# GOVT. POLYTECHNIC. DHANGAR

**Branch: Mechanical Engineering**

**Semester: 3rd**

**Subject: Workshop Technology-I**

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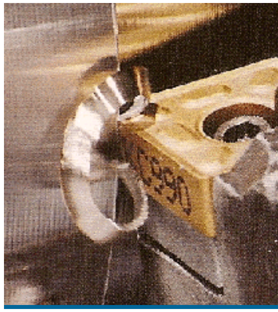
# FOUNDRY TECHNIQUES

1. Moulding Sand
2. Mould Making
3. Casting Processes
4. Melting Furnaces
5. Casting Defects

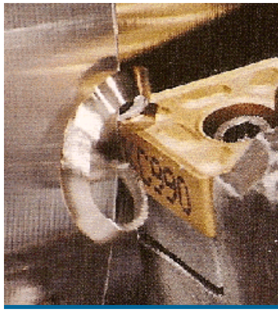


# Two Categories of Casting Processes

1. Expendable mold processes - mold is sacrificed to remove part
   - Advantage: more complex shapes possible
   - Disadvantage: production rates often limited by the time to make mold rather than casting itself
2. Permanent mold processes - mold is made of metal and can be used to make many castings
   - Advantage: higher production rates
   - Disadvantage: geometries limited by need to open mold

# Overview of Sand Casting

- Most widely used casting process, accounting for a significant majority of total tonnage cast
- Nearly all alloys can be sand casted, including metals with high melting temperatures, such as steel, nickel, and titanium
- Castings range in size from small to very large
- Production quantities from one to millions



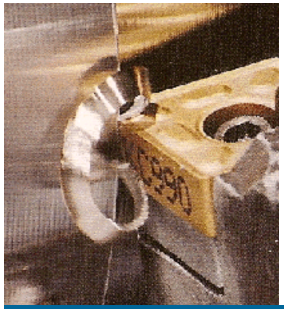

- Sand casting weighing over 680 kg (1500 lb) for an air compressor frame (photo courtesy of Elkhart Foundry).

# Steps in Sand Casting

1. Pour the molten metal into sand mold
2. Allow time for metal to solidify
3. Break up the mold to remove casting
4. Clean and inspect casting
   - Separate gating and riser system
5. Heat treatment of casting is sometimes required to improve metallurgical properties

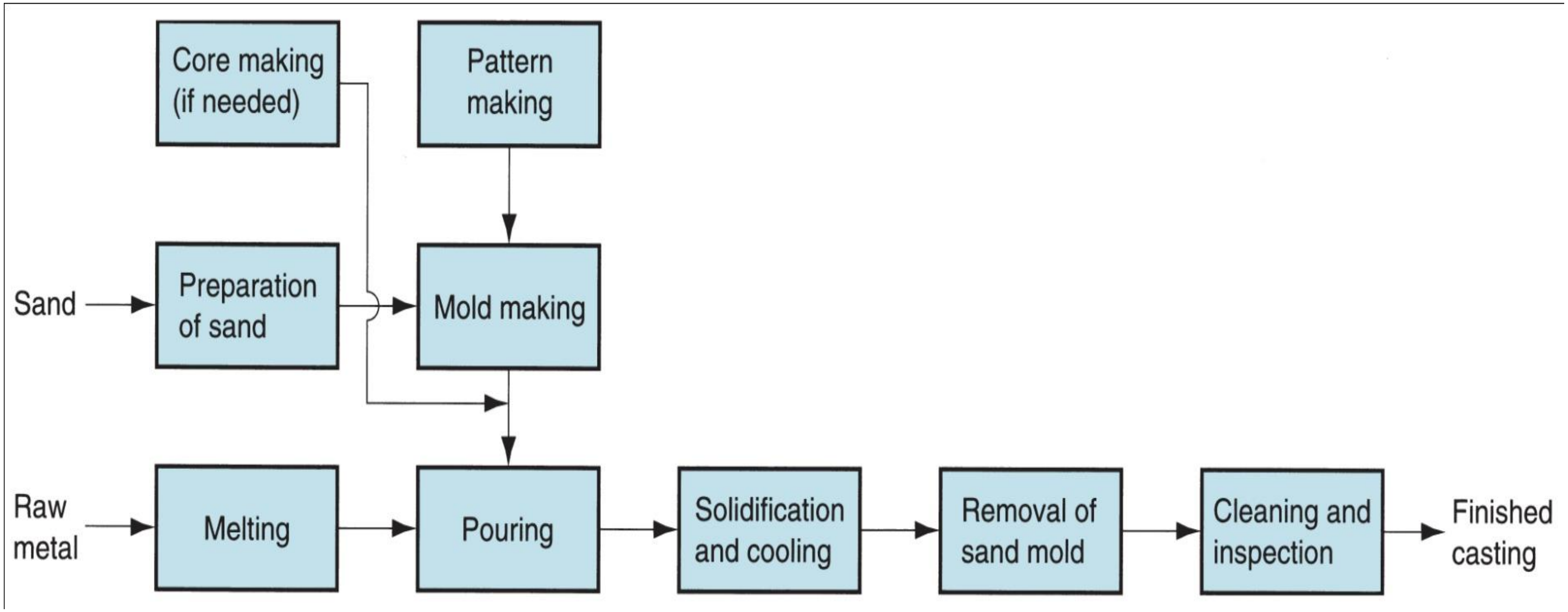
# Making the Sand Mold

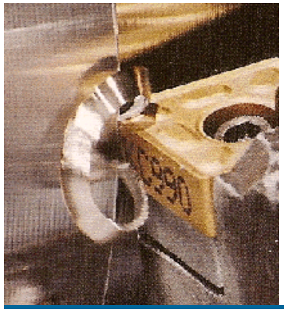
- The *cavity* in the sand mold is formed by packing sand around a pattern, then separating the mold into two halves and removing the pattern
- The mold must also contain gating and riser system
- If casting is to have internal surfaces, a *core* must be included in mold
- A new sand mold must be made for each part produced



# Sand Casting Production Sequence

- Production sequence in sand casting, including pattern-making and mold-making





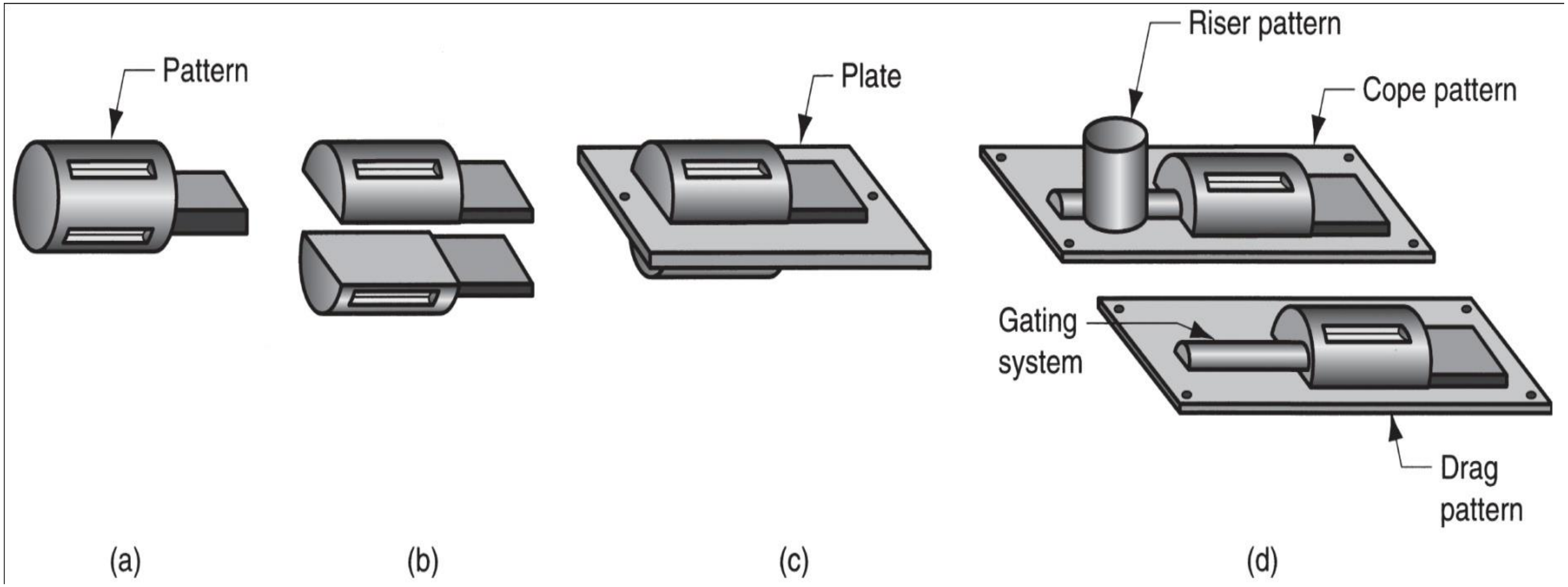
# The Pattern

Full-sized model of part, slightly enlarged to account for shrinkage and machining allowances in the casting

- Pattern materials:
  - Wood - common material because it is easy to work, but it warps
  - Metal - more expensive to fabricate, but lasts longer
  - Plastic - compromise between wood and metal

# Types of Patterns

- Types of patterns used in sand casting: (a) solid pattern, (b) split pattern, (c) match-plate pattern, (d) cope and drag pattern



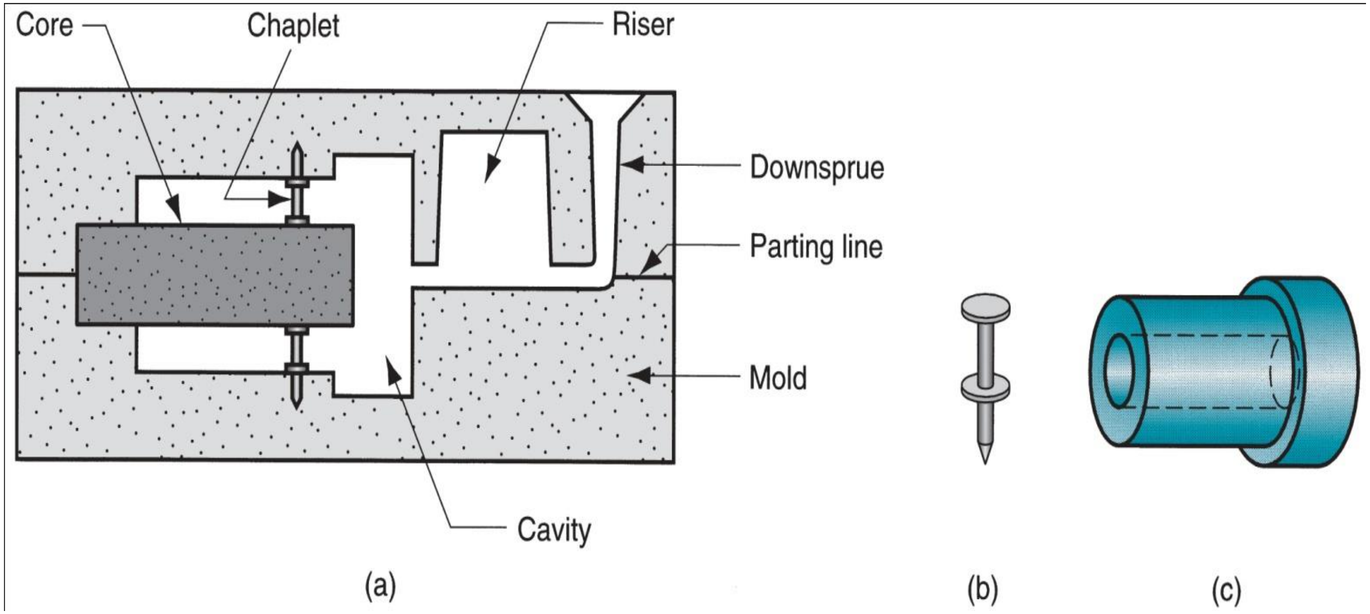
# Core

Full-scale model of interior surfaces of part

- Inserted into mold cavity prior to pouring
- The molten metal flows and solidifies between the mold cavity and the core to form the casting's external and internal surfaces
- May require supports to hold it in position in the mold cavity during pouring, called *chaplets*

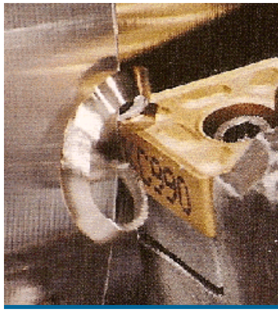
# Core in Mold

- (a) Core held in place in the mold cavity by chaplets, (b) possible chaplet design, (c) casting



# Desirable Mold Properties

- Strength - to maintain shape and resist erosion
- Permeability - to allow hot air and gases to pass through voids in sand
- Thermal stability - to resist cracking on contact with molten metal
- Collapsibility - ability to give way and allow casting to shrink without cracking the casting
- Reusability - can sand from broken mold be reused to make other molds?



