Casting

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Casting – Basic Terminology

- **Definition**
  - **Process of forming objects by putting liquid or viscous material into a prepared mold**
- **Casting**
  - **Object formed by allowing molten material to solidify**
- **Foundry**
  - **Collection of necessary material and equipment to produce a casting**
- **Mold**
  - **Container that has the cavity of the shape to be cast**

Casting – Common Processes

- Sand
- Shell
- Permanent Mold
- Die
- Plaster Mold
- Precision Investment wax
- Continuous
- Centrifugal

Casting Process – Basic Concepts – Mold

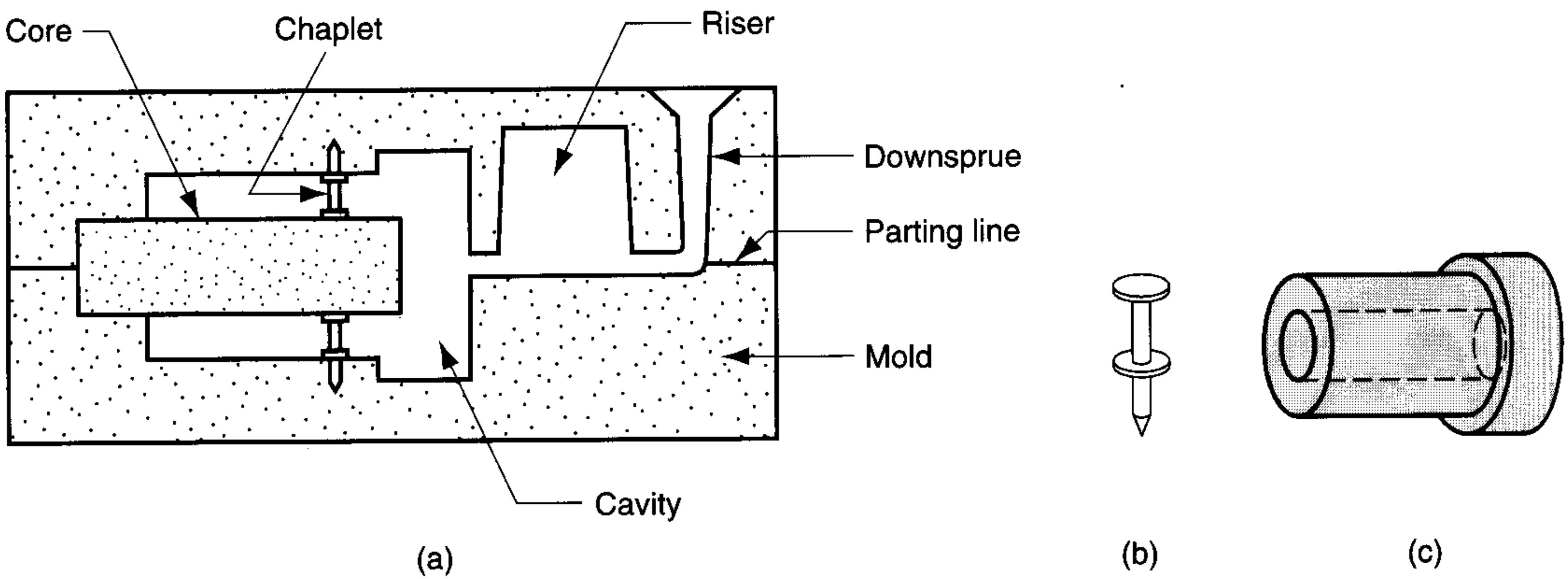


Fig. 13.4, Fundamentals of Modern Manufacturing, by M. P. Groover, Prentice Hall

Sand Casting

- **Mold Characteristics**
  - ➢ Adequate strength
  - ➢ Wear resistance
  - ➢ Escape passages for gases generated
  - ➢ High temperature resistance

- **Pattern**
  - ➢ Duplicate of the part to be cast, with slight modification

- **Vents**
  - ➢ Small holes made in mold but not reaching pattern

    =Prevents gas trapping and back pressure

Casting

Sand Casting – Flask

➢ Wood/metal frame in which mold is made. Consists of

- Cope
  - ❖ Top section
- Drag
  - ❖ Bottom section
- Cheek
  - ❖ Intermediate flask for high molds

