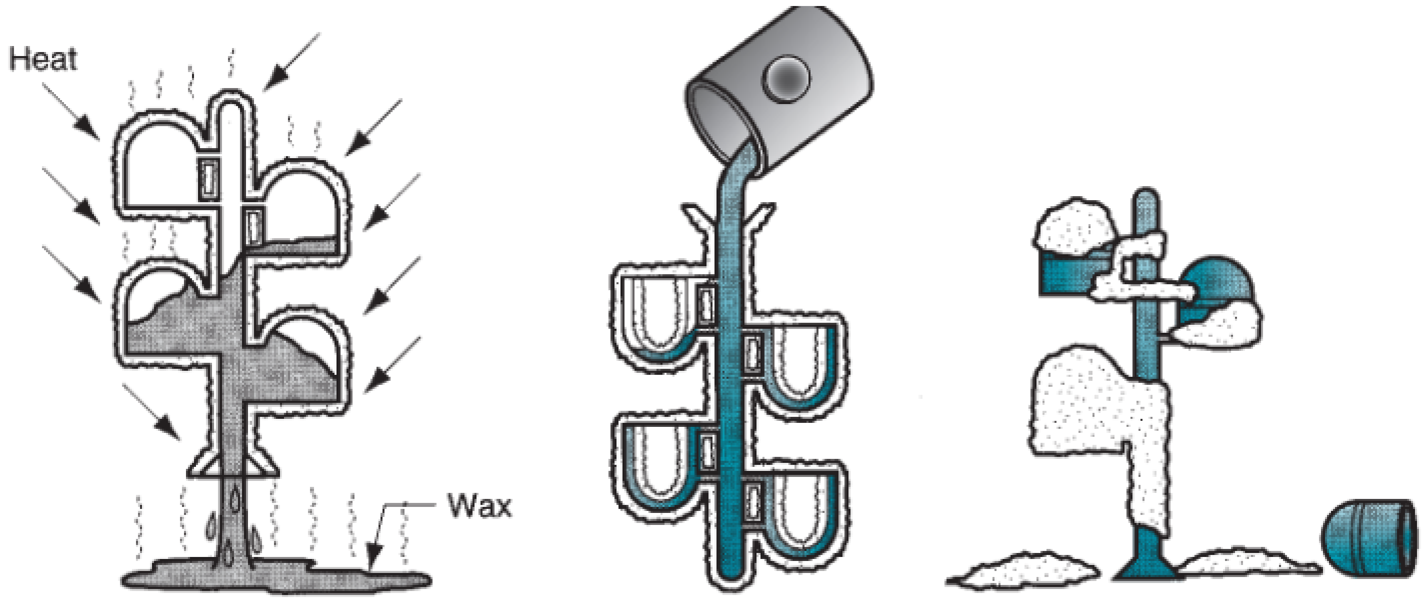
This is a precision casting process. Using this we can make castings of high accuracy with intricate details.



- Master pattern made of wood or metal.
- Master mould is prepared and it is used for making the lost pattern.
- The master mould filled with wax.
- The expendable wax pattern is coated with slurry of silica flour and graphite mixed with water.
- This processed referred as investment.
- The finished mould is dried in air for 2 to 3 hours and baked in an oven for 2 hours to melt out wax. (100◦C to 120 ◦C)



Wax sprue
Wax pattern
(1)
(2)
(3)
(4)
Heat
Wax
(5)
(6)
(7)



- Wax patterns are first made
- several patterns can be attached to a sprue to form a pattern tree, if required
- the pattern tree is coated with a thin layer of refractory material and later covered with thick coating to make the rigid full mold
- Heating of mold in inverted position to melt the wax and permit it to drip out of the cavity
- the mold is preheated to a high temperature so that contaminants are eliminated from the mold
- the molten metal is poured and it solidifies
- the mold is removed from the finished casting

Refractory coating:

- Slurry of very fine grained silica or other refractory, in powder form, mixed with plaster to bond the mold into shape. The small grain size of the refractory material delivers smooth surface and captures the intricate depths of the wax pattern.

- Mold is allowed to dry in air for about 8 hours to harden the binder.

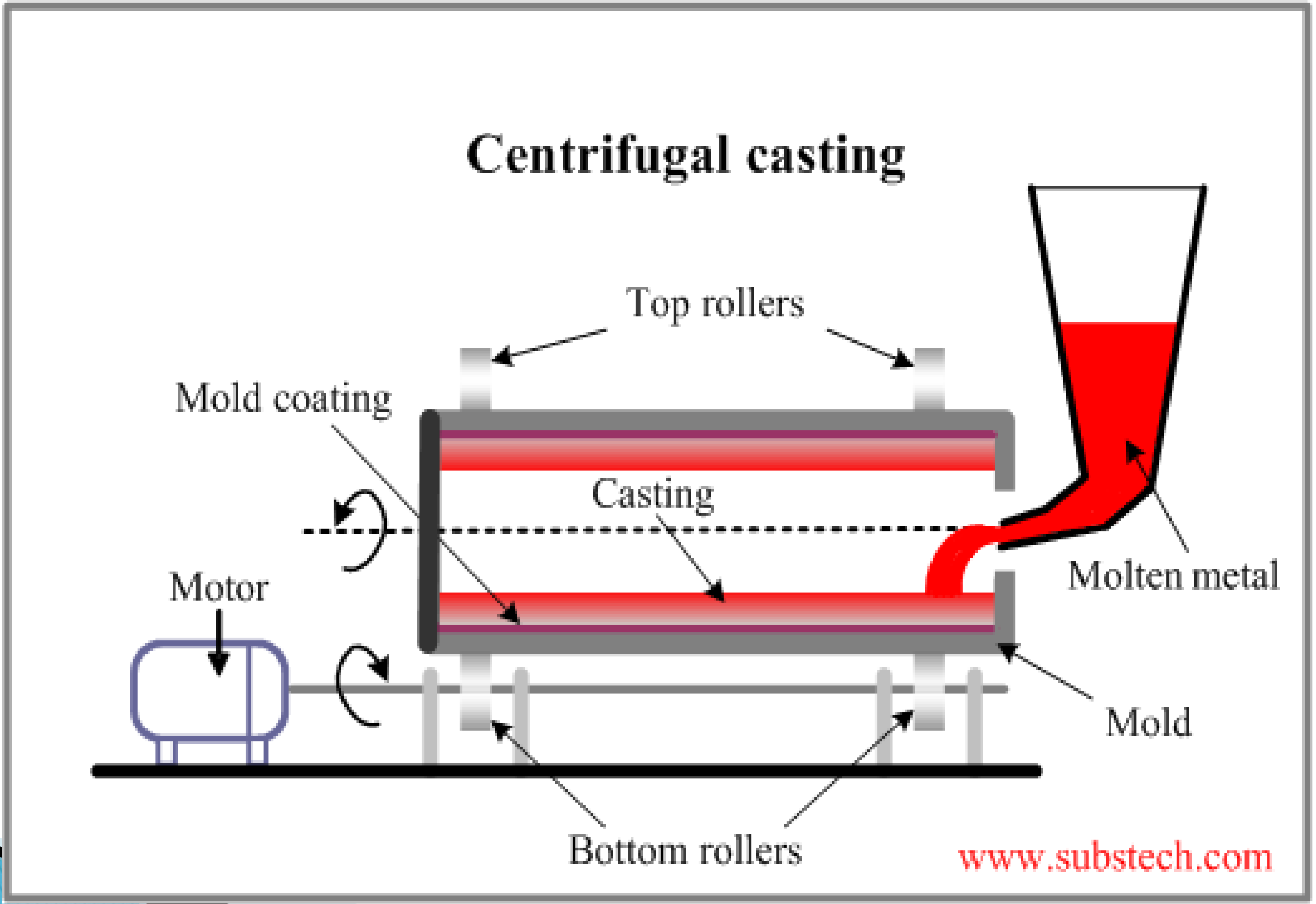
Advantages:

(1) Complex and intricate parts can be cast
(2) tolerances of 0.075 mm are possible
(3) good surface finish is possible
(4) In general, additional machining is not required – neat net shaped part

Applications:

- Steels, stainless steels, high temperature alloys can be cast
- Examples of parts: machine parts, blades, components for turbine engines, jewelry, dental fixtures

Centrifugal Casting

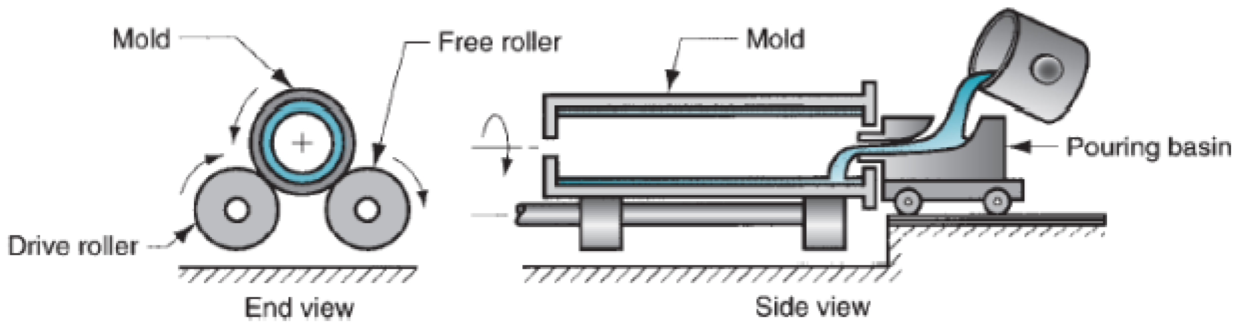


Centrifugal casting

- In this method, the mold is rotated at high speed so that the molten metal is distributed by the centrifugal force to the outer regions of the die cavity

- includes : true centrifugal casting, semicentrifugal casting

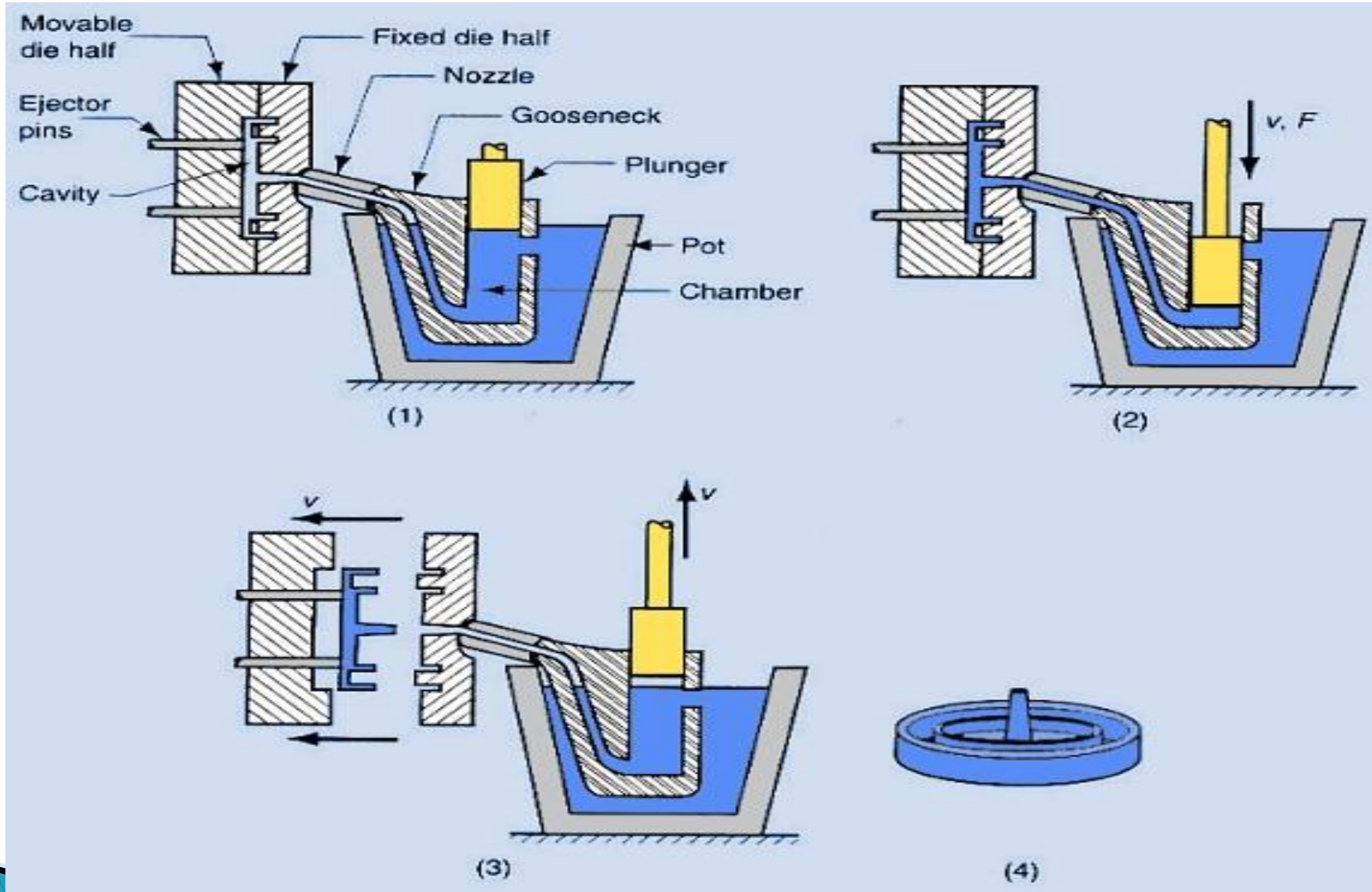
True centrifugal casting:



- Molten metal is poured into a rotating mold to produce a tubular part (pipes, tubes, bushings, and rings)
- Molten metal is poured into a horizontal rotating mold at one end. The high-speed rotation results in centrifugal forces that cause the metal to take the shape of the mold cavity. The outside shape of the casting can be non-round, but inside shape of the casting is perfectly round, due to the radial symmetry w.r.t. forces

Pressure Die Casting

- Hot Chamber Die Casting

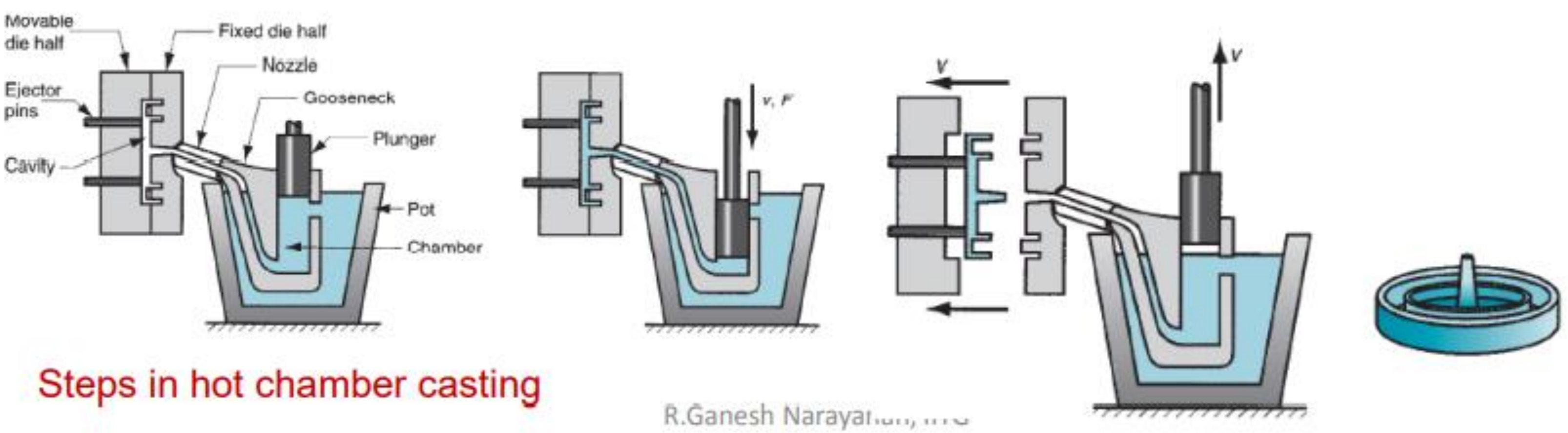


Die casting

In this process, high pressure of app. 7 to 350 MPa is used to pressurize the molten metal into die cavity. The pressure is maintained during solidification.
Category: hot chamber machines, cold chamber machines

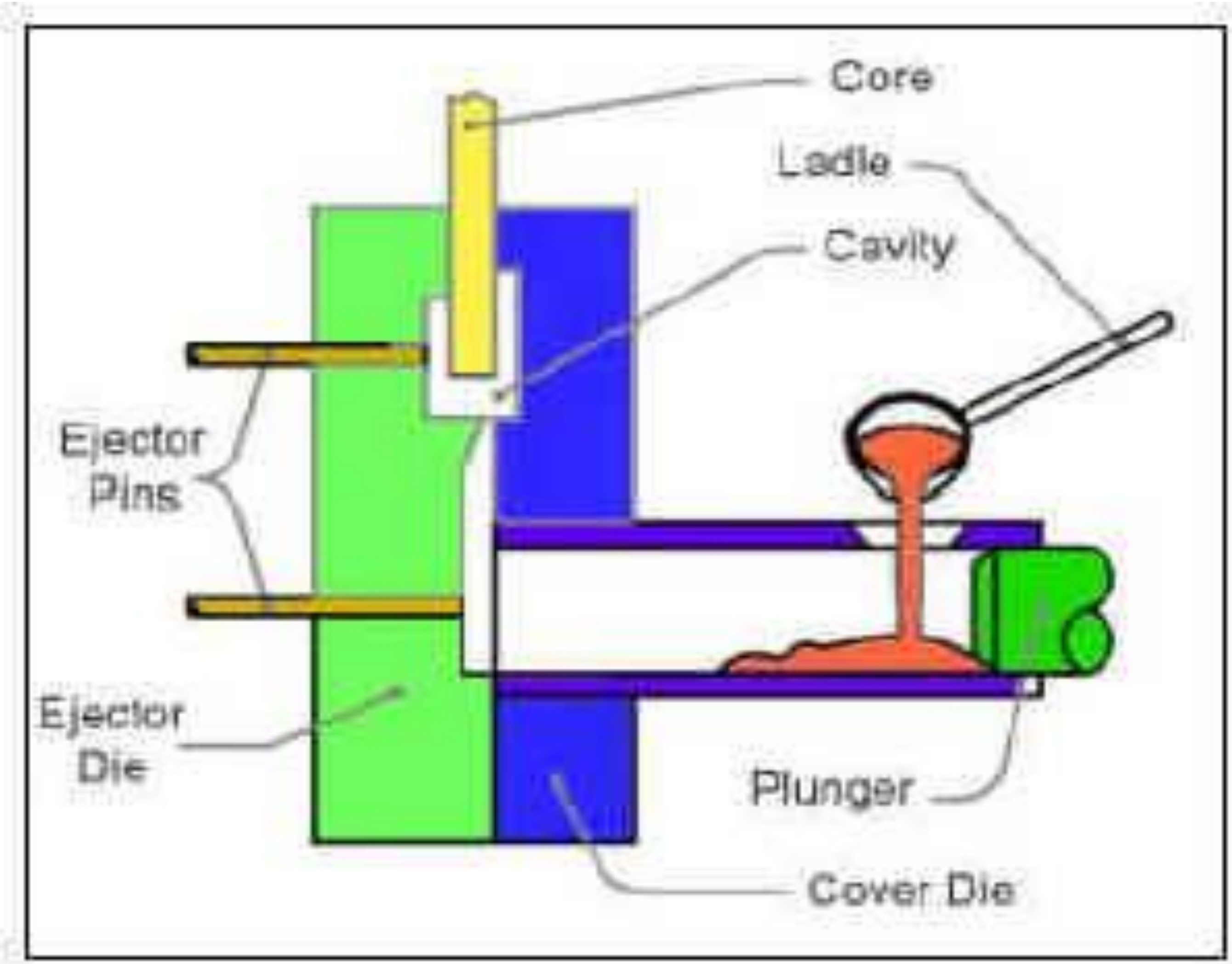
hot chamber machines:

- Molten metal is melted in a container attached to the machine, and a piston is used to pressurize metal under high pressure into the die. Typical injection pressures are between 7 and 35 MPa.
- Production rate of 500 parts/hour are common.
- Injection system is submerged into the molten metal and hence pose problem of chemical attack on the machine components. Suitable for zinc, tin, lead, Mg.



Steps in hot chamber casting

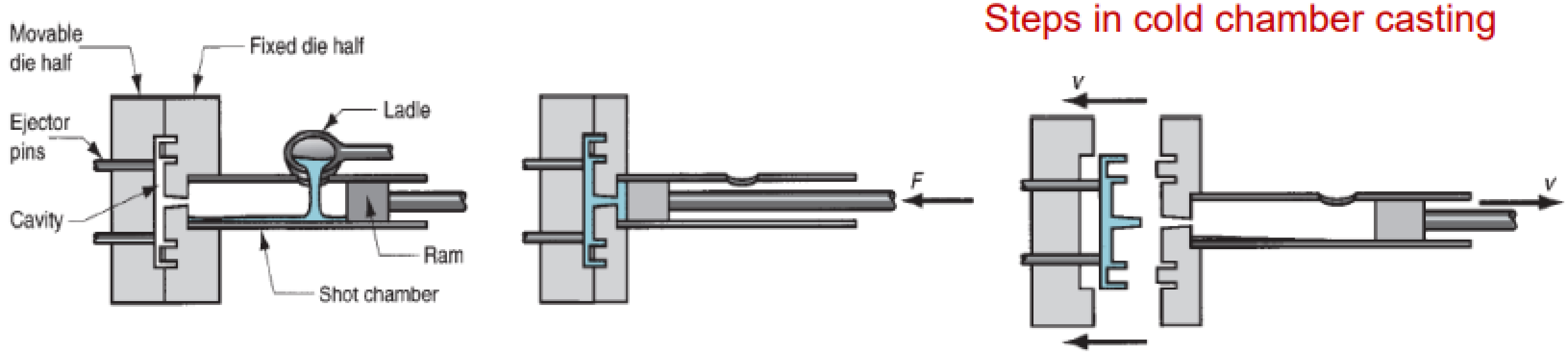
Cold Chamber Die Casting



cold chamber machines:

- Molten metal is poured from an external unheated container into the mold cavity and piston is used to inject the molten metal into the die cavity.
- Injection pressure: 14 to 140 MPa.
- Though it is a high production operation, it is not as fast as hot chamber machines.

Steps in cold chamber casting



Die casting molds are made of tool steel, mold steel, maraging steels. Tungsten and molybdenum with good refractory qualities are also used for die cast steel, CI.

Advantages of die casting:

- high production rates and economical
- Close tolerances possible of the order of ±0.076 mm
- thin section with 0.5 mm can be made
- small grain size and good strength casting can be made because of rapid cooling

Stir Casting

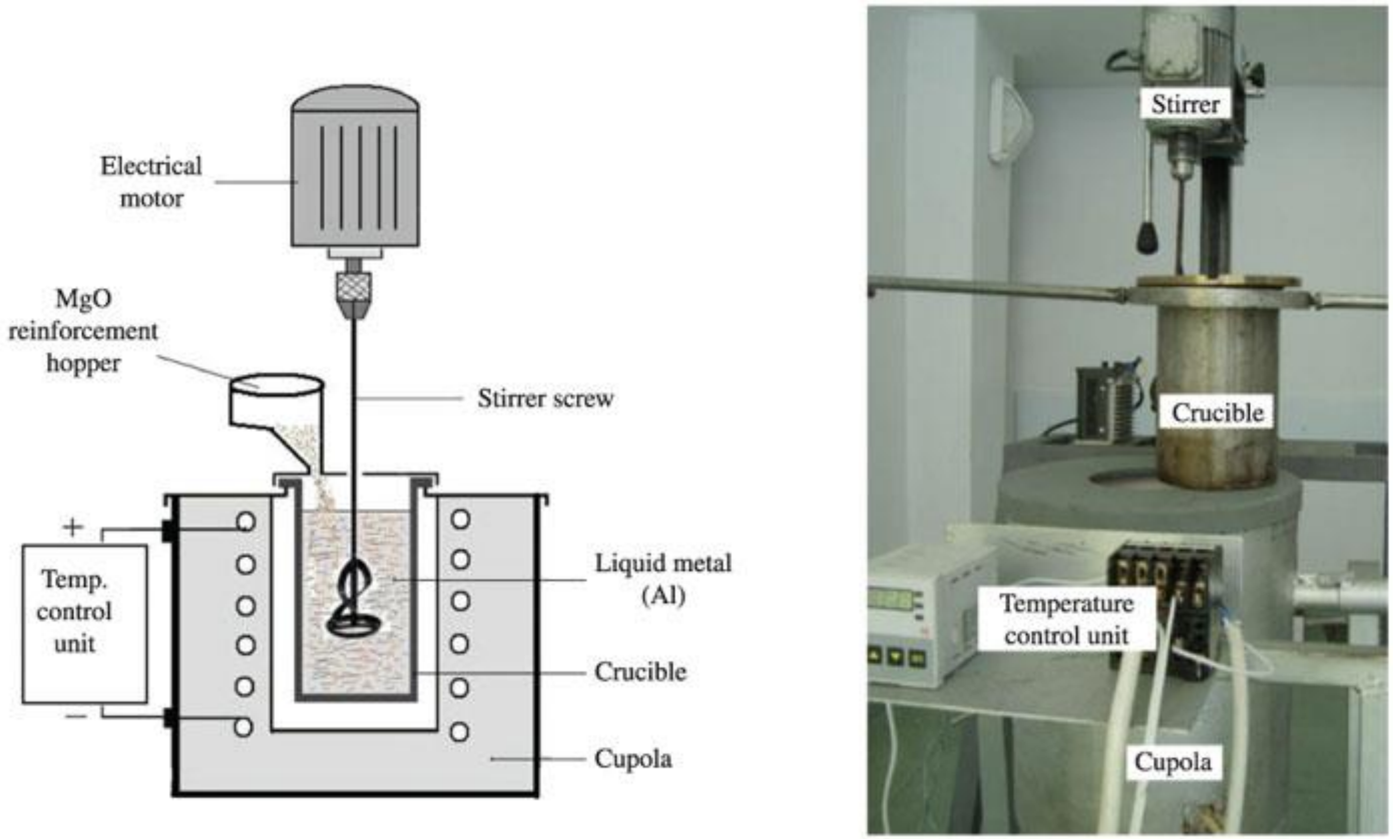
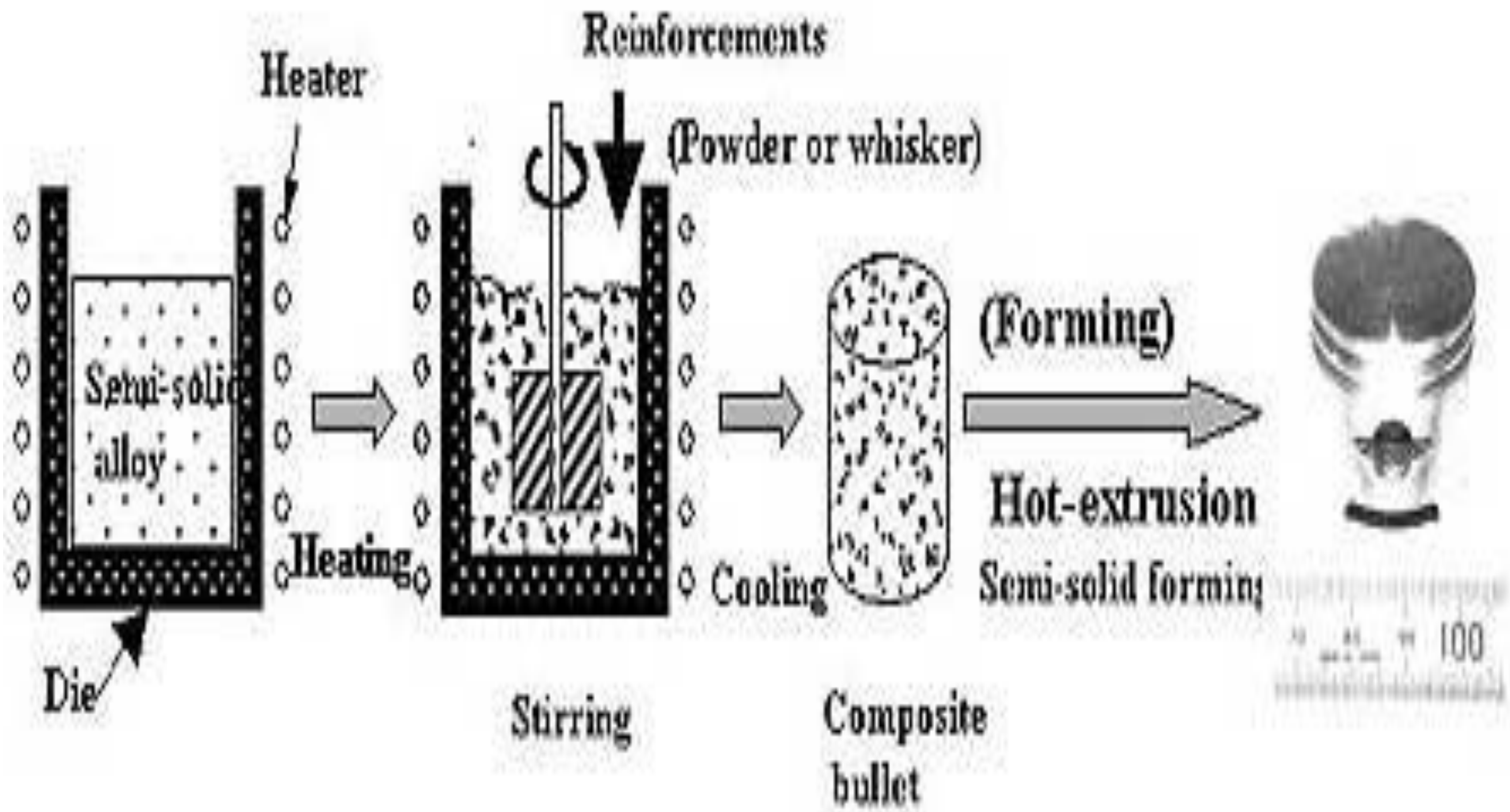


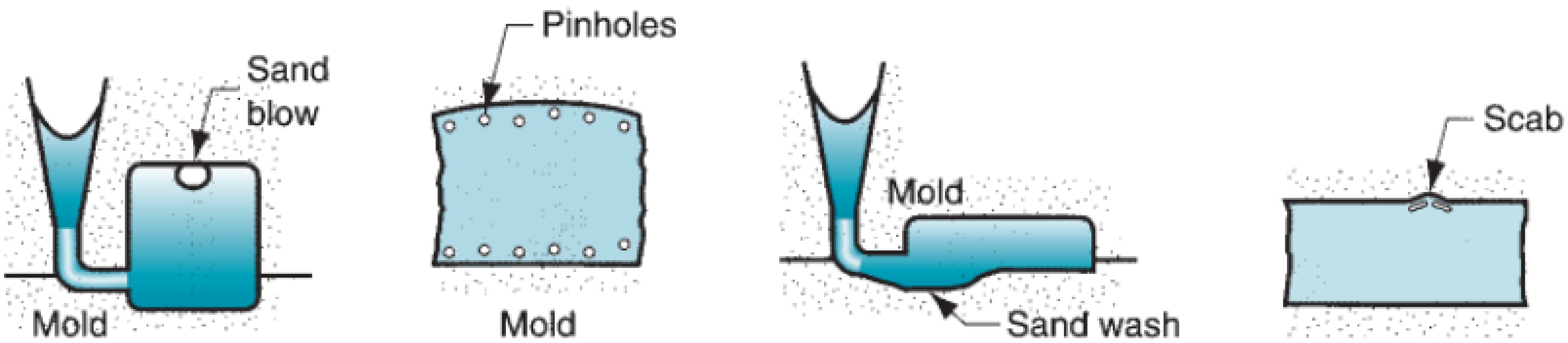
Figure 1. Melt stirring test apparatus (For the production of composite specimens).


Reinforcements
Heater
(Powder or whisker)
Semi-solid alloy
Heating
Cooling
(Forming)
Hot-extrusion
Semi-solid forming
100
Die
Stirring
Composite bullet

Casting Defects

- Defects may occur due to one or more of the following reasons:
  - Fault in design of casting pattern
  - Fault in design on mold and core
  - Fault in design of gating system and riser
  - Improper choice of moulding sand
  - Improper metal composition
  - Inadequate melting temperature and rate of pouring

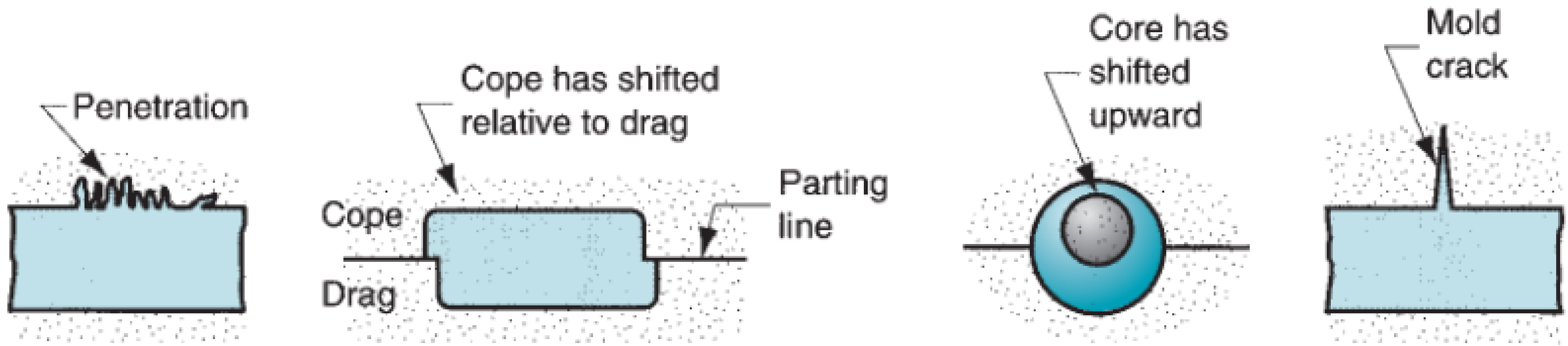
Defects in sand castings



Sand blow and Pinholes: defect consisting of a balloon-shaped gas cavity or gas cavities caused by release of mold gases during pouring. It is present just below the casting top surface. Low permeability, bad gas venting, and high moisture content of the sand mold are the usual causes.

Sand wash: surface dip that results from erosion of the sand mold during pouring. This contour is formed in the surface of the final cast part.

Scab: It is caused by portions of the mold surface flaking off during solidification and gets embedded in the casting surface.



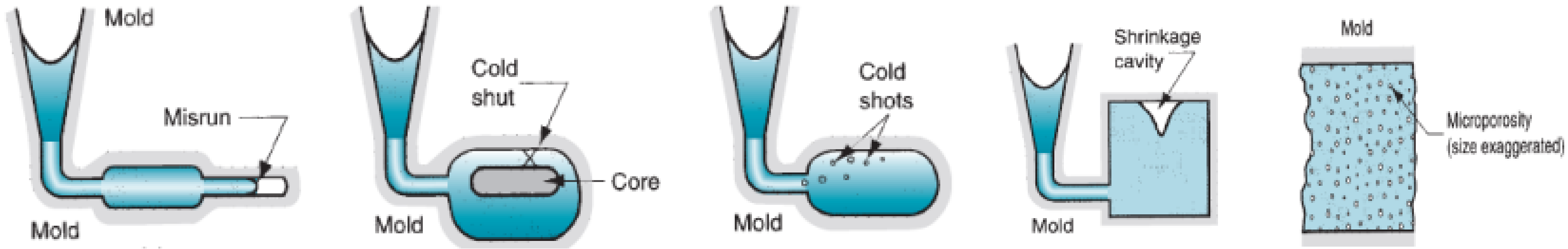
Penetration: surface defect that occurs when the liquid penetrates into the sand mold as the fluidity of liquid metal is high, After solidifying, the casting surface consists of a mixture of sand and metal. Harder ramming of sand mold minimize this defect.

Mold shift: defect caused by displacement of the mold cope in sideward direction relative to the drag. This results in a step in the cast product at the parting line.

Core shift: displacement of core vertically. Core shift and mold shift are caused by buoyancy of the molten metal.

Mold crack: 'fin' like defect in cast part that occurs when mold strength is very less, and a crack develops, through which liquid metal can seep.

Common defects in casting



Misruns: castings that solidify before completely filling the mold cavity. This occurs because of (1) low fluidity of the molten metal, (2) low pouring temperature, (3) slow pouring, (4) thinner cross-section of the mold cavity.

Cold Shuts: This defect occurs when two portions of the metal flow together but no fusion occurs between them due to premature freezing.

Cold shots: forming of solid globules of metal that are entrapped in the casting. Proper pouring procedures and gating system designs can prevent this defect.