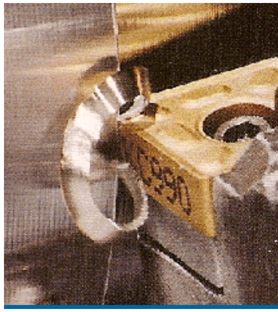
# Foundry Sand

Silica ($SiO_2$) or silica mixed with other minerals

- Good refractory properties - for high temperatures
- Small grain size for better surface finish on cast part
- Large grain size is more permeable, allowing gases to escape during pouring
- Irregular grain shapes strengthen molds due to interlocking, compared to round grains
  - Disadvantage: interlocking reduces permeability

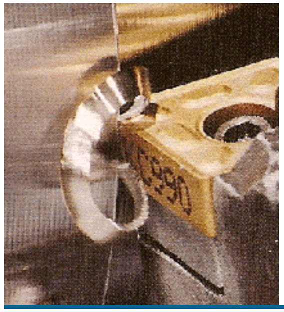
# Binders Used with Foundry Sand

- Sand is held together by a mixture of water and bonding clay
  - Typical mix: 90% sand, 3% water, and 7% clay
- Other bonding agents also used in sand molds:
  - Organic resins (e g , phenolic resins)
  - Inorganic binders (e g , sodium silicate and phosphate)
- Additives are sometimes combined with the mixture to increase strength and/or permeability



# Types of Sand Mold

- Green-sand molds - mixture of sand, clay, and water
  - “Green" means mold contains moisture at time of pouring
- Dry-sand mold - organic binders rather than clay
  - Mold is baked to improve strength
- Skin-dried mold - drying mold cavity surface of a green-sand mold to a depth of 10 to 25 mm, using torches or heating lamps



# Buoyancy in a Sand Casting Operation

- During pouring, buoyancy of the molten metal tends to displace the core, which can cause casting to be defective
- Force tending to lift core = weight of displaced liquid less the weight of core itself

$$F_b = W_m - W_c$$

where $F_b$ = buoyancy force; $W_m$ = weight of molten metal displaced; and $W_c$ = weight of core

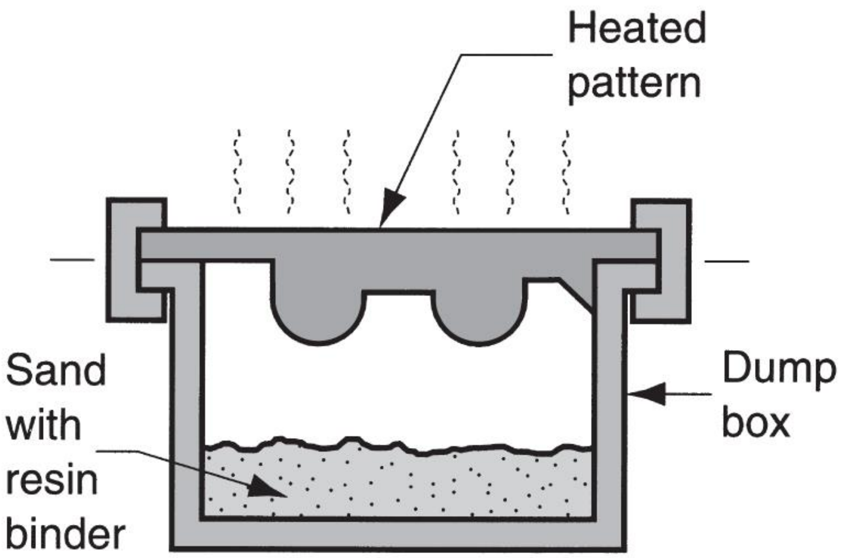
# Other Expendable Mold Processes

- Shell Molding
- Vacuum Molding
- Expanded Polystyrene Process
- Investment Casting
- Plaster Mold and Ceramic Mold Casting

# Shell Molding

Casting process in which the mold is a thin shell of sand held together by thermosetting resin binder

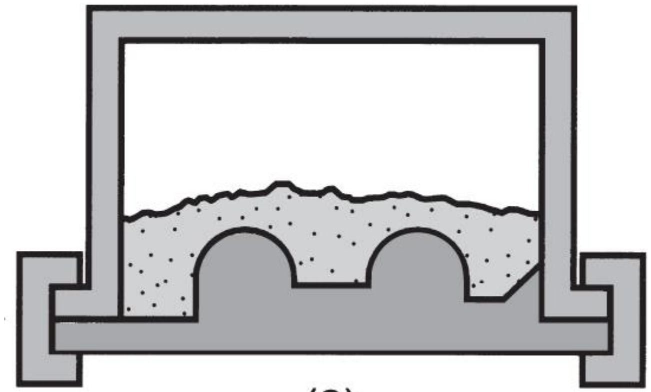
- Steps: (1) A metal pattern is heated and placed over a box containing sand mixed with thermosetting resin




(1)

# Steps in Shell Molding

- (2) Box is inverted so that sand and resin fall onto the hot pattern, causing a layer of the mixture to partially cure on the surface to form a hard shell



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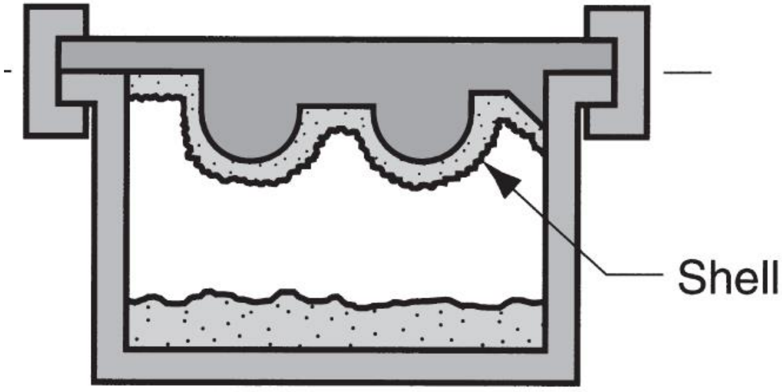
# Steps in Shell Molding

- (3) Box is repositioned so loose uncured particles drop away

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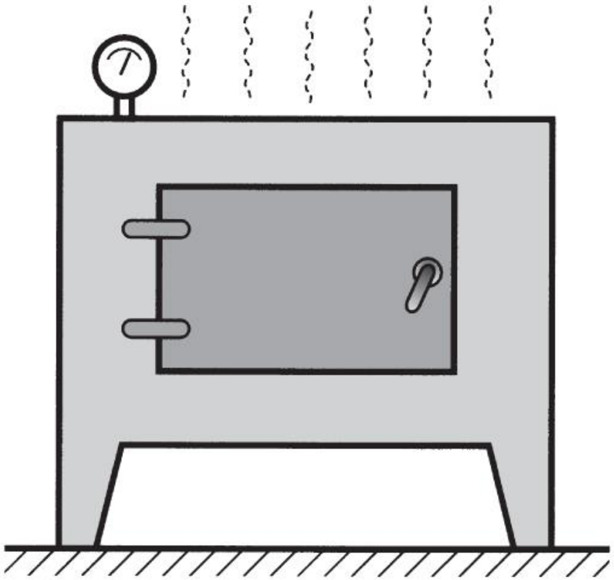
# Steps in Shell Molding

- (4) Sand shell is heated in oven for several minutes to complete curing



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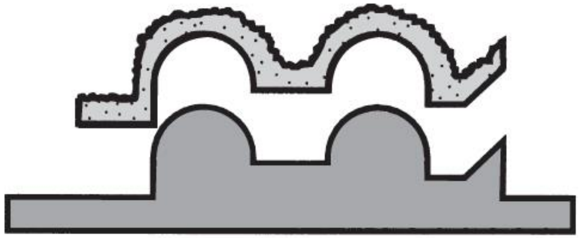
# Steps in Shell Molding

- (5) shell mold is stripped from pattern



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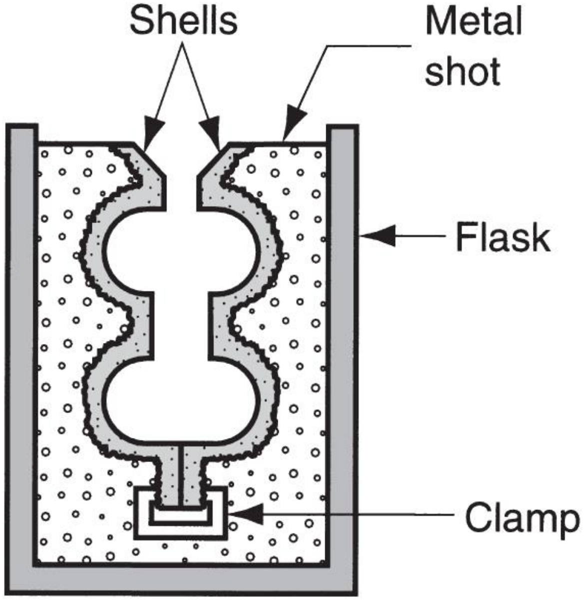
# Steps in Shell Molding

- (6) Two halves of the shell mold are assembled, supported by sand or metal shot in a box, and pouring is accomplished

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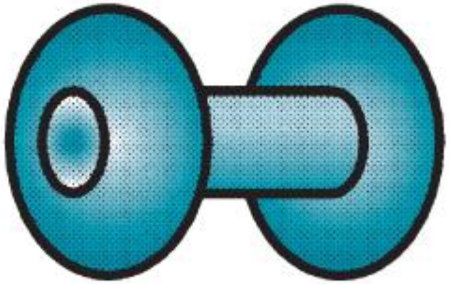
# Steps in Shell Molding

- (7) Finished casting with sprue removed



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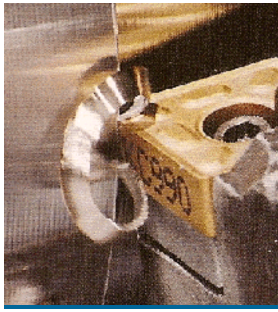
# Shell Molding: Advantages and Disadvantages

- Advantages:
  - Smoother cavity surface permits easier flow of molten metal and better surface finish
  - Good dimensional accuracy
  - Mold collapsibility minimizes cracks in casting
  - Can be mechanized for mass production
- Disadvantages:
  - More expensive metal pattern
  - Difficult to justify for small quantities



# Vacuum Molding

Uses sand mold held together by vacuum pressure rather than by a chemical binder

- The term "vacuum" refers to mold making rather than casting operation itself
- Developed in Japan around 1970

# Vacuum Molding: Advantages and Disadvantages

- Advantages:
  - Easy recovery of the sand, since no binders
  - Sand does not require mechanical reconditioning done when binders are used
  - Since no water is mixed with sand, moisture-related defects are avoided
- Disadvantages:
  - Slow process
  - Not readily adaptable to mechanization

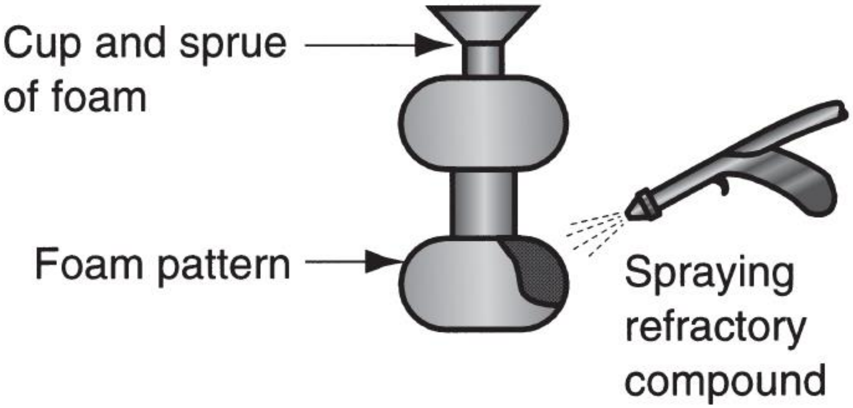
# Expanded Polystyrene Process

Uses a mold of sand packed around a polystyrene foam pattern which vaporizes when molten metal is poured into mold

- Other names: lost-foam process, lost pattern process, evaporative-foam process, and full-mold process
- Polystyrene foam pattern includes sprue, risers, gating system, and internal cores (if needed)
- Mold does not have to be opened into cope and drag sections