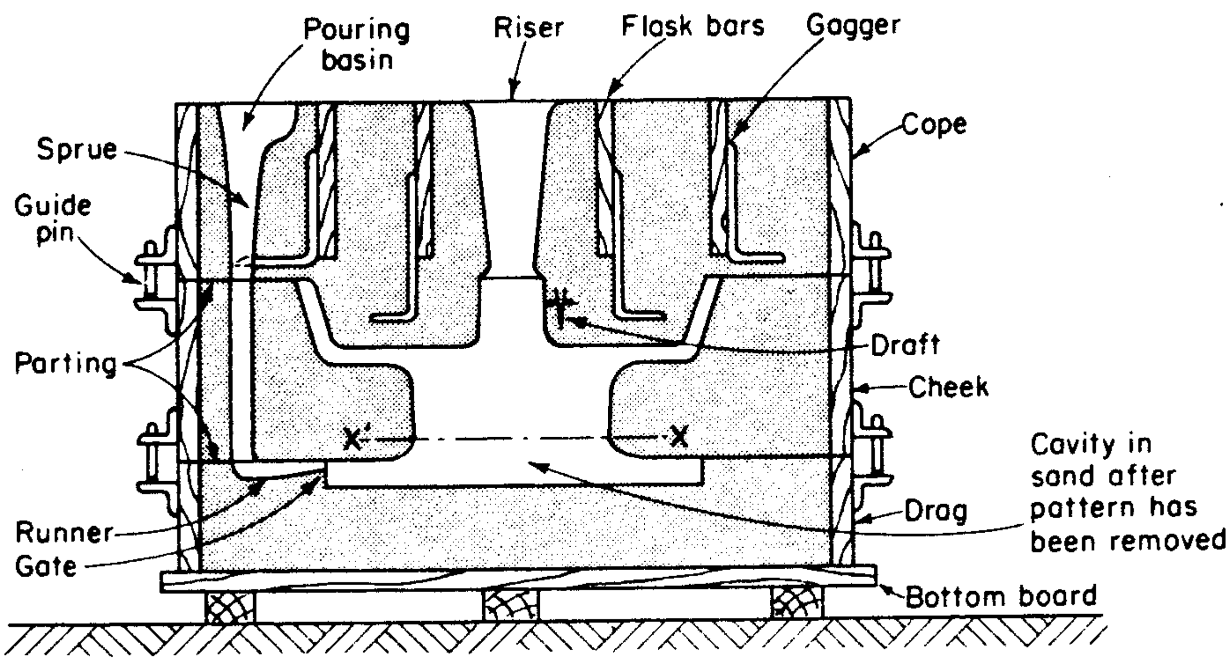


Fig. 8-1. A cross-sectional view of a three-part sand mold, with the parts labeled. The line X′-X indicates parting in the pattern.

Sand Casting – Gating System

- **Consists of:**
  - **Pouring basin**
  - **Sprue**
    =Tapered with melt being poured into larger end
  - **Runner**
    =Directs fluid from sprue to mold cavity
  - **Gate**
    =Opening at end of runner

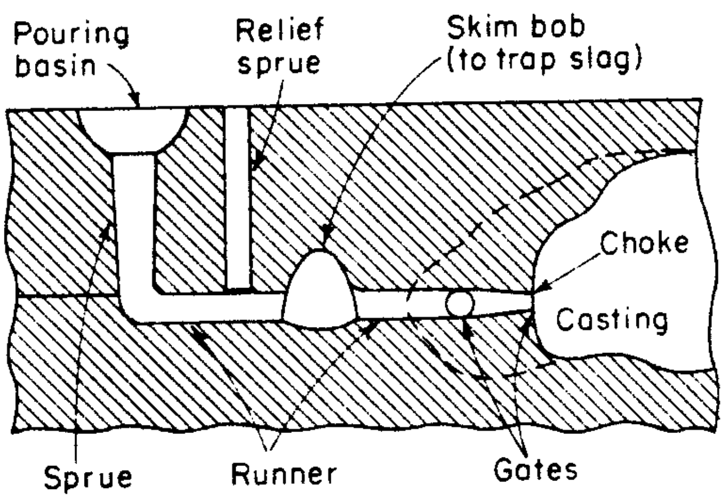


Fig. 8-5. An example of a gating system.

Sand Casting – Gating System – Some Key Issues

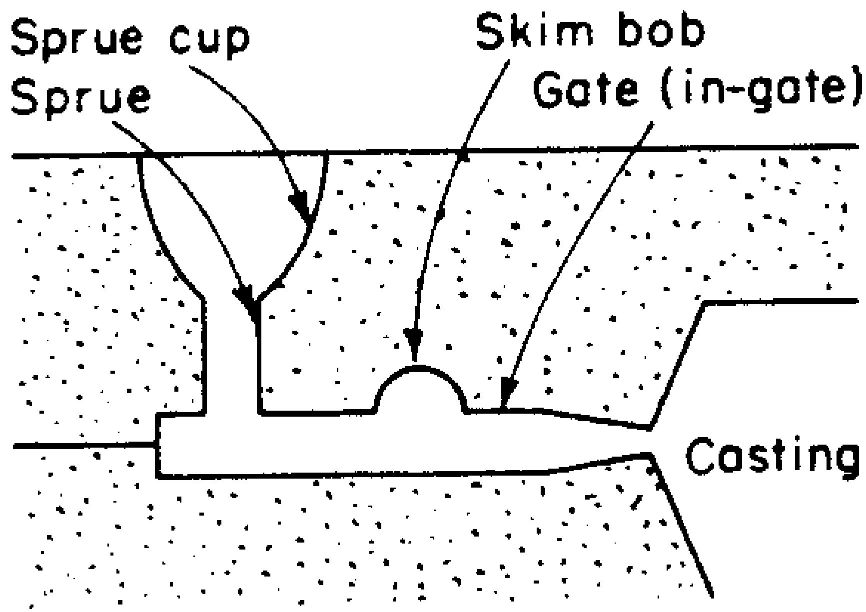
- Gate is usually made circular to reduce resistance to flow