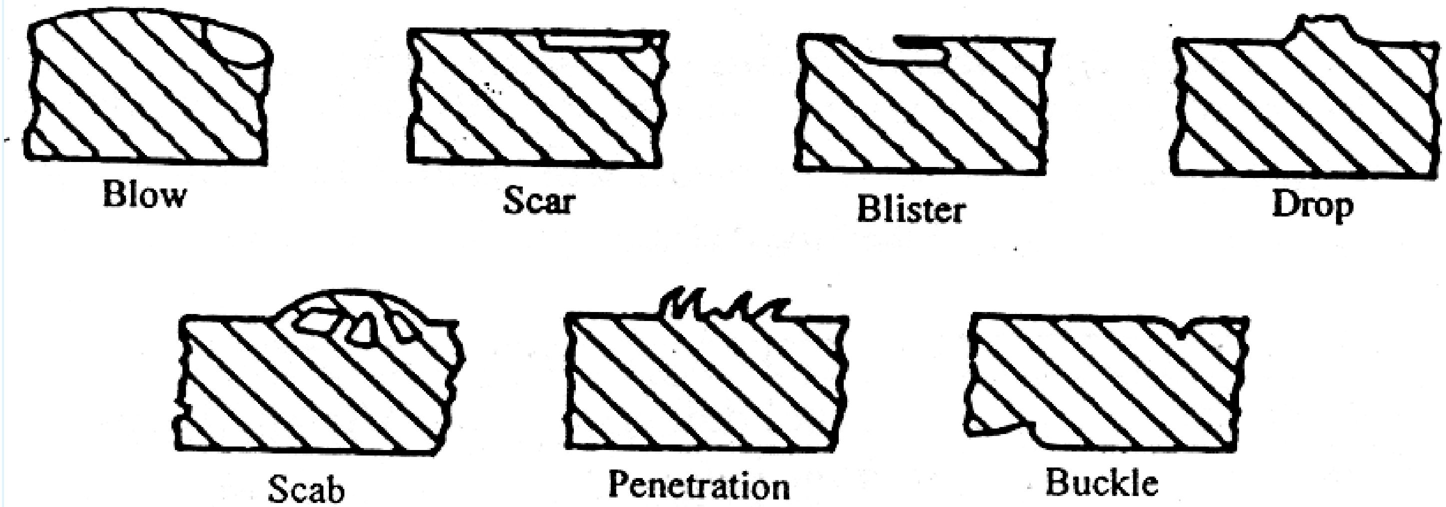
Shrinkage cavity: cavity in the surface or an internal void in the casting, caused by solidification shrinkage that restricts the amount of molten metal present in the last region to freeze. It is sometimes called as 'pipe'. Proper riser design can solve this problem.

Microporosity: network of small voids distributed throughout the casting caused by localized solidification shrinkage of the final molten metal.

Classification of casting defects

Casting defects		
Surface Defect	**Internal Defect**	**Visible defects**
Blow	*Blow holes*	*Wash*
Scar	*Porosity*	*Swell*
Blister	*Pin holes*	*Misrun*
Drop	*Inclusions*	*Cold shut*
Scab	*Dross*	*Hot tear*
Penetration		*Shrinkage/Shift*
Buckle		

Surface Defects

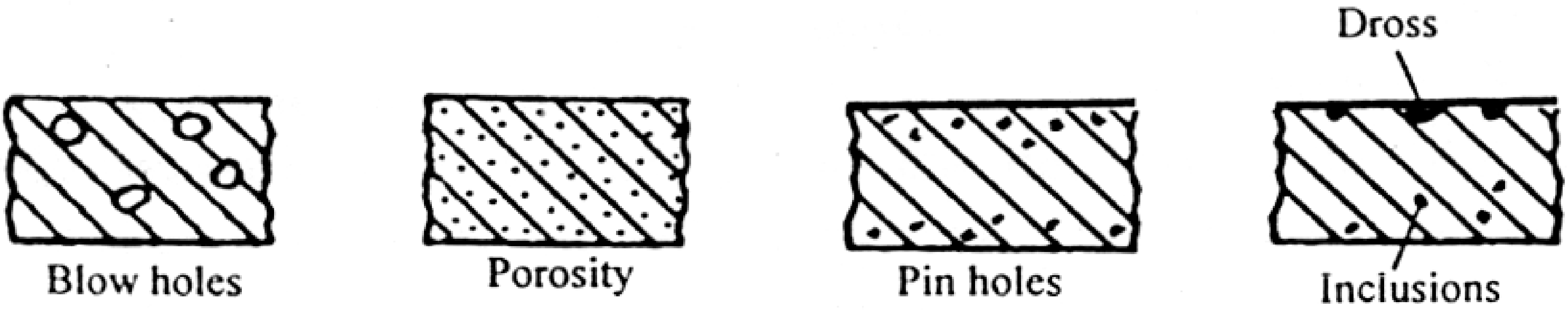


(a) Surface defects

- These are due to poor design and quality of sand molds and general cause is poor ramming
- Blow is relatively large cavity produced by gases which displace molten metal from convex surface. Scar is shallow blow generally occurring on a flat surface. A scar covered with a thin layer of metal is called blister. These are due to improper permeability or venting. Sometimes excessive gas forming constituents in moulding sand

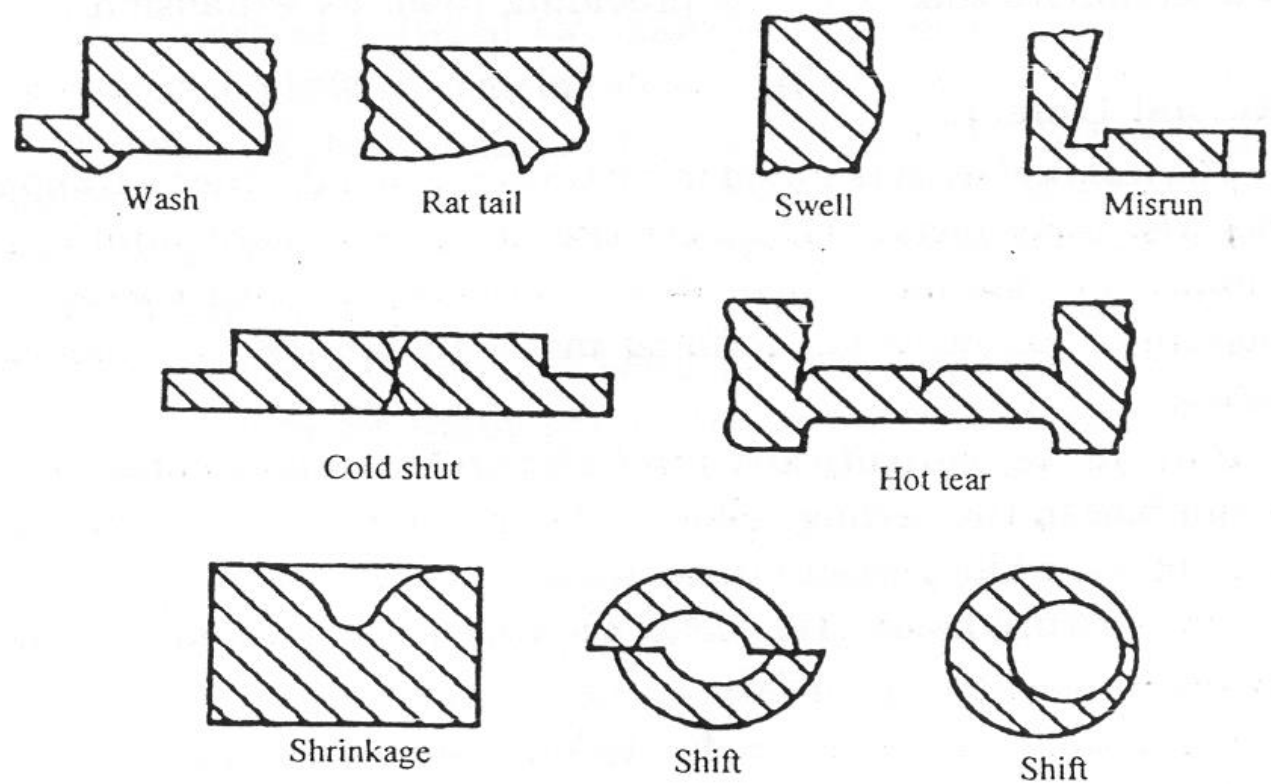
- Drop is an irregularly-shaped projection on the cope surface caused by dropping of sand.
- A scab when an up heaved sand gets separated from the mould surface and the molten metal flows between the displaced sand and the mold.
- Penetration occurs when the molten metal flows between the sand particles in the mould. These defects are due to inadequate strength of the mold and high temperature of the molten metal adds on it.
- Buckle is a vee-shaped depression on the surface of a flat casting caused by expansion of a thin layer of sand at the mould face. A proper amount of volatile additives in moulding material could eliminate this defect by providing room for expansion.

Internal Defects

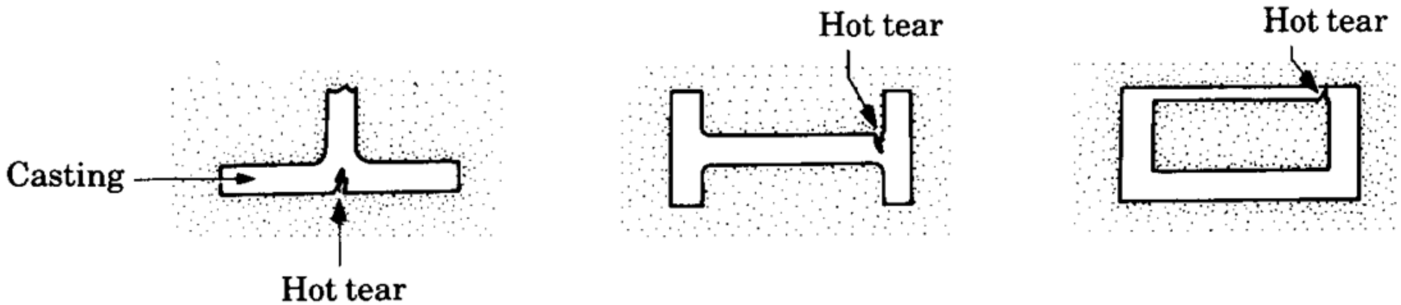


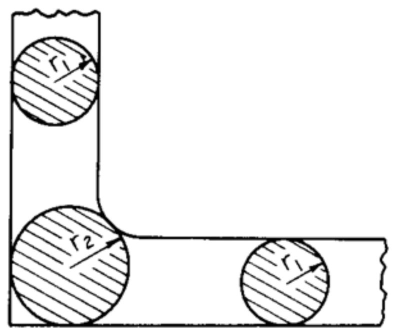
- The internal defects found in the castings are mainly due to trapped gases and dirty metal. Gases get trapped due to hard ramming or improper venting. These defects also occur when excessive moisture or excessive gas forming materials are used for mould making.
- Blow holes are large spherical shaped gas bubbles, while porosity indicates a large number of uniformly distributed tiny holes. Pin holes are tiny blow holes appearing just below the casting surface.
- Inclusions are the non-metallic particles in the metal matrix, Lighter impurities appearing the casting surface are dross.

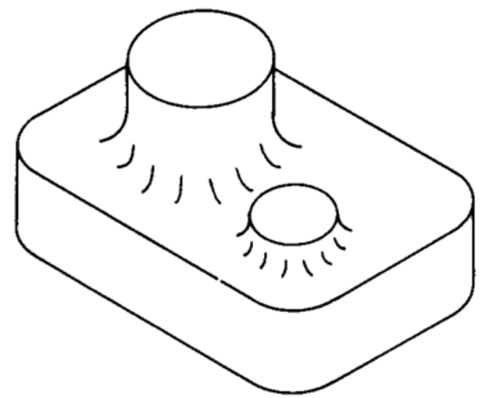
Visible Defects

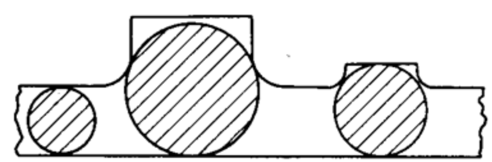


(c) Visible defects

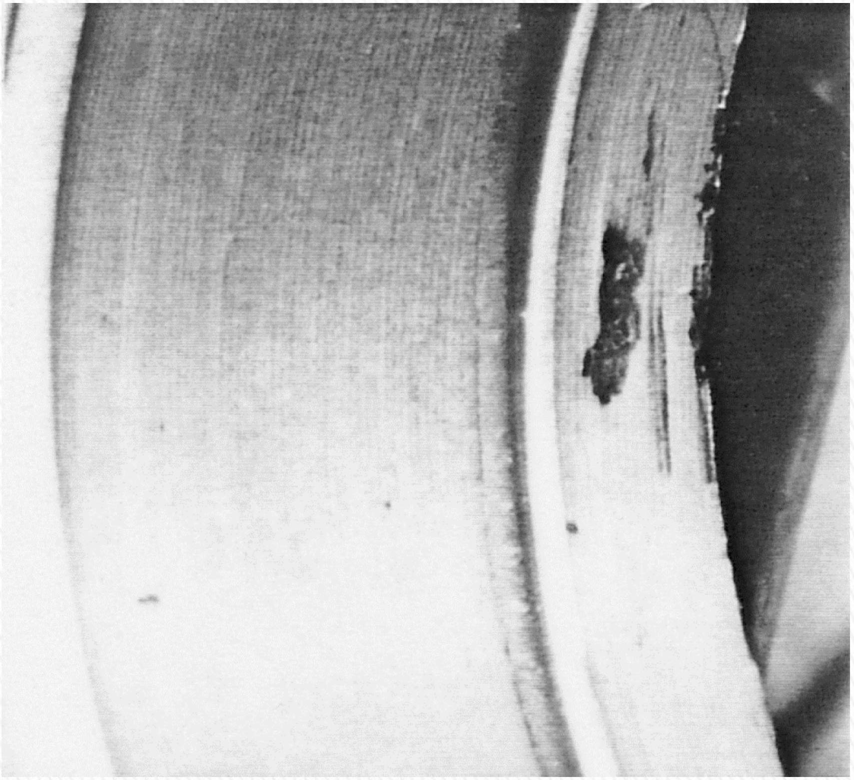

Casting
Hot tear
Hot tear
Hot tear







- Insufficient mould strength, insufficient metal, low pouring temperature, and bad design of casting are some of the common causes.
- Wash is a low projection near the gate caused by erosion of sand by the flowing metal. Rat tail is a long, shallow, angular depression caused by expansion of the sand. Swell is the deformation of vertical mould surface due to hydrostatic pressure caused by moisture in the sand.
- Misrun and cold shut are caused by insufficient superheat provided to the liquid metal.
- Hot tear is the crack in the casting caused by high residual stresses.
- Shrinkage is essentially solidification contraction and occurs due to improper use of Riser.
- Shift is due to misalignment of two parts of the mould or incorrect core location.



Blister

Inclusions

UNIT II
METAL JOINING PROCESSES

Welding

- Process of Joining Similar metals by the application of heat
- Can be done with or without application of Pressure or Filler
- Edge of the metal is melted or brought into plastic or condition

A Brief History of Welding

- Late 19th Century
  - Scientists/engineers apply advances in electricity to heat and/or join metals (Le Chatelier, Joule, etc.)
- Early 20th Century
  - Prior to WWI welding was not trusted as a method to join two metals due to crack issues
- 1930's and 40's
  - Industrial welding gains acceptance and is used extensively in the war effort to build tanks, aircraft, ships, etc.
- Modern Welding
  - the nuclear/space age helps bring welding from an art to a science

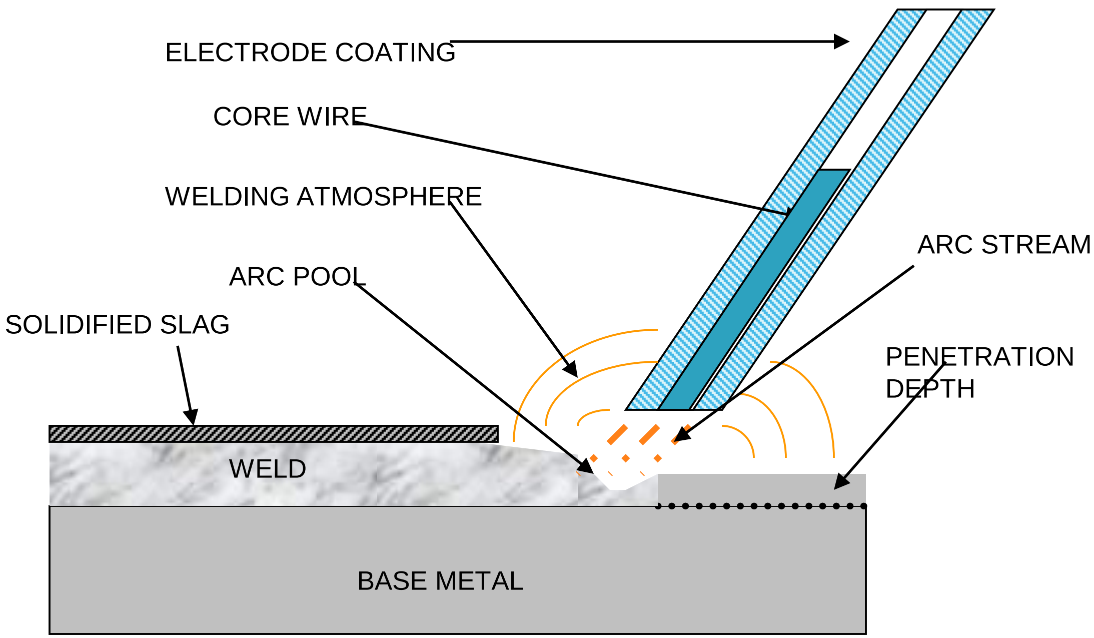
Application of Welding

- Structural Joints of Bridges and buildings, Pipelines
- Air craft Frame works
- Railway wagons
- Automobile bodies
- Ship building

Types of Welding

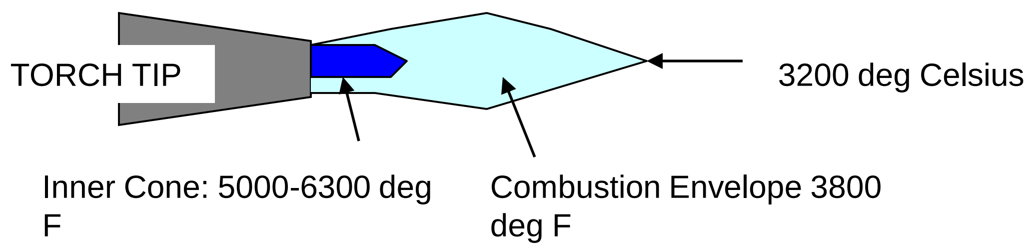
- Fusion
  - Thermit
    - Submerged
    - Atomic Hydrogen Atom
    - Metal Arc
    - Electro Slag
  - Arc
    - MIG
  - Gas
    - Oxyacetylene
    - Oxy Hydrogen

Fusion Welding



Oxyacetylene Welding

- Flame formed by burning a mix of acetylene (C_2H_2) and oxygen



- Fusion of metal is achieved by passing the inner cone of the flame over the metal
- Oxyacetylene can also be used for cutting metals

Types of System

- High Pressure System– 0.1 to 3.5 bar
- Low Pressure System– 0.5 to 1.5 bar

- Air acetylene Welding
  - Air is used instead of oxygen
  - Air is taken from atmosphere compressed in a compressor and mixed with acetylene
  - Lead and Low melting alloys
  - Temperature is lower than obtained By other gas processes

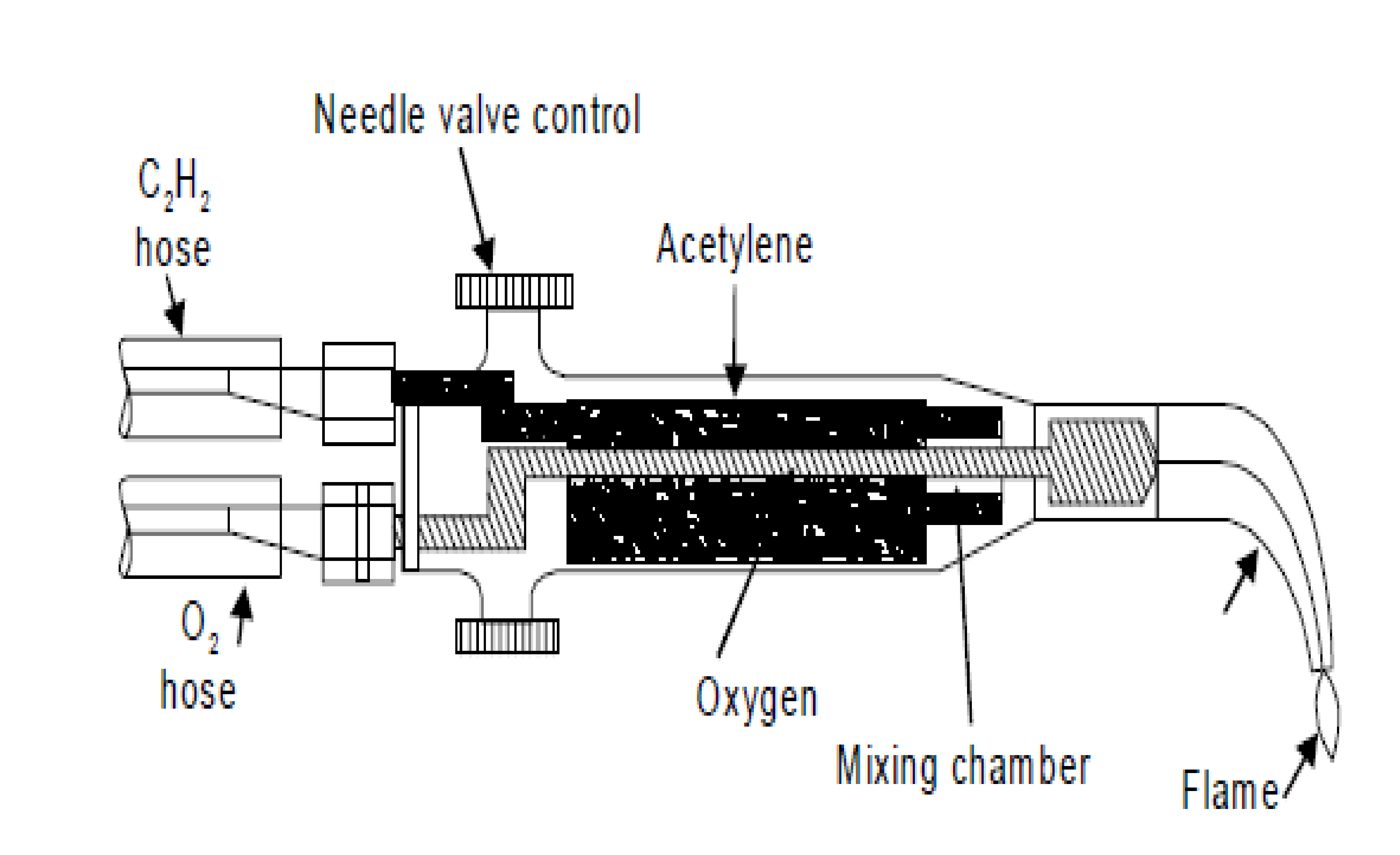
- Oxy Hydrogen Welding
  - Oxygen and Hydrogen are mixed with Required Proportion
  - Special Regulator used for monitoring the Hydrogen Gas
  - Low Temperature Material like Aluminum, Lead and magnesium

- Gas Welding Equipments
- Gas Cylinder
  - Standard Color for Oxygen is **black**(**125** to **140** kg/cm^2)
  - Standard color for acetylene is **maroon**(**16** kg/cm^2)

- Pressure Regulator
  - Working Pressure of Oxygen is 0.7 to 2.8 kg/cm3
  - Working Pressure of acetylene is 0.07 to 1.03 kg/cm3

- Pressure Gauges
  - Cylinder Pressure
  - Working pressure of welding
  - Two of them on oxygen and acetylene cylinder
- Houses
  - Oxygen cylinder is with black color hoses
  - Acetylene Cylinder is with red color.

Welding Torch



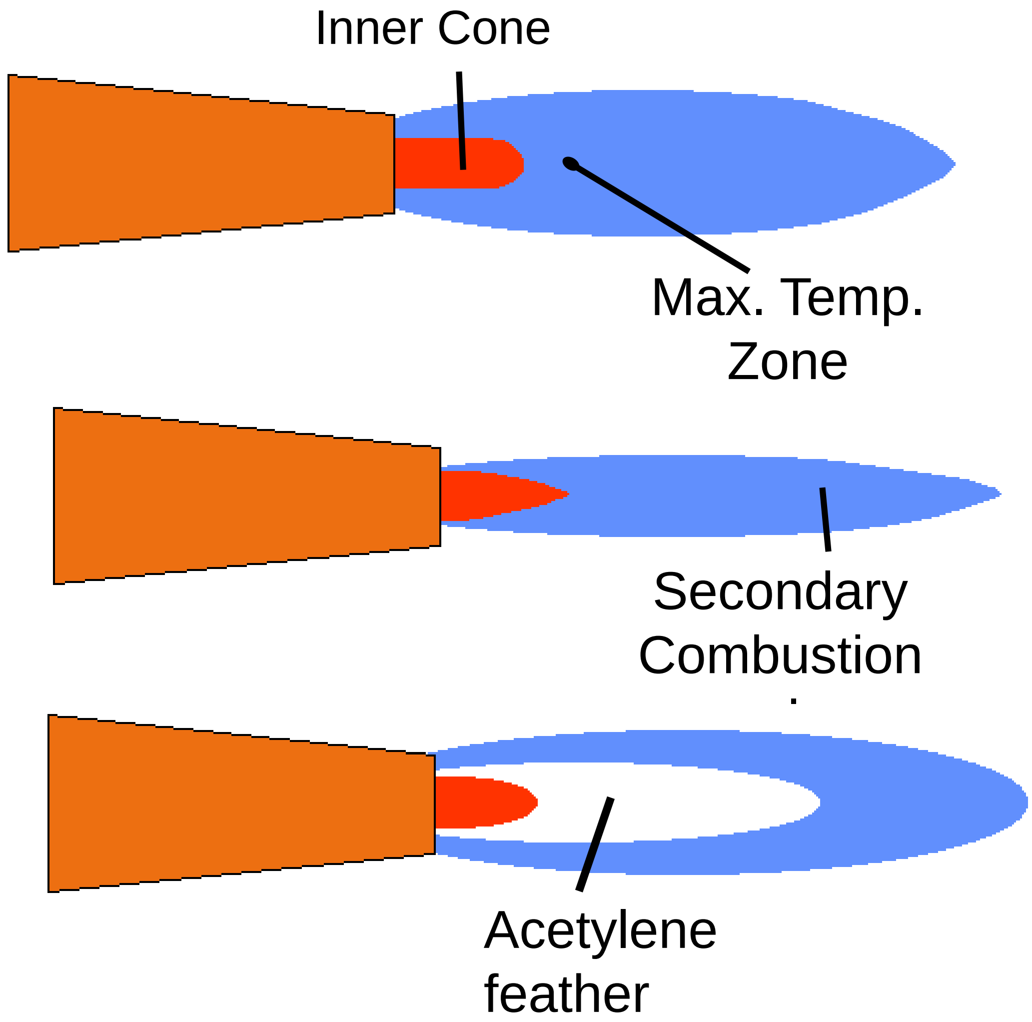
- Goggles
    - To protect eyes from flame and UV and Infrared rays
- Welding Gloves
    - To protect hand from Injury caused by heat and splashes
- Spark Lighter
    - Igniter to start burning of oxy acetylene gases
- Wire Brush
    - Used to clean the weld joint before and after welding

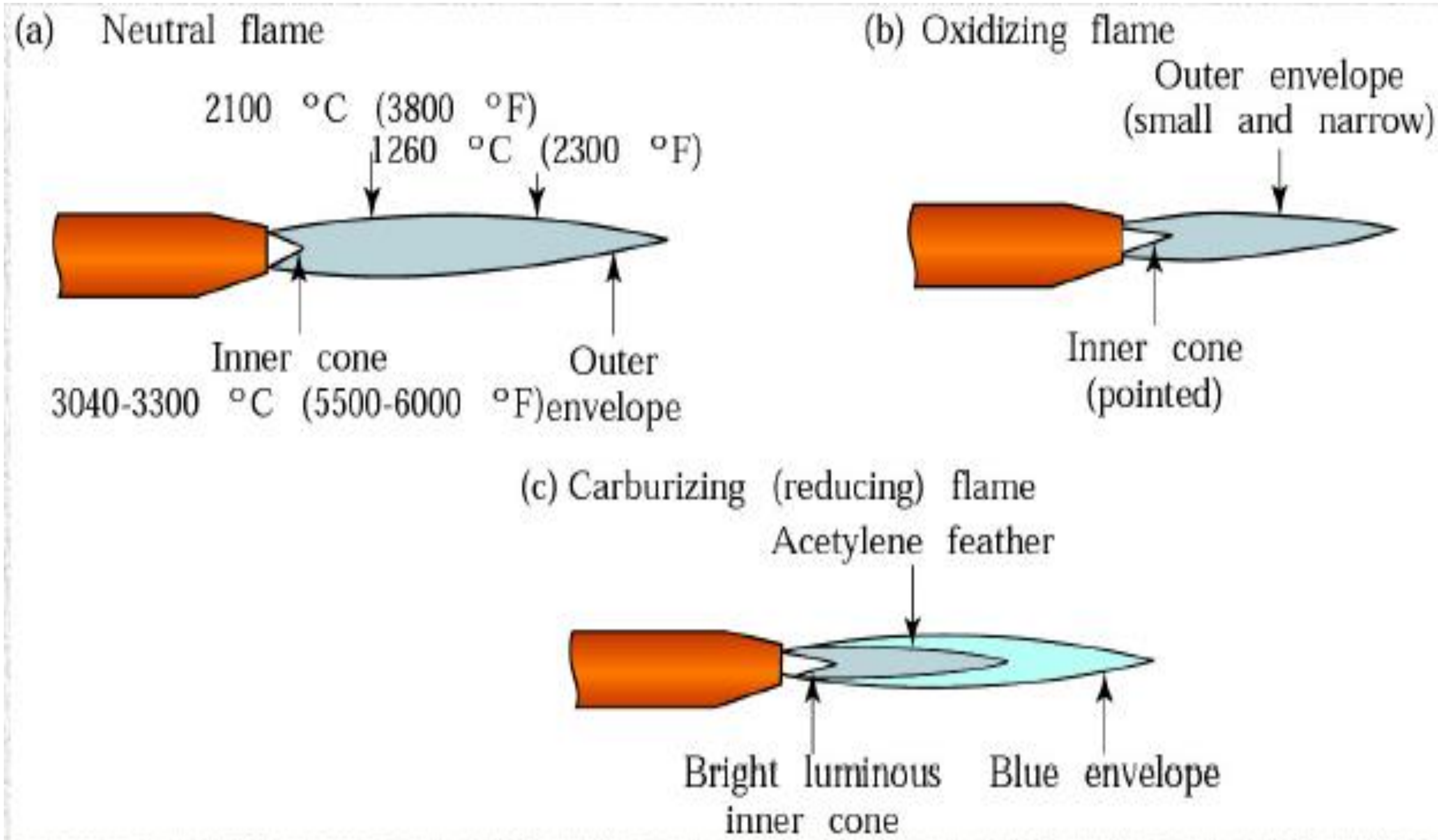
The Oxy-acetylene welding Flame

Reducing or Carburizing
Excess acetylene (0.9:1)
(Alloy steels and aluminium alloys)

Oxidizing
Excess oxygen (1.5:1)
(Brasses, Bronzes, copper)

Neutral
Equal acetylene & oxygen
(low carbon steel, mild steels).





(a) Neutral flame
2100 °C (3800 °F)
1260 °C (2300 °F)
Inner cone
3040-3300 °C (5500-6000 °F)
Outer envelope
(b) Oxidizing flame
Outer envelope
(small and narrow)
Inner cone
(pointed)
(c) Carburizing (reducing) flame
Acetylene feather
Bright luminous inner cone
Blue envelope

The Oxy-acetylene welding Flame

Carburising

Neutral

Oxidising

Gas Welding Technique

- Torch Size
- Filler Material
- Method of Moving the torch
- Angle At which the torch is held

- Leftward or Forward Welding
  - Torch flames moves from right to left
  - Torch is held on right hand and Welding Rod on the Left hand
  - Torch is held at an angle of **60˚ to 70˚** and Welding Rod is at **30˚ to 40˚**
  - This method is suitable for **5mm** thickness and also welding for cast iron and non-ferrous metals

- Rightward or Backward Welding
  - Torch flames moves from left to right
  - There is no sideway movement in the welding
  - Torch is held at an angle of **40° to 50°** and Welding Rod is at **30° to 40°**
  - Welding Speed is **20 to 25%** higher and the fuel consumption is **15 to 25 %** lower than rightward Welding

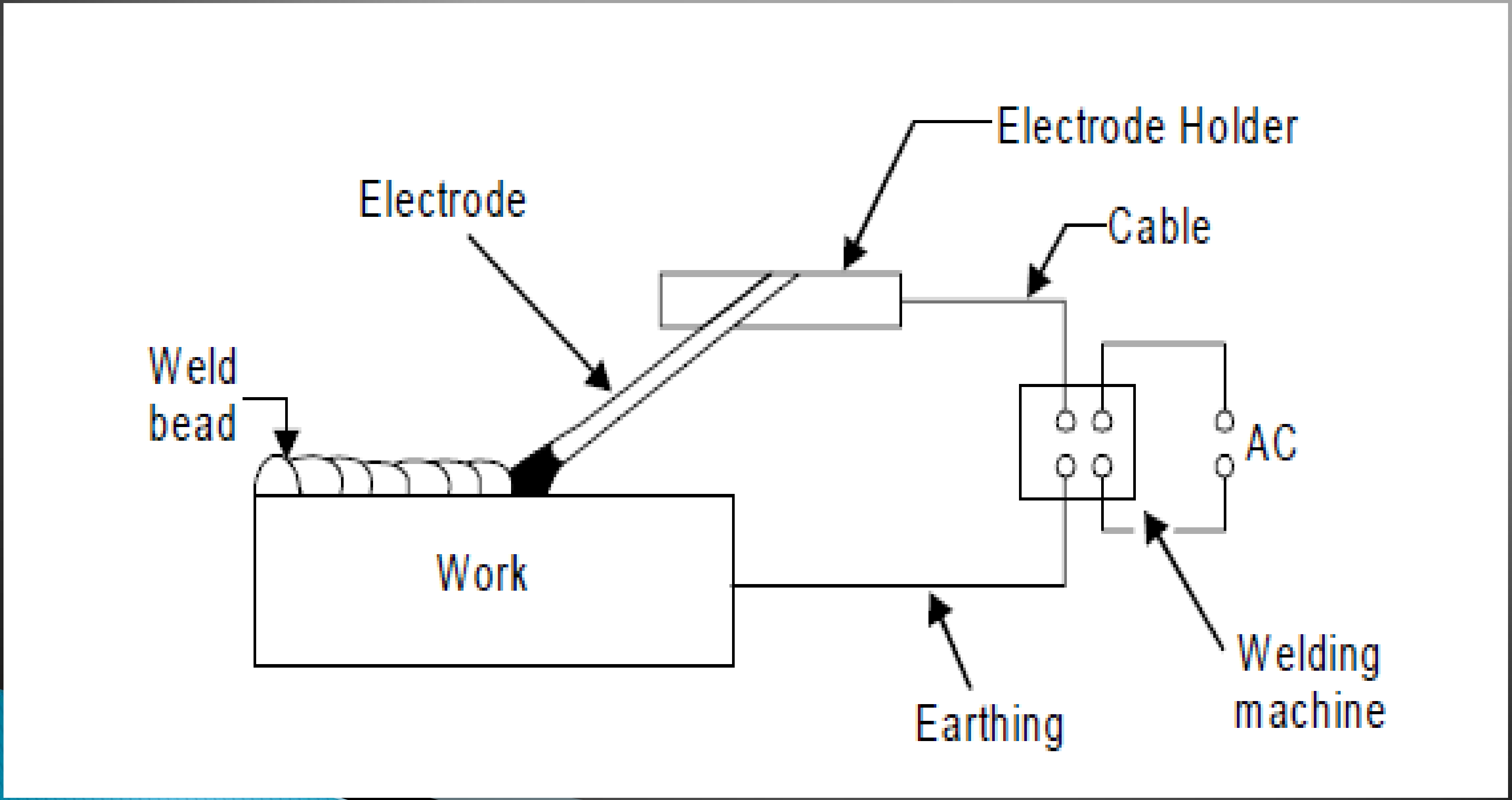
Filler Rod

- Used in gas welding to supply additional metal to make the joint
- Different alloying elements such as chromium and nickel can be added to filler rod
- Filler rods are coated with copper used to prevent the oxidation of the molten metal.