# Steps in Expanded Polystyrene Process

- (1) Polystyrene foam pattern is coated with refractory compound

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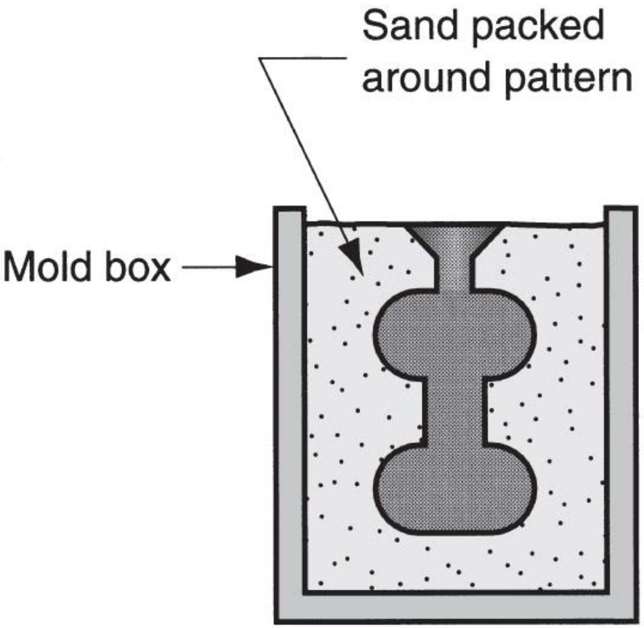
# Steps in Expanded Polystyrene Process

- (2) Foam pattern is placed in mold box, and sand is compacted around the pattern

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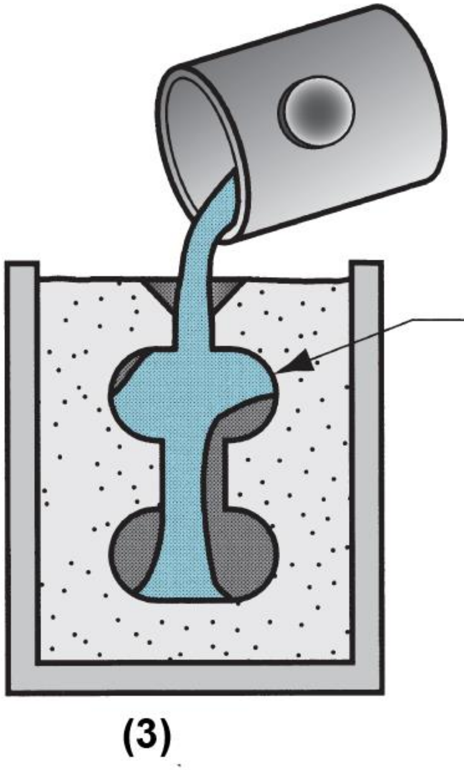
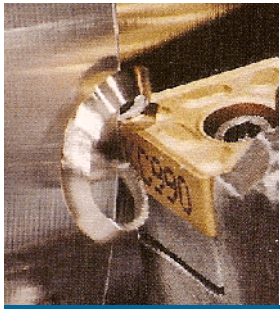
# Steps in Expanded Polystyrene Process

- (3) Molten metal is poured into the portion of the pattern that forms the pouring cup and sprue
- As the metal enters the mold, the polystyrene foam is vaporized ahead of the advancing liquid, thus filling the mold cavity





# Expanded Polystyrene Process: Advantages and Disadvantages

- Advantages of expanded polystyrene process:
  - Pattern need not be removed from the mold
  - Simplifies and speeds mold-making, because two mold halves are not required as in a conventional green-sand mold
- Disadvantages:
  - A new pattern is needed for every casting
  - Economic justification of the process is highly dependent on cost of producing patterns

# Expanded Polystyrene Process

- Applications:
  - Mass production of castings for automobile engines
  - Automated and integrated manufacturing systems are used to
    1. Mold the polystyrene foam patterns and then
    2. Feed them to the downstream casting operation

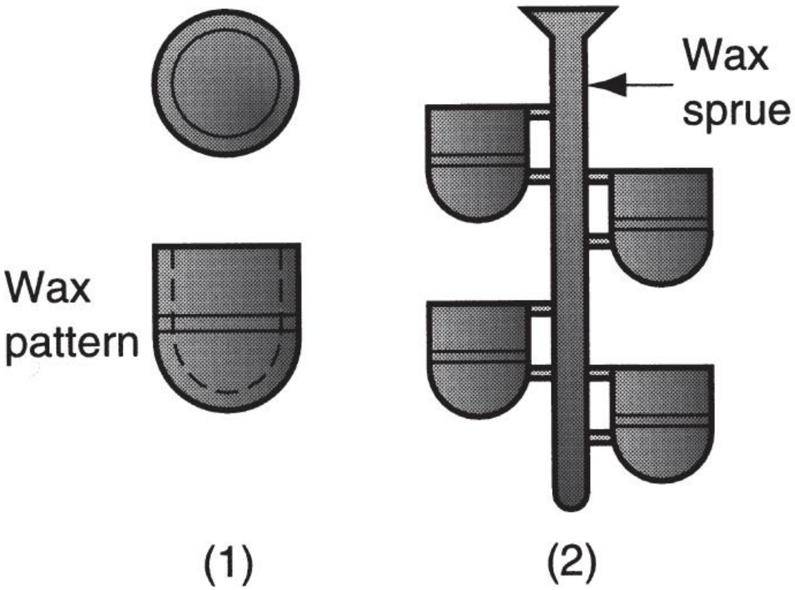
# Investment Casting (a.k.a. Lost Wax Process)

A pattern made of wax is coated with a refractory material to make the mold, after which wax is melted away prior to pouring molten metal

- "Investment" comes from a less familiar definition of "invest" - "to cover completely," which refers to coating of refractory material around wax pattern
- It is a precision casting process
  - Capable of producing castings of high accuracy and intricate detail

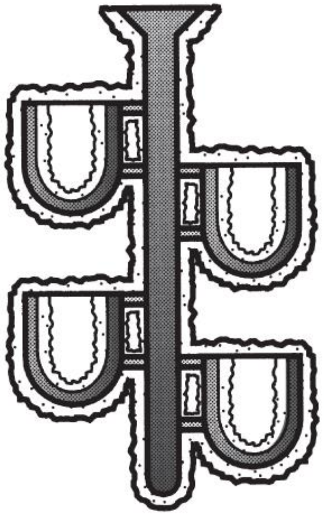
# Steps in Investment Casting

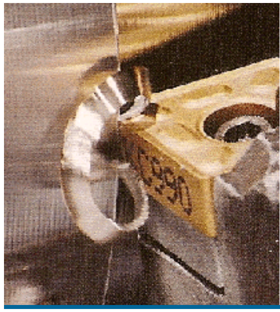
- (1) Wax patterns are produced
- (2) Several patterns are attached to a sprue to form a pattern tree



# Steps in Investment Casting

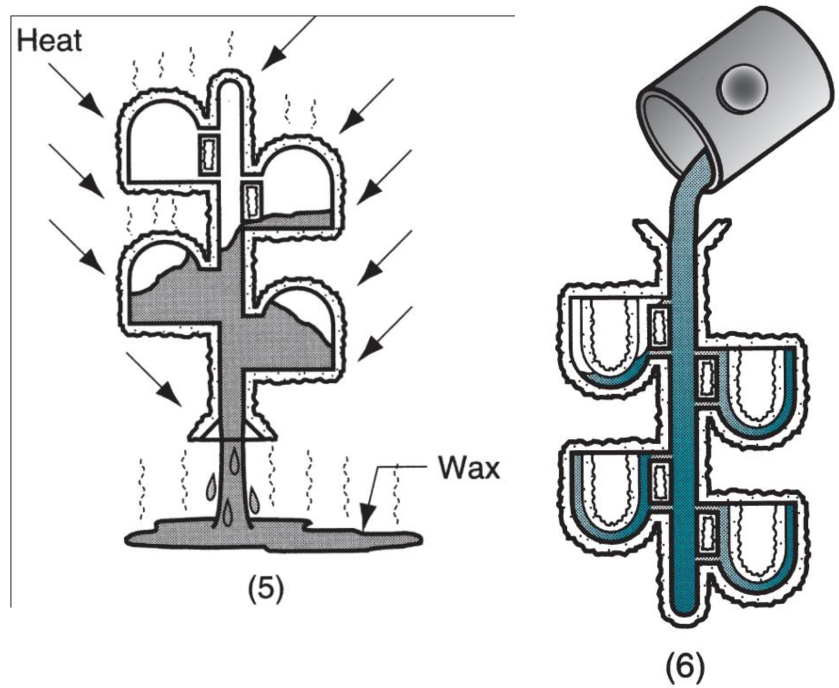
- (3) Pattern tree is coated with a thin layer of refractory material
- (4) Full mold is formed by covering the coated tree with sufficient refractory material to make it rigid

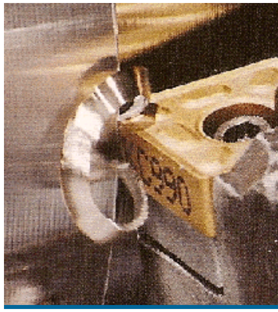





# Steps in Investment Casting

- (5) Mold is held in an inverted position and heated to melt the wax and permit it to drip out of the cavity
- (6) Mold is preheated to a high temperature, the molten metal is poured, and it solidifies





# Steps in Investment Casting

- (7) Mold is broken away from the finished casting and the parts are separated from the sprue

(7)

## One-piece compressor stator with 108 separate airfoils made by investment casting (photo courtesy of Howmet Corp.)

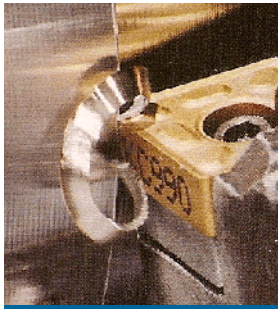
# Investment Casting: Advantages and Disadvantages

- Advantages:
  - Parts of great complexity and intricacy can be cast
  - Close dimensional control and good surface finish
  - Wax can usually be recovered for reuse
  - This is a net shape process
    - Additional machining is not normally required
- Disadvantages:
  - Many processing steps are required
  - Relatively expensive process

# Plaster Mold Casting

Similar to sand casting except mold is made of plaster of Paris (gypsum - $CaSO_4$-$2H_2O$)

- In mold-making, plaster and water mixture is poured over plastic or metal pattern and allowed to set
  - Wood patterns not generally used due to extended contact with water
- Plaster mixture readily flows around pattern, capturing its fine details and good surface finish



# Plaster Mold Casting: Advantages and Disadvantages

- Advantages:
  - Good accuracy and surface finish
  - Capability to make thin cross sections
- Disadvantages:
  - Mold must be baked to remove moisture
    - Moisture can cause problems in casting
  - Mold strength is lost if over-baked
  - Plaster molds cannot stand high temperatures
    - Limited to lower melting point alloys

# Ceramic Mold Casting

Similar to plaster mold casting except that mold is made of refractory ceramic material that can withstand higher temperatures than plaster

- Can be used to cast steels, cast irons, and other high-temperature alloys
- Applications similar to those of plaster mold casting except for the metals cast
- Advantages (good accuracy and finish) also similar

# Permanent Mold Casting Processes

- Economic disadvantage of expendable mold casting:
  - A new mold is required for every casting
- In permanent mold casting, the mold is reused many times
- The processes include:
  - Basic permanent mold casting
  - Die casting
  - Centrifugal casting

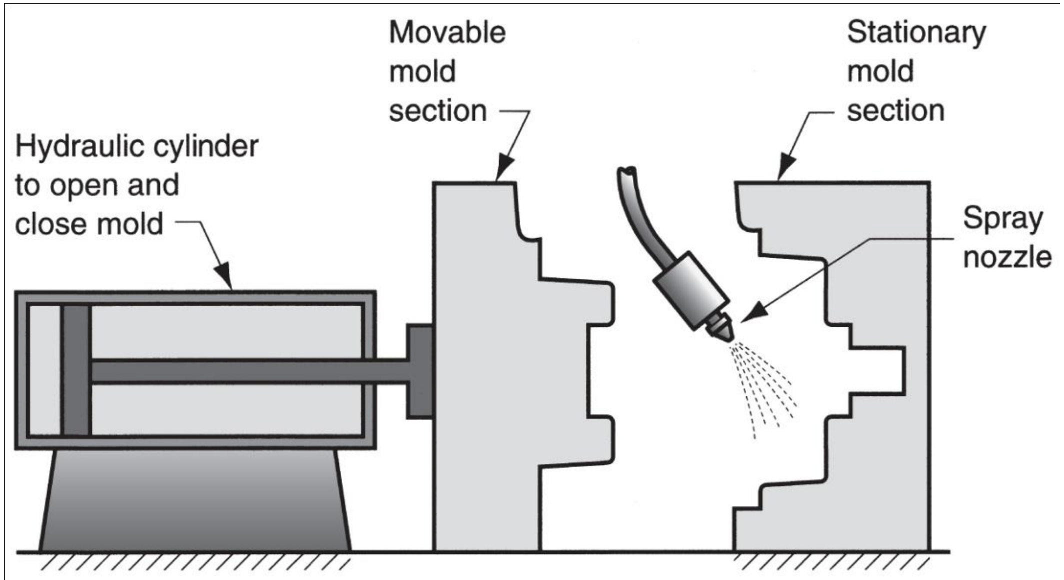

# The Basic Permanent Mold Process

Uses a metal mold constructed of two sections designed for easy, precise opening and closing