- No sudden changes in section or direction
    - Turbulence results in gas pick-up

Sand Casting – Gating System – Gate Types

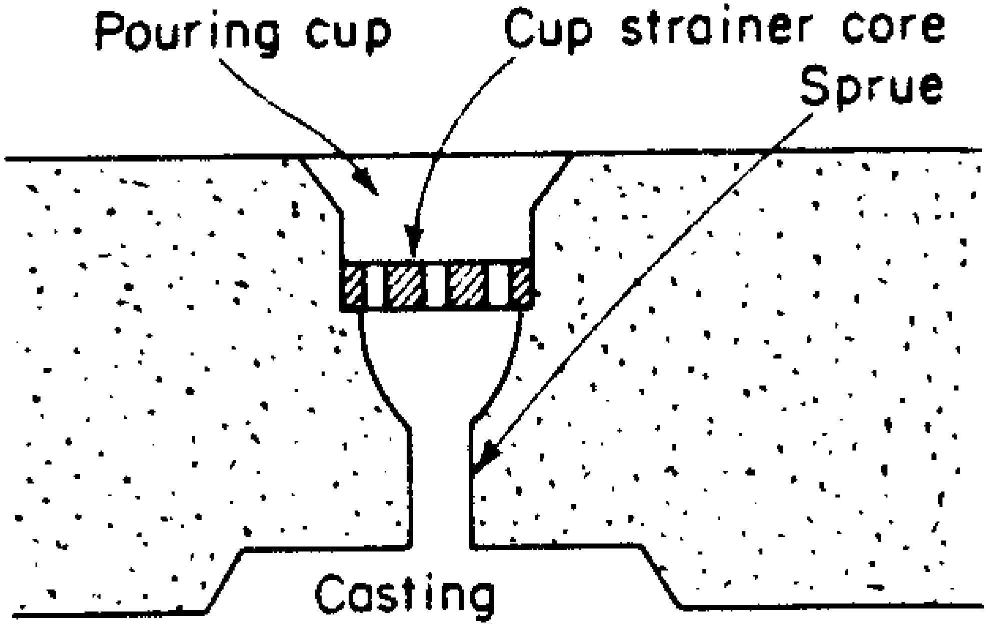
•Parting Gate

- ➢Molten Metal enters from side, between cope and drag
- ➢Advantages
  - =Easy and fast to make
- ➢Disadvantages
  - =Problem with erosion as melt drops into drag cavity



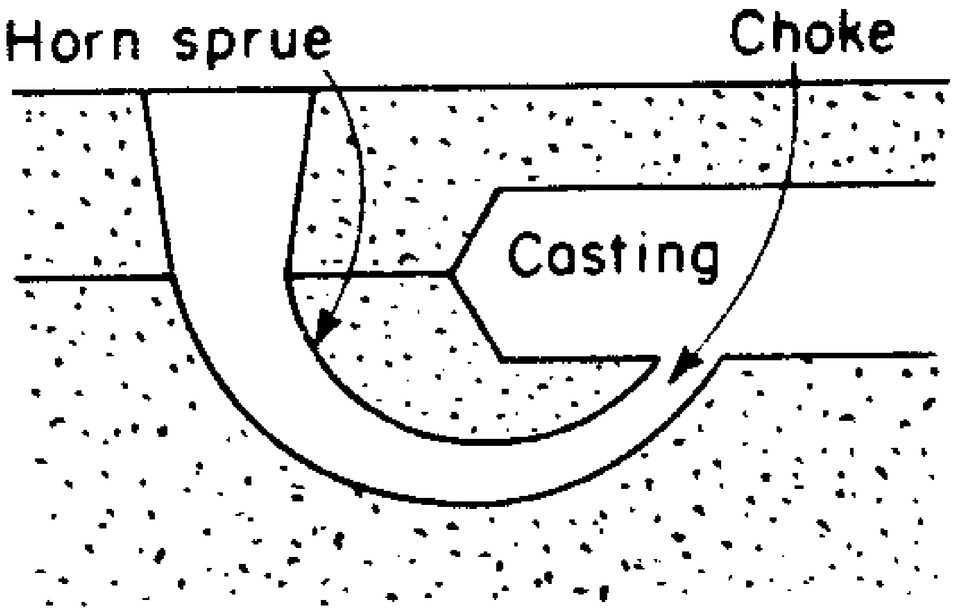
Sand Casting – Gating System – Gate Types