Gas Welding

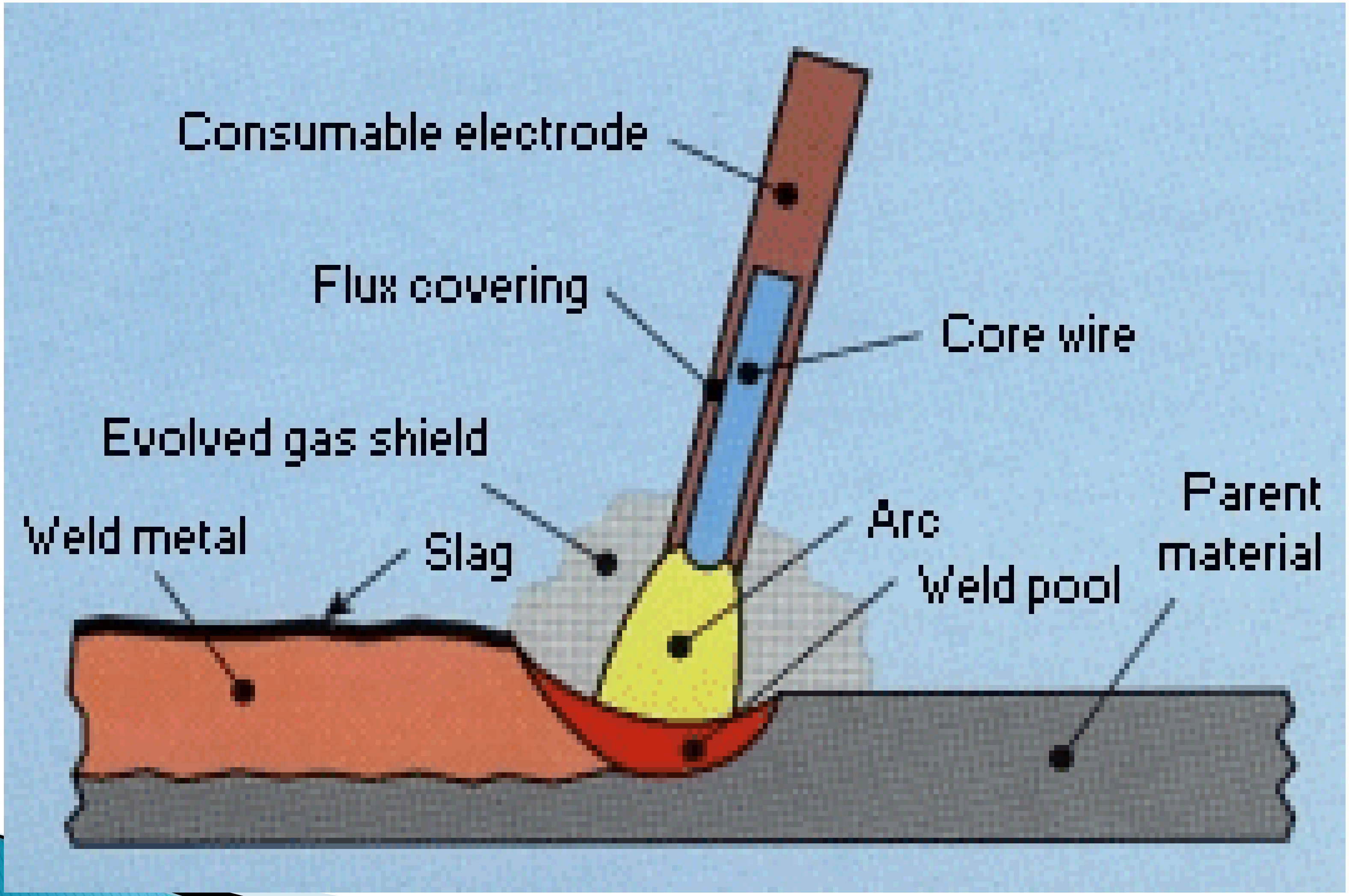
Advantage	Disadvantage
Temp of Flame can be controlled	Not suitable for joining thick plates
Amount of filler can be controlled	Slow Process
Flame can be used for cutting and welding	Strength is not good
All types of metal can be welded	Handling of gas need more care
Cost is less	Gas flame takes longer time to heat up the metal
Maintenance cost is also less	

Arc Welding


Electrode Holder
Electrode
Cable
Weld
bead
AC
Work
Earthing
Welding
machine

Manual Metal Arc Welding

- Heat is Developed by an electric arc
- Arc is produced between an electrode and the work
- Arc welding is the process of joining the metal by melting their edges


Consumable electrode
Flux covering
Core wire
Evolved gas shield
Weld metal
Slag
Arc
Parent material
Weld pool

Manual Metal Arc Welding Equipment

- Welding Generator(DC) or Transformer(AC)
- Electrode
- Electrode Holder
- Gloves
- Protective shield
- Apron
- Wire Bush
- Chipping Hammer
- Safety Goggles

- Voltage–220/440V(Requirement 20 to 90 Volts)
- Generator– Separately or Self Excited 3 Phases
- Current Range– 30 V to 80 V
- Arc Voltage – 20 V to 40 V
- Power Factor– 0.7
- Efficiency– 60%

A.C. Machine(Transformer)	D.C.Machine(Generator)
Efficiency- 80 to 85 %	Efficiency- 30 to 60 %
Power Consumption is less	Power Consumption is more
Cost of Equipment is less	Cost of Equipment is more
Any terminal Can be connected to work or electrode	Positive Terminal is connected to work and negative terminal is connected to electrode
Noiseless operation	Noisy Operation
Voltage is high and hence it is not safe	Voltage is low
Not suitable for nonferrous materials	Suitable for Ferrous and non-ferrous metals
Only coated electrode have to be used	Bare Electrode can be used
Not Preferred for Thin Sections	Preferred for Thin Sections
Maintenance is costly and difficult	Maintenance is cheaper and simple

Arc Welding	Gas Welding
Heat is Produced by Electric Arc	Heat is Produced by Gas Arc
Temperature is about 4000℃	Temperature is about 3200℃
Filler Rod is Used	Filler Rod is Used separately
Suitable for medium and Thick work	Suitable for Thin work.
Have very High strength	Do not have High strength
Filler metal should be same or Alloy of Parent metal	Filler metal should not be same or Alloy of Parent metal
Brazing and Soldering	Brazing and Soldering

Electrode Types

- Consumable Electrode
  - Not only used to produce arc but also provides filler materials during welding.
  - It may varies depends upon purpose and chemical composition of metals to be welded
  - Since It is melting , the electrode should move towards the work to maintain constant arc length
    - **Bare Electrode**
    - **Lightly Coated Electrode**
    - **Heavily Coated Electrode**

- **Bare Electrode**
  - Don’t have coating flux on their surface
  - Used for welding Wrought iron and mild steel
  - When bare electrodes are used, the molten metal reacts with atmosphere. It causes defects in weld
  - **Submerged Arc Welding** and **Inert Gas Welding**
  - Atmosphere Reaction is prevented by supplying flux or Inert Gas
- **Light Coated Electrodes**
  - Several tenths of a millimeter and 1 to 5 % of electrode weight.
  - Increases stability by ***Ionizing Coating*** and Prevent oxidation of the molten metal

- **Heavily Coated Electrode**
  - Coating is composed of ionizing, deoxidizing, gas generating, Slag forming alloying and binding materials.(1 mm to 3 mm thick).
  - Weight of such a coating material is from 15 t0 30% of the electrode

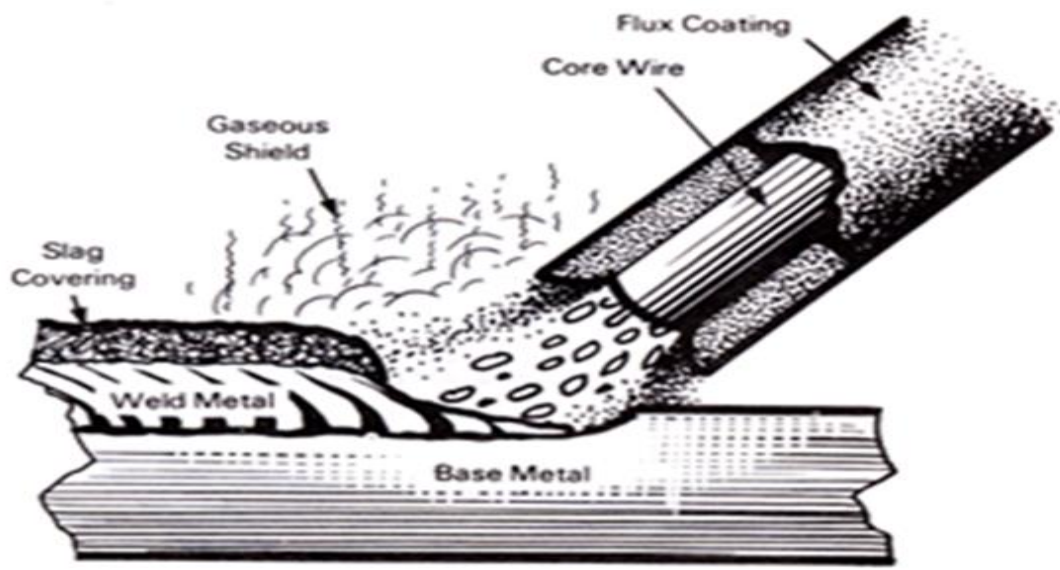


Fig. 6

- **Flux Coating Purpose**
  - Give stability to arc
  - Create a shield and prevents atmospheric reactions
  - Provide the formation of slag and protect the welding
  - Different alloying elements increases the Strength of the weld
- **Non Consumable Electrode**
  - Made up of carbon, graphite or tungsten which do not consume during welding.
  - Tungsten electrode – A.C and D.C Welding
  - Atomic hydrogen Welding and TIG welding

Electrode Material

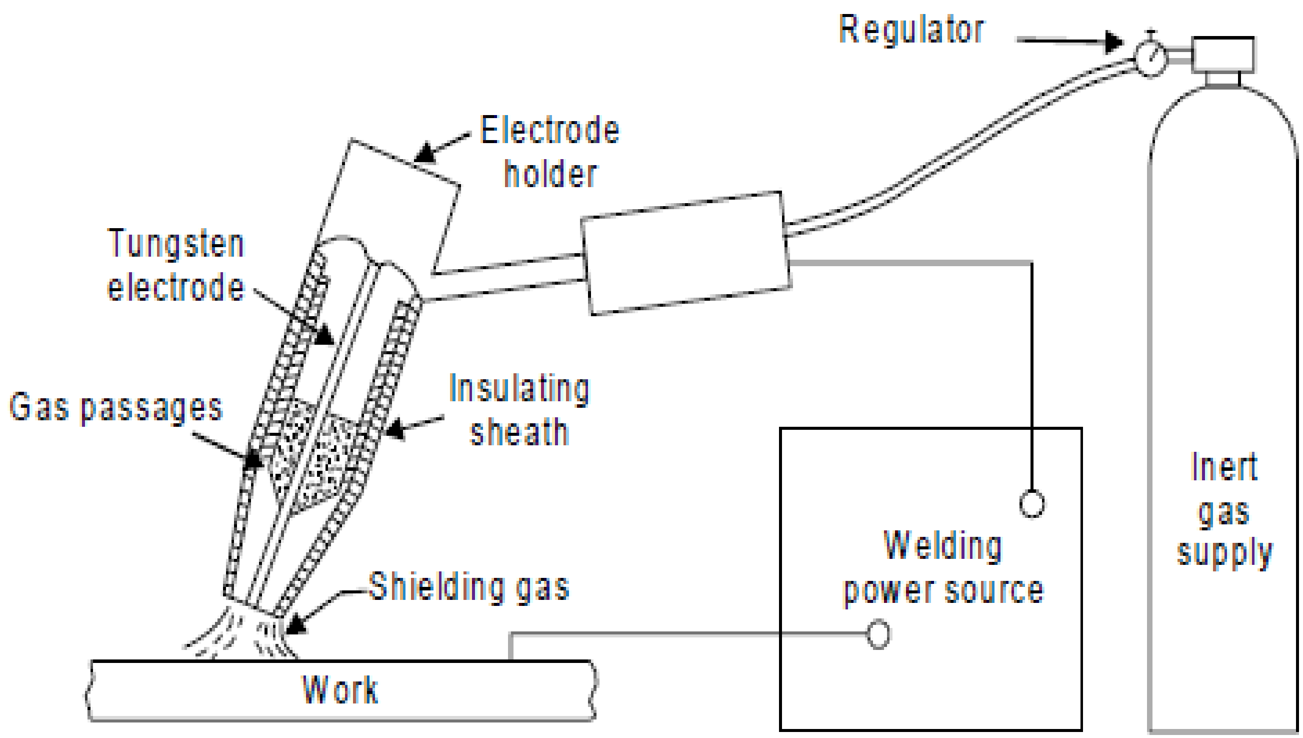
Work Piece	Electrode
Wrought Iron	Low Carbon Steel Rod
Cast Iron	Cast Iron Rods
Mild Steel	Mild Steel Copper Coated Rod
Alloy Steel	Low Alloy steel rod containing 0.25% Carbon
Aluminium	Cost Aluminium Alloy Rod
Carbon Steel	Soft Steel wire
Copper Casting	Copper Rod
Brass	Drawn Brass Rod

Filler and Flux Material in Arc Welding Process

- Flux is the area that protect the weld area from oxidation by producing CO2 gas
- Electrode Core itself act as Filler material
- This process is limited to ferrous material and further the electrodes have made possible for welding of cast iron, nickel , aluminium, Copper and other metals

Gas Tungsten Arc Welding(GTAW)

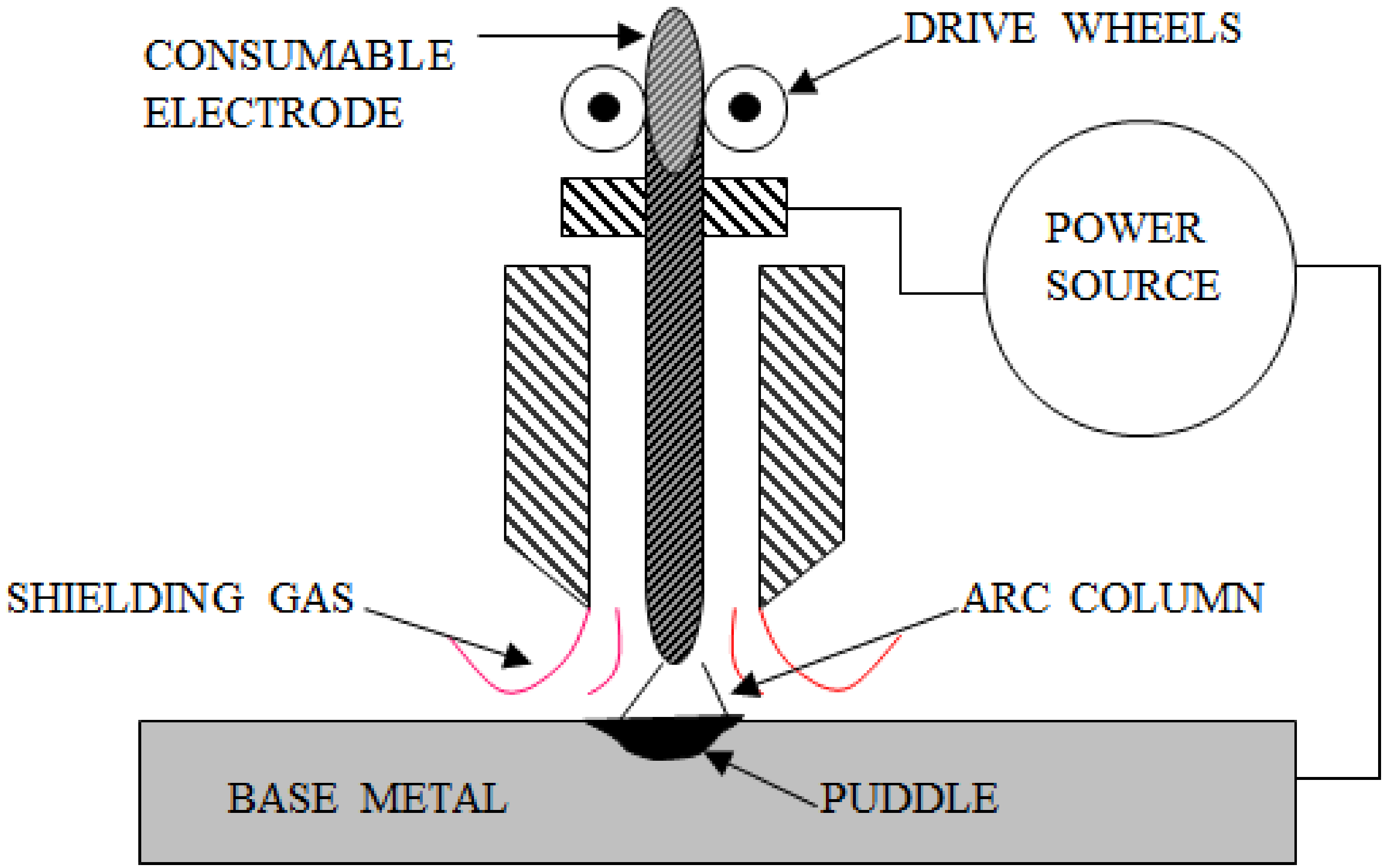
- It is also called as TIG Welding
- Electric Arc is produced between non consumable tungsten electrode and work piece



- Filler material may or may not be used.
- When a filler metal is used, it is fed manually into weld pool
- It has a high melting point of 330°C therefore it is not melted during welding
- Used for steel, Aluminium, CI, Magnesium, Stainless steel based alloys, Copper based alloys and low alloy steel
- Used for dissimilar metals
- Thickness Less than 6.5mm

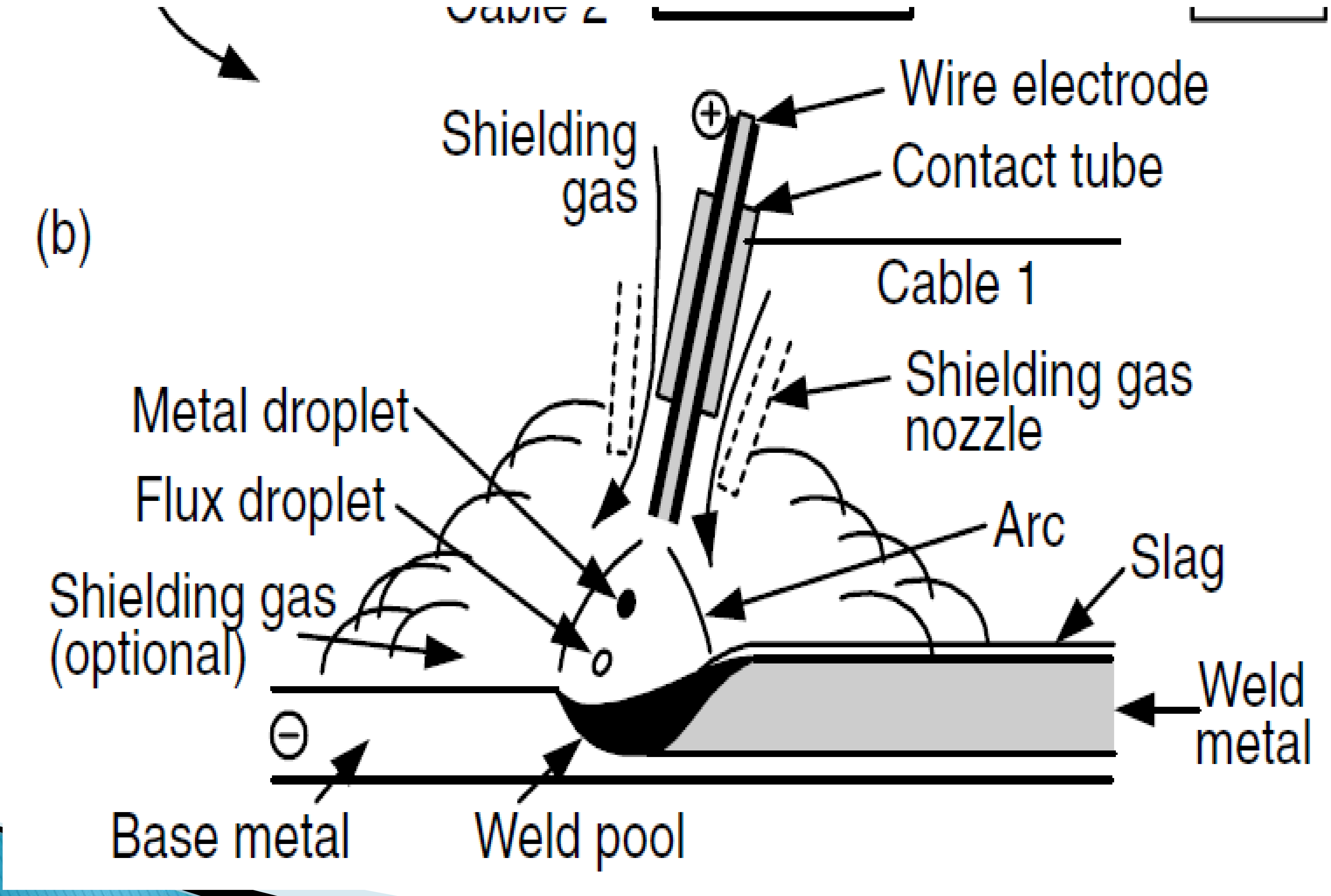
Gas Metal Arc Welding(GMAW)

- It is also called as Metal Inert Gas Welding(MIG)
- Arc is produced between a consumable metal electrode and Work Piece
- Argon or Helium Inert Gas is used
- Electrode is fed continuously through the welding head because during welding the electrode is melted and Deposited over work Piece.
- Air or Water Cooled Depends upon the current being Used.

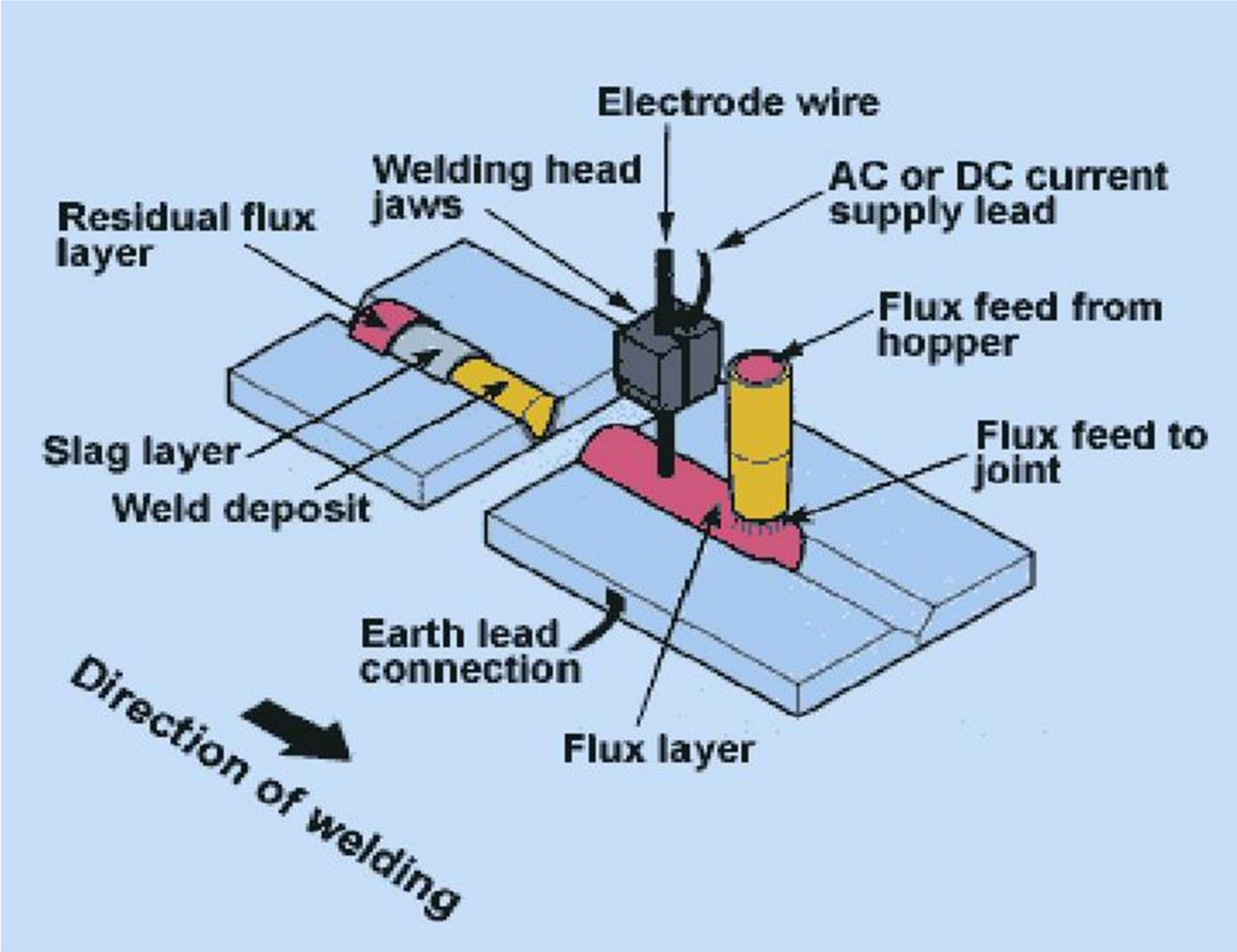

CONSUMABLE
ELECTRODE
DRIVE WHEELS
POWER
SOURCE
SHIELDING GAS
ARC COLUMN
BASE METAL
PUDDLE

Submerged Arc Welding(SAW)

- When the large Quantity of Flux is required on that time , the form of wire wound on a rotating drum or feel called as Flux Core.
- Flux is mainly used to avoid oxidation reaction with oxygen present in the atmosphere
- It is also called as **Sub Arc Welding or Hidden Arc Welding.**
- An electric arc is produced between electrode and work piece
- But the arc is submerged ie.., hidden under the flux



Cable 2
(b)
Shielding gas
Wire electrode
Contact tube
Cable 1
Shielding gas nozzle
Metal droplet
Flux droplet
Shielding gas (optional)
Arc
Slag
Weld metal
Base metal
Weld pool



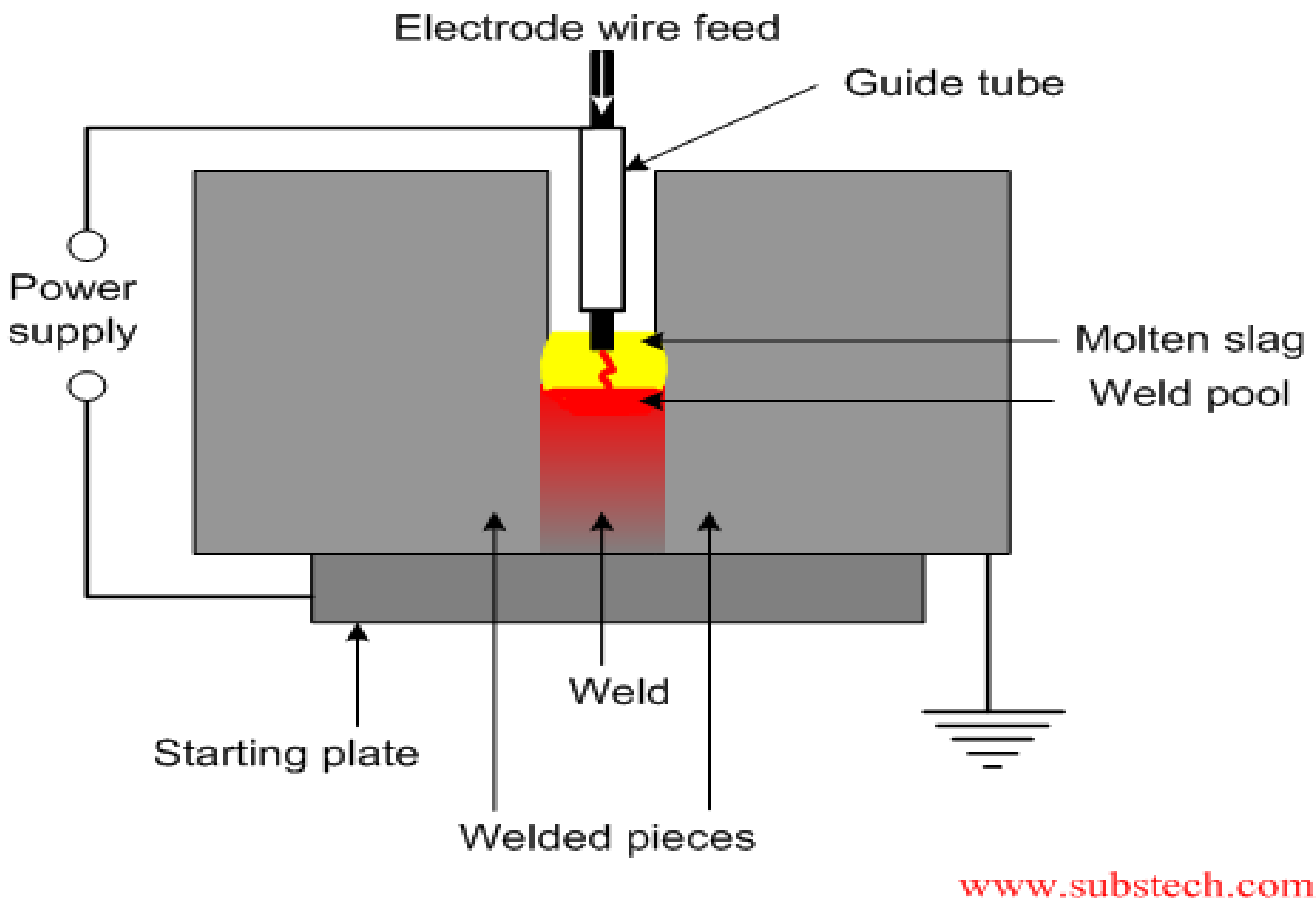
Electrode wire
Welding head jaws
AC or DC current supply lead
Residual flux layer
Flux feed from hopper
Flux feed to joint
Slag layer
Weld deposit
Earth lead connection
Flux layer
Direction of welding

- Metal electrode is continuously fed from reel by a moving head
- Flux will be supplied on the moving head i.e.., from Hopper
- Flux powder is made up of Silica, Metal Oxide and other compounds fused together and crushed on proper size.
- Voltage is 25 to 40 V
- D.C is 600 A to 1000 V and A.C. is 200 A

Electro Slag Welding (ESW)

- Electric Arc is struck in between electrode and work jointed by the use of steel wood
- Welding flux is added and melted by the use of heat flux added and further melted by the use of heat from arc.
- Temperature of slag remains between 1600 to 1900˚C
- This high amount of heat energy is enough for melting the work piece and electrode

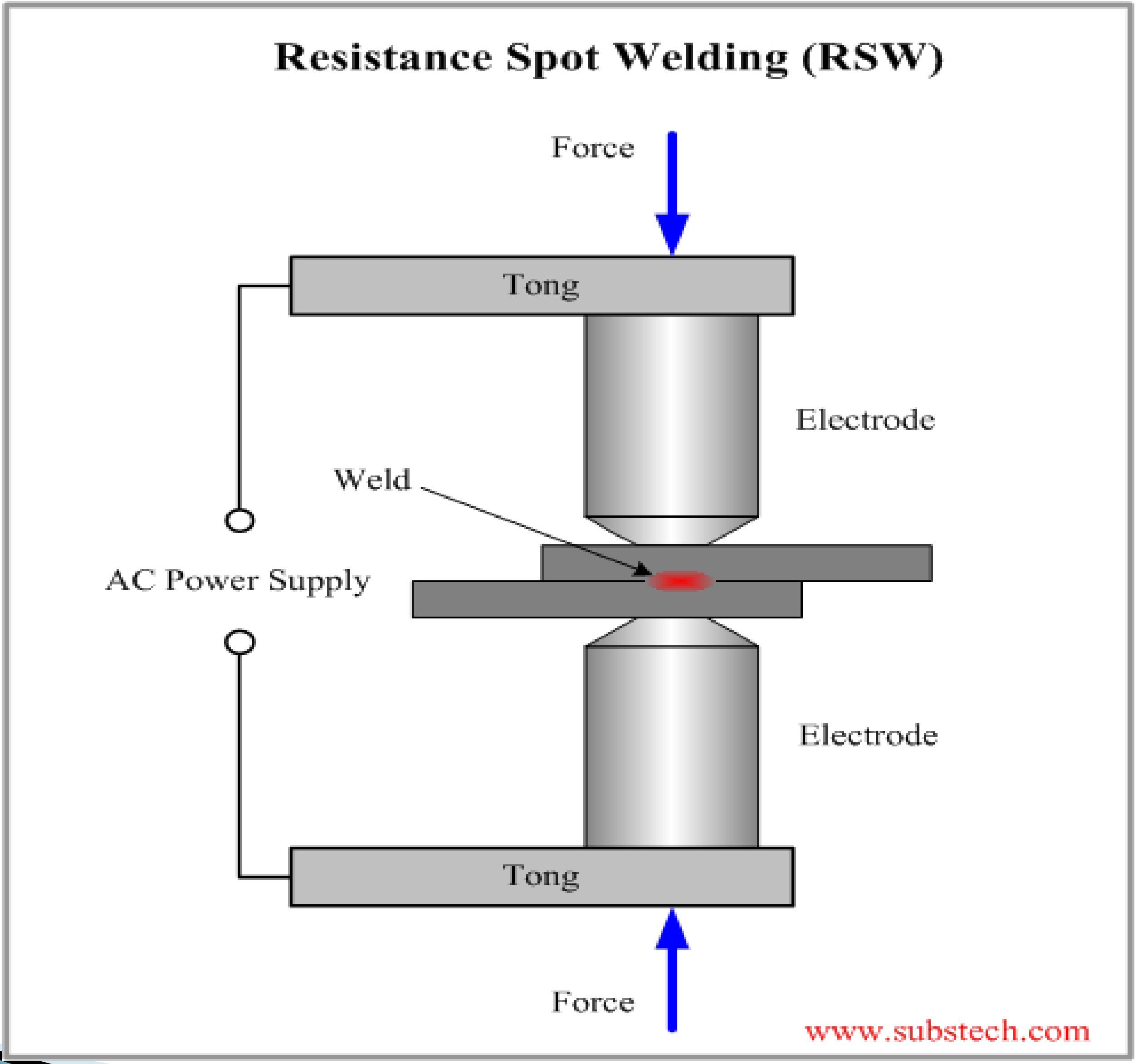
Electroslag Welding



- **Applications**
  - Used for welding carbon alloy steels and nickel alloys
  - Heavy plates can be welded
- **Advantages**
  - Heavy Thickness metals
  - Low stress formation
  - Low distortion and High deposition of the welds
- **Disadvantages**
  - Hot cracking
  - Grain size become larger
  - Difficult for cylindrical objects

Resistance Welding

- Parts to be joined are heated to plastic state by their resistance to the flow of electric current and mechanical pressure is applied to complete the weld.
- Metal parts to be welded are p[laced between the electrodes
- When electric current is passed the metals become red hot plastic condition.
- Now the mechanical pressure is applied to complete the weld

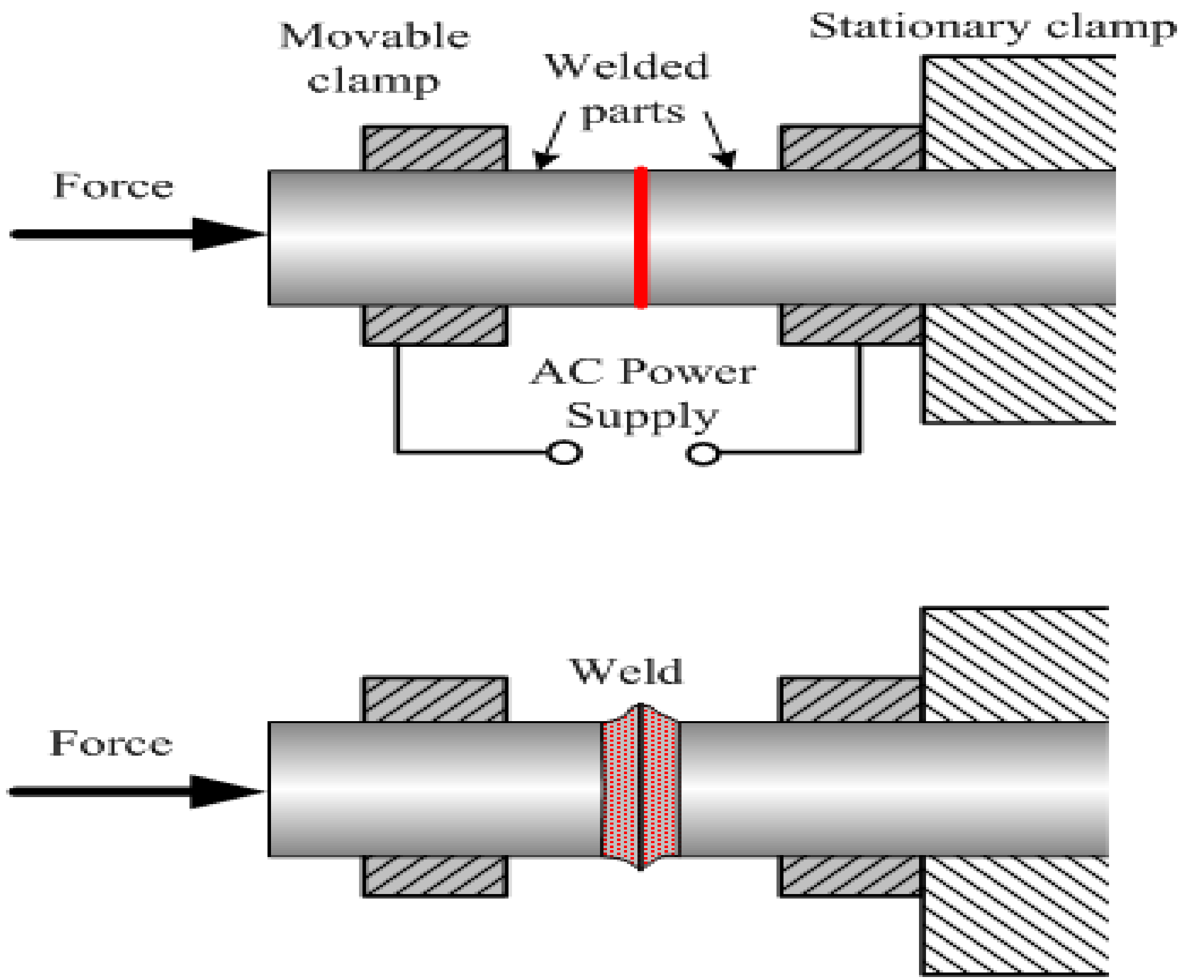

Resistance Spot Welding (RSW)
Force
Tong
Electrode
Weld
AC Power Supply
Electrode
Tong
Force
www.substech.com

- $Q=I^2RT$
- 4 to 12 volts is used depends on the composition
- Power supply ranges from 6 to 18 KW per cm^3
- **Spot welding**
  - Metal thickness from 0.0025 mm to 1.25 mm can be easily welded
  - Copper electrode is used
  - Electrode pressure is up to 2 KN
  - Up to 12 mm thick can be welded

Upset Butt Welding

- Edges of the work pieces has to be cleaned perfectly and flatten the parts to be welded are clamped in copper jaws
- Jaws are act as electrodes.
- When the current flows through the point of contact of jaws to form a locality of high electric resistance
- At this point the applied pressure upsets or forges the part together.
- non ferrous material of smaller cross section suc as bars , rods, wire , tubes etc..,

Butt Welding (UW)



Flash Butt Welding

- Jaws are brought together and the flash produced in between the jaws
- Once the ends reached fusing temperature and power is switched OFF
- Now the ends are forced together by the mechanical forces to complete the weld.
- The projection is finished by grinding
- Used for larger cross sections
- Non ferrous material can be welded and their alloys cannot be welded.