- Molds used for casting lower melting point alloys are commonly made of steel or cast iron
- Molds used for casting steel must be made of refractory material, due to the very high pouring temperatures

# Steps in Permanent Mold Casting

- (1) Mold is preheated and coated for lubrication and heat dissipation

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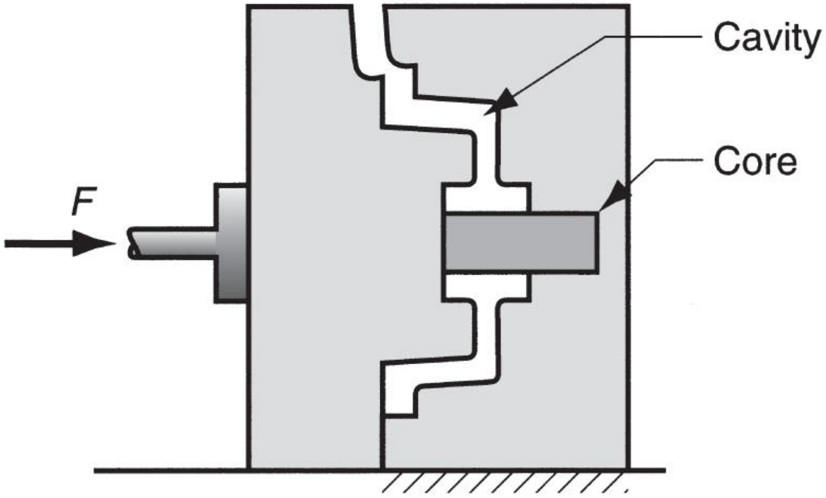
# Steps in Permanent Mold Casting

- (2) Cores (if any are used) are inserted and mold is closed

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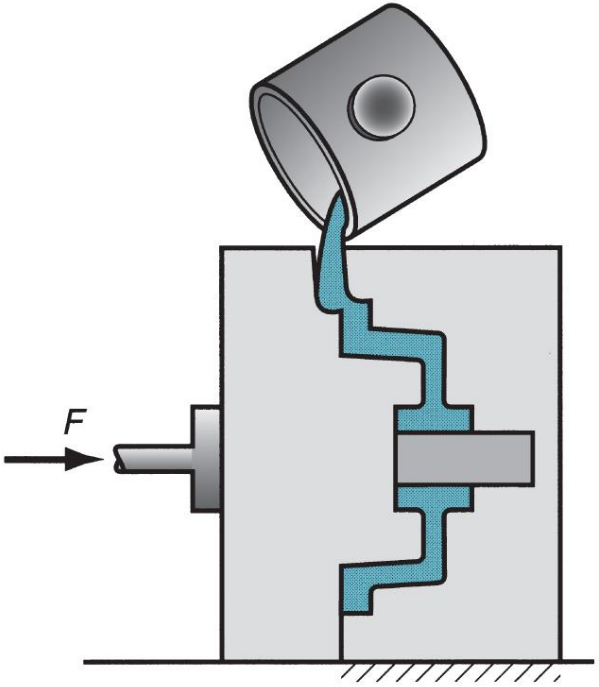
# Steps in Permanent Mold Casting

- (3) Molten metal is poured into the mold, where it solidifies

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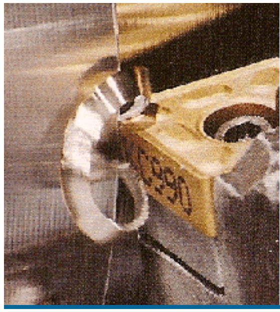
# Permanent Mold Casting: Advantages and Limitations

- Advantages of permanent mold casting:
  - Good dimensional control and surface finish
  - Rapid solidification caused by metal mold results in a finer grain structure, so castings are stronger
- Limitations:
  - Generally limited to metals of lower melting point
  - Simpler part geometries compared to sand casting because of need to open the mold
  - High cost of mold

# Applications and Metals for Permanent Mold Casting

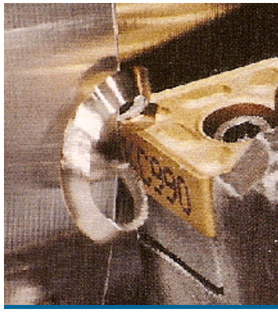
- Due to high mold cost, process is best suited to high volume production and can be automated accordingly
- Typical parts: automotive pistons, pump bodies, and certain castings for aircraft and missiles
- Metals commonly cast: aluminum, magnesium, copper-base alloys, and cast iron
  - Unsuited to steels because of very high pouring temperatures



# Die Casting

A permanent mold casting process in which molten metal is injected into mold cavity under high pressure

- Pressure is maintained during solidification, then mold is opened and part is removed
- Molds in this casting operation are called *dies*; hence the name die casting
- Use of high pressure to force metal into die cavity is what distinguishes this from other permanent mold processes



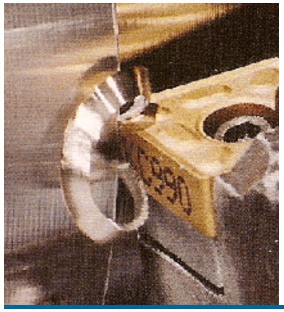
# Die Casting Machines

- Designed to hold and accurately close two mold halves and keep them closed while liquid metal is forced into cavity
- Two main types:
  1. Hot-chamber machine
  2. Cold-chamber machine

# Hot-Chamber Die Casting

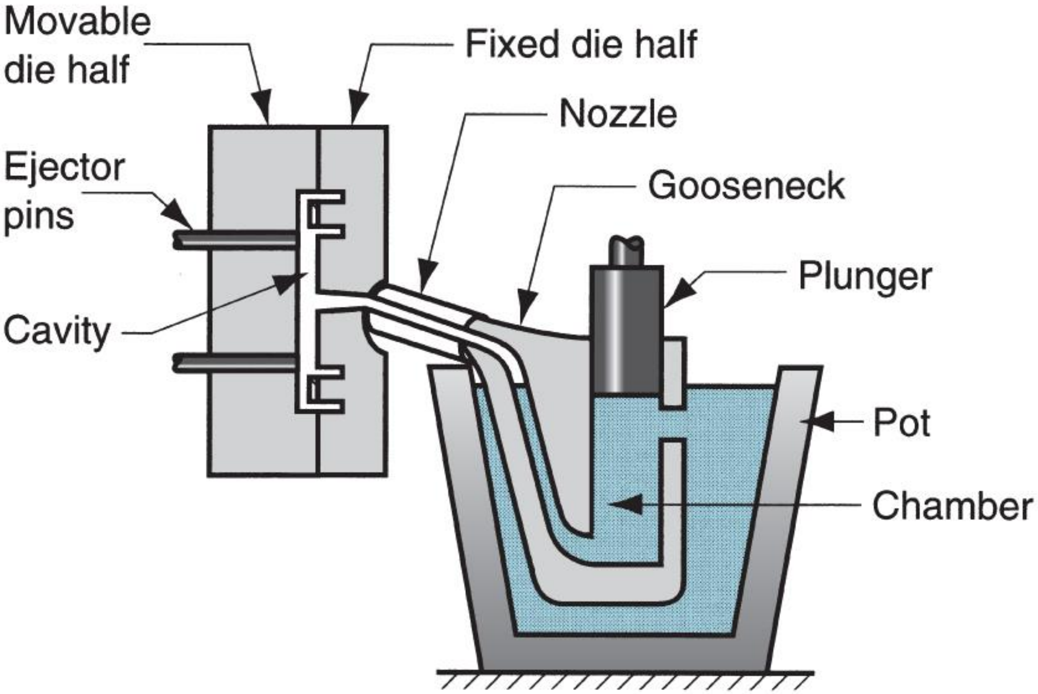
Metal is melted in a container, and a piston injects liquid metal under high pressure into the die

- High production rates
  - 500 parts per hour not uncommon
- Applications limited to low melting-point metals that do not chemically attack plunger and other mechanical components
- Casting metals: zinc, tin, lead, and magnesium



# Hot-Chamber Die Casting

- Hot-chamber die casting cycle: (1) with die closed and plunger withdrawn, molten metal flows into the chamber



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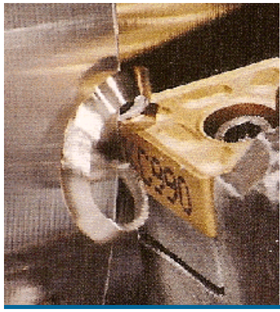
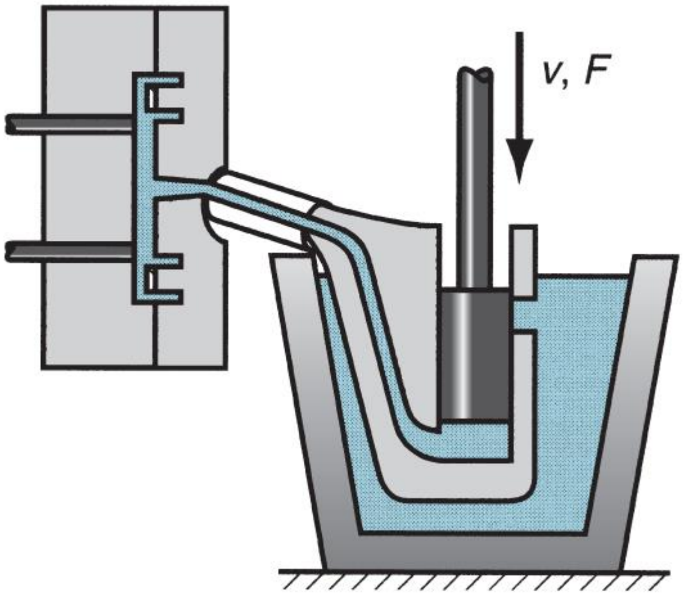


# Hot-Chamber Die Casting

- (2) plunger forces metal in chamber to flow into die, maintaining pressure during cooling and solidification.

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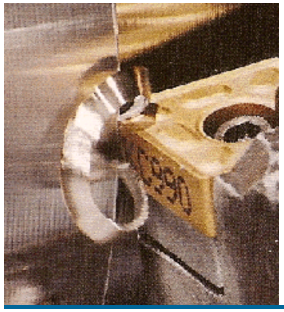
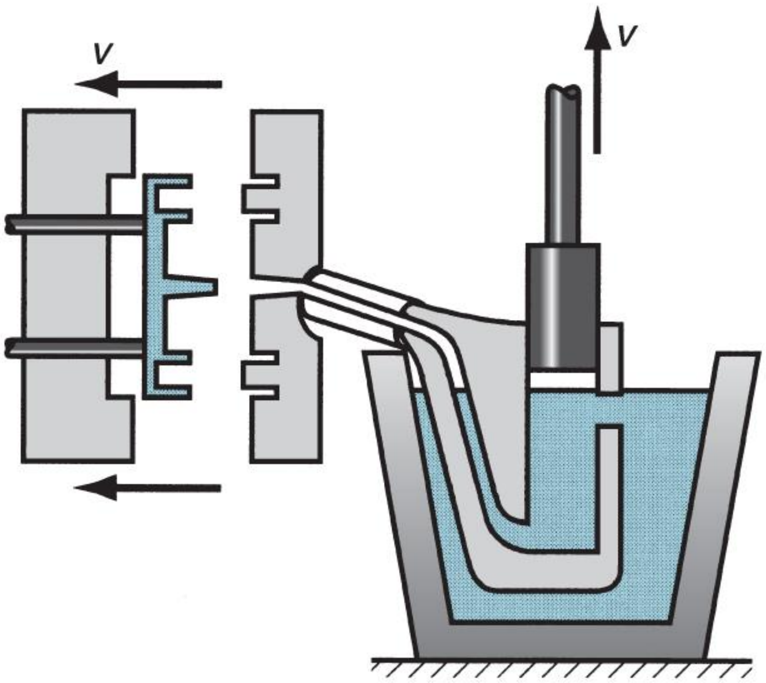