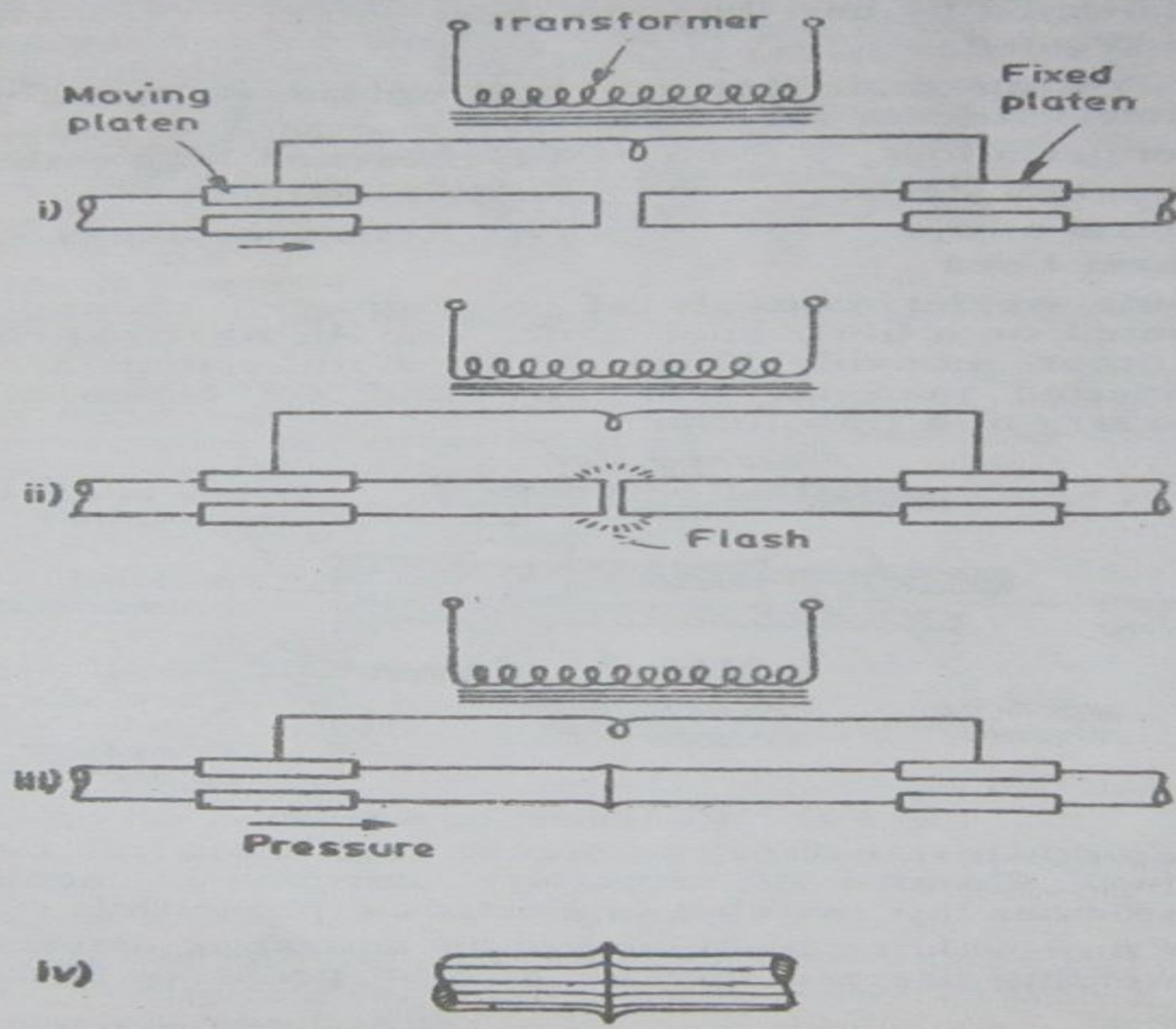
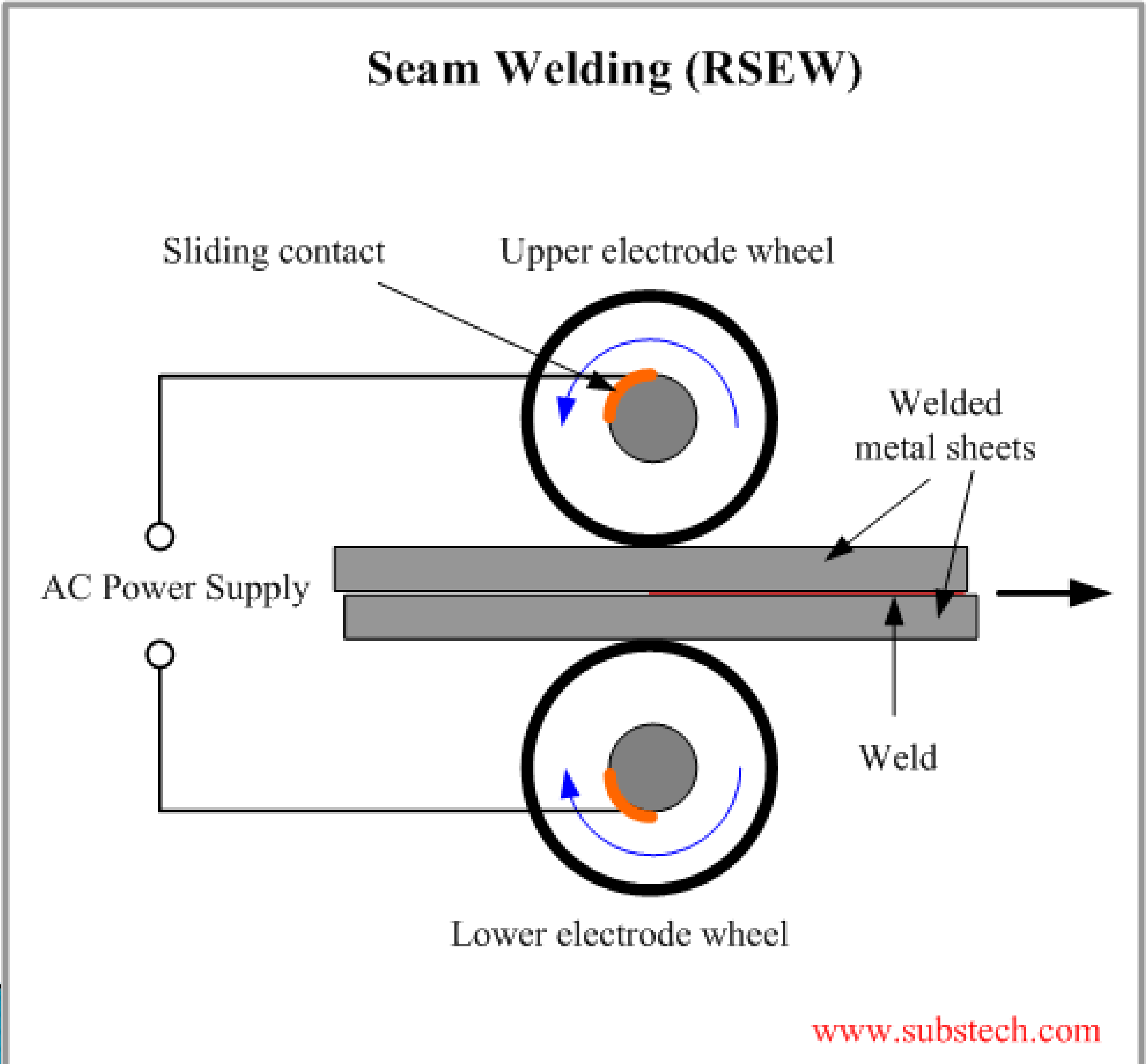


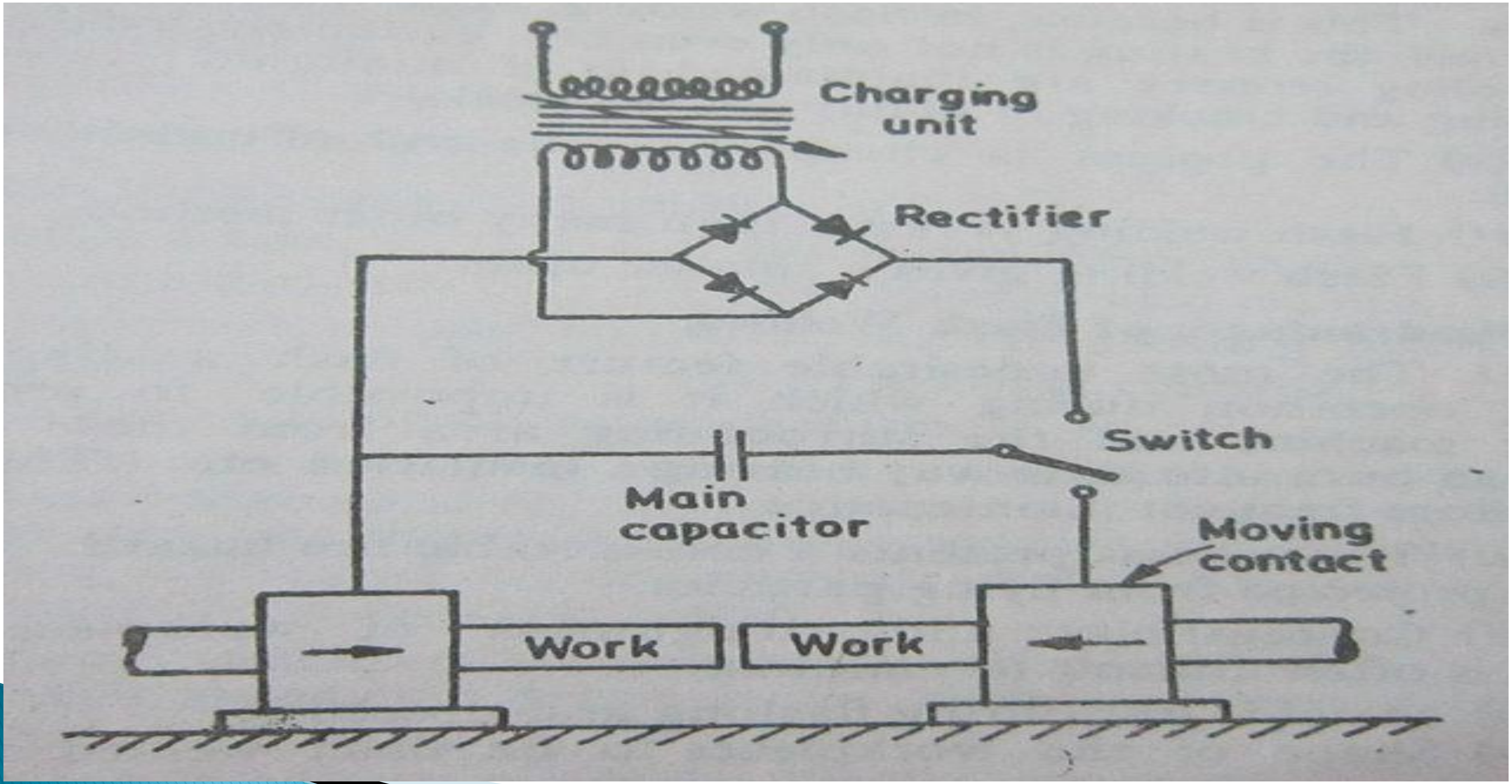
Fig. 5·25. Flash butt welding.

Seam Welding

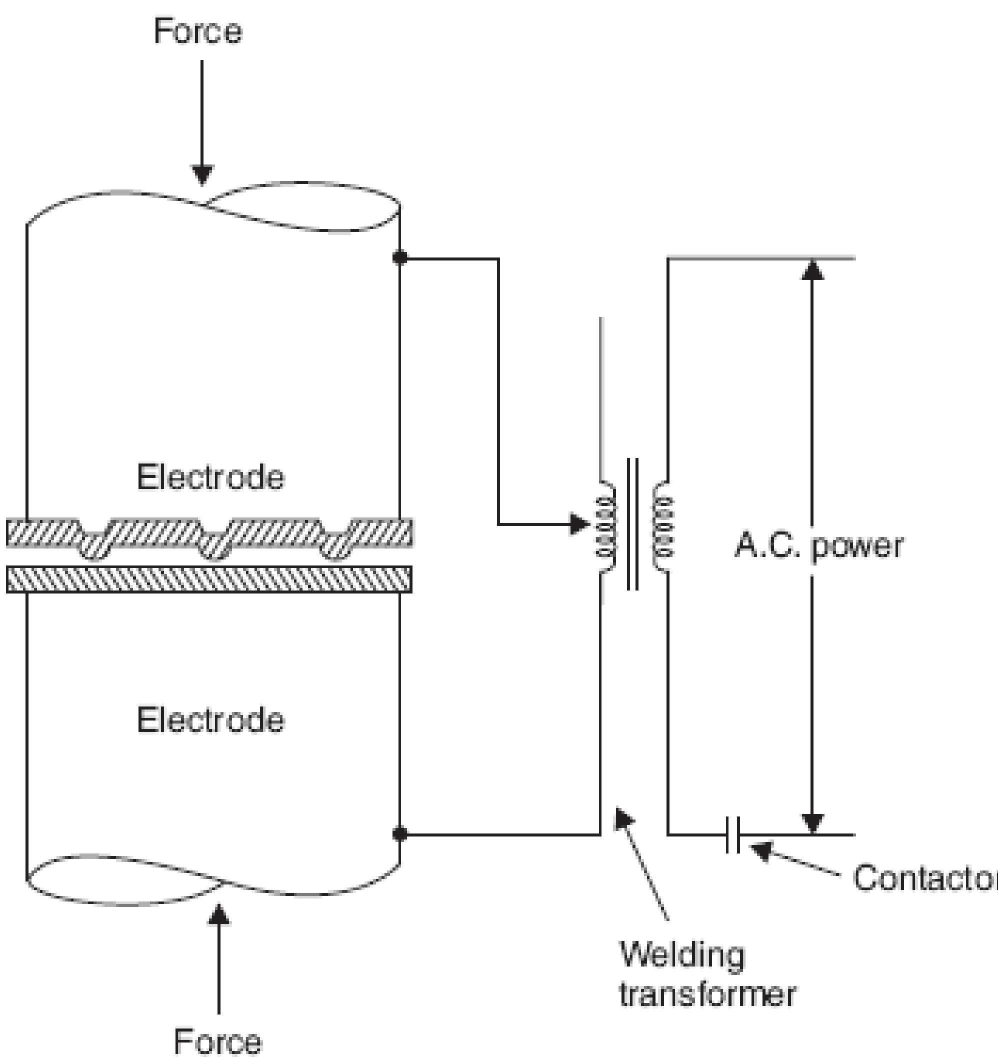
- It is Continuous Welding Joint between two overlapping pieces of sheet metal.
- When the electric current is applied between the wheel electrodes, High heat is produced between the electrodes and the pressure is applied to complete the weld.
- Work piece is continuously moved in between the wheels
- It is used for Leak proof tanks, Drums, Radiators, Automobile bodies etc..,


Seam Welding (RSEW)
Sliding contact
Upper electrode wheel
Welded
metal sheets
AC Power Supply
Weld
Lower electrode wheel
www.substech.com

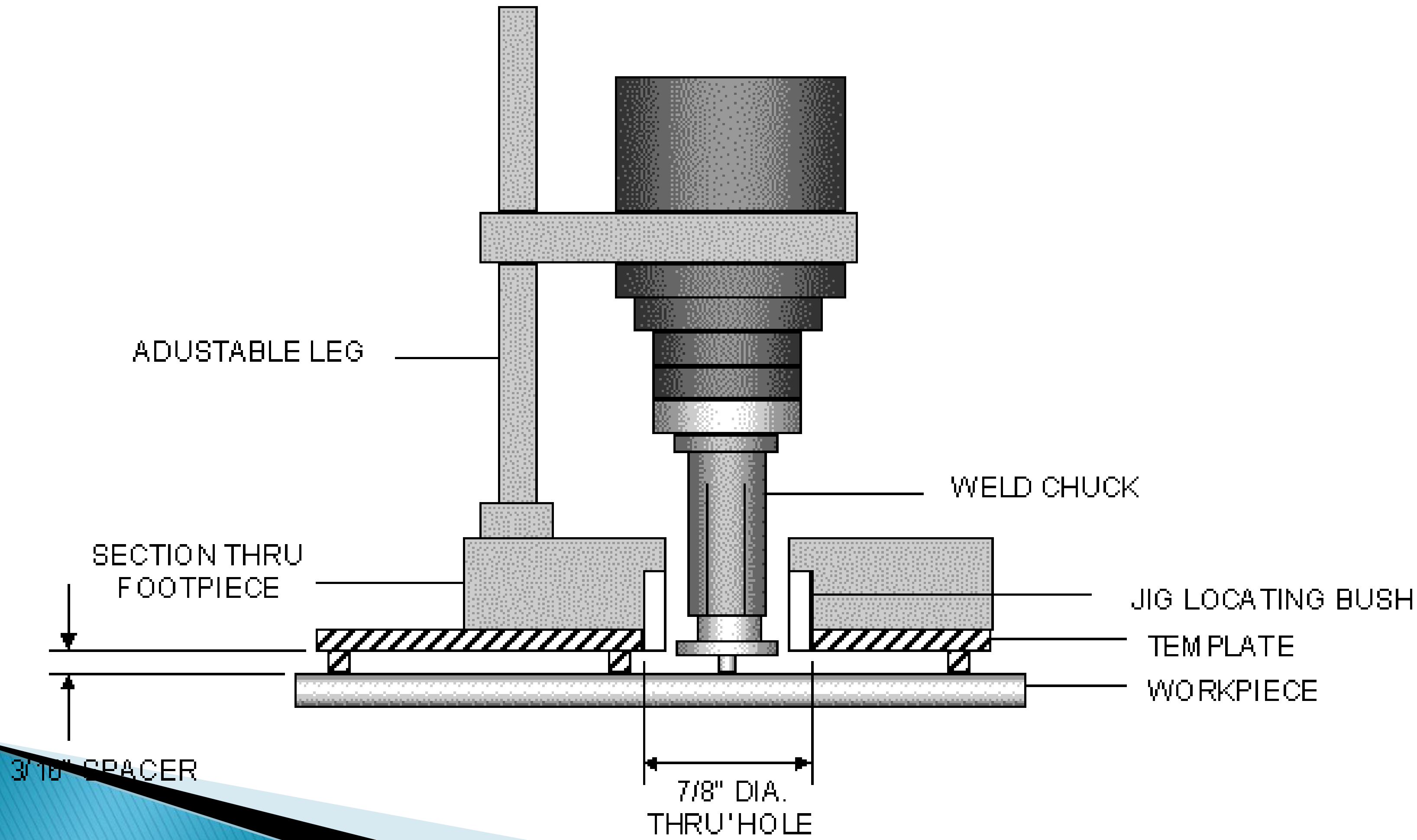
Percussion welding



Projection Welding

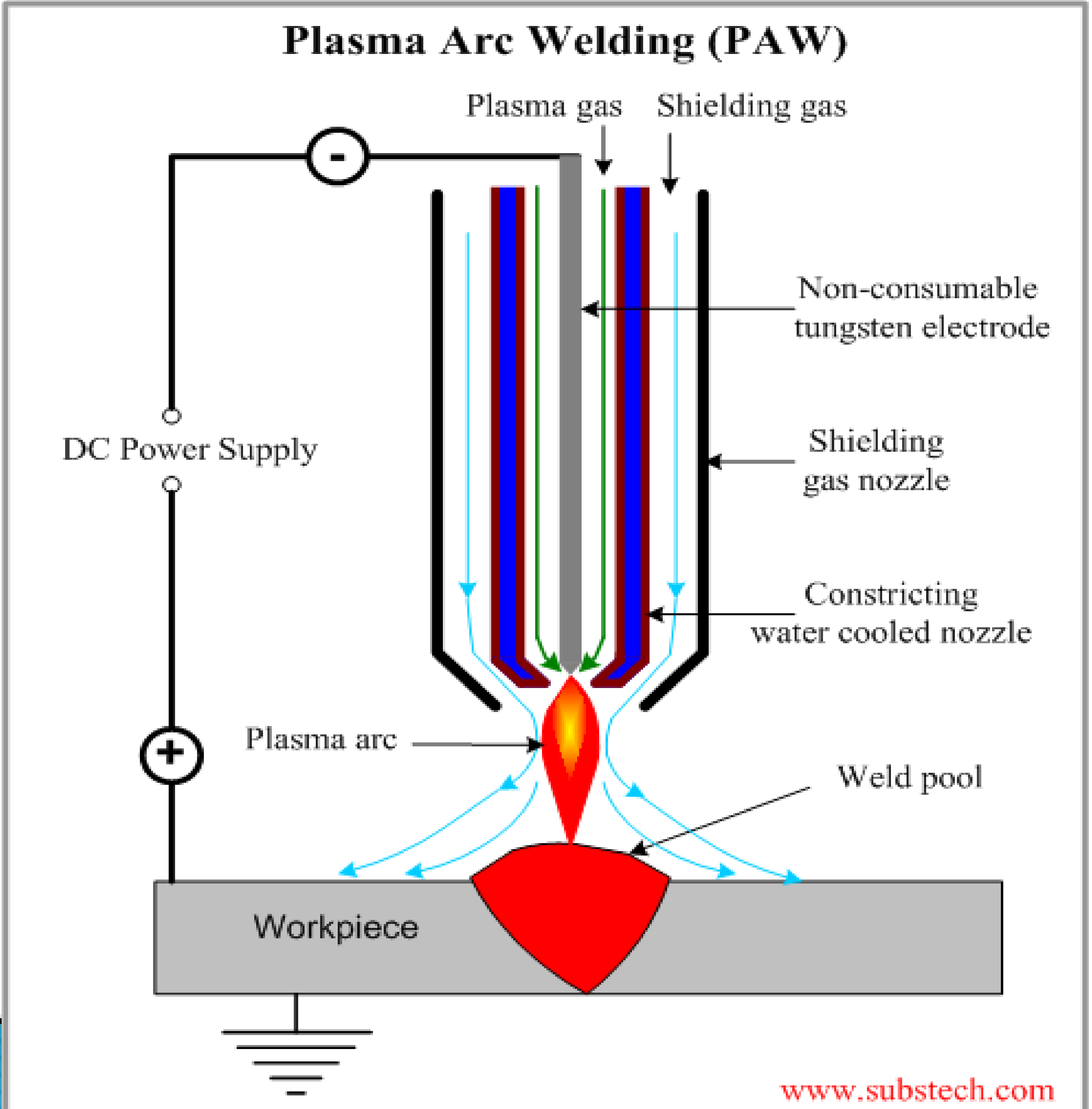


Stud Welding



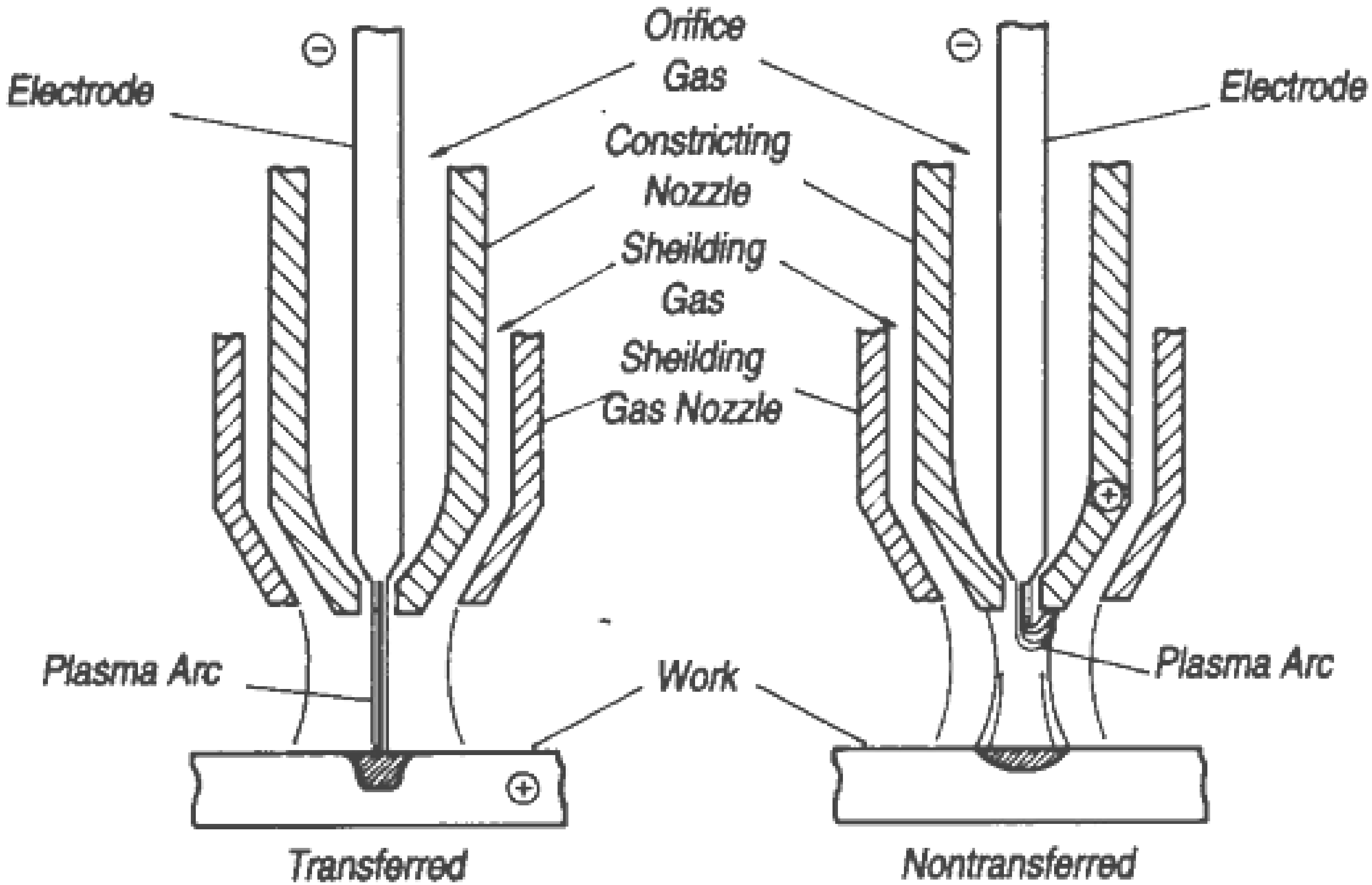
Plasma Arc Welding

- Plasma is a high temperature Ionized Gas is used
- Mixture of neutral atoms, Positively charged atoms and free elements
- When the proportion is passed through orifice the proportion of ionized gas increase plasma arc welding is formed.
- The arc is initiated by supplying electrical energy between nozzle and tungsten electrode
- Heat is normally 10000˚C to 30000˚C


Plasma Arc Welding (PAW)
Plasma gas
Shielding gas
Non-consumable tungsten electrode
DC Power Supply
Shielding gas nozzle
Constricting water cooled nozzle
Plasma arc
Weld pool
Workpiece
www.substech.com

- **Transferred Type**
  - Tungsten Electrode is connected to negative terminal and work piece connected to positive terminal
  - An pilot arc is used to for initiation.

- **Non-Transferred Type**
  - Power is directly connected with the electrode and torch of the nozzle



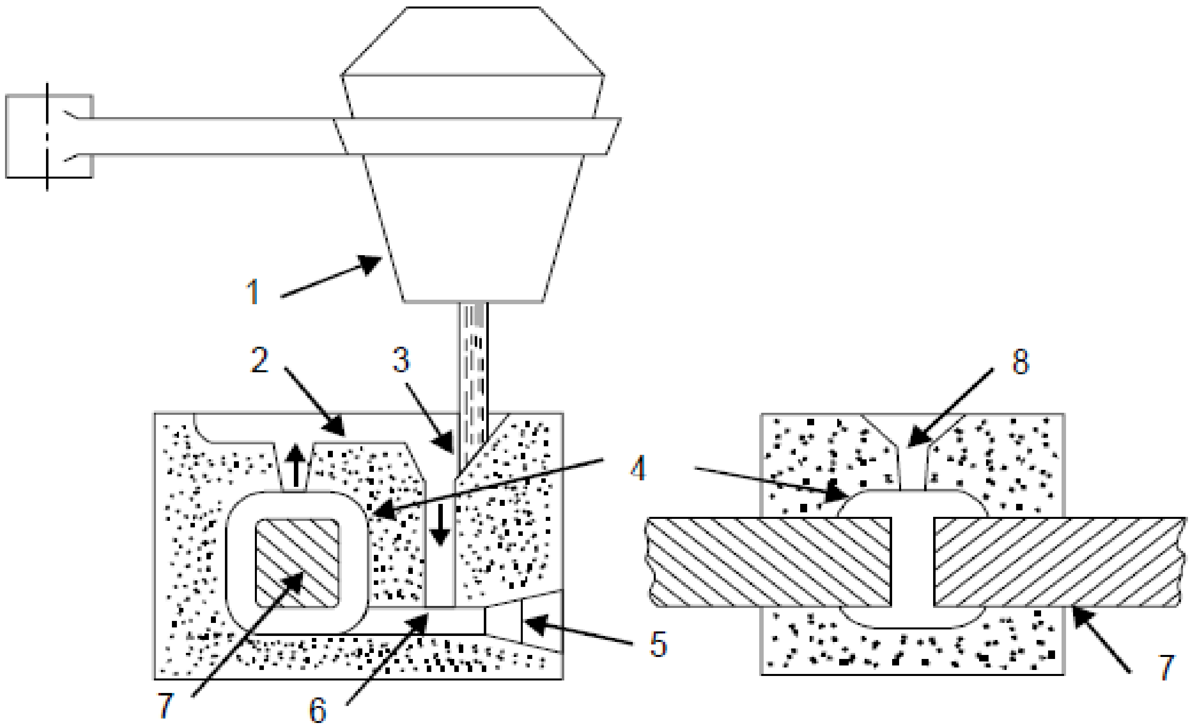
Orifice
Gas
Electrode
Constricting
Nozzle
Sheilding
Gas
Sheilding
Gas Nozzle
Electrode
Plasma Arc
Work
Plasma Arc
Transferred
Nontransferred

- Applications
  - Aerospace
  - High melting Points
  - Welding titanium Plates
  - Welding Nickel Alloys
  - Tube Mill Applications
- Advantages
  - Penetration is uniform
  - High Accuracy and Speed
- Disadvantage
  - Huge Noise
  - UV Radiations
  - Electric Hazards

Thermit Welding

- It may be of forge or fusion kind of welding.
- It is a process which uses a mixture of iron oxide
- and granular aluminium. This mixture in superheat liquid state is poured around the parts to be joined. The joint is equipped with the refractory mould structure all around.
- only the heat of Thermit reaction is utilized to bring the surface of metal to be welded in plastic state and pressure is the applied to complete the weld
- The thermit reaction is of the order of 3000°C

$$8Al + 3Fe_3O_4 = 4Al_2O_3 + 9Fe$$



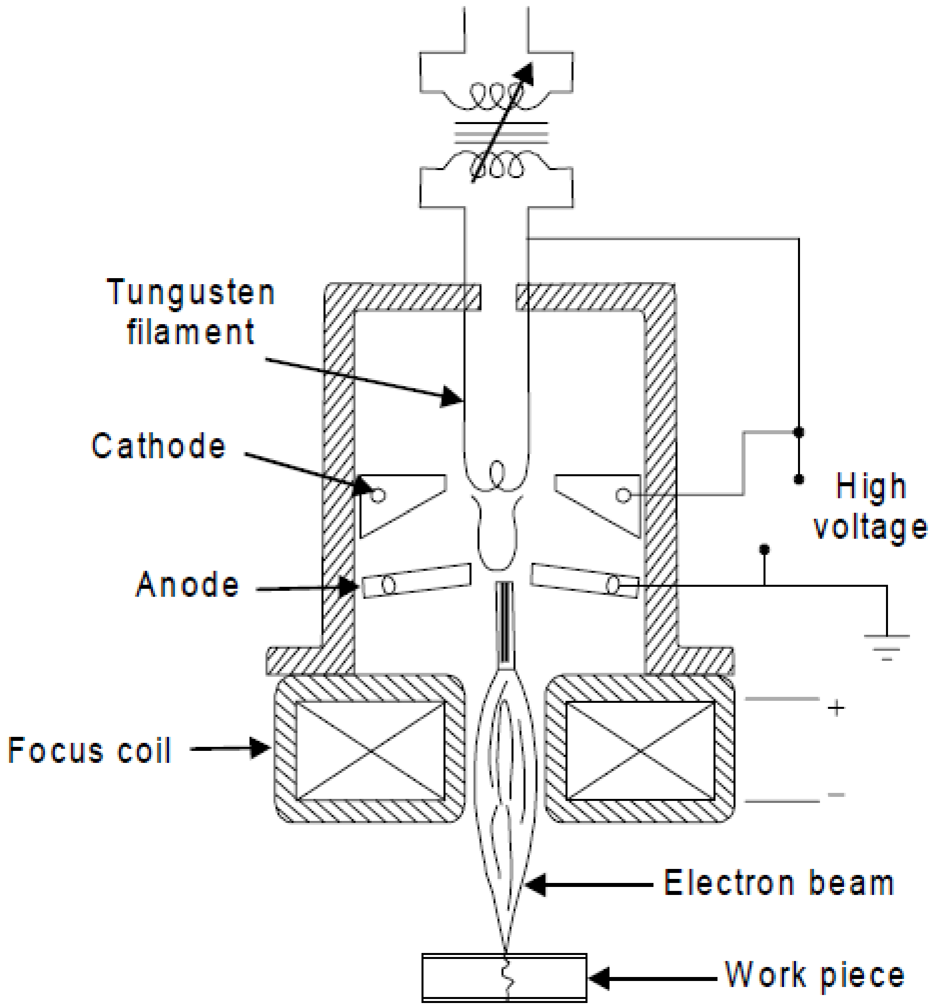
1. Crucible,
2. Slag basin,
3. Runner,
4. Wax pattern,
5. Sand plug,
6. Preheating,
7. Workpiece,
8. Riser.

Electron Beam Welding

- The heat is generated when the electron beam impinges on work piece. As the high velocity electron beam strikes the surfaces to be welded, their kinetic energy changes to thermal energy and hence causes the work piece metal to melt and fuse.
- The potential differences that are used are of the order

of 30 kV to 175 kV

- The current levels are low ranging between 50 mA to 1000 mA.



Tungsten filament
Cathode
Anode
Focus coil
High voltage
+
–
Electron beam
Work piece

- The EBW process is mainly used for welding of reactive metals (nuclear reactor components), titanium, zirconium, stainless steel, etc. for aero-space and automotive industries.

Laser Beam Welding

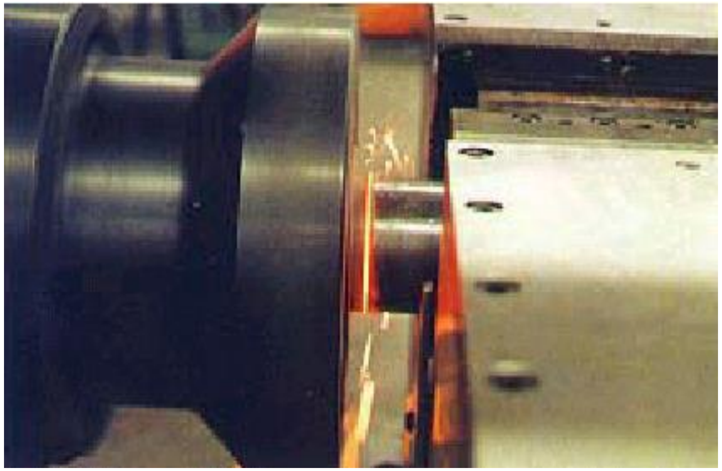
- Due to electrical Discharge from capacitors, the flash tube converts electrical energy into light flashes

- Application
  - Thin metals about 0.5 to 1.5 mm thick can be welded.
  - Electronic Component welding
  - Used in aircraft components joining
  - Can Joint dissimilar Metals
  - Joining metal alloys

Friction welding

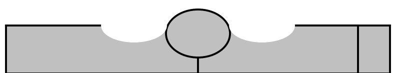
One part is held stationary while the other part is rotated

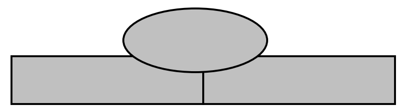
When the parts are hot enough the rotation is stopped and the parts forged together



Weld Defects

- Undercuts/Overlaps
- Grain Growth

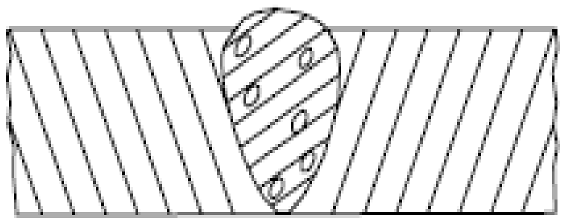




  - A wide ΔT will exist between base metal and HAZ. Preheating and cooling methods will affect the brittleness of the metal in this region
- Blowholes
  - Are cavities caused by gas entrapment during the solidification of the weld puddle. Prevented by proper weld technique (even temperature and speed)

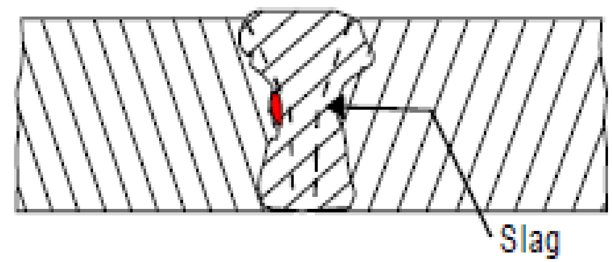
Weld Defects

- Inclusions
  - Impurities or foreign substances which are forced into the weld puddle during the welding process. Has the same effect as a crack. Prevented by proper technique/cleanliness.
- Segregation
  - Condition where some regions of the metal are enriched with an alloy ingredient and others aren't. Can be prevented by proper heat treatment and cooling.
- Porosity
  - The formation of tiny pinholes generated by atmospheric contamination. Prevented by keeping a protective shield over the molten weld puddle.



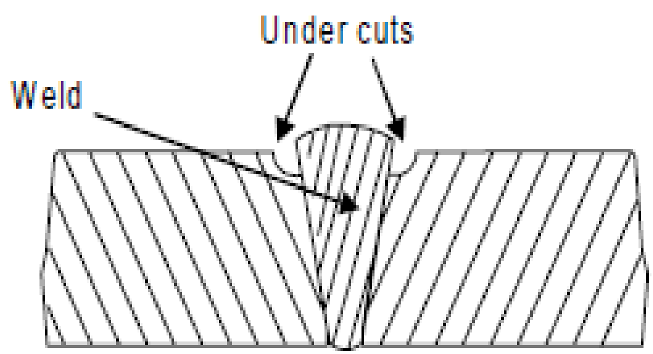
Porosity

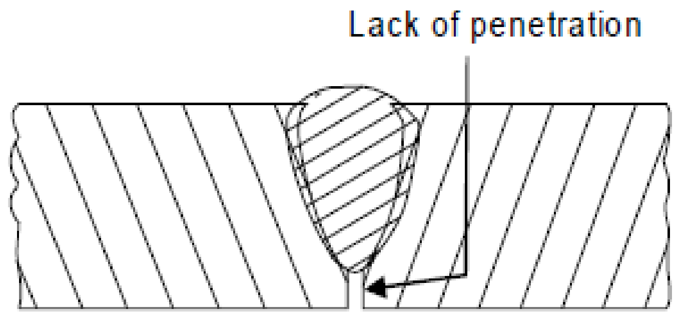
Fig. 17.31(iii)



Slag Inclusion

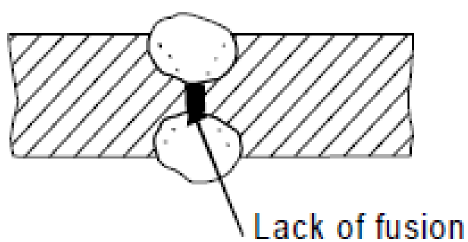
Fig. 17.31(iv)



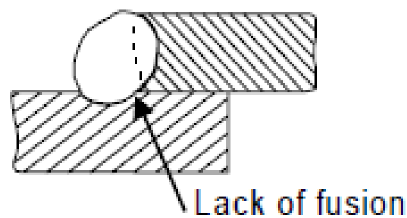


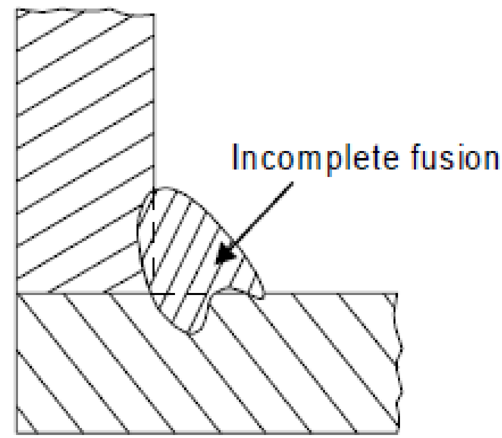
Lack of penetration

Fig. 17.31(i)



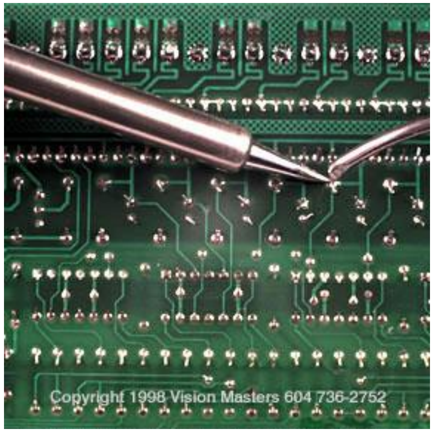
Lack of Fusion





Incomplete Fusion

Soldering & Brazing



- Only filler metal is melted, not base metal
- Lower temperatures than welding
- Filler metal distributed by capillary action
- Metallurgical bond formed between filler & base metals

- Strength of joint typically
  - stronger than filler metal itself
  - weaker than base metal
  - gap at joint important (0.001 – 0.010”)
- Pros & Cons
  - Can join dissimilar metals
  - Less heat - can join thinner sections (relative to welding)
  - Excessive heat during service can weaken joint

Soldering

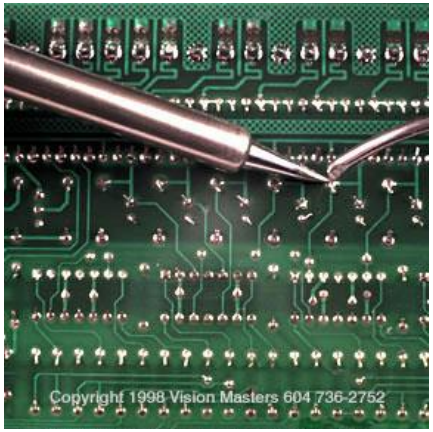
Solder = Filler metal

- Alloys of Tin (silver, bismuth, lead)
- Melt point typically below 840 F

Flux used to clean joint & prevent oxidation

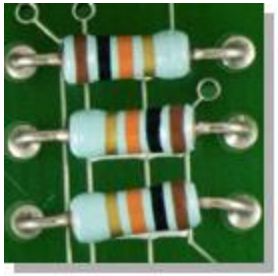
- separate or in core of wire (rosin-core)

Tinning = pre-coating with thin layer of solder



Applications:

- Printed Circuit Board (PCB) manufacture
- Pipe joining (copper pipe)
- Jewelry manufacture
- Typically non-load bearing



Easy to solder: copper, silver, gold

Difficult to solder: aluminum, stainless steels

(can pre-plate difficult to solder metals to aid process)

Brazing

Use of low melt point filler metal to fill thin gap between mating surfaces to be joined utilizing capillary action

- Filler metals include Al, Mg & Cu alloys (melt point typically above 840 F)
- Flux also used
- Types of brazing classified by heating method:
  - Torch, Furnace, Resistance

Applications:

- Automotive - joining tubes
- Pipe/Tubing joining (HVAC)
- Electrical equipment - joining wires
- Jewelry Making
- Joint can possess significant strength

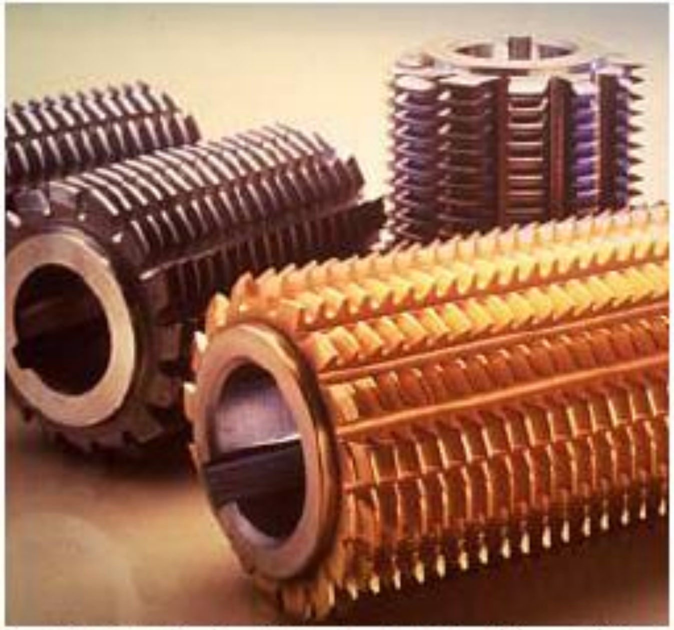


Figure 9. Typical carbide cutting tools brazed to metal in a brazing furnace. (Photo courtesy of Handy & Harman)

Brazing

Figuring length of lap for flat joints.

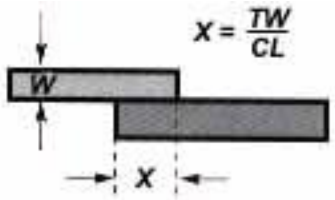
X = Length of lap

T = Tensile strength of weakest member

W = Thickness of weakest member

C = Joint integrity factor of .8

L = Shear strength of brazed filler metal



Let’s see how this formula works, using an example.

Problem: *What length of lap do you need to join .050" annealed Monel sheet to a metal of equal or greater strength?*
Solution:

C = .8 T = 70,000 psi (annealed Monel sheet)

W = .050"

L **=** 25,000 psi (Typical shear strength for silver brazing filler metals)

X = (70,000 x .050) /(.8 x 25,000) = .18" lap length

Brazing

Figuring length of lap for tubular joints.

X = Length of lap area

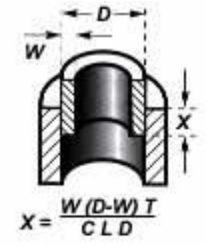
W = Wall thickness of weakest member

D = Diameter of lap area

T = Tensile strength of weakest member

C = Joint integrity factor of .8

L = Shear strength of brazed filler metal



Again, an example will serve to illustrate the use of this formula. Problem: *What length of lap do you need to join 3/4" O.D. copper tubing (wall thickness .064") to 3/4" I.D. steel tubing?*

Solution:

W = .064"

D = .750"

C= .8

T = 33,000 psi (annealed copper)

L **=** 25,000 psi (a typical value)

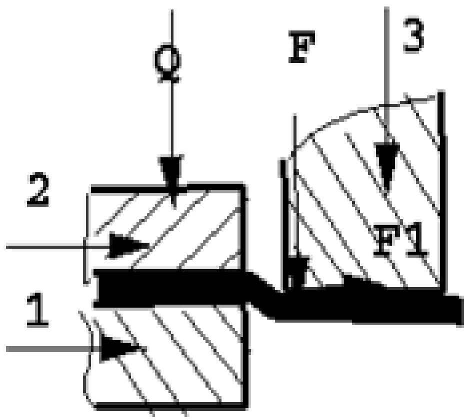
X = (.064 x (.75 – .064) x 33,000)/(.8 x .75 x 25,000)

X = .097" (length of lap)

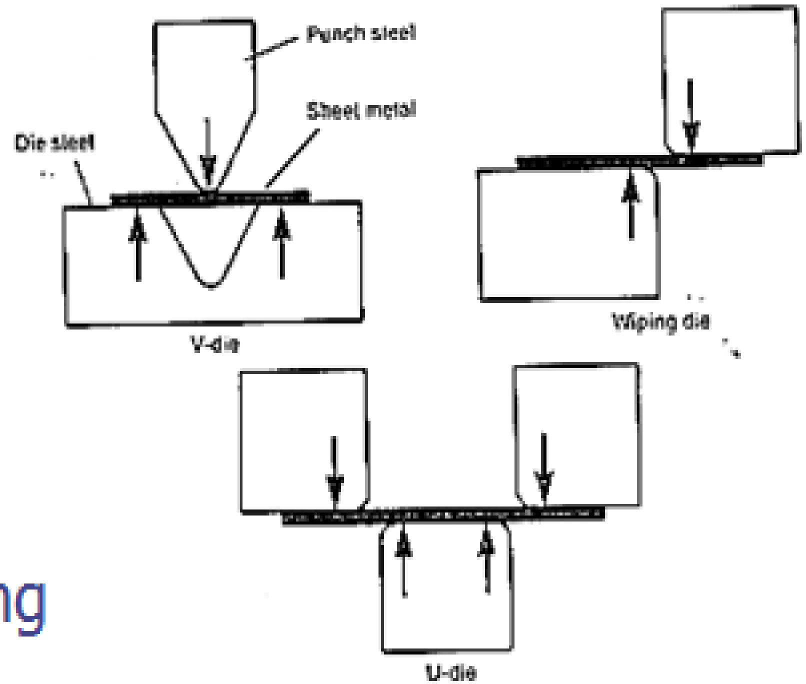
UNIT IV SHEET METAL PROCESSES

Shearing Operation

- Shearing
- Bending
- Drawing and
- Squeezing
- The process of cutting a straight lines across a strip , sheet or bar is known as shearing process
  - Plastic Deformation
  - Fracture and
  - Shear

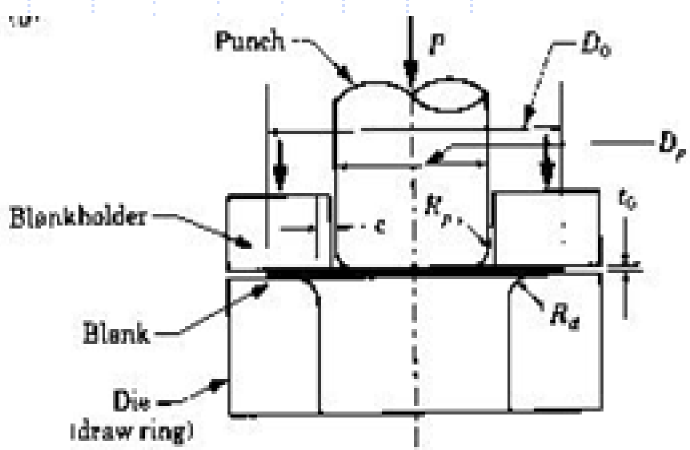


Shearing



Bending

Drawing



Selection of Press

- Force required to cut the metal
- Die Space
- Size and types of die
- Stroke Length
- Method of feeding and size of sheet blank
- Shut height **It is the distance from the top of the bed to the bottom of the slide when stroke down and the adjustment up**
- Type of Operation
- Speed of Operation

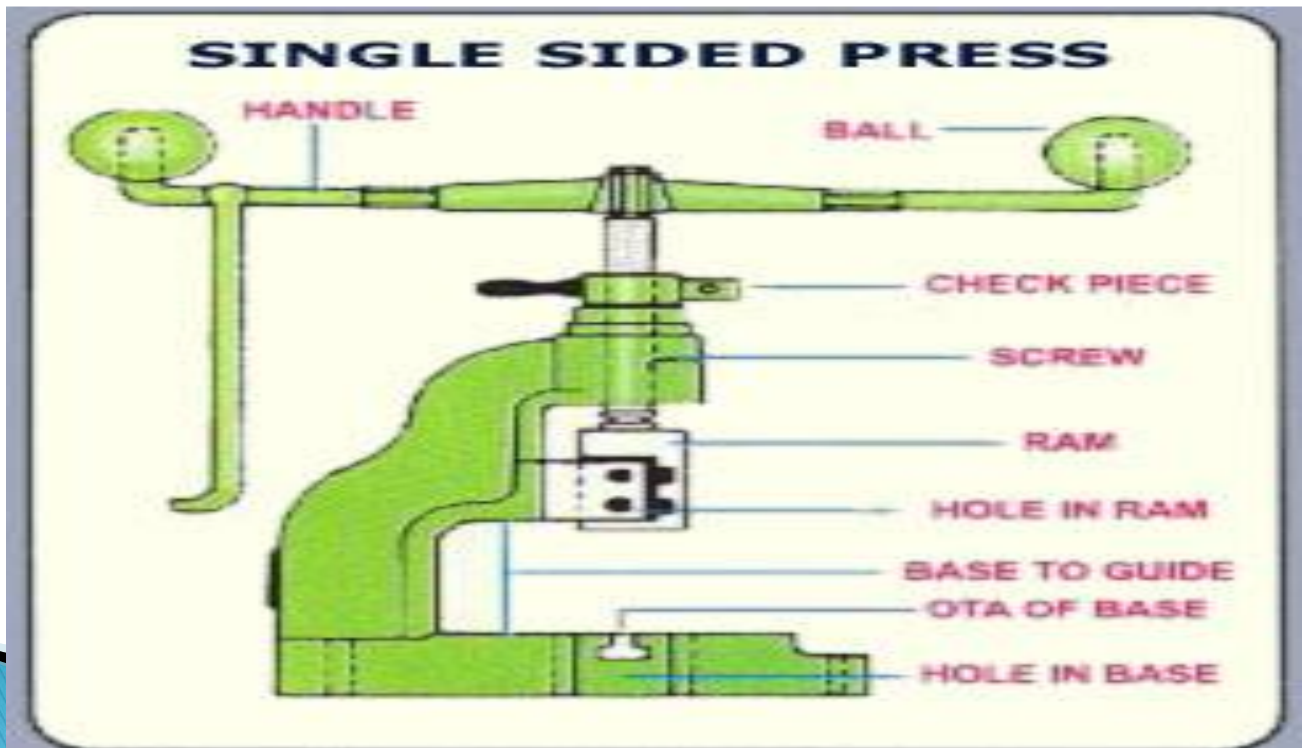
- Advantages
  - Material Economy
  - Reduction of weight and Considerable cost reduction of fabricated parts
  - High Productivity
  - Use of Unskilled Labour
  - High Degree of Precision
  - Uniformity of parts
  - Predictable strength characteristics
  - Use of Less Labour
  - Possibility of Automation

Types of Press

- According to the source of power
  - Manually Operated- Hand , ball or fly presses
  - Power Press- Mechanical ,hydraulic
- Type of Design
  - Inclinable
  - Straight side
  - Gap frame
  - Horning
  - Adjustable rod
  - Open rod

Fly Press

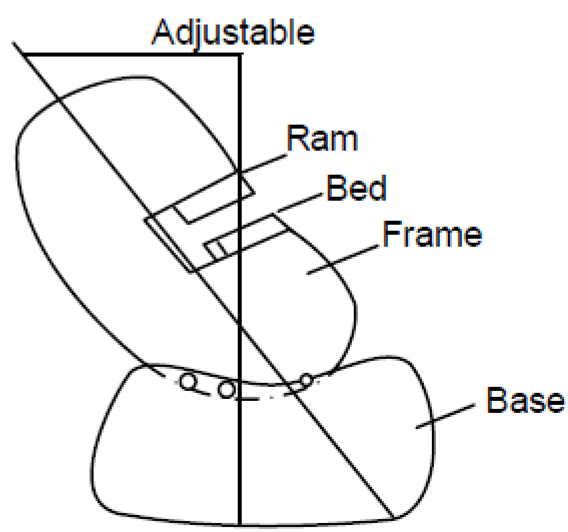
- Punch is connected at the bottom of the ram and die is tightly fixed at the press plate
- Arm and weights are replaced by a heavy flywheel.



Mechanically operated power press

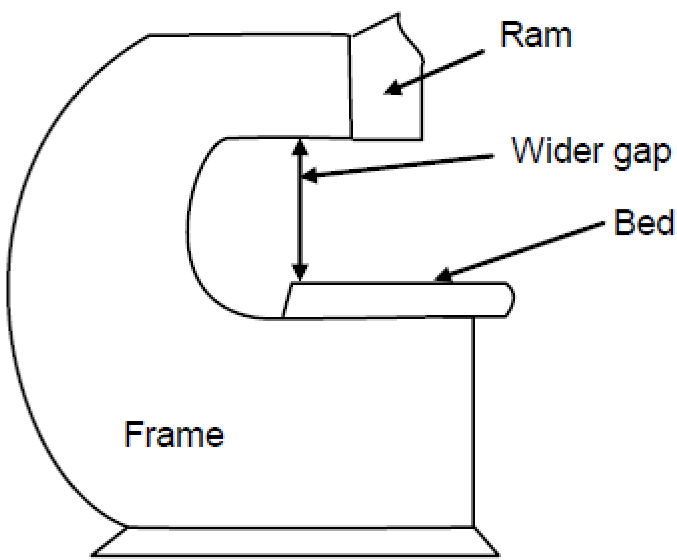
Inclinable Press

- Can be used in both vertical as well as inclined position
- Higher production rate with smaller parts

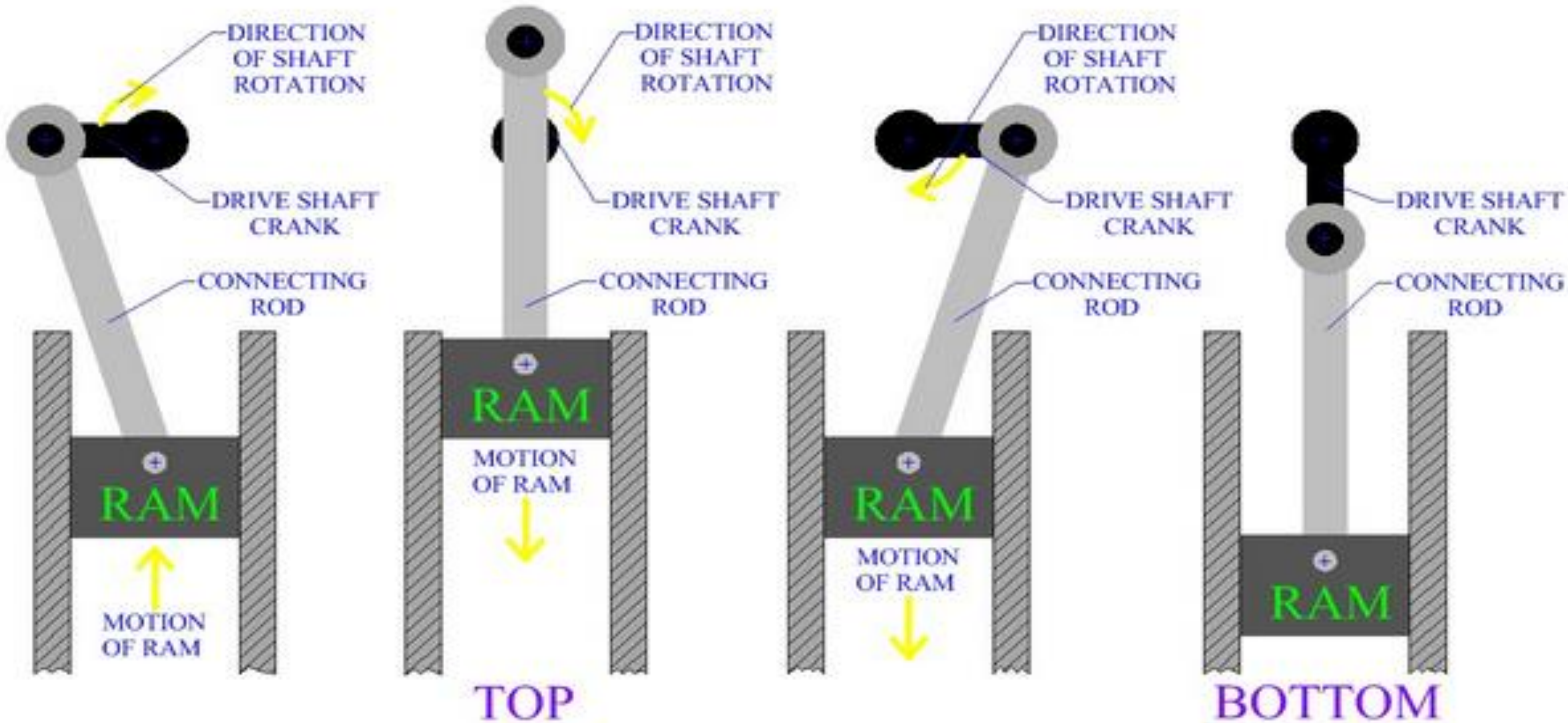


Gap Press

These presses have larger frame openings, that means a wide gap between its base and ram to accommodate larger workpieces. It also has longer beds, as shown in Figure 3.3.

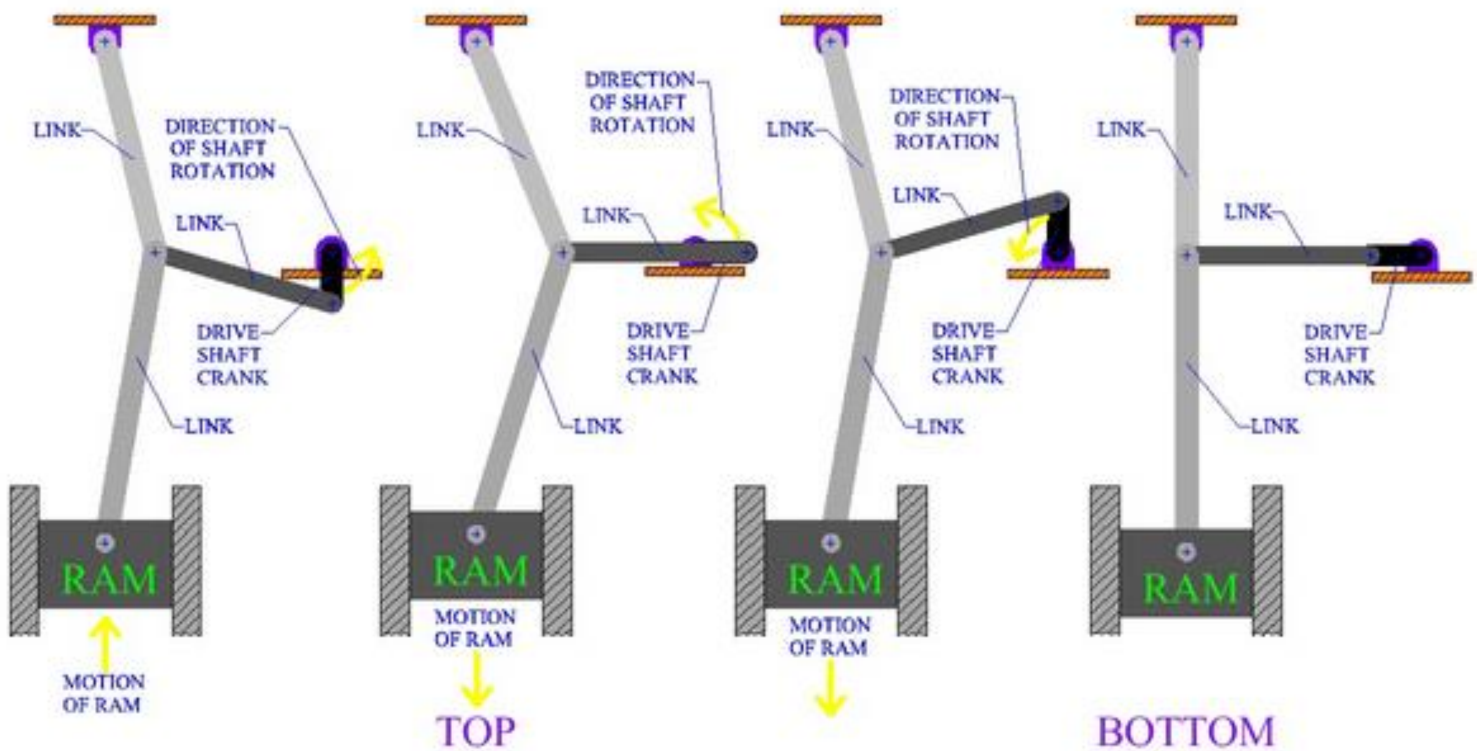


Crank Press

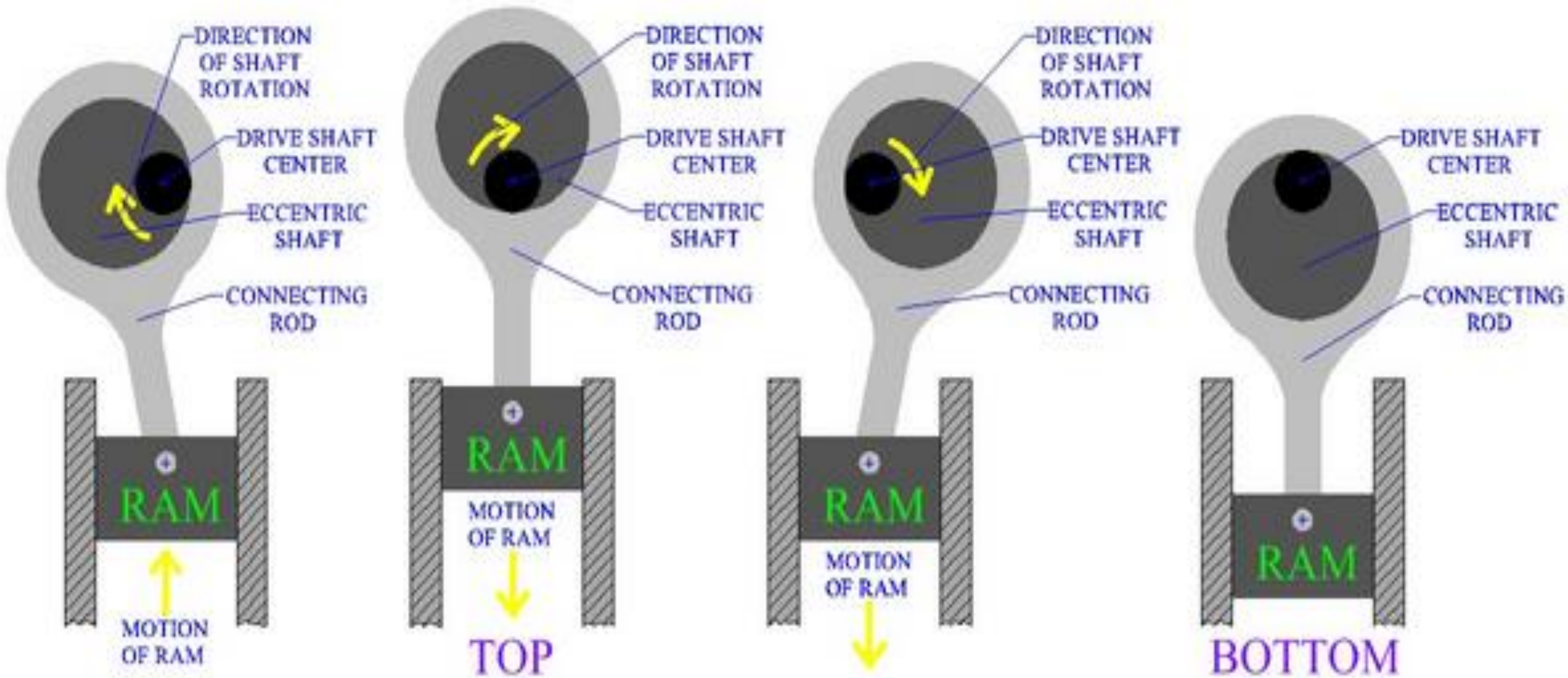


DIRECTION OF SHAFT ROTATION
DRIVE SHAFT CRANK
CONNECTING ROD
RAM
MOTION OF RAM
DIRECTION OF SHAFT ROTATION
DRIVE SHAFT CRANK
CONNECTING ROD
RAM
MOTION OF RAM
TOP
DIRECTION OF SHAFT ROTATION
DRIVE SHAFT CRANK
CONNECTING ROD
RAM
MOTION OF RAM
DRIVE SHAFT CRANK
CONNECTING ROD
RAM
BOTTOM