# Hot-Chamber Die Casting

- (3) Plunger is withdrawn, die is opened, and casting is ejected

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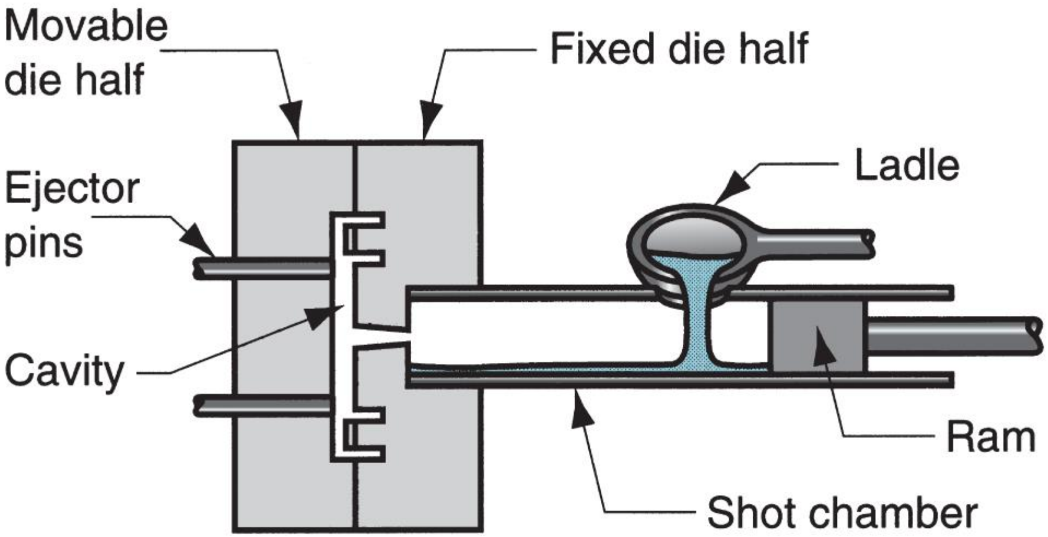
# Cold-Chamber Die Casting Machine

Molten metal is poured into unheated chamber from external melting container, and a piston injects metal under high pressure into die cavity

- High production but not usually as fast as hot-chamber machines because of pouring step
- Casting metals: aluminum, brass, and magnesium alloys
- Advantages of hot-chamber process favor its use on low melting-point alloys (zinc, tin, lead)

# Cold-Chamber Die Casting Cycle

- (1) With die closed and ram withdrawn, molten metal is poured into the chamber

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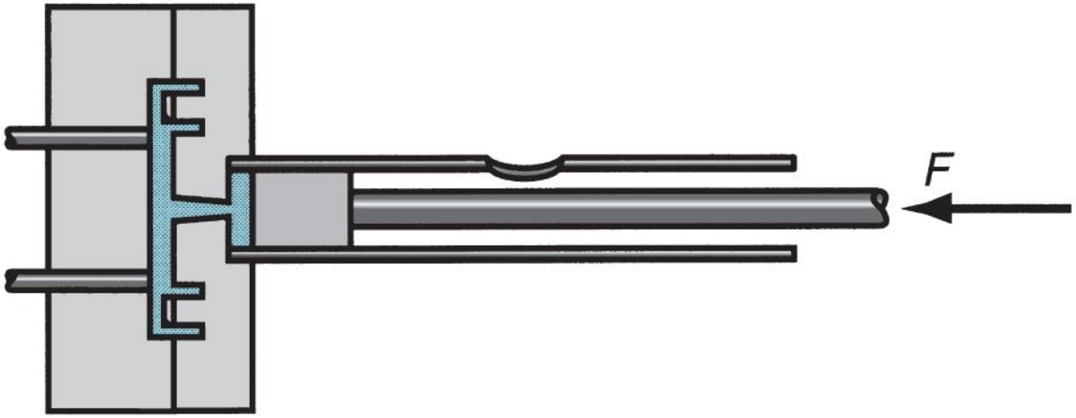
# Cold-Chamber Die Casting Cycle

- (2) Ram forces metal to flow into die, maintaining pressure during cooling and solidification

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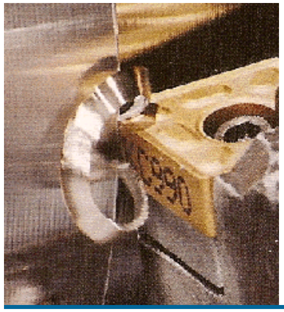
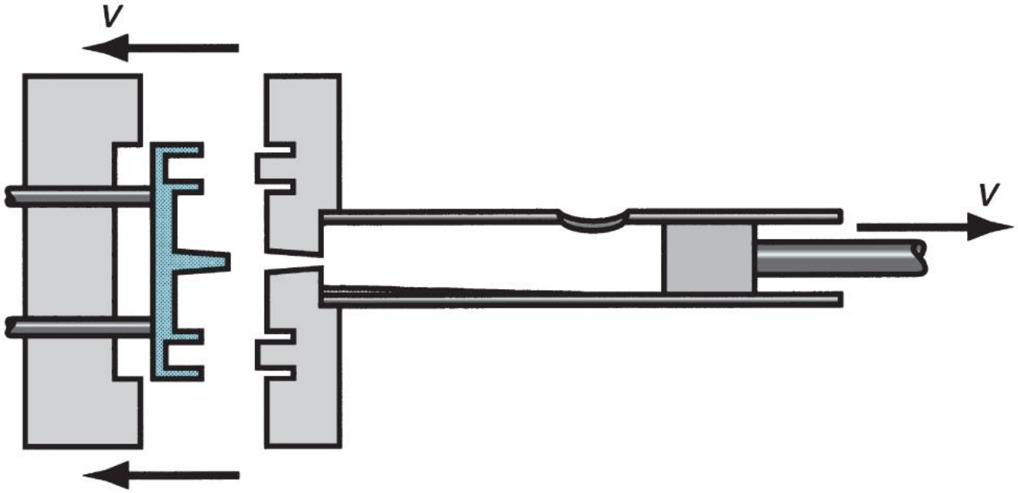


# Cold-Chamber Die Casting Cycle

- (3) Ram is withdrawn, die is opened, and part is ejected




(3)

# Molds for Die Casting

- Usually made of tool steel, mold steel, or maraging steel
- Tungsten and molybdenum (good refractory qualities) used to die cast steel and cast iron
- Ejector pins required to remove part from die when it opens
- Lubricants must be sprayed onto cavity surfaces to prevent sticking

# Die Casting: Advantages and Limitations

- Advantages:
  - Economical for large production quantities
  - Good accuracy and surface finish
  - Thin sections possible
  - Rapid cooling means small grain size and good strength in casting
- Disadvantages:
  - Generally limited to metals with low metal points
  - Part geometry must allow removal from die

# Squeeze Casting

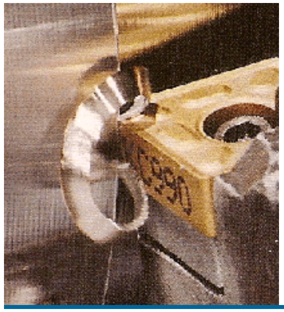
Combination of casting and forging in which a molten metal is poured into a preheated lower die, and the upper die is closed to create the mold cavity after solidification begins

- Differs from usual closed-mold casting processes in which die halves are closed before introduction of the molten metal
- Compared to conventional forging, pressures are less and finer surface details can be achieved


# Semi-Solid Metal Casting

Family of net-shape and near net-shape processes performed on metal alloys at temperatures between liquidus and solidus

- Thus, the alloy is a mixture of solid and molten metals during casting (mushy state)
  - To flow properly, the mixture must consist of solid metal globules in a liquid
    - Achieved by stirring the mixture to prevent dendrite formation



# Semi-Solid Metal Casting: Advantages

- Complex part geometries
- Thin part walls possible
- Close tolerances
- Zero or low porosity, resulting in high strength of the casting

# Centrifugal Casting

A family of casting processes in which the mold is rotated at high speed so centrifugal force distributes molten metal to outer regions of die cavity

- The group includes:
  - True centrifugal casting
  - Semicentrifugal casting
  - Centrifuge casting

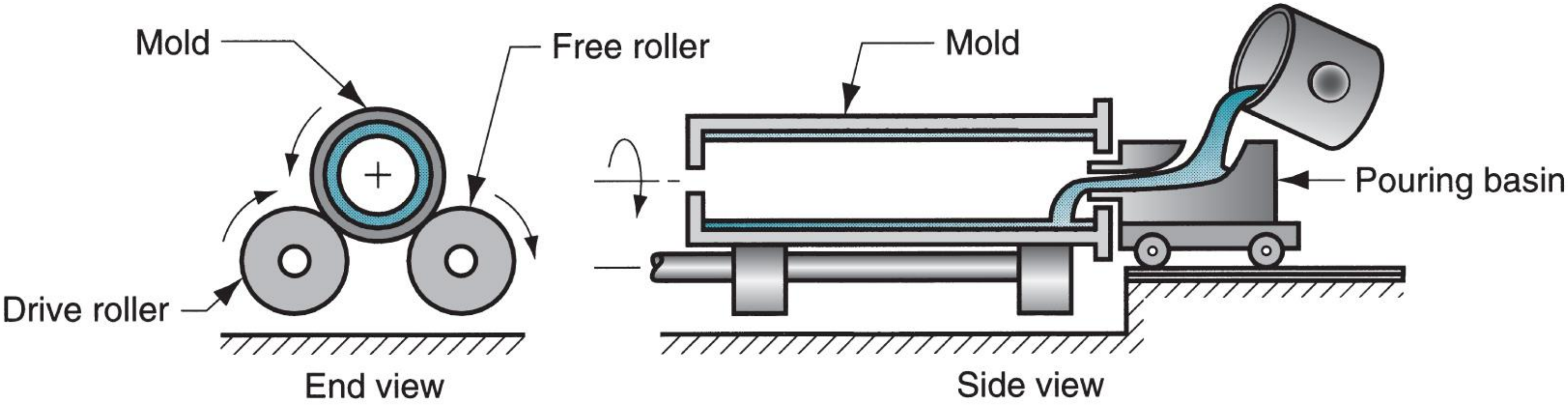
# True Centrifugal Casting

Molten metal is poured into rotating mold to produce a tubular part

- In some operations, mold rotation commences after pouring rather than before
- Parts: pipes, tubes, bushings, and rings
- Outside shape of casting can be round, octagonal, hexagonal, etc , but inside shape is (theoretically) perfectly round, due to radially symmetric forces

# True Centrifugal Casting

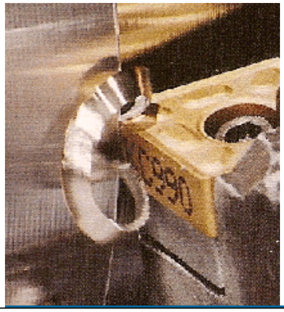
- Setup for true centrifugal casting



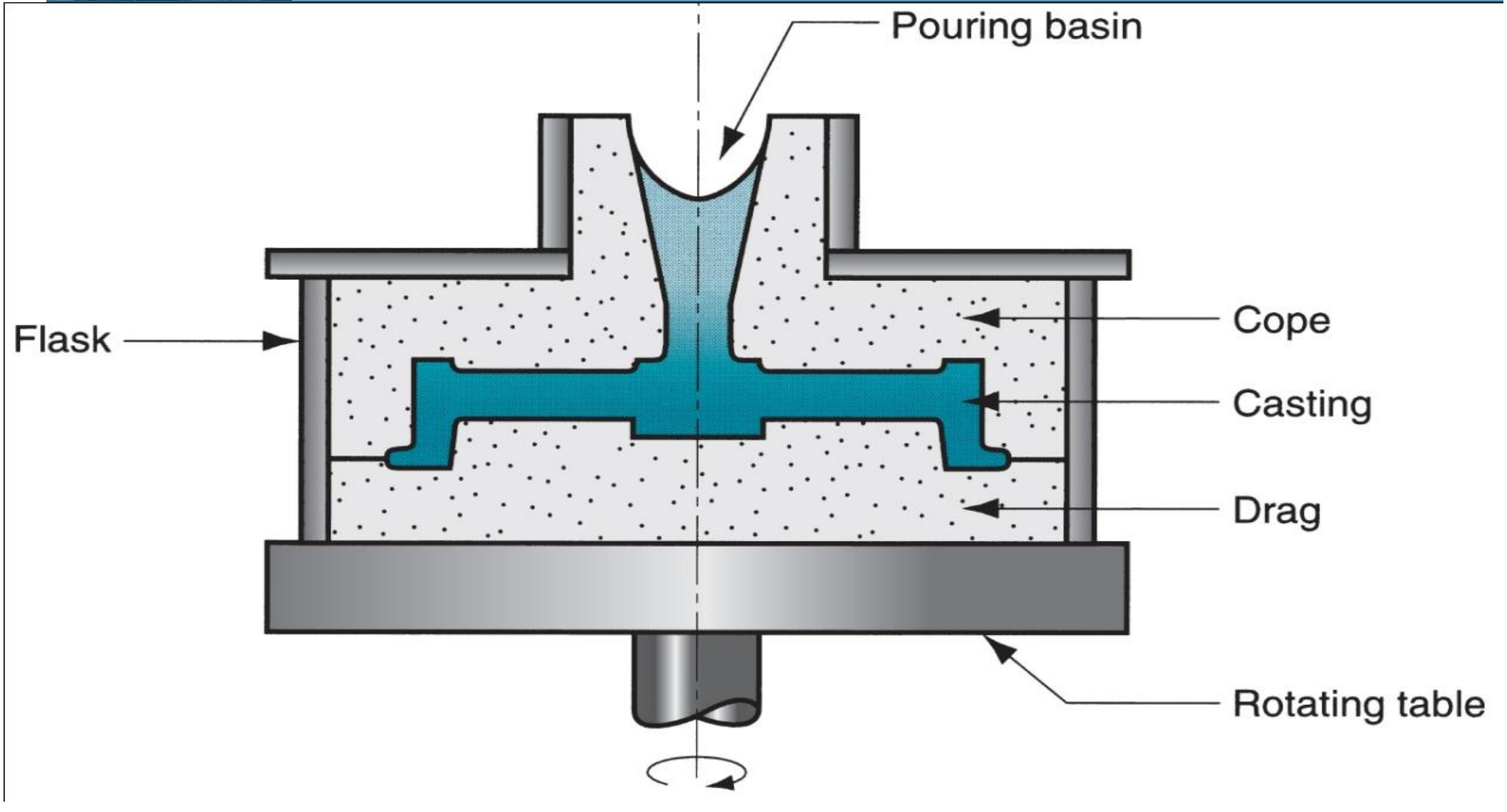

# Semicentrifugal Casting

Centrifugal force is used to produce solid castings rather than tubular parts

- Molds use risers at center to supply feed metal
- Density of metal in final casting is greater in outer sections than at center of rotation
- Often used on parts in which center of casting is machined away, thus eliminating the portion where quality is lowest
  - Examples: wheels and pulleys