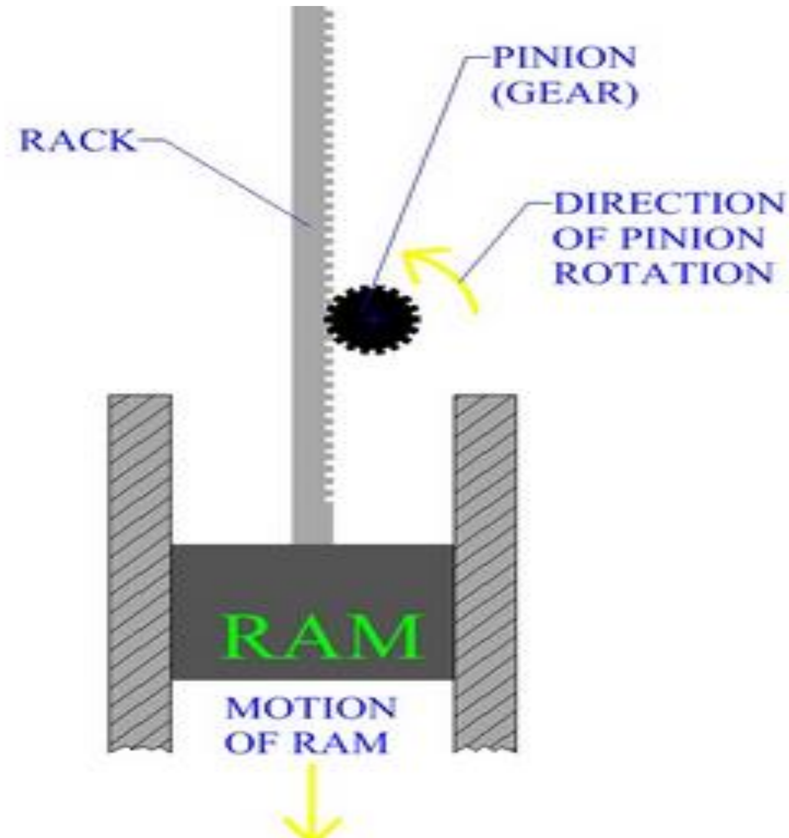
Knuckle Joint Press



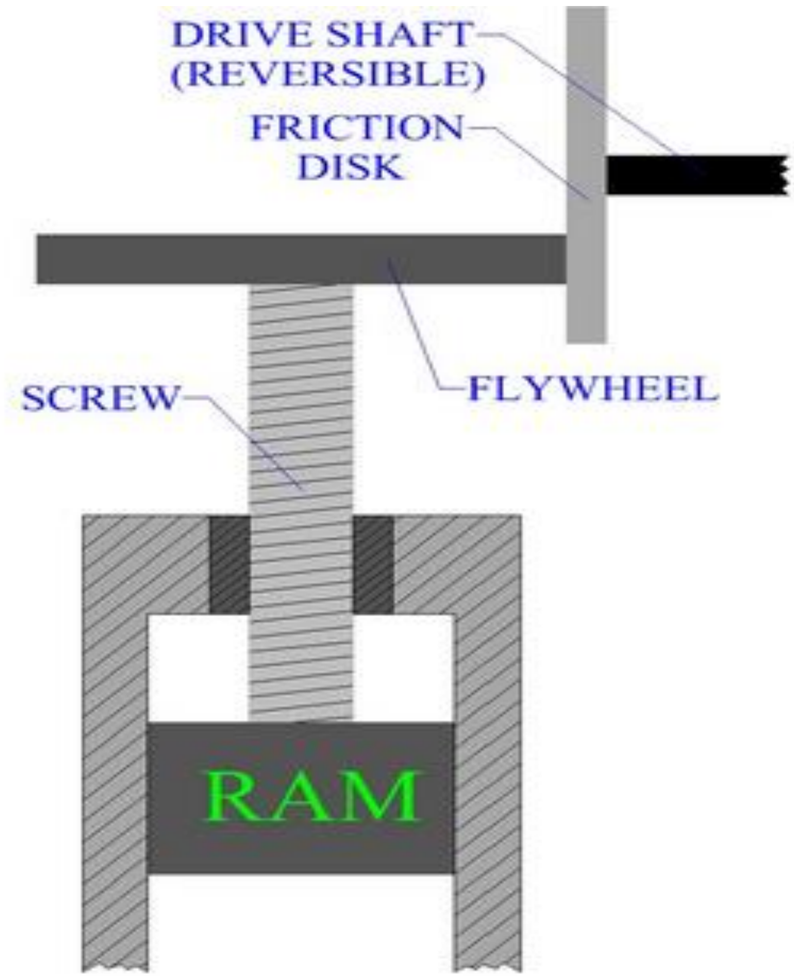
Rack and Pinion Press



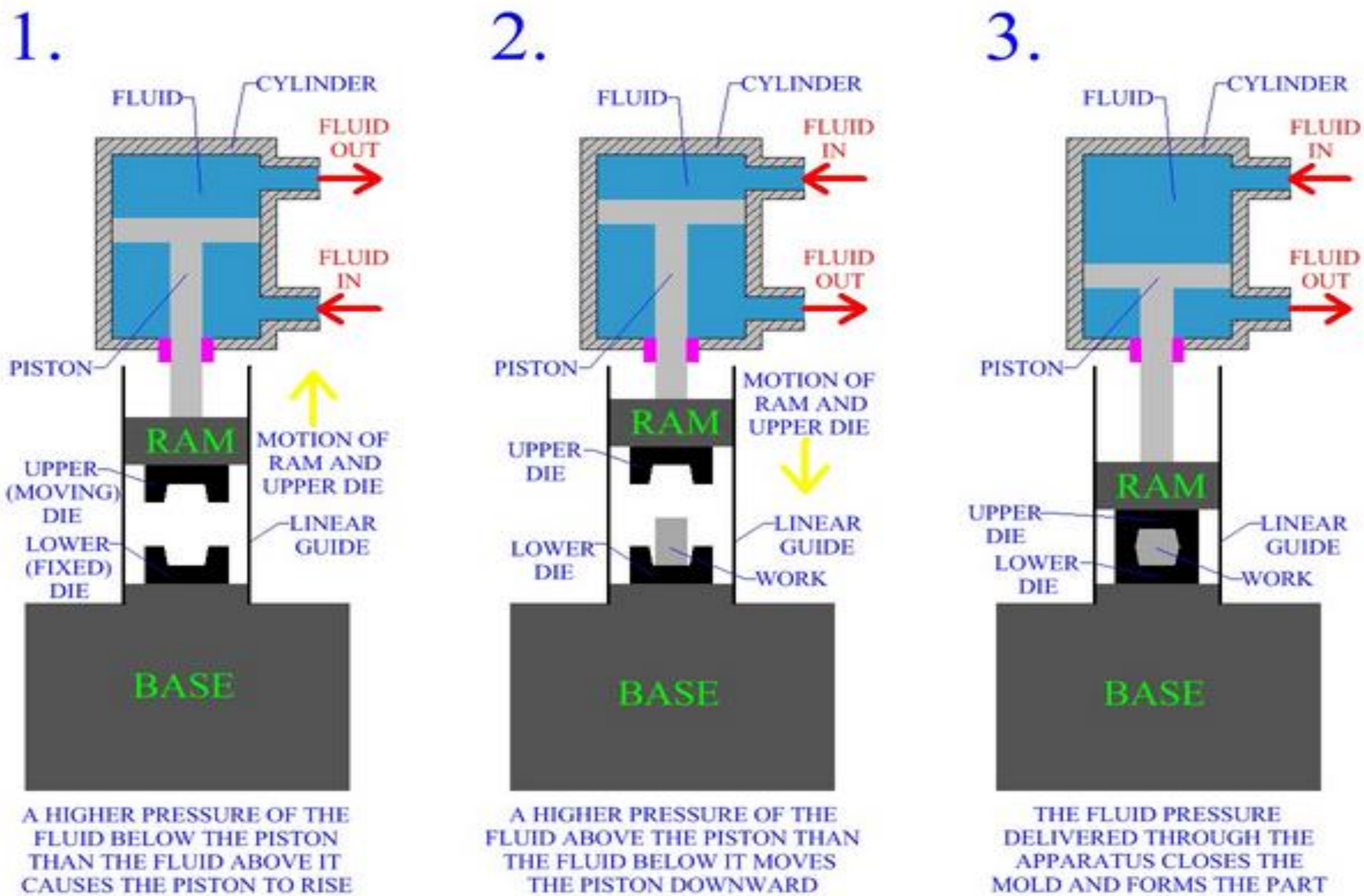
Rack and Pinion Press



Screw Press



Hydraulic Press

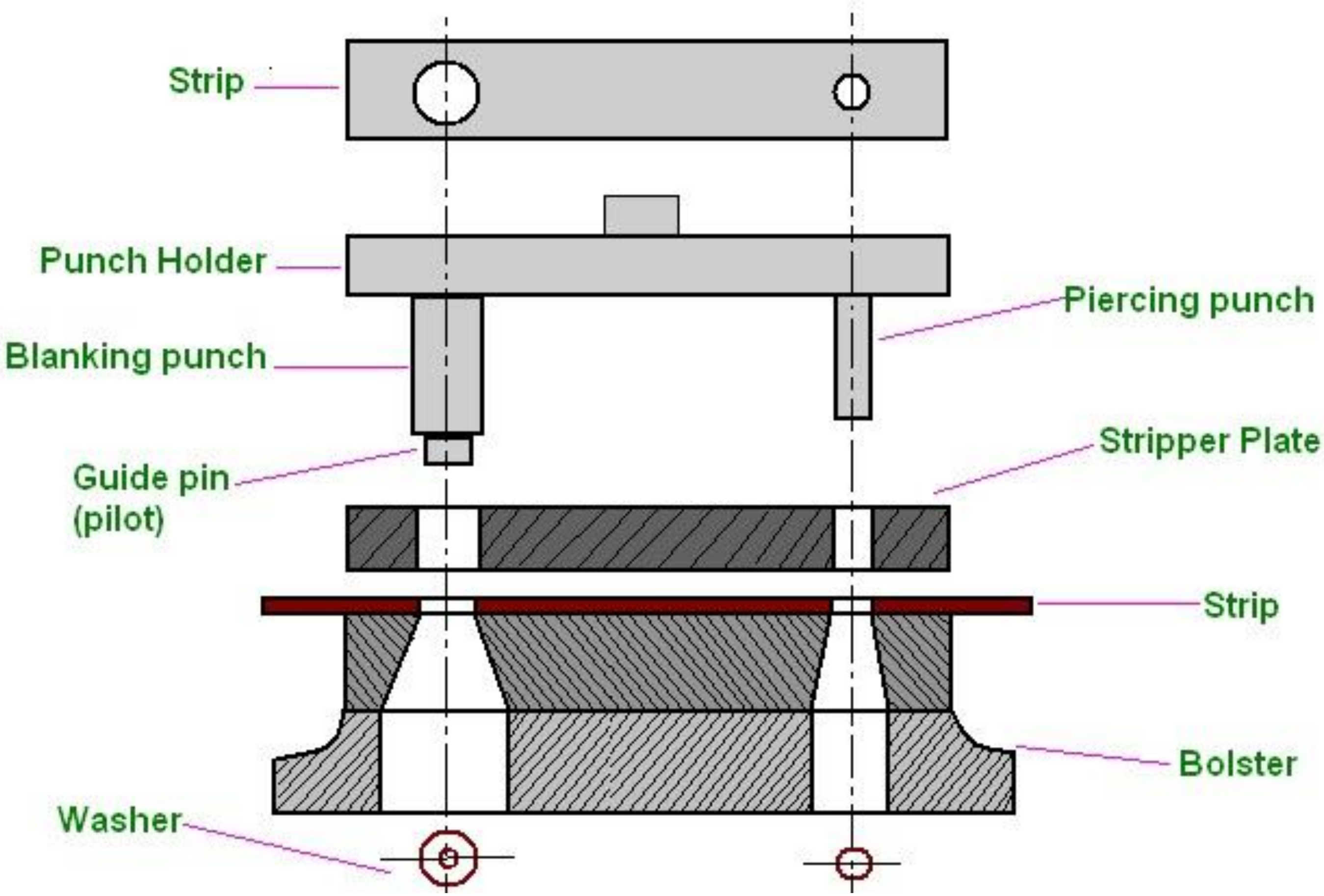


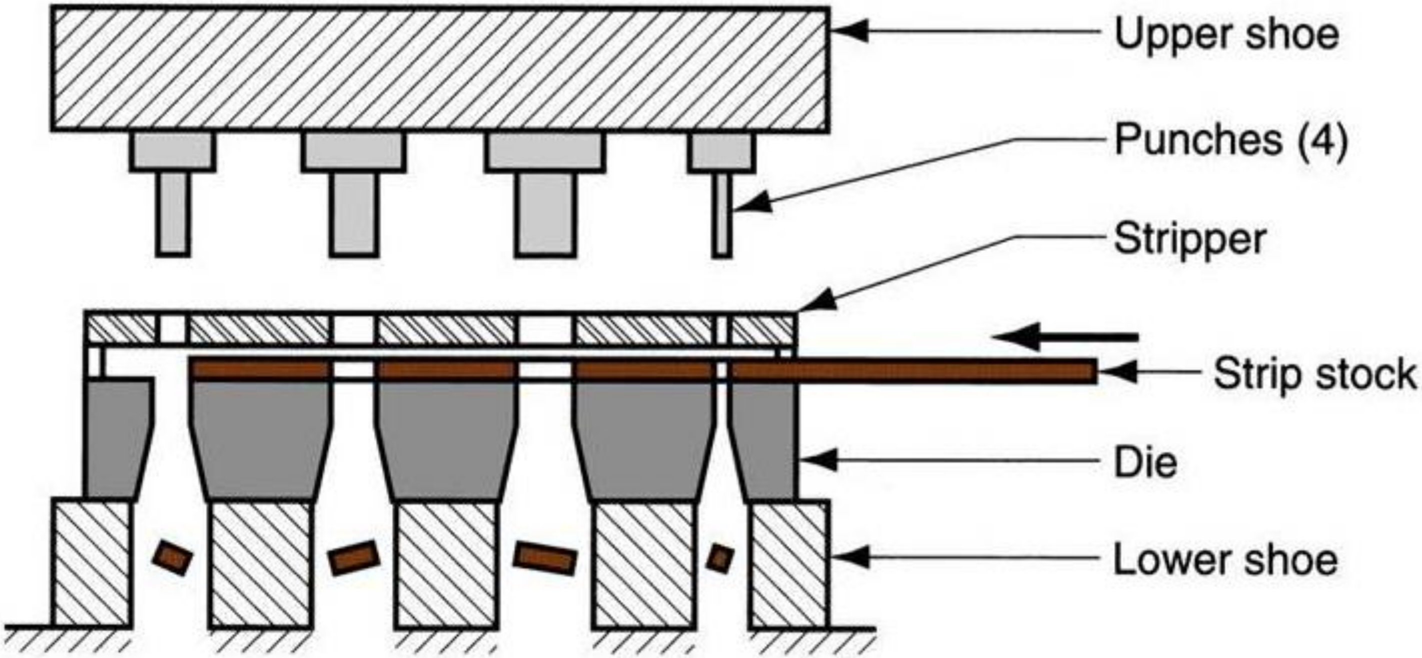
Types of Cutting Dies

Progressive Die

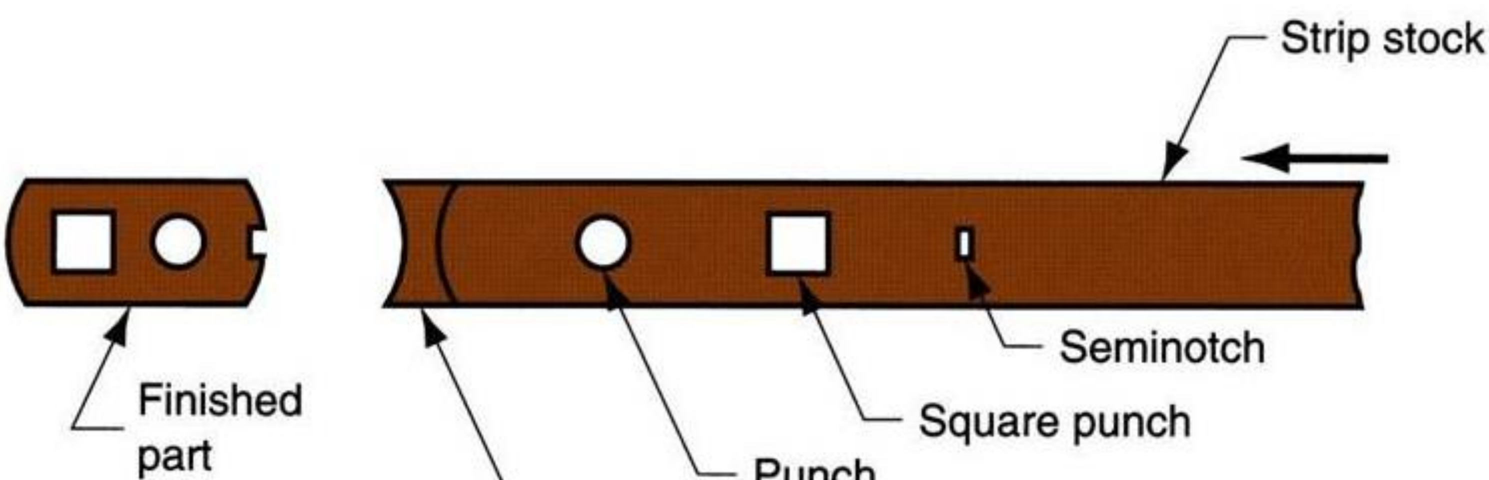
- Designed to perform two or more operation at the different stages
- Stock strip is feed into the die mechanically or by hand. And it is hold against the lead end of the sheet metal.
- The Primary die will pierce the hole into the die set in the first cutting stroke of the ram.

Progressive Die




Upper shoe
Punches (4)
Stripper
Strip stock
Die
Lower shoe

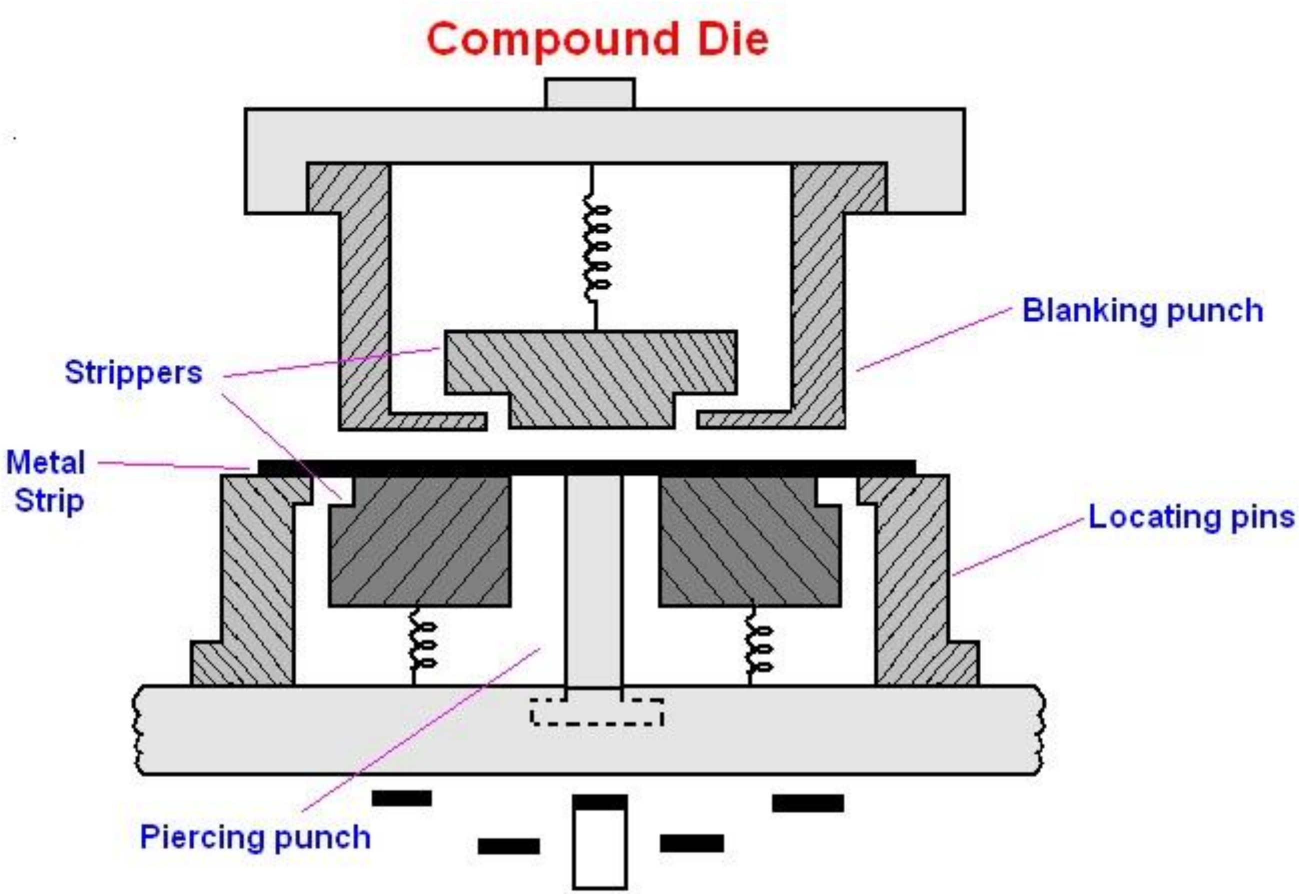
(a)


Strip stock
Seminotch
Finished part
Square punch
Punch

- While the blanking operation is performed , the piercing punch produce a hole for a next washer at the first station
- Advantage
  - Number of operation can be performed
  - For every stroke of the arm, one work piece is made
  - Simple in construction and suitable for mass production
- Disadvantage
  - Complicated design of die set
  - Bending or tearing take place

Compound Dies

- Two or more cutting operation such as blanking, piercing operation are combined and carried out in one stroke of the press at one station only.
- The main difference between progressive die and compound die is N+1 stroke is produced in case of compound die, whereas N stroke is produced in case of Progressive die


Compound Die
Blanking punch
Strippers
Metal
Strip
Locating pins
Piercing punch

- Advantage
  - More Accurate
  - Large parts can be blanked
  - Shorter length of strip Cost of production is very less

- Disadvantages
  - More expensive to construct and repair
  - Slower in operation
  - Complicated die set design

Cutting Operation

- Blanking
- Punching or Piercing
- Shearing
- Parting
- Notching
- Trimming
- Shaving
- Perforating
- Slitting
- Lancing

Forming Operation

- Bending
- Drawing
- Squeezing
- Embossing
- Nibbling

Types of Bending Operation

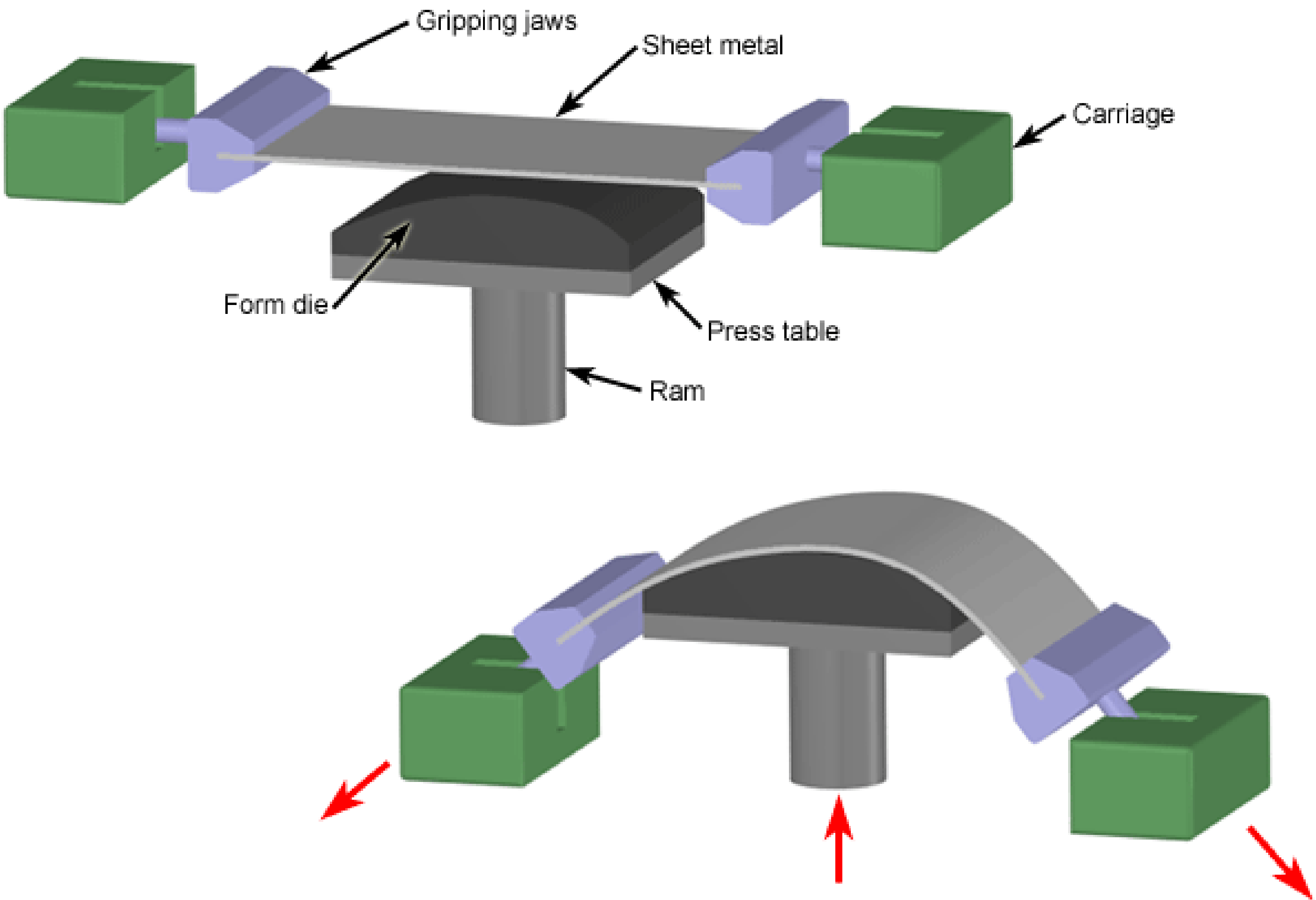
- Angle Bending
- Roll Bending
- Roll Forming and
- Seaming
- Edge Bending using wiping die

Stretch Forming Operation

- Form Block Method
  Mating Die Method

Form Block Method

- Two ends are held tightly by gripper
- Then the form block is moved towards the blank to make the required shape
- Form block is operated by hydraulic cylinder


Gripping jaws
Sheet metal
Carriage
Form die
Press table
Ram

Mating die method

- Blank is held in movable gripper. The blank is placed between upper and lower die

- The lower die is kept stationary and the upper die is movable one which is operated by either hydraulic or pneumatic cylinder.

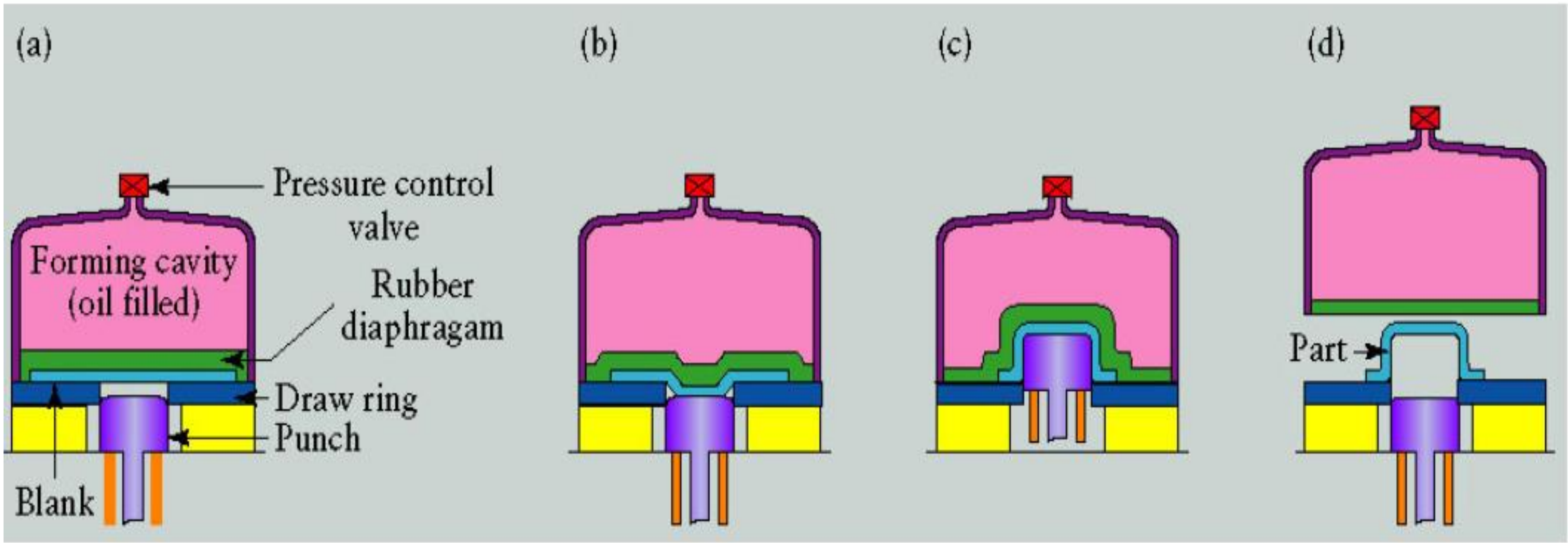
- First the gripper is moved to make the material into plastic deformation and the upper die is punched to produce the stretching of the blank

Special Forming Process

Hydro mechanical forming Process

- Required shape is formed on the punch
- Correct position of the upper and lower die is set
- Hydraulic pressure is applied over the blank, Simultaneously the punch is pushed into the blank
- Convex shape of the punch is made as concave shape on the blank and vice versa

Hyrdoforming



Hydroforming

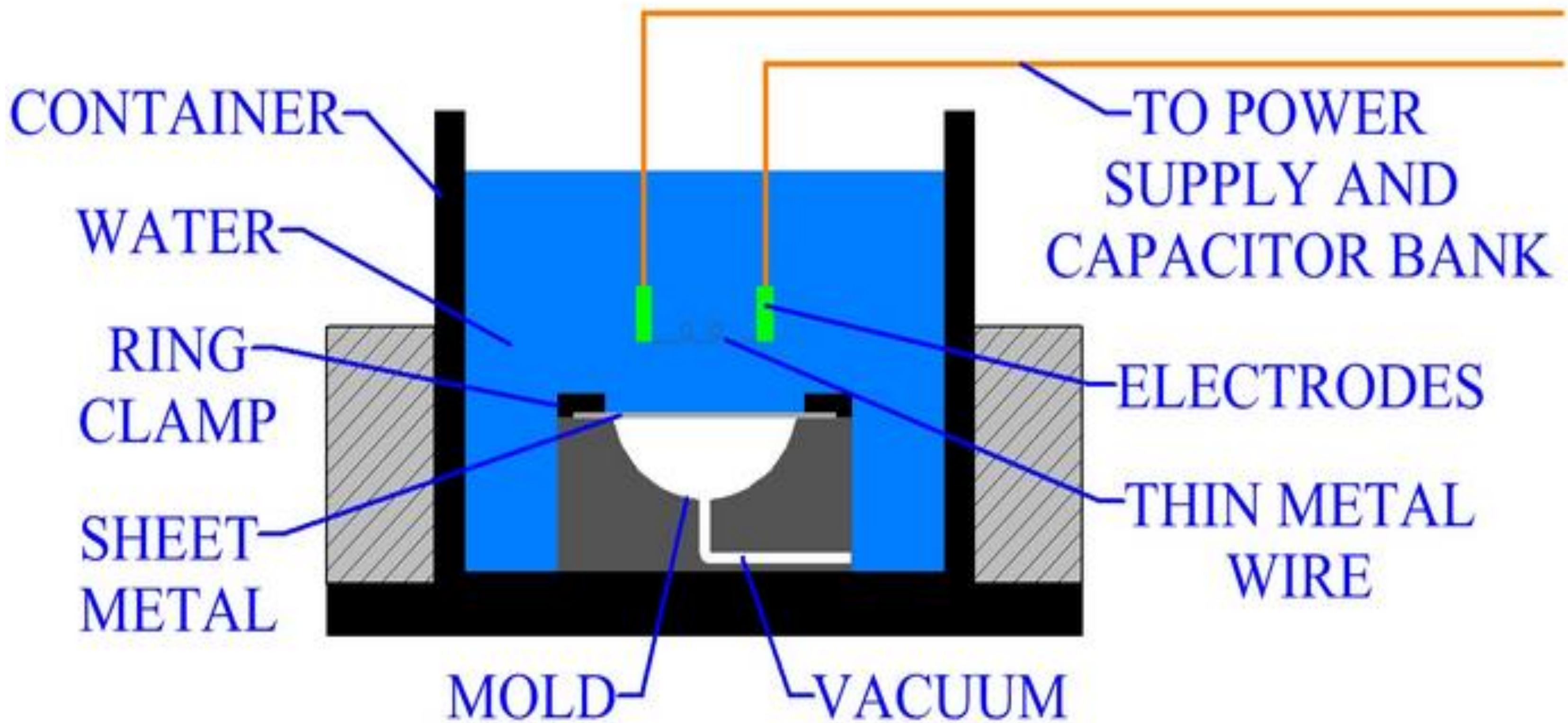
Electrohydraulic Forming Process

- The pressure applied over the chamber is different by means of electrical means

- When the electrical energy is supplied inside the chamber shock waves and pressure are produced.

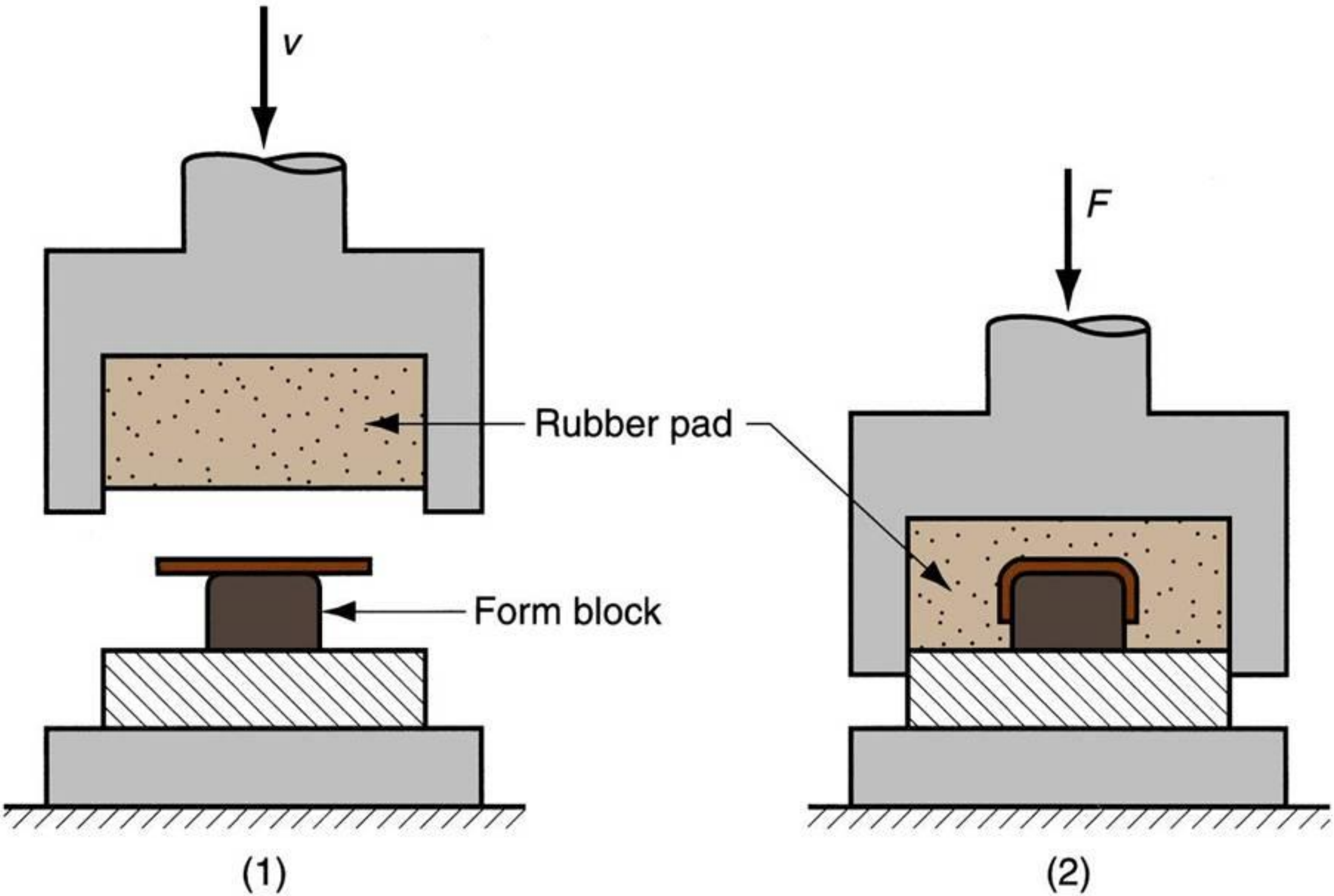
Figure:318

ELECTROHYDRAULIC FORMING



Rubber Pad Forming Process

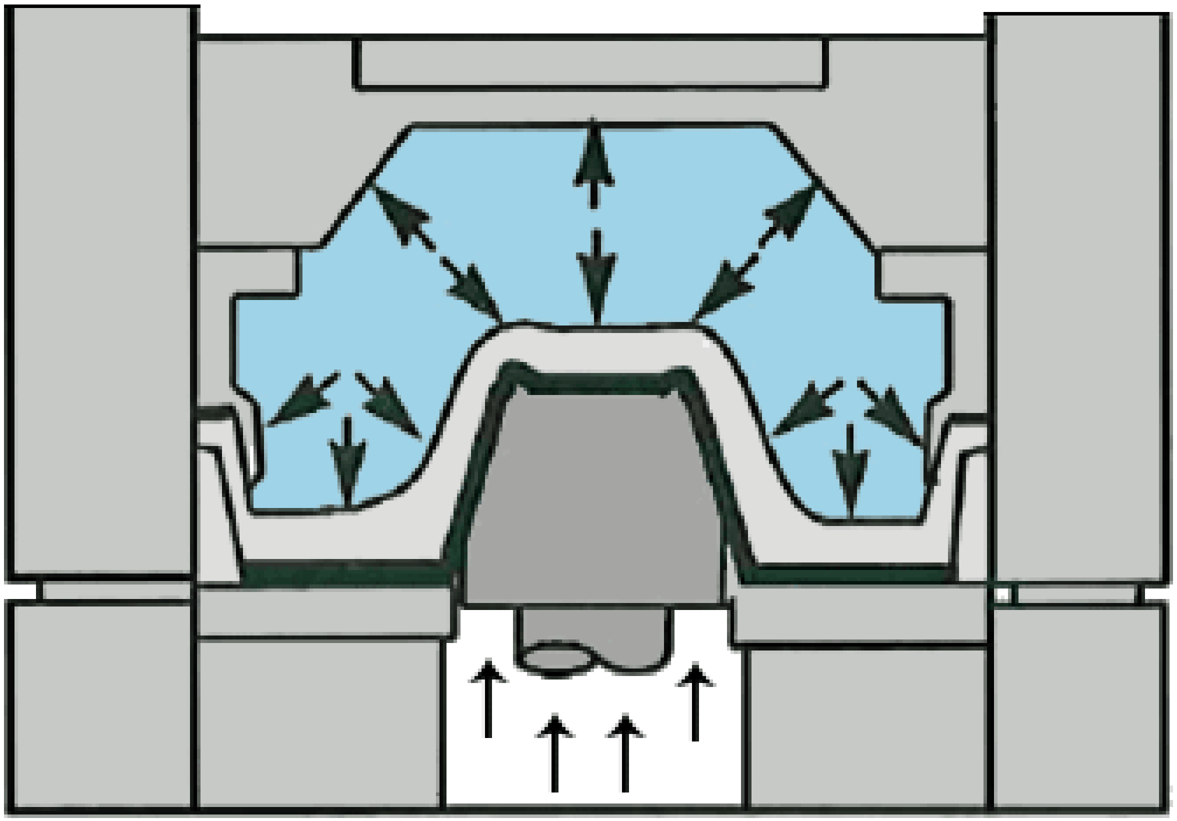
- It is also called as marform process
- In this process mainly bending and stretching or drawing operations
- Pad is made up of rubber or polyurethane
- Force is applied on the blank by means of hydraulic cylinder



v
F
Rubber pad
Form block
(1)
(2)

Rubber Hydro forming Process

- Here the force is applied through the pressurized liquid behind the rubber pad
- Pressure is applied over the surface of the blank by the hydraulic ram which is operated by hydraulic ram
- Advantage
  - Hammering action is avoided
- Disadvantage
  - Pressure Loss occurs

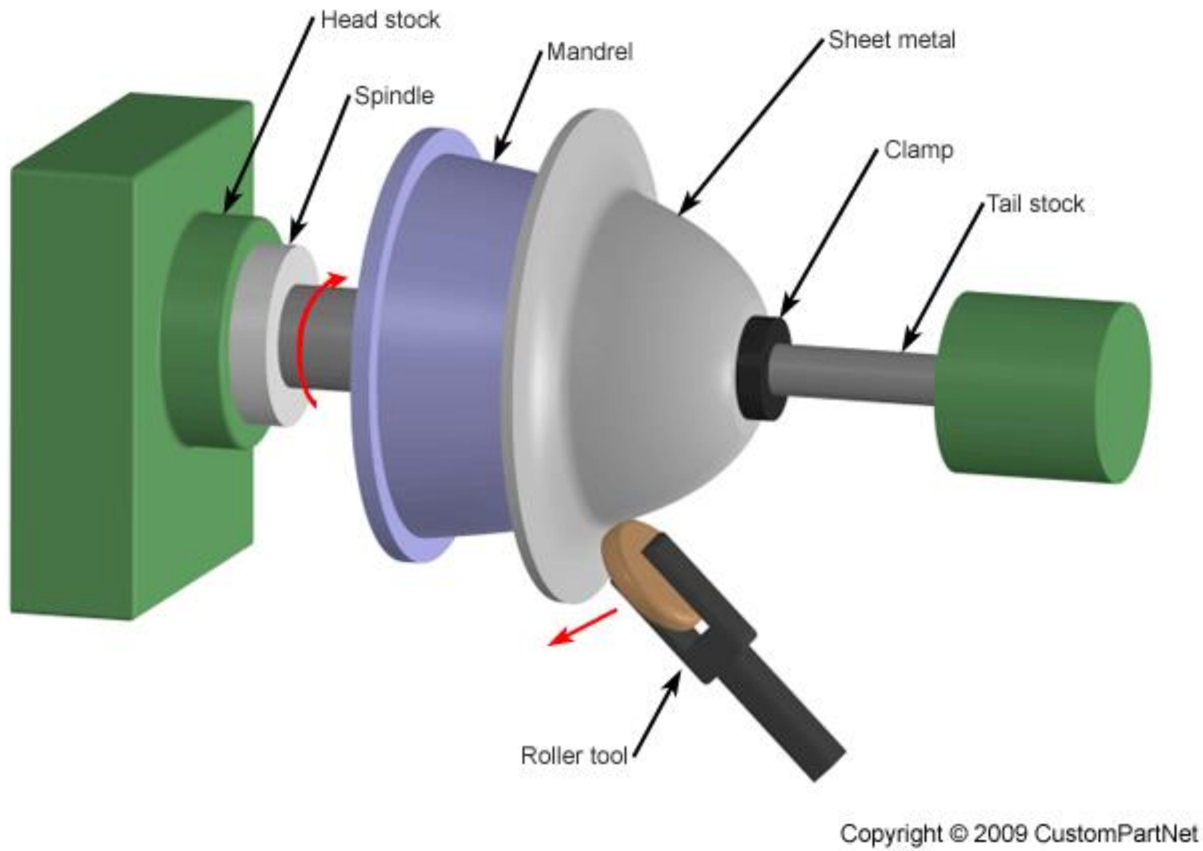


STEP 3

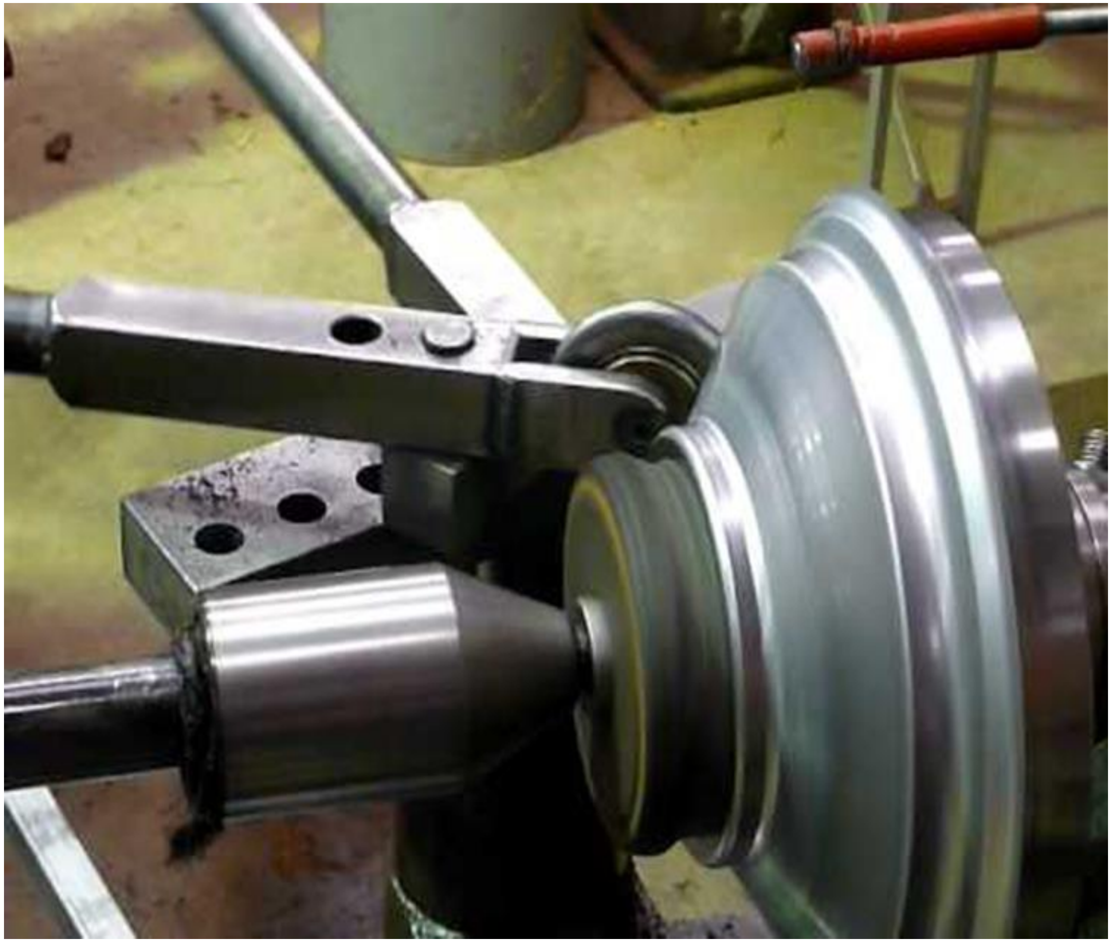
Punch pushes upward, forming metal blank against pressure chamber.

Metal Spinning Process

- Process of Forming seamless parts from a circular sheet metal or form a tube length of a lathe
- Only Symmetrical Shapes can be produced
  - Manual Spinning
  - Power Spinning



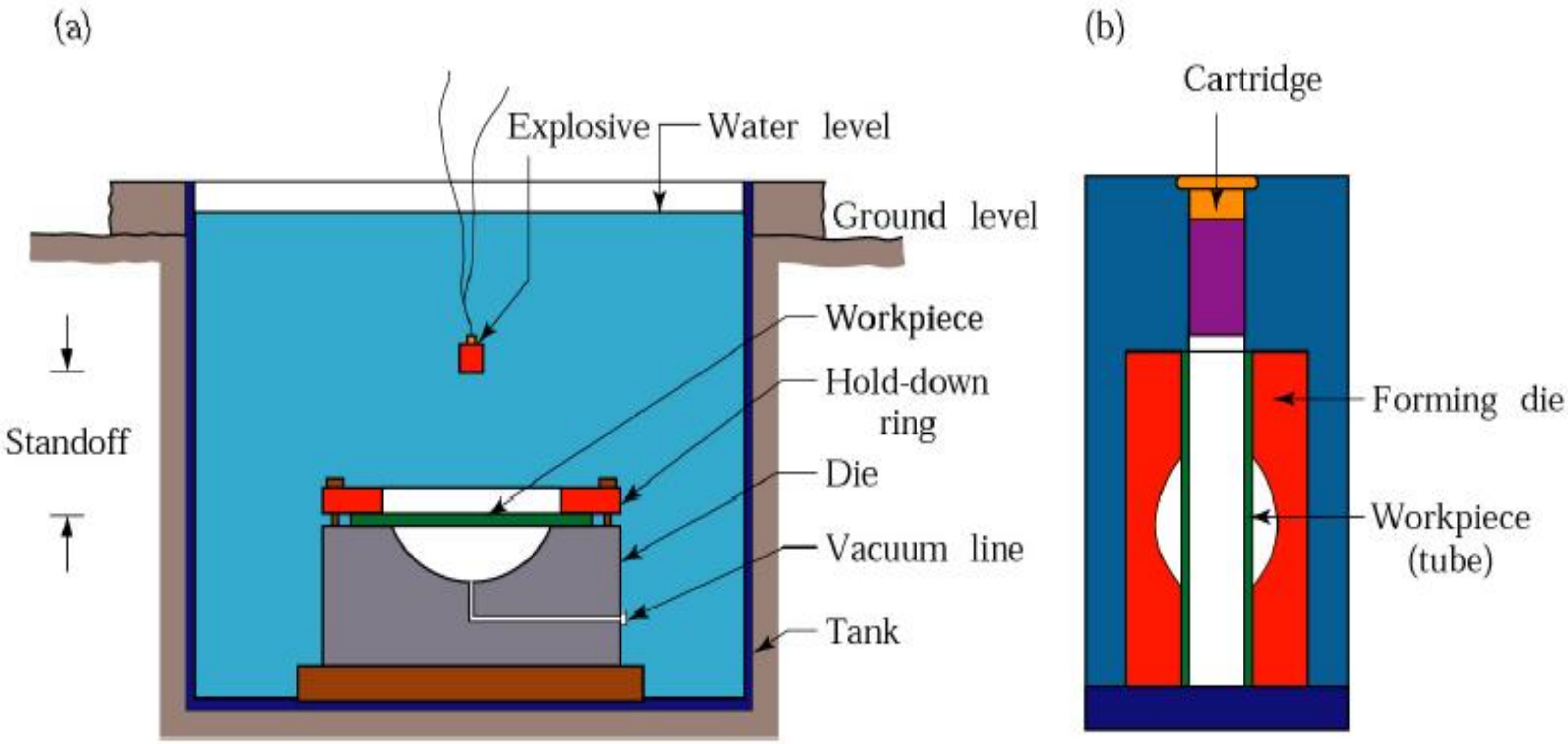
Head stock
Mandrel
Sheet metal
Spindle
Clamp
Tail stock
Roller tool
Copyright © 2009 CustomPartNet



Explosive Forming Process

- Used for blanking, Cutting, Expanding, coining, embossing, flanging, powder compacting, drawing and sizing operations
- Stand Off Distance
  - Explosive charge is located at some distance away from the blank and its energy is transmitted through some fluidic medium such as water
- Contact operations
  - Explosive charge is directly located over the blank.

Explosive Forming



Magnetic Pulse Forming Process

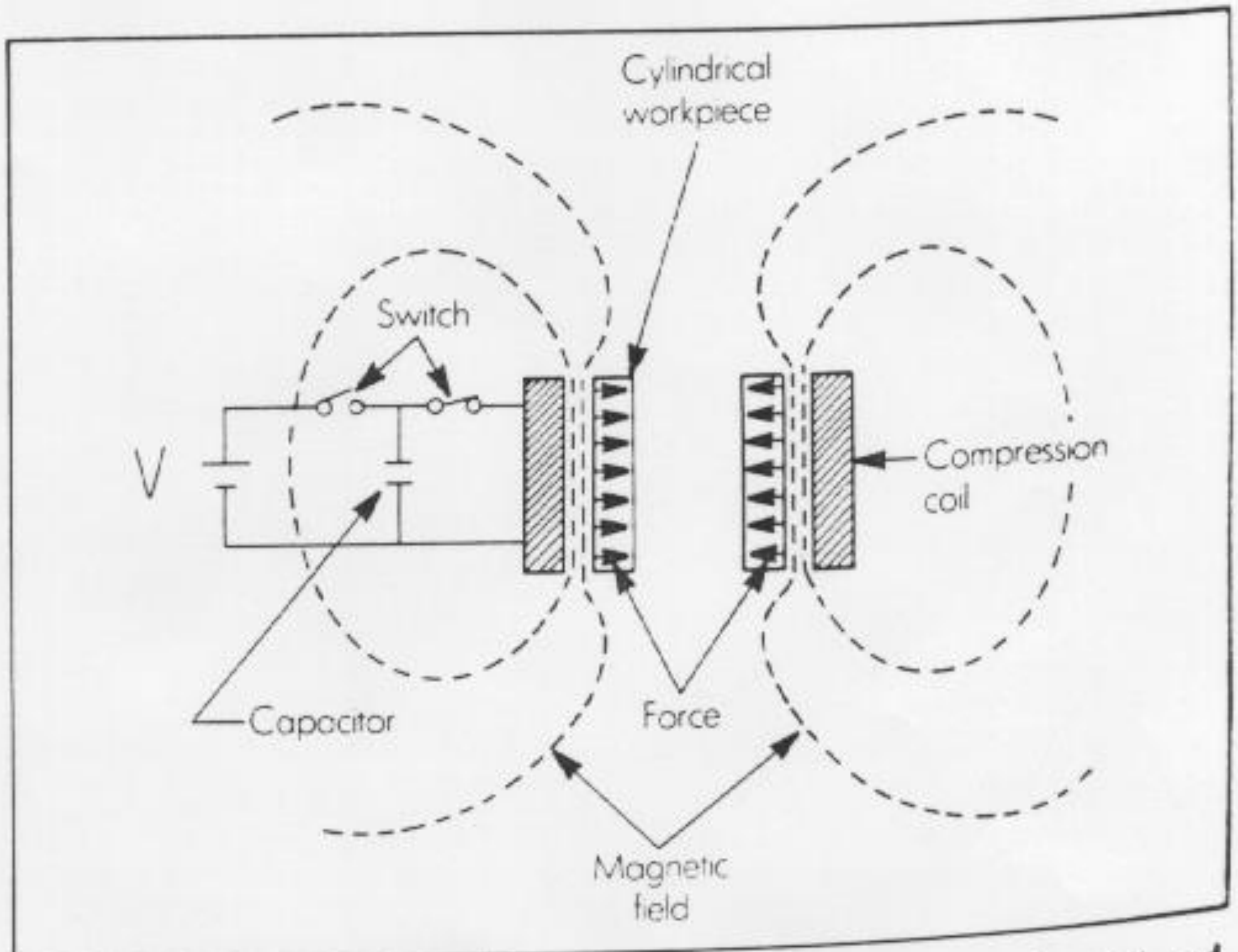
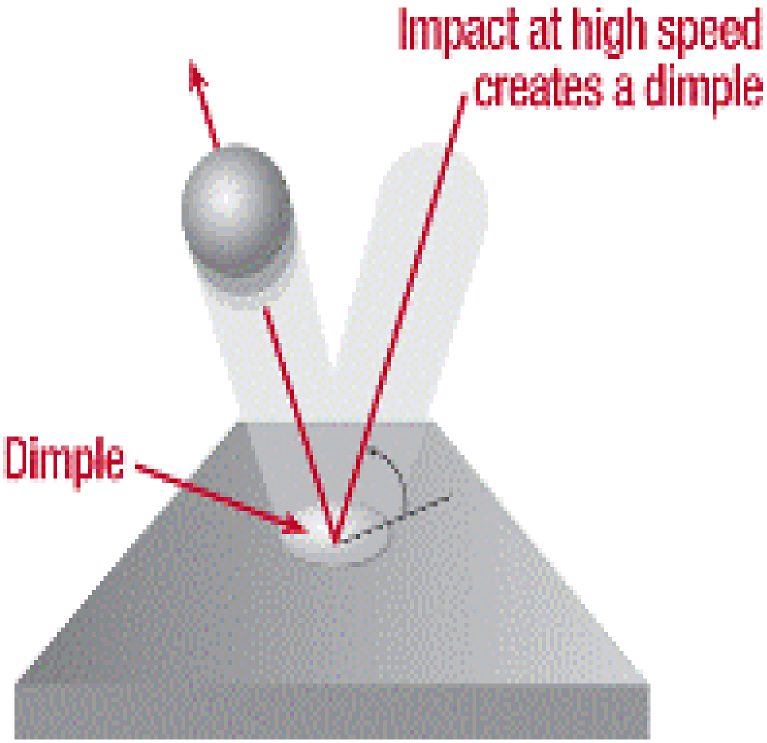
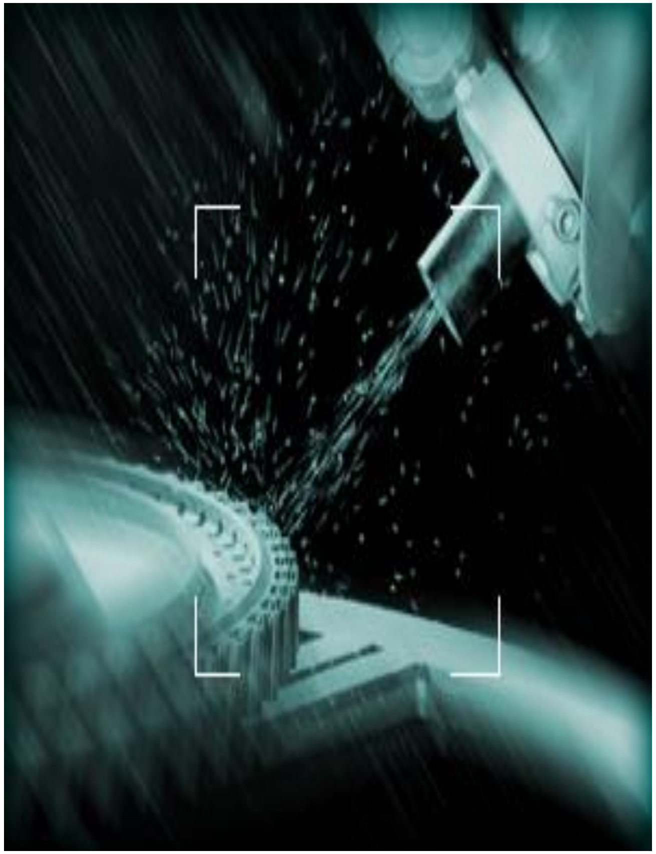


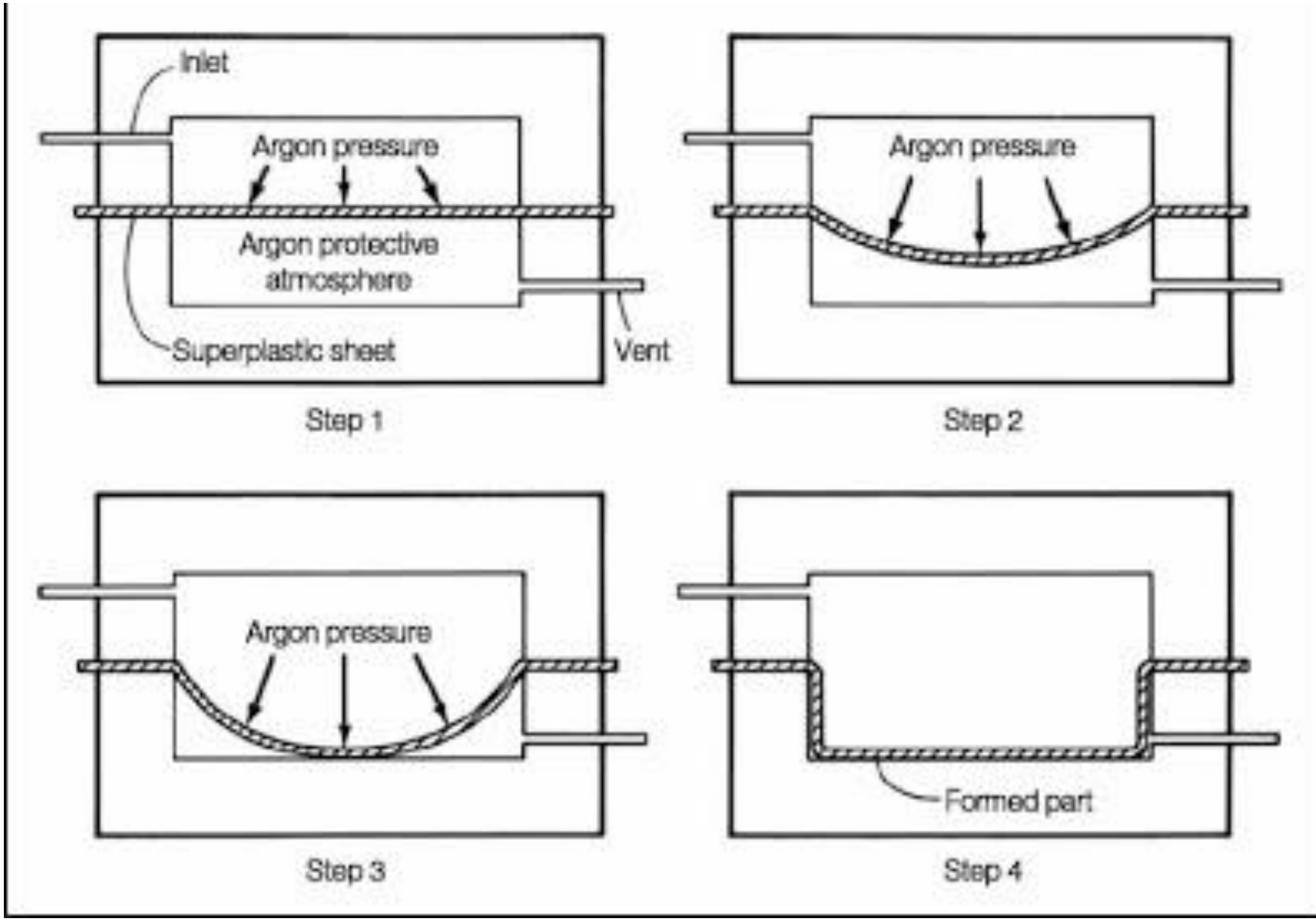
Fig. 19-13 A magnetic field of high intensity between the coil and workpiece produces a magnetic pressure which deforms the workpiece.

Peen Forming Process





Super Plastic forming Process



Micro Forming in Sheet metal process

- Cellular Telephones
- Electronics
- IC lead Frames
- Electronics
- Health Care
- Miniature Fasteners
- Hard Disc Drives
- National Security & Defense
- Automobiles
- Sensor

Process Characteristics

- Elongation
- Yield Point Elongation
- Anisotropy
  - Planar
  - Normal
- Grain Size
- Residual Stress
- Spring Back
- Wrinkling
- Quality of Sheared Edges
- Surface Condition of Sheet

UNIT V
MANUFACTURE OF PLASTIC COMPONENTS

Introduction

- Plastics are belonged to a family of organic material
- Organic materials are those which is obtained from carbon and chemically combined with oxygen, hydrogen and other metallic compounds
  - Natural Organic Materials
  - Synthetic Organic Materials

- Natural Organic Material
  - Wood, coal, petroleum and natural rubber
- Synthetic Organic materials
  - Plastics, Synthetic rubbers, ceramic glass
- **Polymer**
  - Poly means many and Mers means parts
  - Plastic is one kind of polymer which can be moulded into required shape with help of application heat or pressure or both
  - Liquid form is called as resins and it contains carbon as a central element. Oxygen, nitrogen and chlorine are linked to it

Polymerization Process

- Addition polymerization
  - Similar monomers are joined together to form a long chain of component which is added by chemically
  - Principle used here is Vander Wall's Force
  - No catalyst is used. Addition of monomers take place by applying energy in the form of pressure.
  - Addition of two or more monomers is called co-polymerization process

- Condensation Polymerization
  - Two or more unlike monomers are linked and there is a repetitive elimination of smaller molecules to form a by product
  - By products like water or ammonia is formed
  - Require high pressure and hours or days to complete the process
  - The properties of Polymer can be modified by addition of additives and fillers

Additives

- **Plasticizers**
  - It is used to separate the macromolecules and thus enables decreasing inter molecular forces and facilitating the relative movement between the molecules of polymer *Water, organic Solvents, resins*
- **Catalyst**
  - used to promote and complete polymerization process
- **Dyes and Pigments**
  - Impart a desire color on the material

- **Initiators**
  - Initiate and stabilize the end reaction of the molecular chains
- **Modifiers**
  - Mechanical properties of plastics such as strength, damping capacity, toughness, ductility, plasticity etc.,
- **Lubricants**
  - Reduce friction during the process to prevent the parts stick on the walls, also polymer material sticking on others

- **Flame retardants**
  - Enhances non inflammability of plastics
    - Compounds of chlorine, bromine and phosphorous
- **Solvents**
  - Used for dissolving certain fillers and plasticizers
    - Alcohol
- **Elastomers**
  - Enhance elastic properties
- **Stabilizers**
  - To retard the degradation of the polymers
- **Fillers**
  - Used to improve the properties of strength and stability of plastics
  - Examples Mica and Asbestos used to improve heat resistance capacity of the plastics

Properties of Plastics

- Elongation
- Heat Resistance
- Insensitive to tension cracks
- High Rigidity
- Surface hardness
- High Viscosity
- Maximum Temperature
- Minimum Temperature
- Density
- Ignition Temperature
- Humidity Absorption
- Chemical Resistance

PLASTICS

- Light weight
- Higher strength to weight ratio
- Wider design freedom
- Easy to process
- Low energy requirement
- Minimum post finishing
- Wide colour range

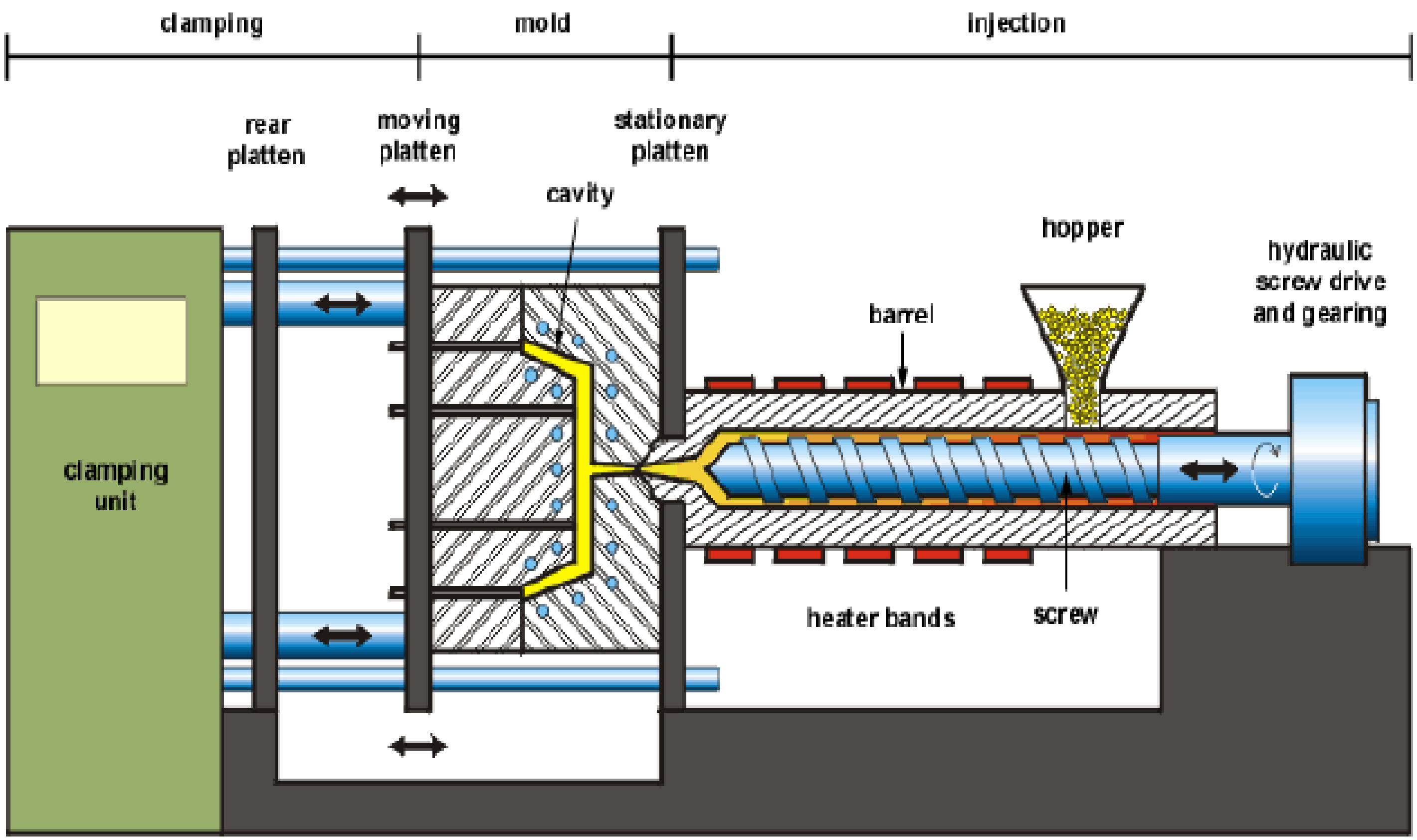
Plastics classification

- THERMOPLASTICS are materials that can be repeatedly heated, melted and cooled and converted into a solid product- Physical change is taking place
- THERMOSETS are materials that undergo a chemical reaction during conversion to form a three-dimensional network product. It cannot be remelted and converted to a product again

Injection Moulding

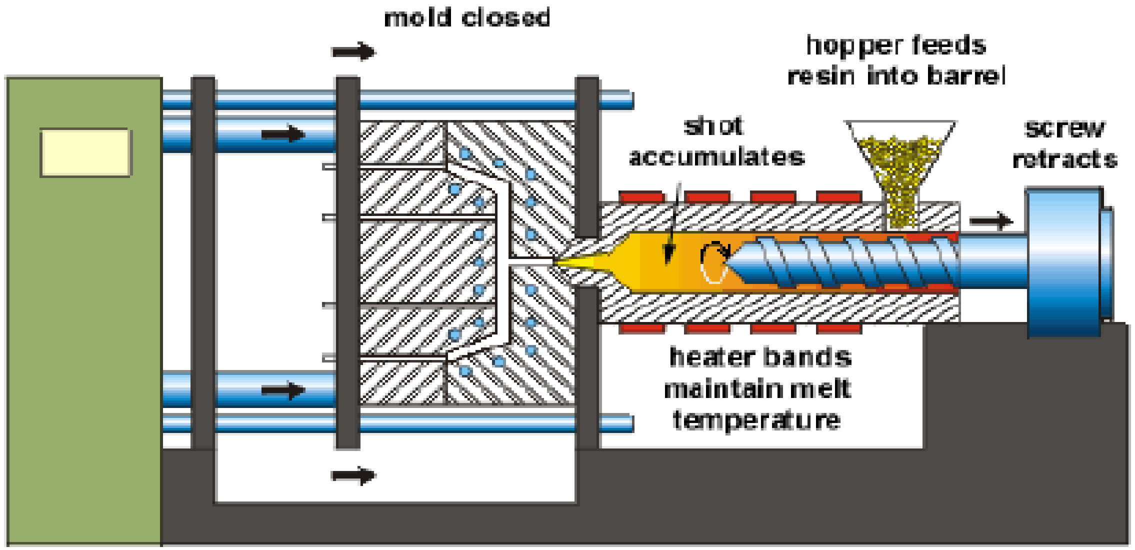
- Plasticizes the material by reciprocating Screw.
- Injects the molten material to a closed mould
  - via a channel system of runners and gate.
- Cools the Mould.
- Refills the material for the next cycle.
- Ejects the Product.
- Closes the Mould for further cycle.

Injection Moulding machine



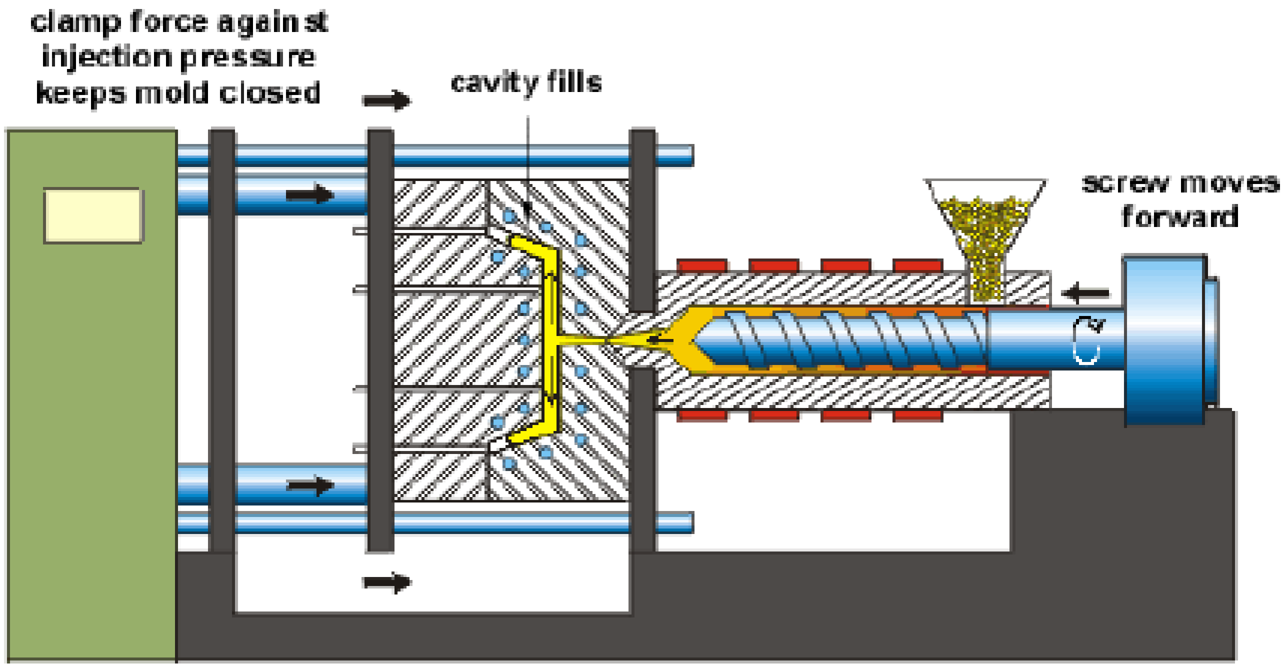
schematic of thermoplastic injection molding machine

1.Plasticizing the resin



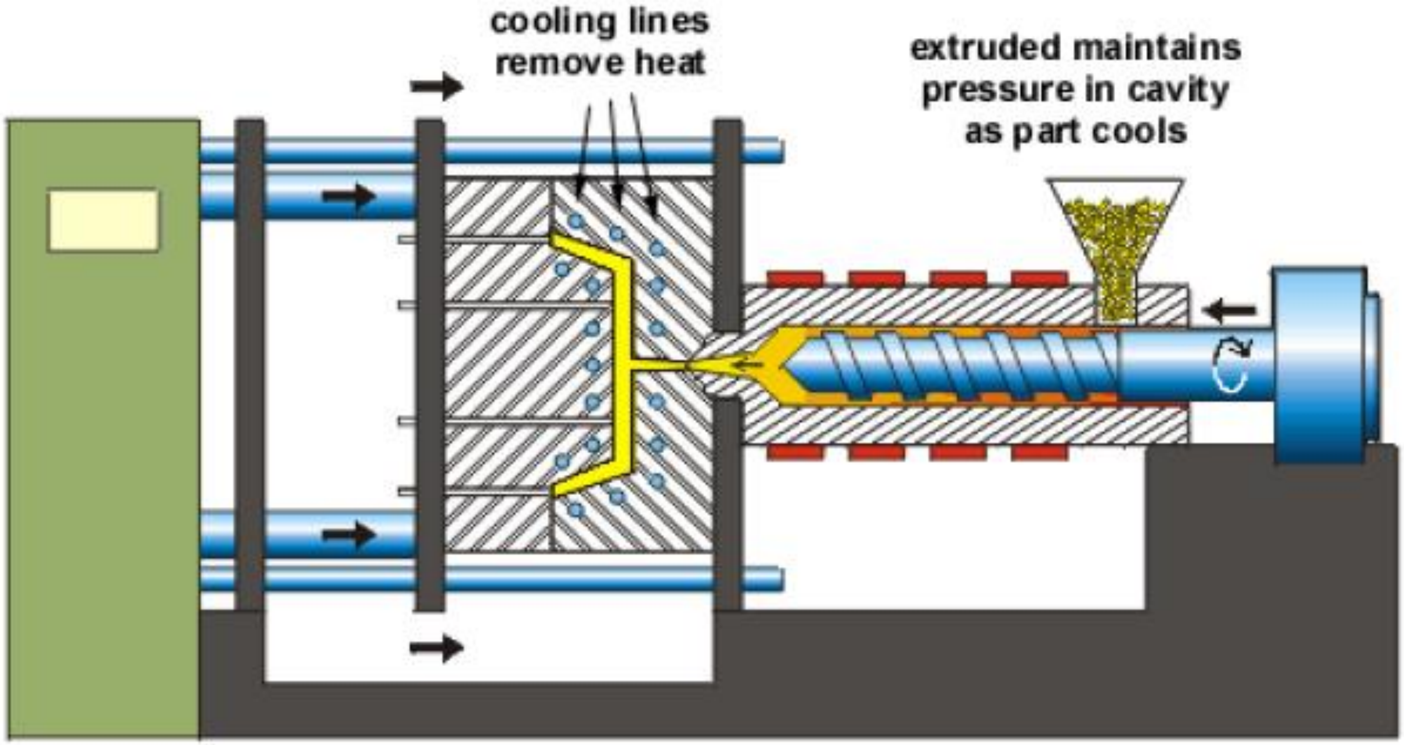
1. plasticizing the resin

2. Injecting the resin



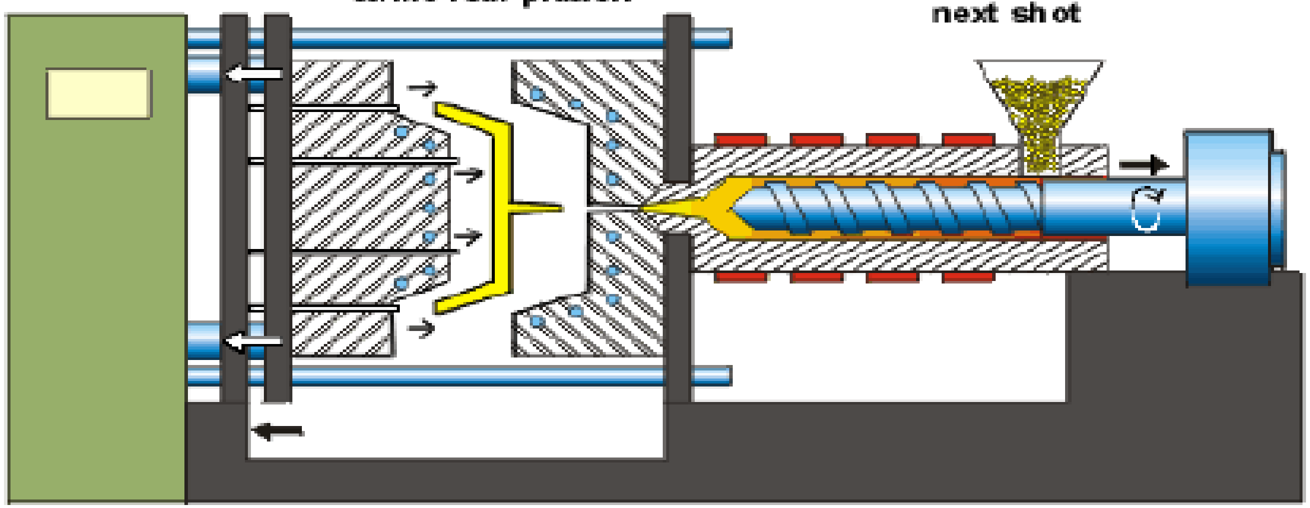
2. injecting the resin

3. Cooling the part



3. cooling the part

4. Ejecting the part

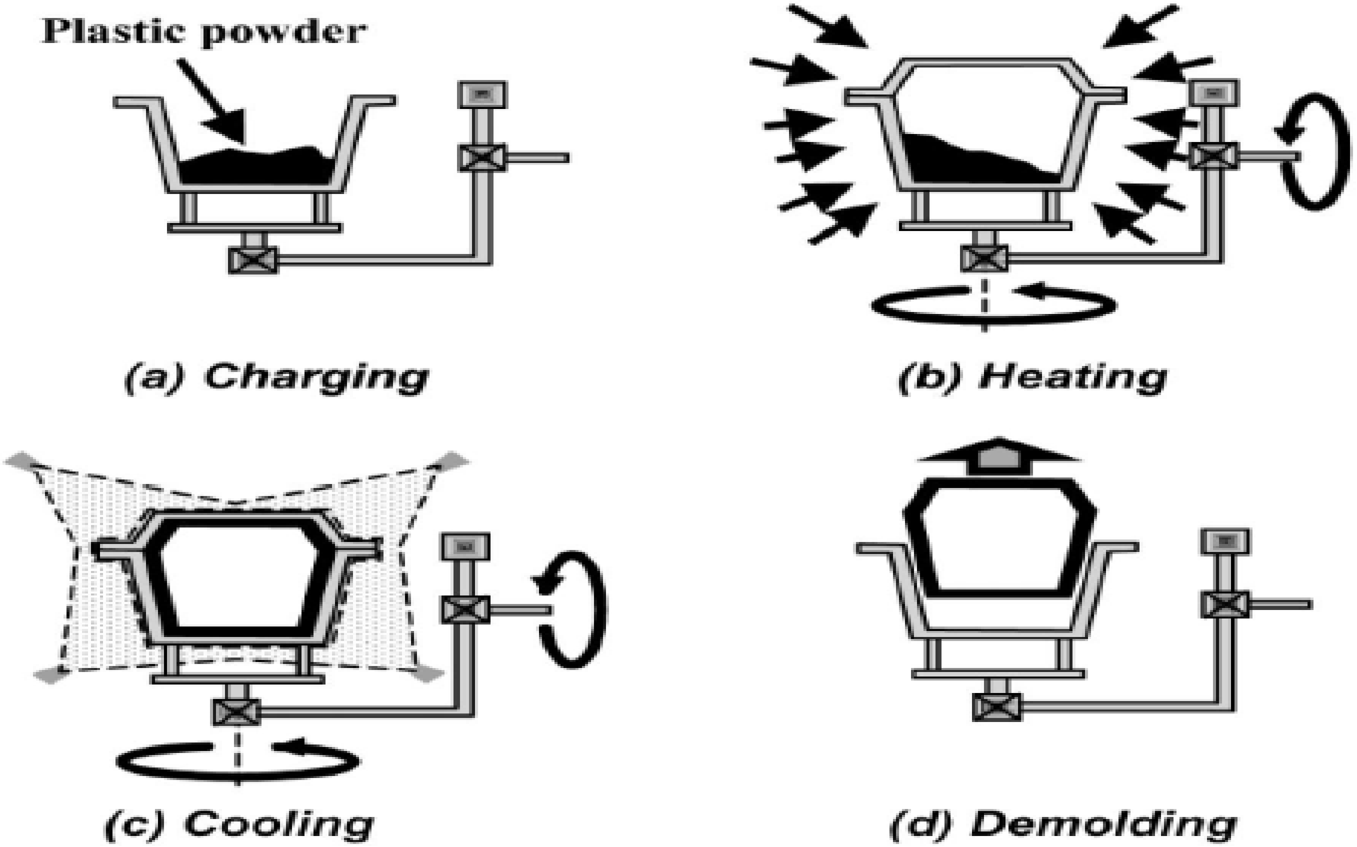


4. ejecting the part

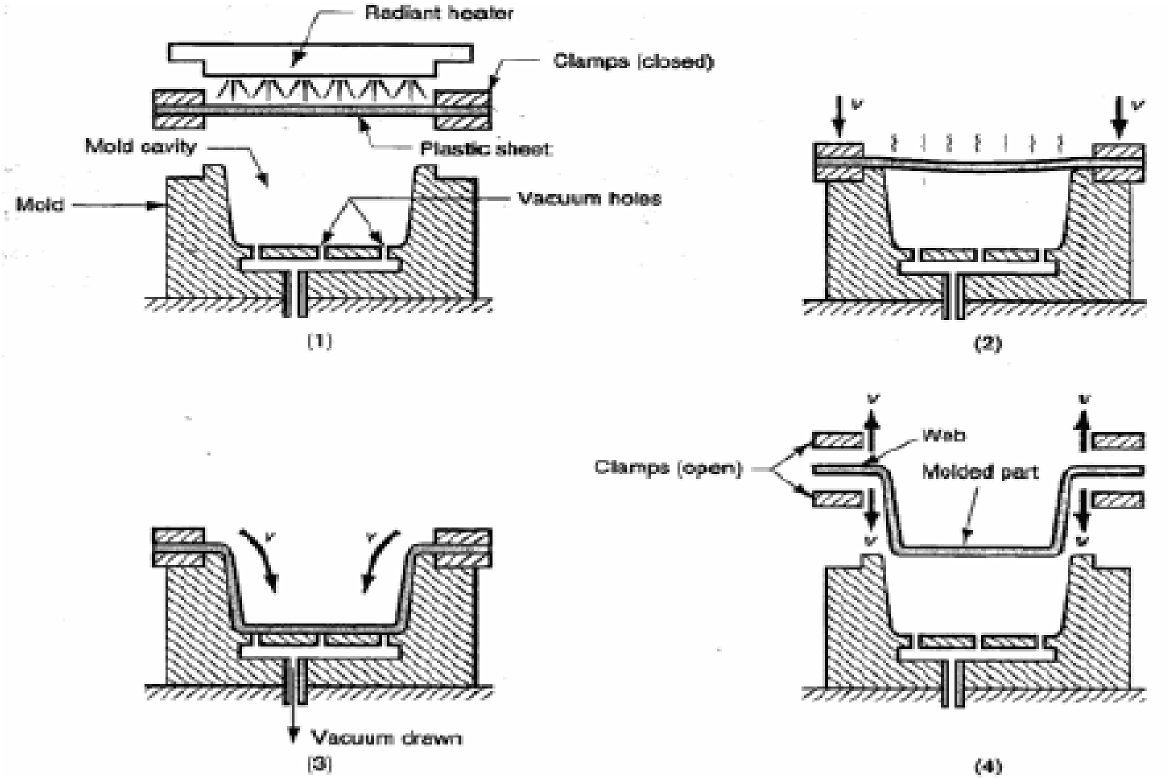
Applications (Injection Moulding)