# Semicentrifugal Casting

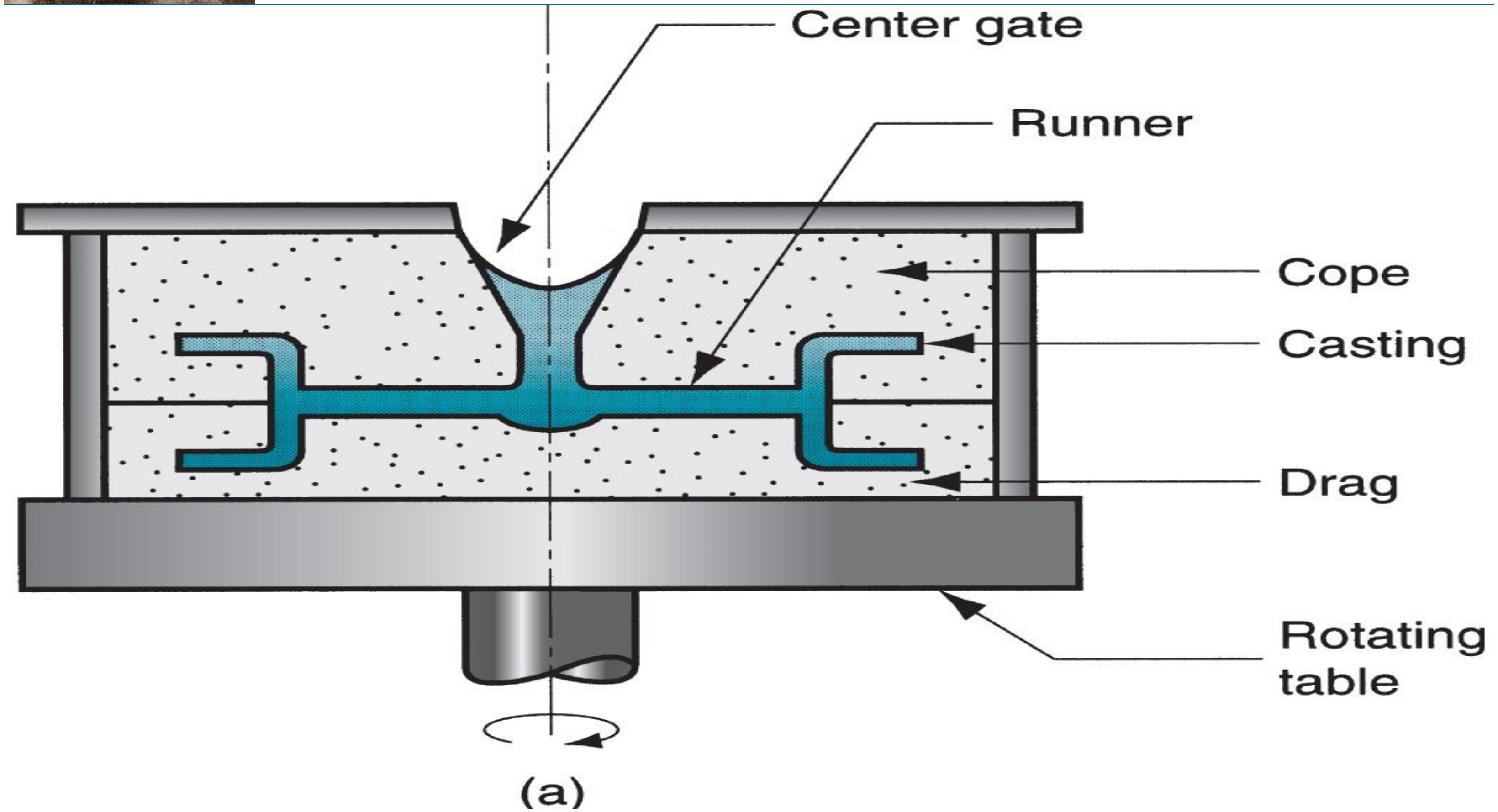


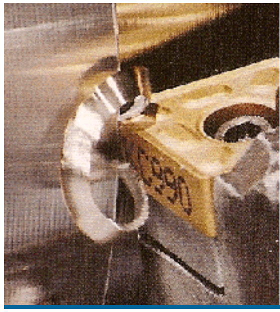
# Centrifuge Casting

Mold is designed with part cavities located away from axis of rotation, so molten metal poured into mold is distributed to these cavities by centrifugal force

- Used for smaller parts
- Radial symmetry of part is not required as in other centrifugal casting methods

# Centrifugal Casting





# Furnaces for Casting Processes

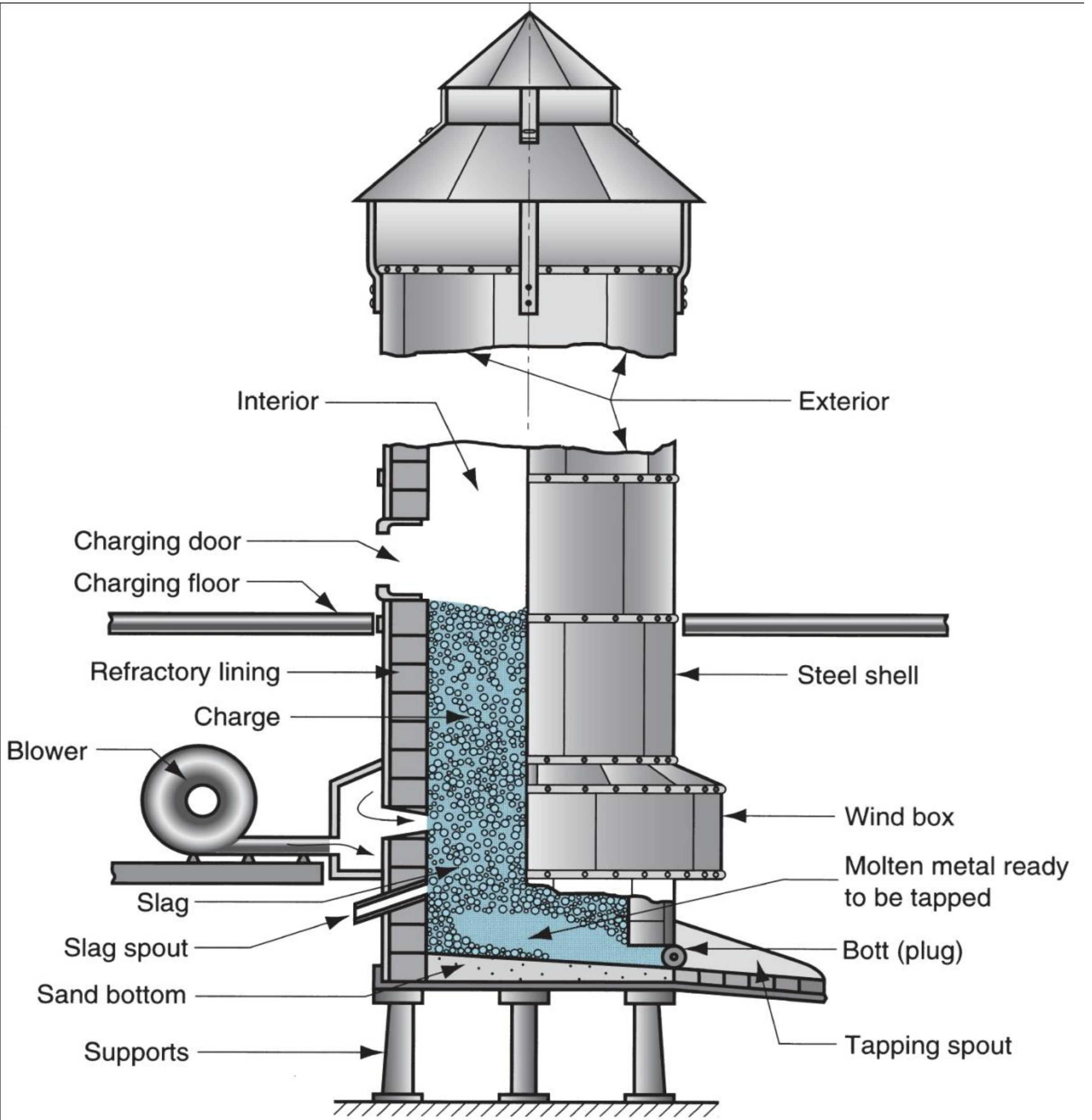
- Furnaces most commonly used in foundries:
  - Cupolas
  - Direct fuel-fired furnaces
  - Crucible furnaces
  - Electric-arc furnaces
  - Induction furnaces

# Cupolas

Vertical cylindrical furnace equipped with tapping spout near base

- Used only for cast irons
  - Although other furnaces are also used, the largest tonnage of cast iron is melted in cupolas
- The "charge," consisting of iron, coke, flux, and any alloying elements, is loaded through a charging door located less than halfway up height of cupola

- Cupola for melting cast iron



# Direct Fuel-Fired Furnaces

Small open-hearth in which charge is heated by natural gas fuel burners located on side of furnace

- Furnace roof assists heating action by reflecting flame down against charge
- At bottom of hearth is a tap hole to release molten metal
- Generally used for nonferrous metals such as copper-base alloys and aluminum

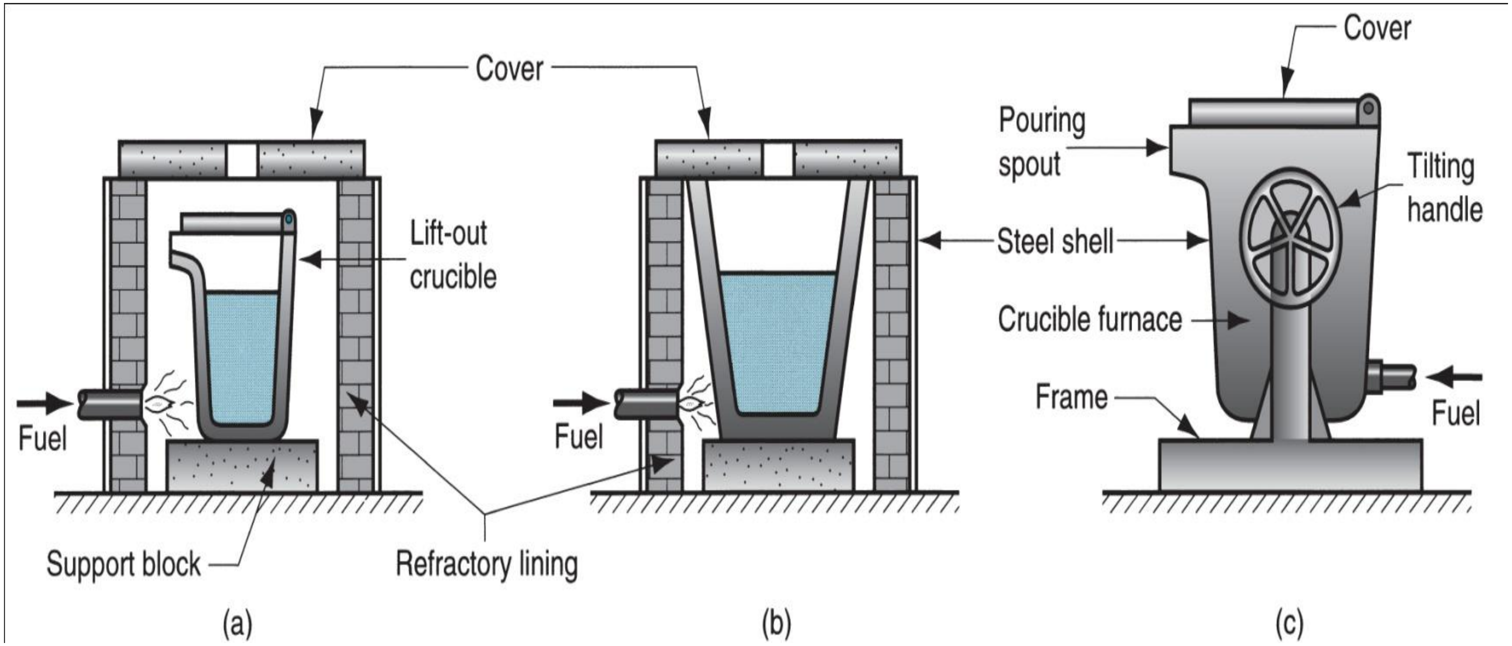
# Crucible Furnaces

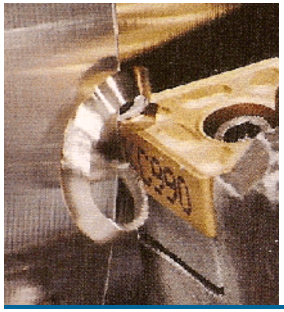
Metal is melted without direct contact with burning fuel mixture

- Sometimes called *indirect fuel-fired furnaces*
- Container (crucible) is made of refractory material or high-temperature steel alloy
- Used for nonferrous metals such as bronze, brass, and alloys of zinc and aluminum
- Three types used in foundries: (a) lift-out type, (b) stationary, (c) tilting

# Three Types of Crucible Furnaces

- (a) Lift-out crucible, (b) stationary pot - molten metal must be ladled, and (c) tilting-pot furnace





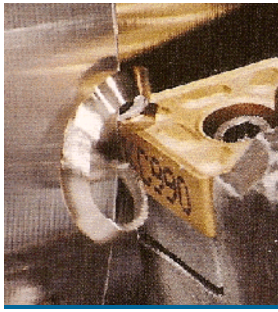
# Electric-Arc Furnaces

Charge is melted by heat generated from an electric arc

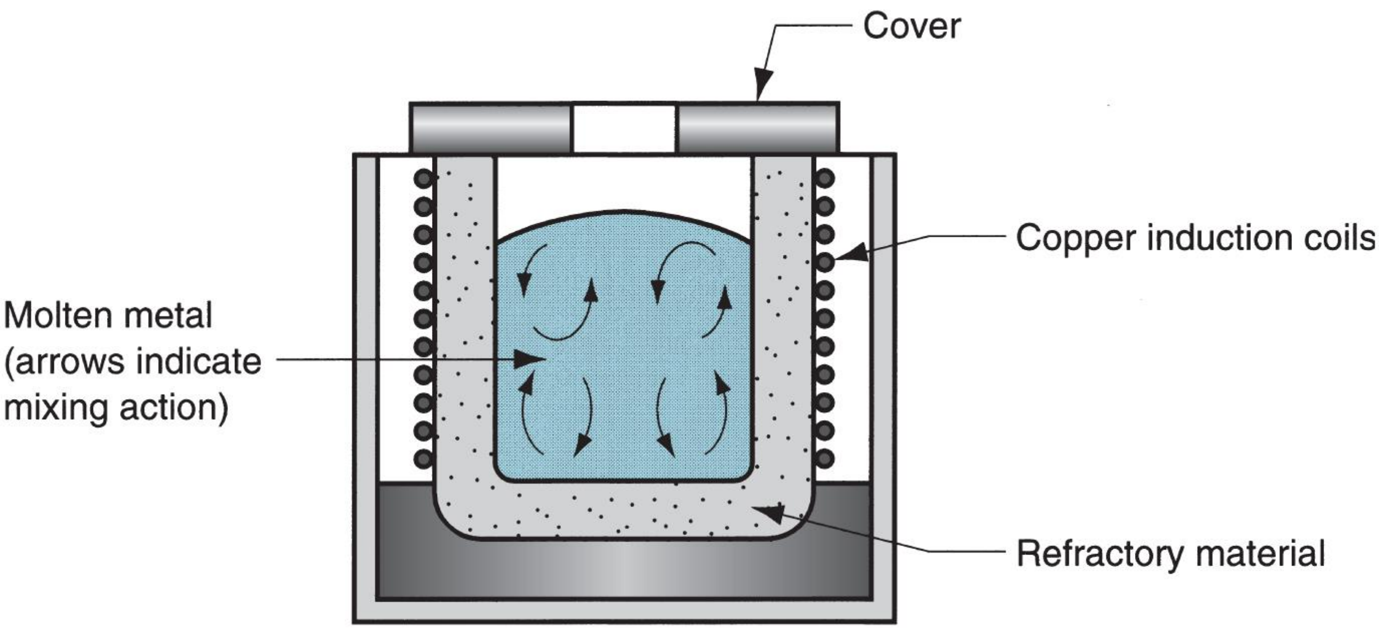
- High power consumption
  - But electric-arc furnaces can be designed for high melting capacity
- Used primarily for melting steel

# Induction Furnaces

- Uses alternating current passing through a coil to develop magnetic field in metal
  - Induced current causes rapid heating and melting
  - Electromagnetic force field also causes mixing action
- Since metal does not contact heating elements, environment can be closely controlled to produce molten metals of high quality and purity
- Common alloys: steel, cast iron, and aluminum

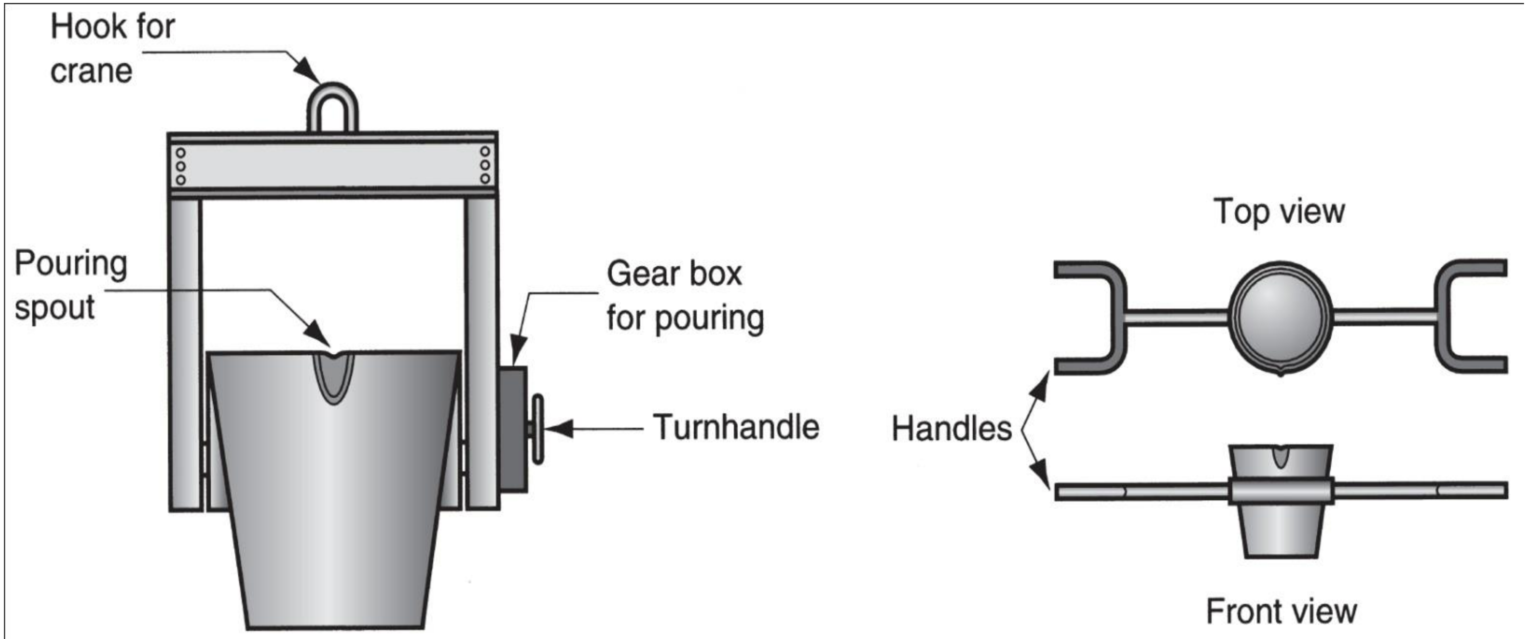


# Induction Furnace



# Ladles

- Two common types of ladles to transfer molten metals to molds: (a) crane ladle, and (b) two-man ladle




(a)

(b)

# Additional Steps After Solidification

- Trimming
- Removing the core
- Surface cleaning
- Inspection
- Repair, if required
- Heat treatment

# Trimming

Removal of sprues, runners, risers, parting-line flash, fins, chaplets, and any other excess metal from the cast part

- For brittle casting alloys and when cross sections are relatively small, appendages can be broken off
- Otherwise, hammering, shearing, hack-sawing, band-sawing, abrasive wheel cutting, or various torch cutting methods are used

# Removing the Core

- If cores have been used, they must be removed
  - Most cores are bonded, and they often fall out of casting as the binder deteriorates
  - In some cases, they are removed by shaking the casting, either manually or mechanically
  - In rare cases, cores are removed by chemically dissolving bonding agent
  - Solid cores must be hammered or pressed out

# Surface Cleaning and Inspection

Removal of sand from casting surface and otherwise enhancing appearance of surface

- Cleaning methods: tumbling, air-blasting with coarse sand grit or metal shot, wire brushing, buffing, and chemical pickling
- Surface cleaning is most important for sand casting
  - In many permanent mold processes, this step can be avoided
- Defects are possible in casting, and inspection is needed to detect their presence


# Heat Treatment

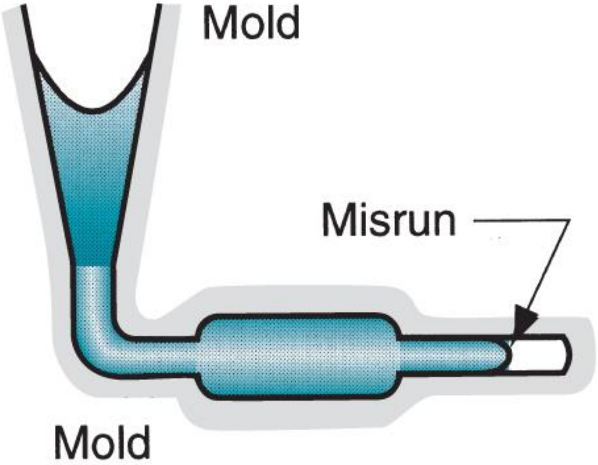
- Castings are often heat treated to enhance properties
- Reasons for heat treating a casting:
  - For subsequent processing operations such as machining
  - To bring out the desired properties for the application of the part in service

# Casting Quality

- There are numerous opportunities for things to go wrong in a casting operation, resulting in quality defects in the product
- The defects can be classified as follows:
  - General defects common to all casting processes
  - Defects related to sand casting process

# General Defects: Misrun

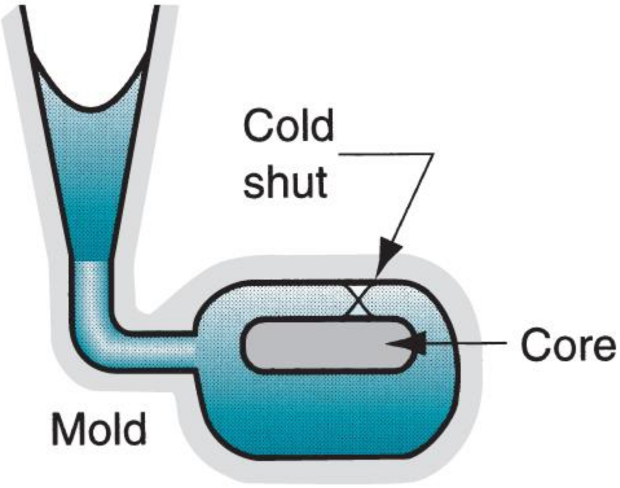
- A casting that has solidified before completely filling mold cavity



(a)

# General Defects: Cold Shut

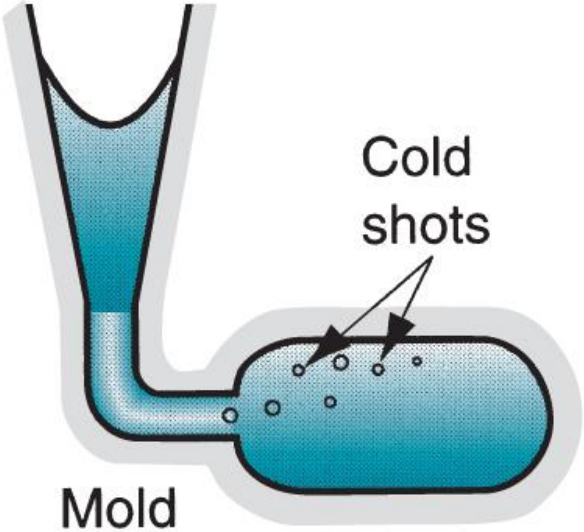
- Two portions of metal flow together but there is a lack of fusion due to premature freezing