- Moulded chairs,
- Computer/ TV/ Radio Cabinets,
- Washing machine Cabinets,
- Telephone handsets,
- Power-tool housings etc.
- Moulded House hold items

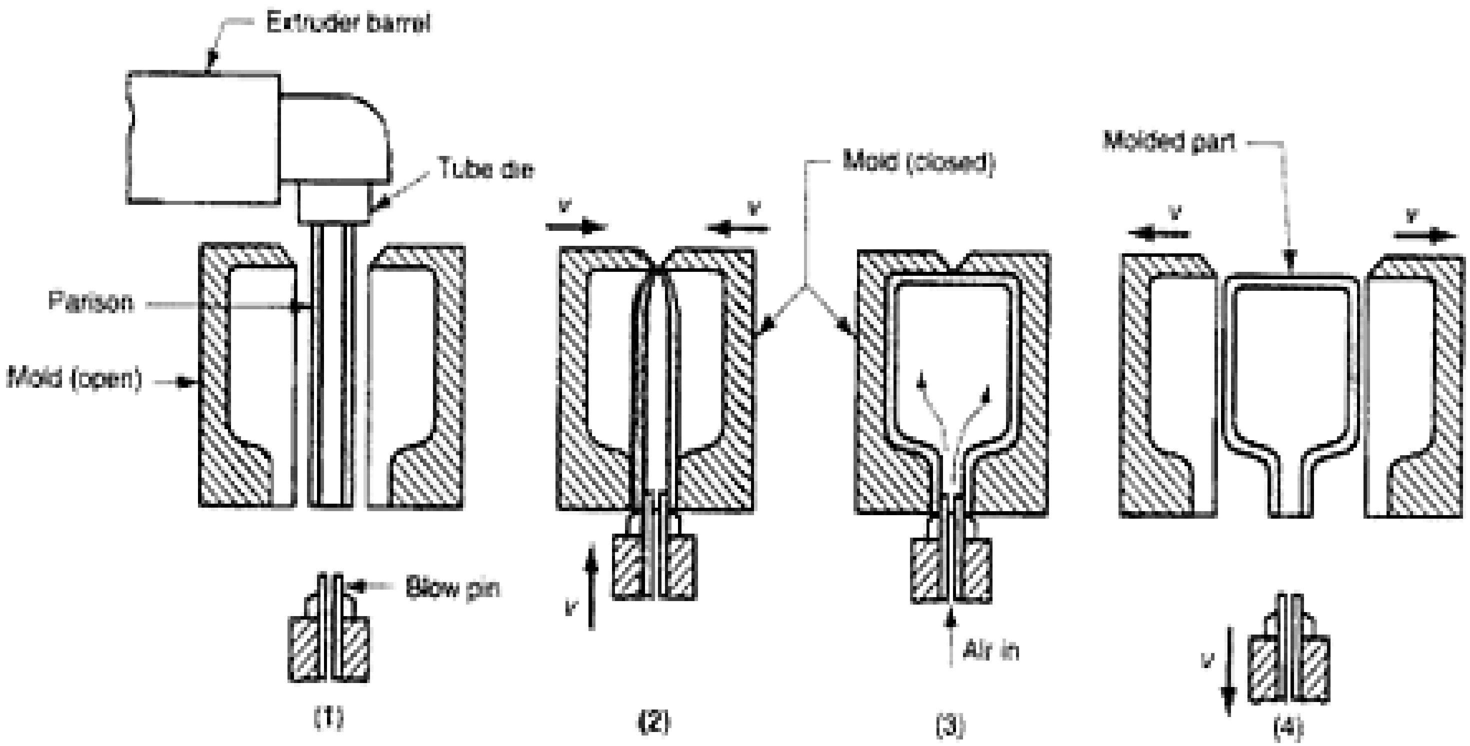
Rotational Molding Process



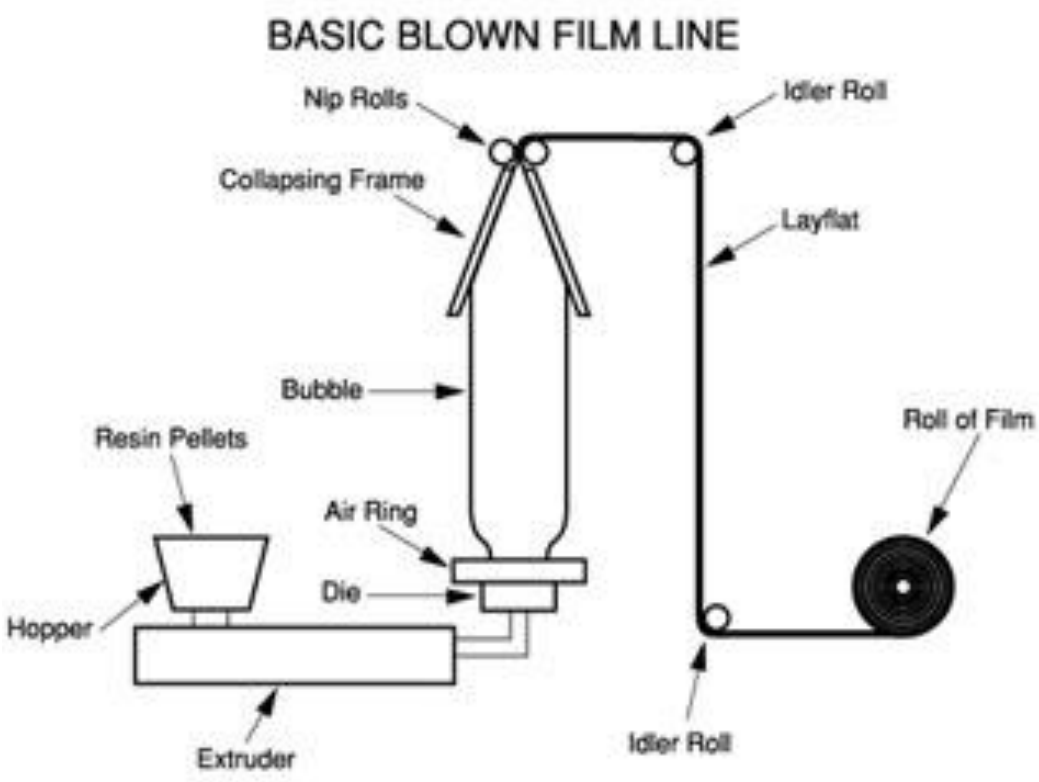
Vacuum Forming



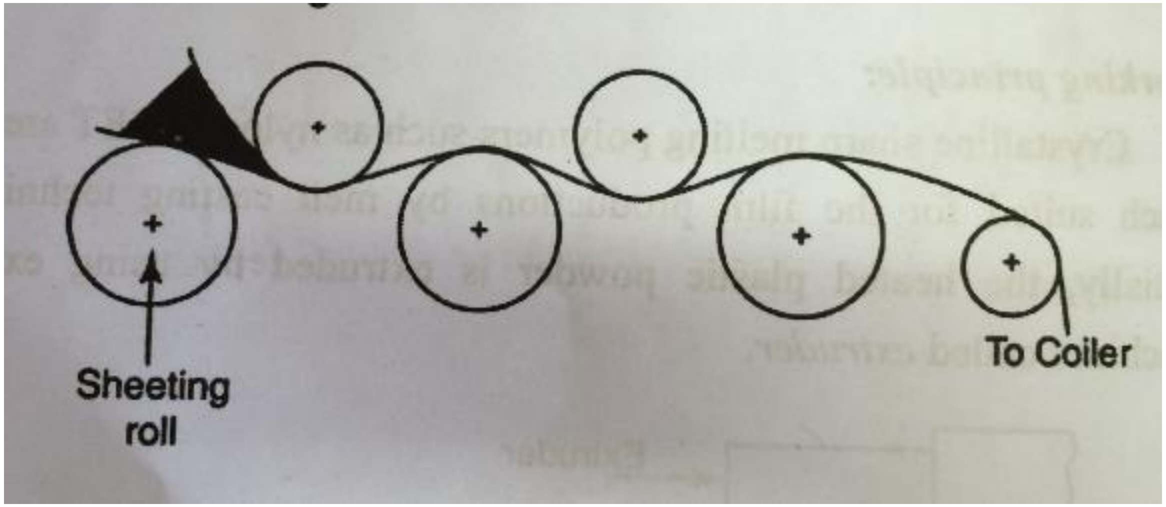
Blow Moulding



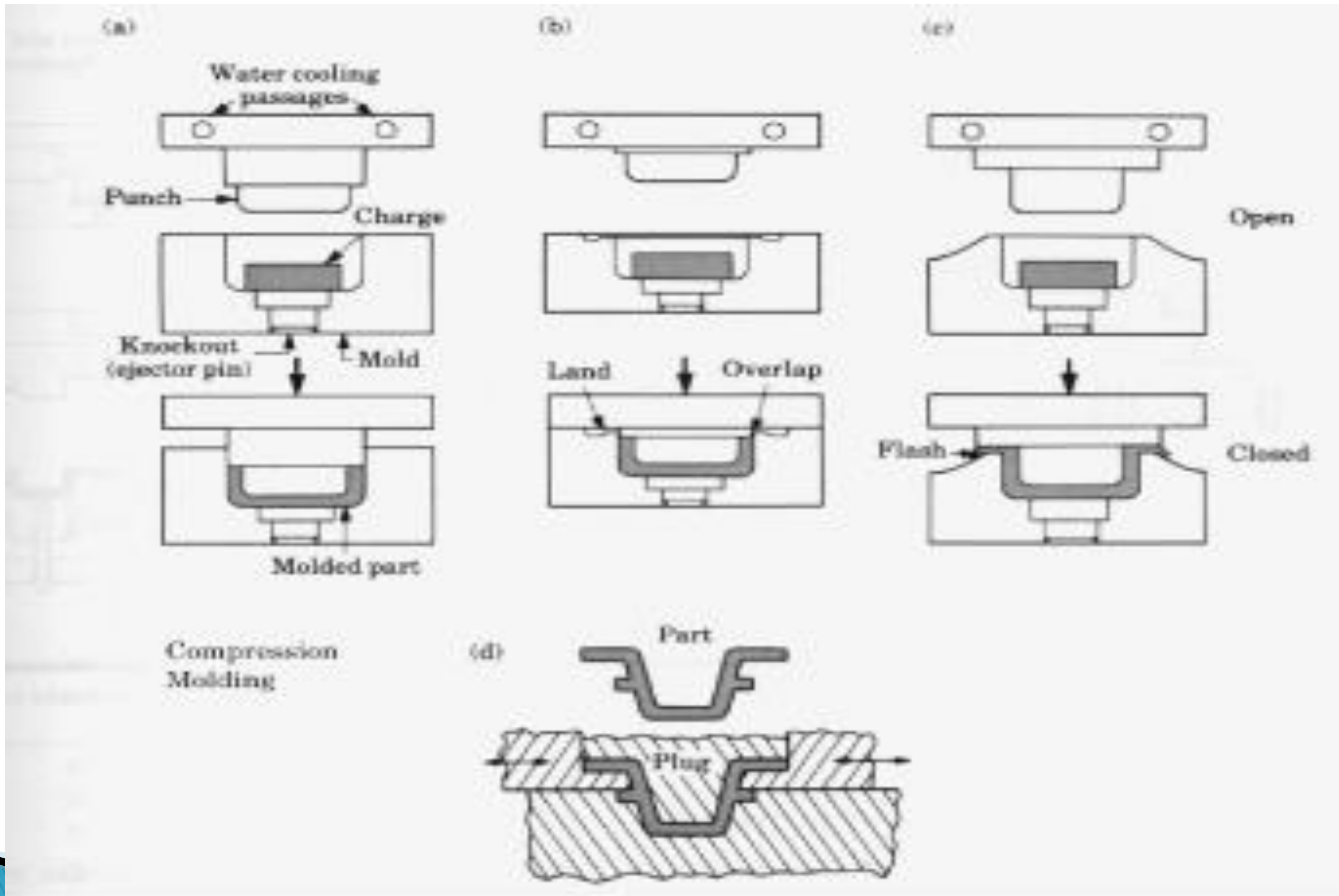
Film Blowing



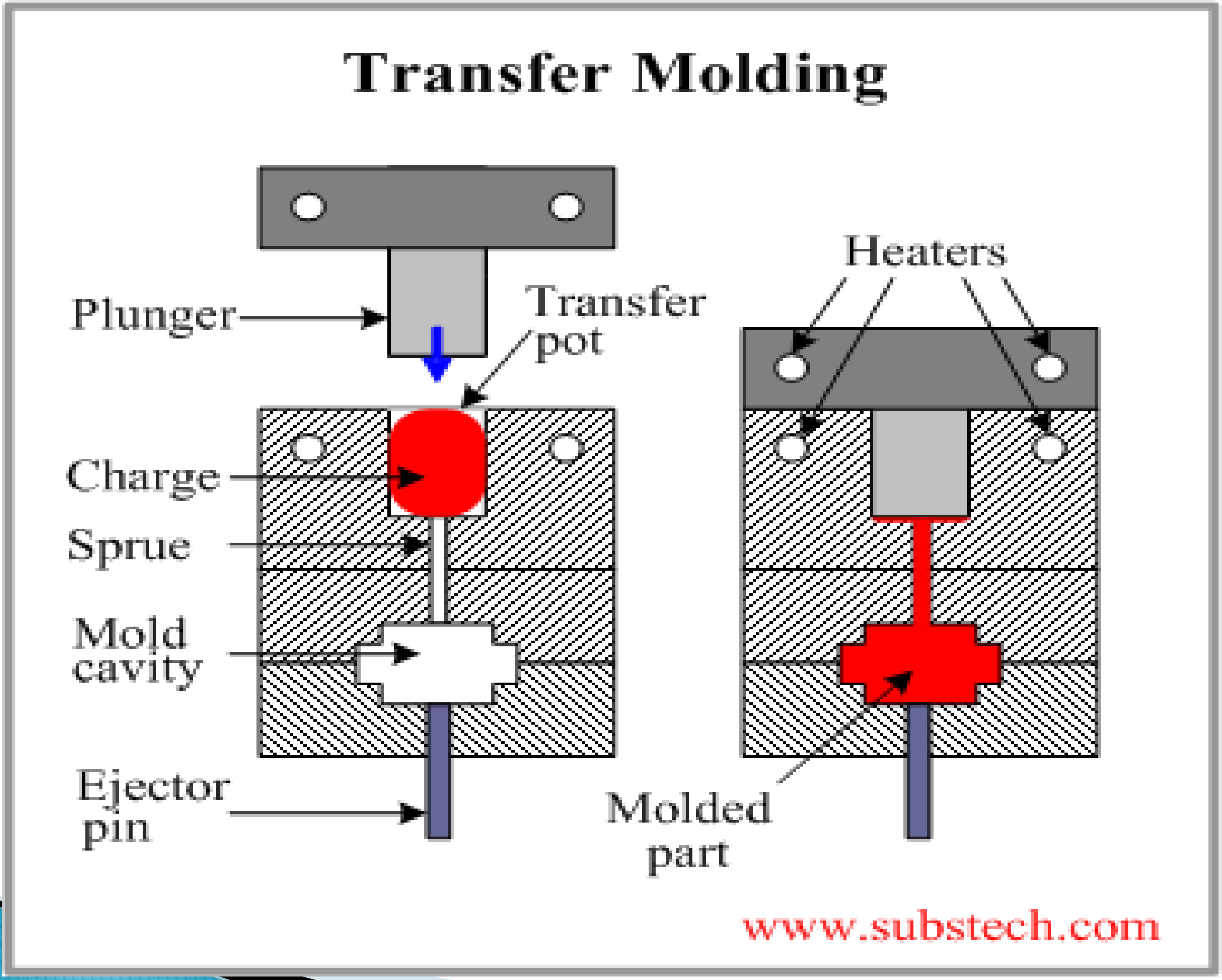
Sheet Making



Compression Moulding

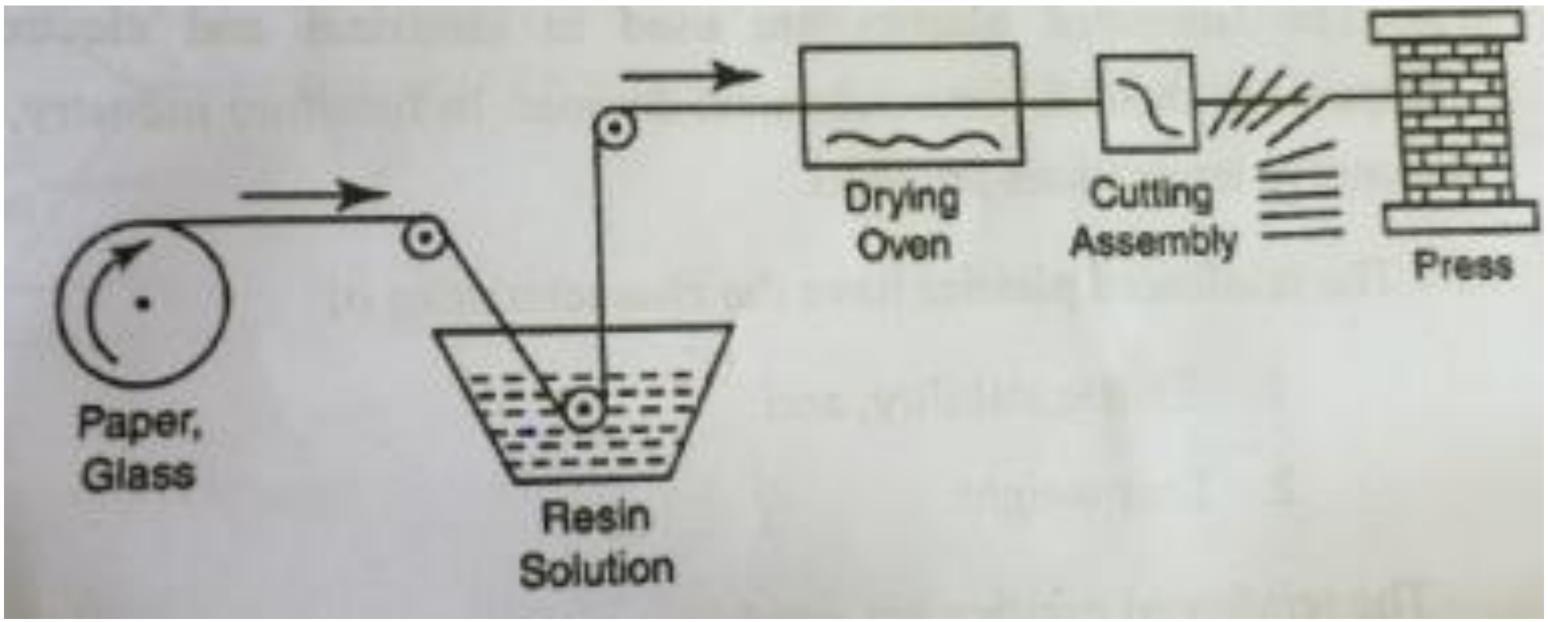


- Polyester and epoxy
- Moulding pressure = 3.5 Mpa
- Moulding Temp = 1100 to 2200 $^{\circ}$C
- Cycle = 10 sec <2.5 mm thick
- 5 to 10 mins Depends on thickness

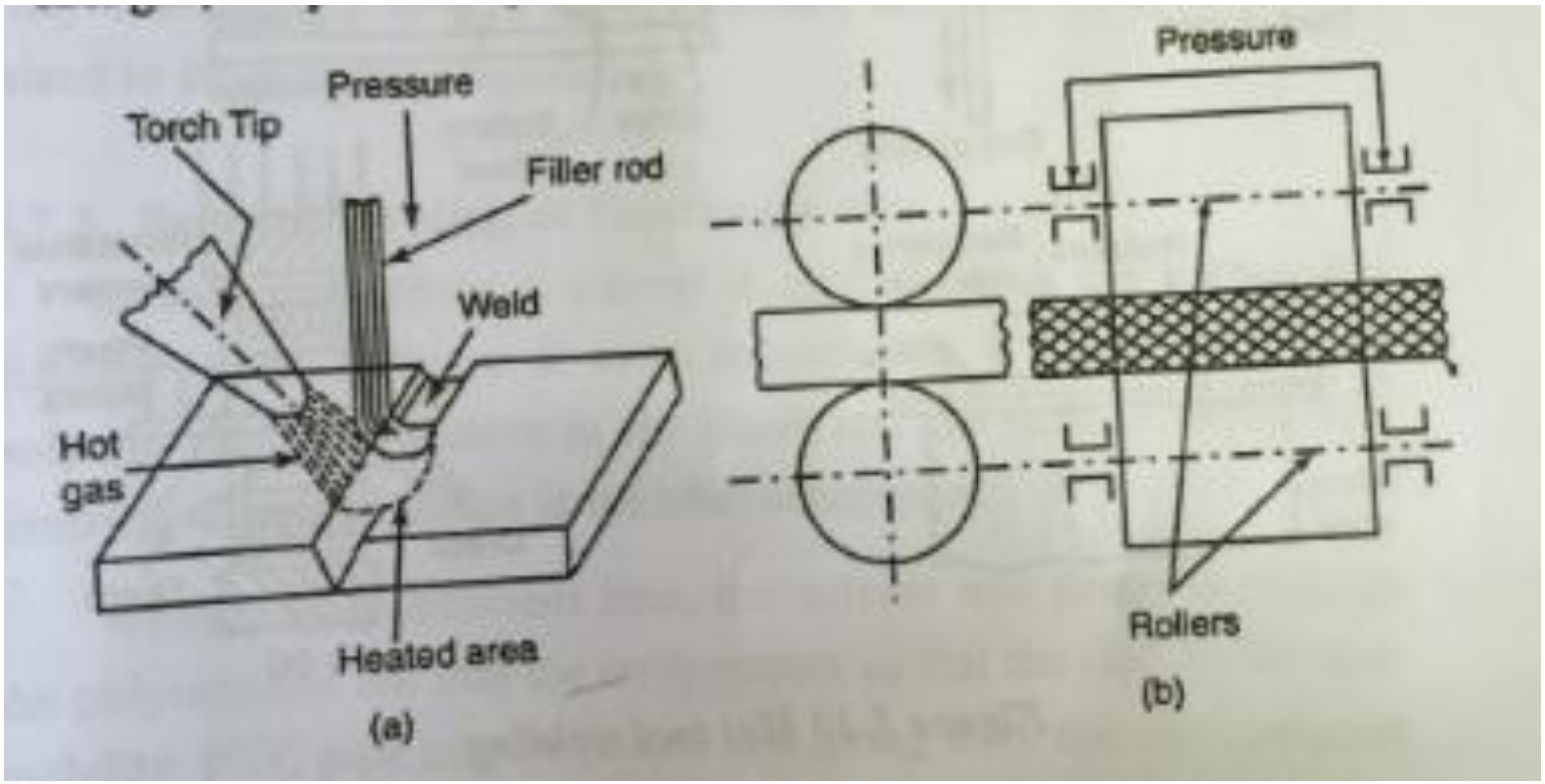


Transfer Molding
Plunger
Transfer pot
Charge
Sprue
Mold cavity
Ejector pin
Heaters
Molded part
www.substech.com

Bonding of Thermoplastics



Hot Gas Welding



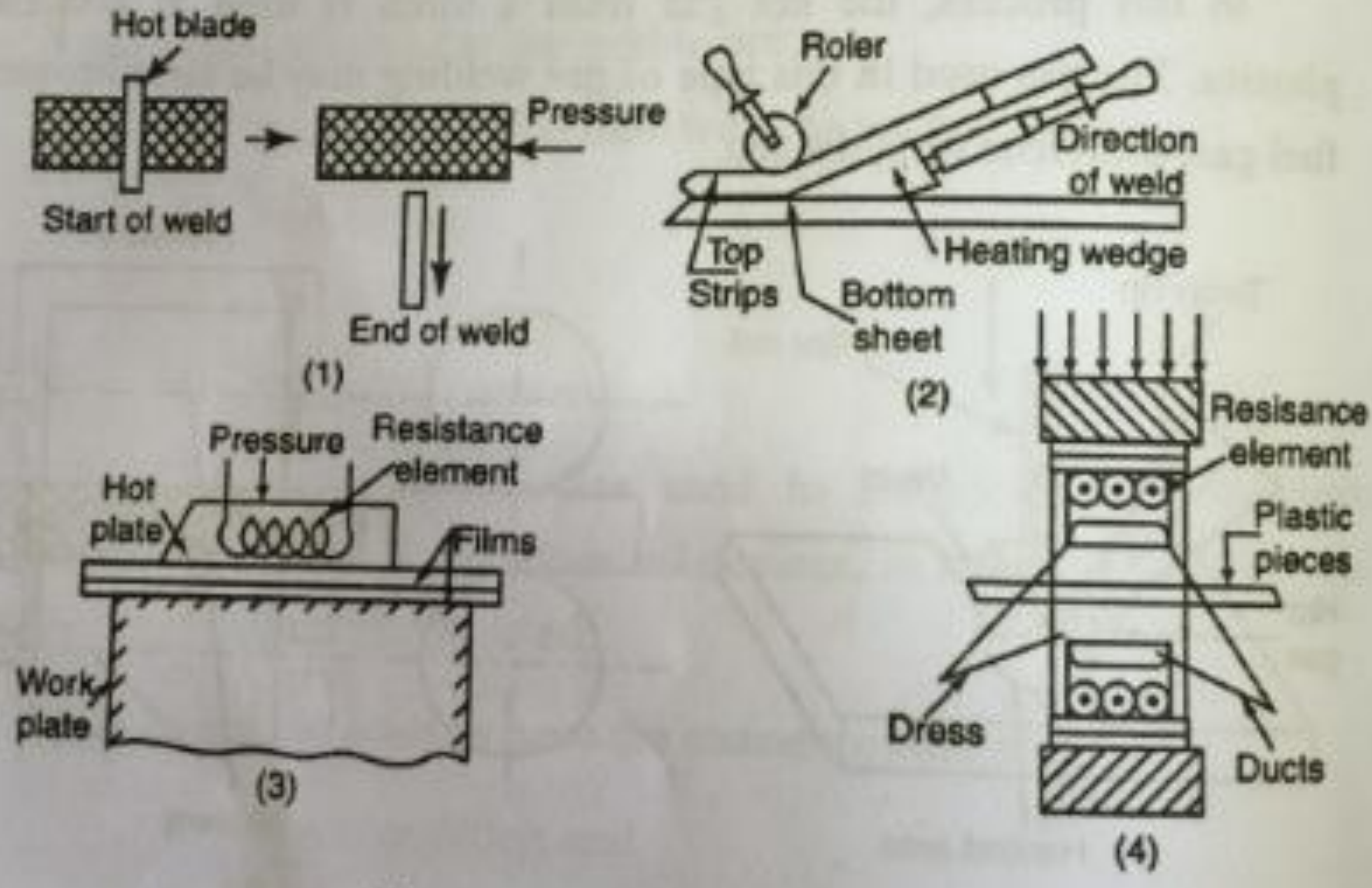
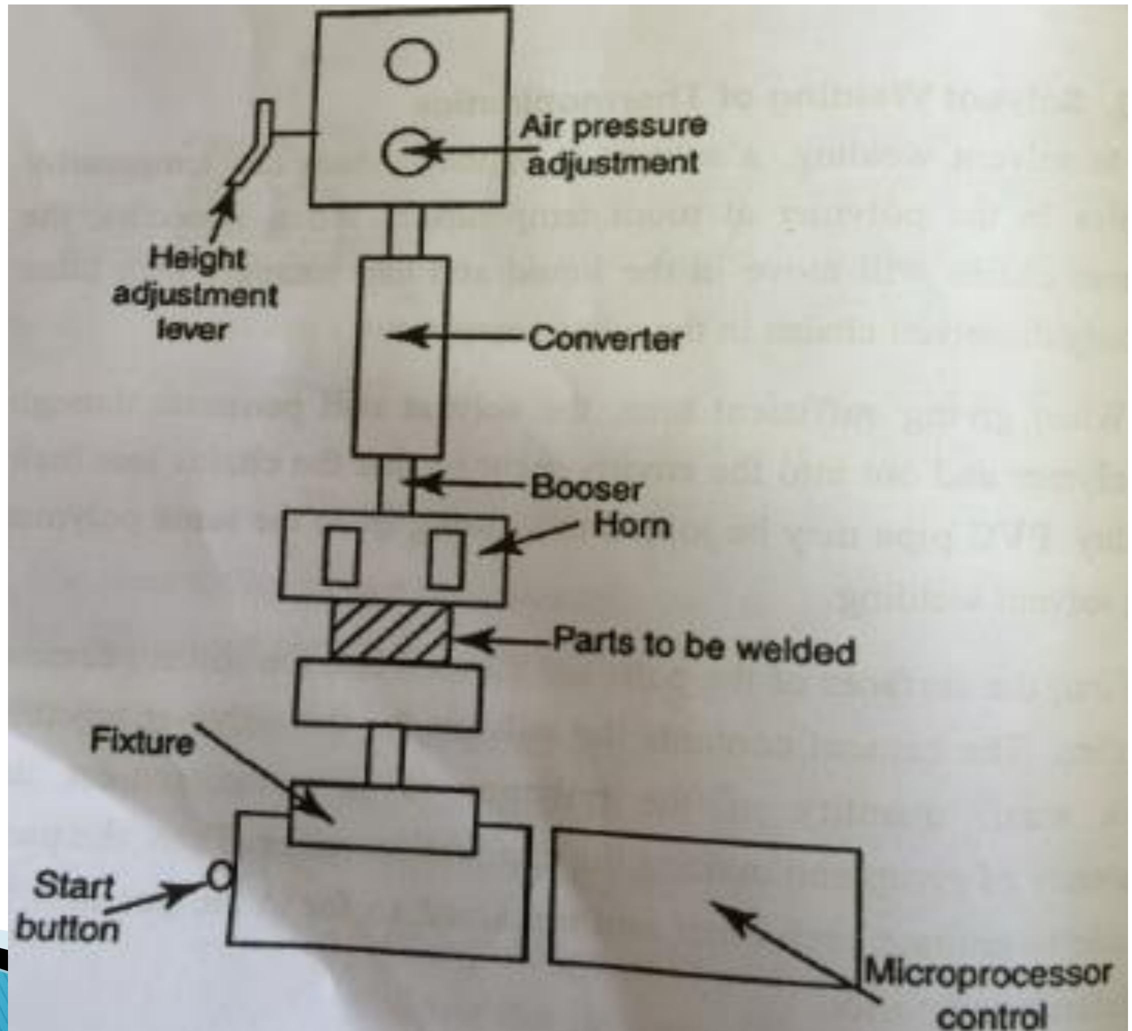
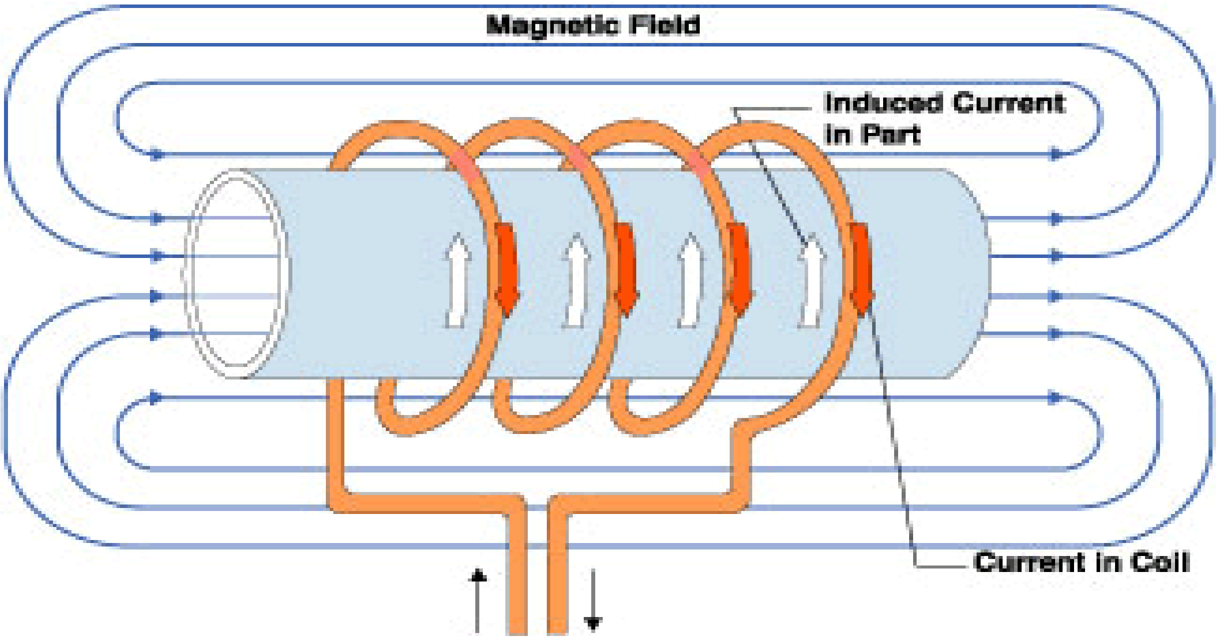
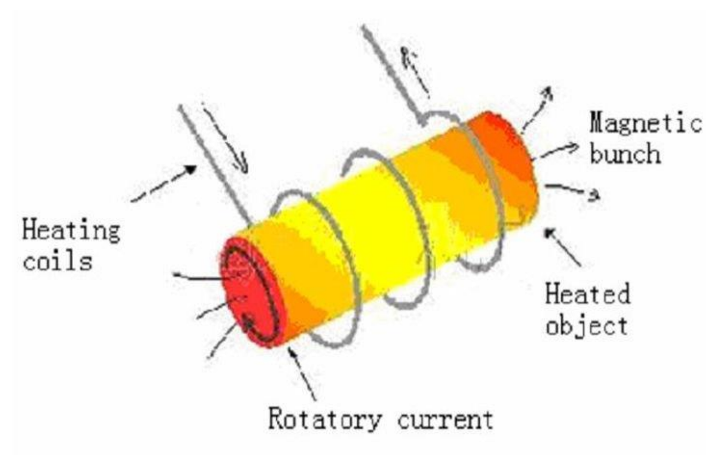


Figure 5.13 Hot tool welding

Ultrasonic Welding







Theory Diagram of Inductive Heat Power