(b)

# General Defects: Cold Shot

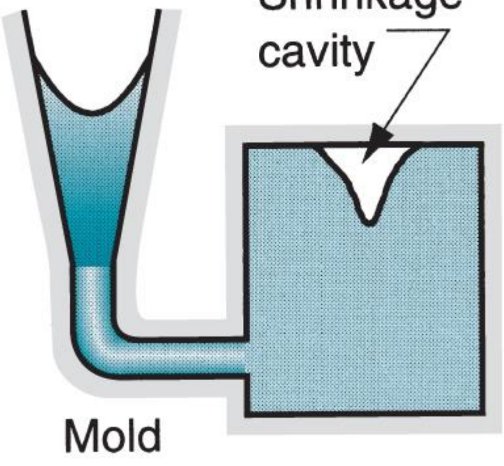
- Metal splatters during pouring and solid globules form and become entrapped in casting




(c)

# General Defects: Shrinkage Cavity

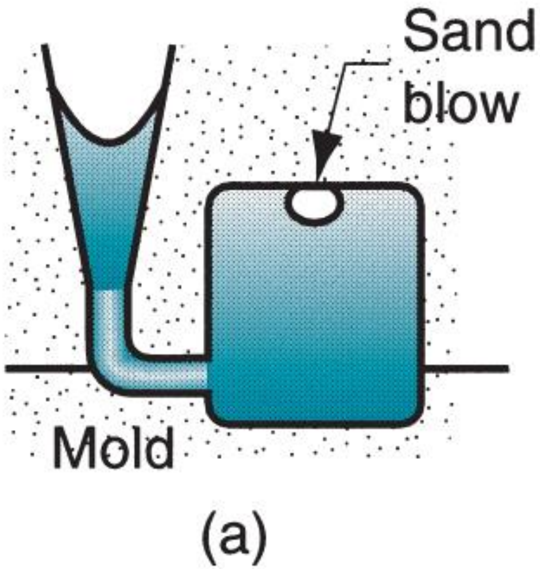
- Depression in surface or internal void caused by solidification shrinkage that restricts amount of molten metal available in last region to freeze



(d)

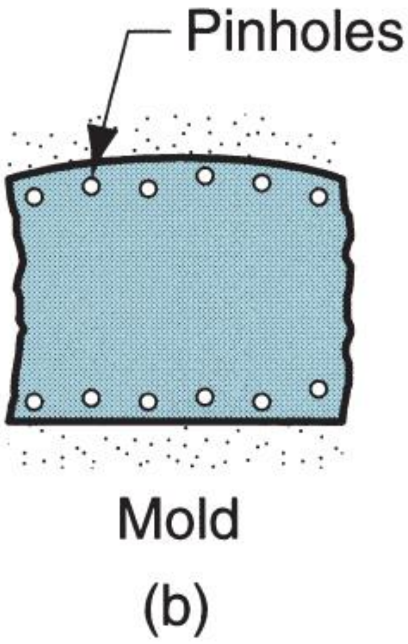
# Sand Casting Defects: Sand Blow

- Balloon-shaped gas cavity caused by release of mold gases during pouring



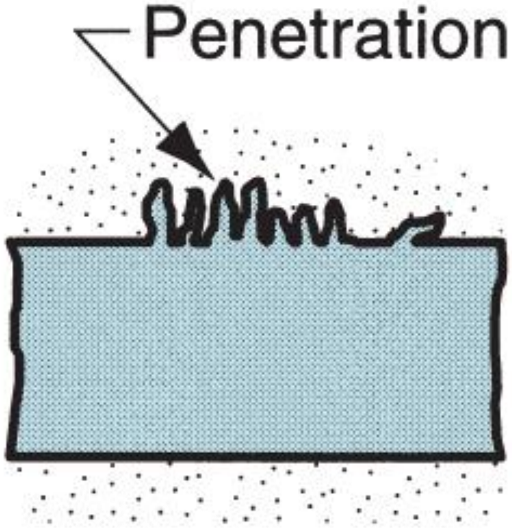
# Sand Casting Defects: Pin Holes

- Formation of many small gas cavities at or slightly below surface of casting



# Sand Casting Defects: Penetration

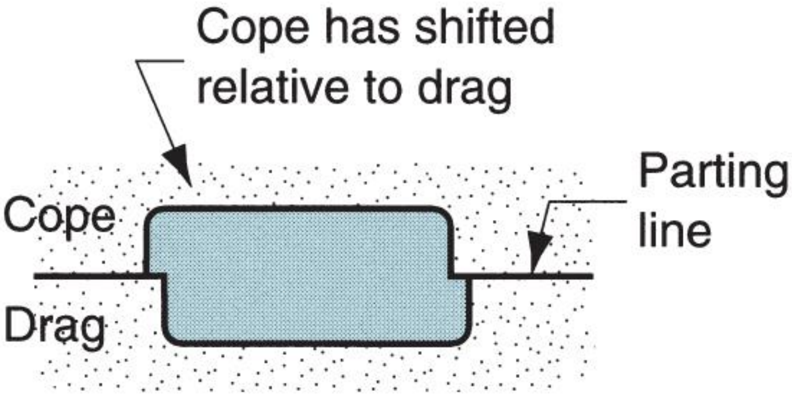
- When fluidity of liquid metal is high, it may penetrate into sand mold or core, causing casting surface to consist of a mixture of sand grains and metal




(e)

# Sand Casting Defects: Mold Shift

- A step in the cast product at parting line caused by sidewise relative displacement of cope and drag



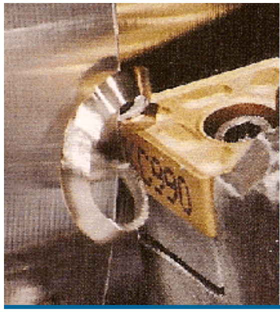

(f)

# Foundry Inspection Methods

- Visual inspection to detect obvious defects such as misruns, cold shuts, and severe surface flaws
- Dimensional measurements to insure that tolerances have been met
- Metallurgical, chemical, physical, and other tests concerned with quality of cast metal

# Metals for Casting

- Most commercial castings are made of alloys rather than pure metals
  - Alloys are generally easier to cast, and properties of product are better
- Casting alloys can be classified as:
  - Ferrous
  - Nonferrous



# Ferrous Casting Alloys: Cast Iron

- Most important of all casting alloys
- Tonnage of cast iron castings is several times that of all other metals combined
- Several types: (1) gray cast iron, (2) nodular iron, (3) white cast iron, (4) malleable iron, and (5) alloy cast irons
- Typical pouring temperatures $\sim$ 1400°C (2500°F), depending on composition

# Ferrous Casting Alloys: Steel

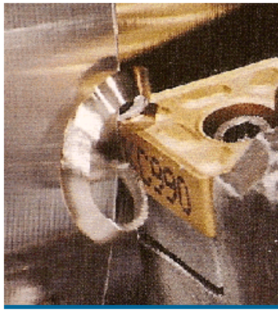
- The mechanical properties of steel make it an attractive engineering material
- The capability to create complex geometries makes casting an attractive shaping process
- Difficulties when casting steel:
  - Pouring temperature is high ~ 1650°C (3000°F)
    - At such temperatures, steel readily oxidizes, so molten metal must be isolated from air
  - Molten steel has relatively poor fluidity

# Nonferrous Casting Alloys: Aluminum

- Generally considered to be very castable
- Low pouring temperatures due to low melting temperature
  - Pure Aluminum $T_m$ = 660°C (1220°F)
- Properties:
  - Light weight
  - Range of strength properties by heat treatment
  - Easy to machine

# Nonferrous Casting Alloys: Copper Alloys

- Includes bronze, brass, and aluminum bronze
- Properties:
  - Corrosion resistance
  - Attractive appearance
  - Good bearing qualities
- Limitation: high cost of copper
- Applications: pipe fittings, marine propeller blades, pump components, ornamental jewelry

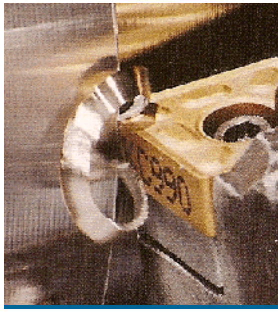


# Nonferrous Casting Alloys: Zinc Alloys

- Very castable, commonly used in die casting
- Low pouring temperatures due to low melting temperature
  - Pure zinc $T_m$ = 419°C (786°F)
- Good fluidity for ease of casting
- Properties:
  - Low creep strength, so castings cannot be subjected to prolonged high stresses

# Product Design Considerations

- Geometric simplicity
  - Although casting can be used to produce complex part geometries, simplifying the part design usually improves castability
  - Avoiding unnecessary complexities:
    - Simplifies mold-making
    - Reduces the need for cores
    - Improves the strength of the casting



# Product Design Considerations

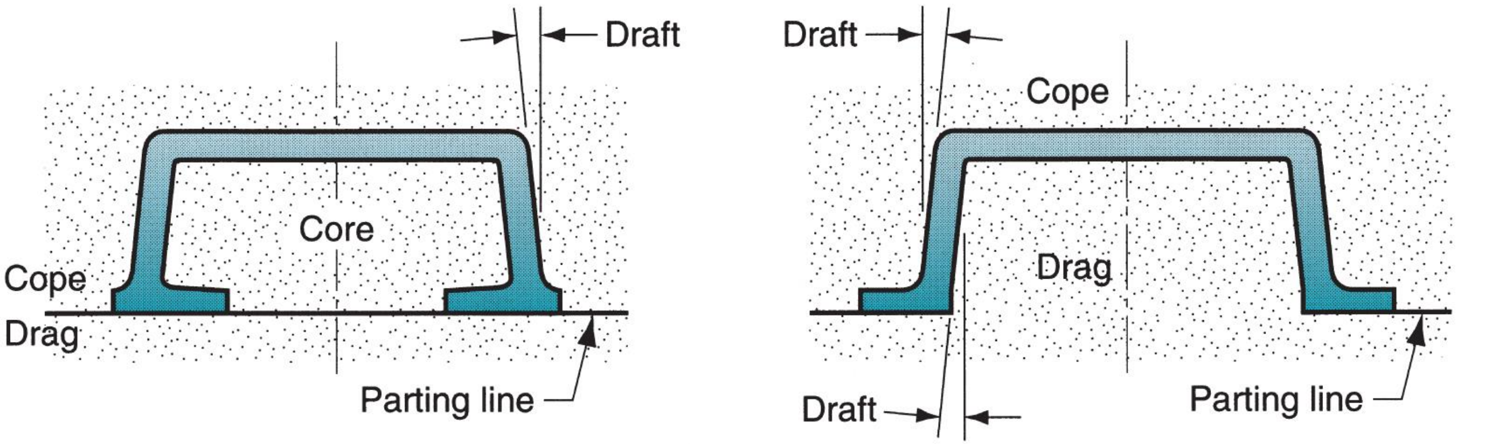
- Corners on the casting
  - Sharp corners and angles should be avoided, since they are sources of stress concentrations and may cause hot tearing and cracks
  - Generous fillets should be designed on inside corners and sharp edges should be blended

# Product Design Considerations

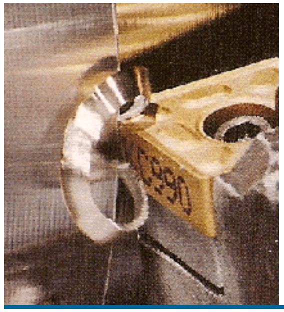
- Draft Guidelines
  - In expendable mold casting, draft facilitates removal of pattern from mold
    - Draft = 1° for sand casting
  - In permanent mold casting, purpose is to aid in removal of the part from the mold
    - Draft = 2° to 3° for permanent mold processes
  - Similar tapers should be allowed for solid cores

# Draft

- Design change to eliminate need for using a core: (a) original design, and (b) redesign




(a) (b)



# Product Design Considerations

- Dimensional Tolerances and Surface Finish
  - Dimensional accuracy and finish vary significantly, depending on process
    - Poor dimensional accuracies and finish for sand casting
    - Good dimensional accuracies and finish for die casting and investment casting

# Product Design Considerations

- Machining Allowances
  - Almost all sand castings must be machined to achieve the required dimensions and part features
  - Additional material, called the *machining allowance*, is left on the casting in those surfaces where machining is necessary
  - Typical machining allowances for sand castings are around 1.5 and 3 mm (1/16 and 1/4 in)