- **Top Gate**
  - Molten Metal introduced from the top
  - Advantages
    - =Favorable temperature gradient
  - Disadvantages
    - =Tends to be erosive



Sand Casting – Gating System – Gate Types

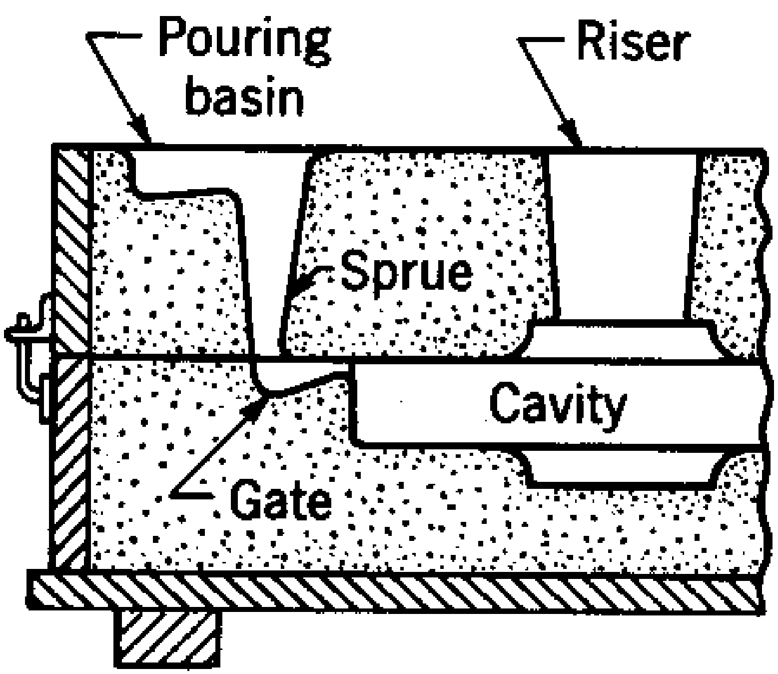
- **Bottom Gate**
  - ➢ Molten Metal enters from the bottom
  - ➢ Advantages
    - =Minimum erosion
  - ➢ Disadvantages
    - =Unfavorable temperature gradient



Casting

Sand Casting – Gating System – Riser

- Acts as a reservoir and vent
  - Must be big enough to supply all needed molten metal
  - Metal in riser must be hot and last to solidify
  - Cylindrical to reduce heat loss rate



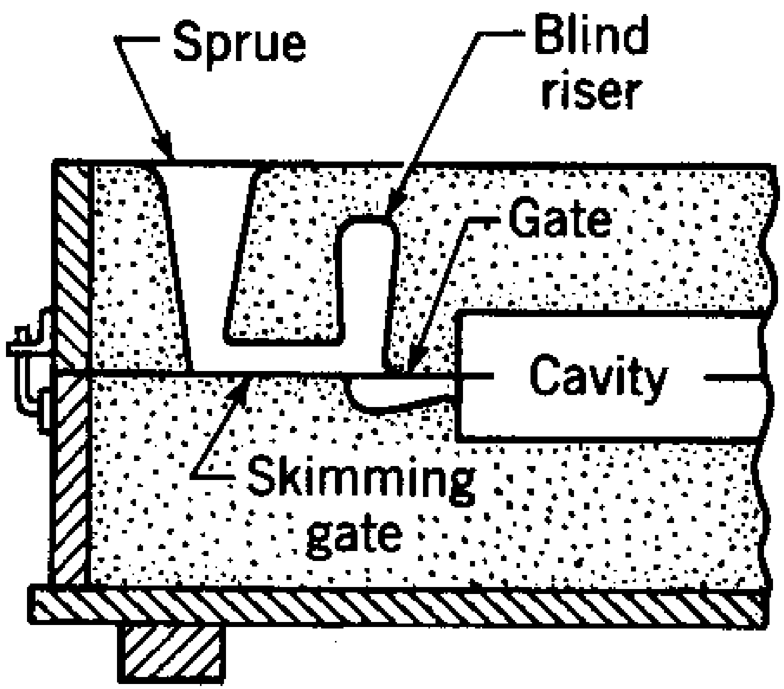


Fig. 5.4, Manufacturing Processes, by Amstead, Ostwald, Begeman, Wiley

Sand Casting – Chills

- Metal objects placed in mold to accelerate solidification
- Can be internal or external
  - ➢Internal chills must be same material as the casting

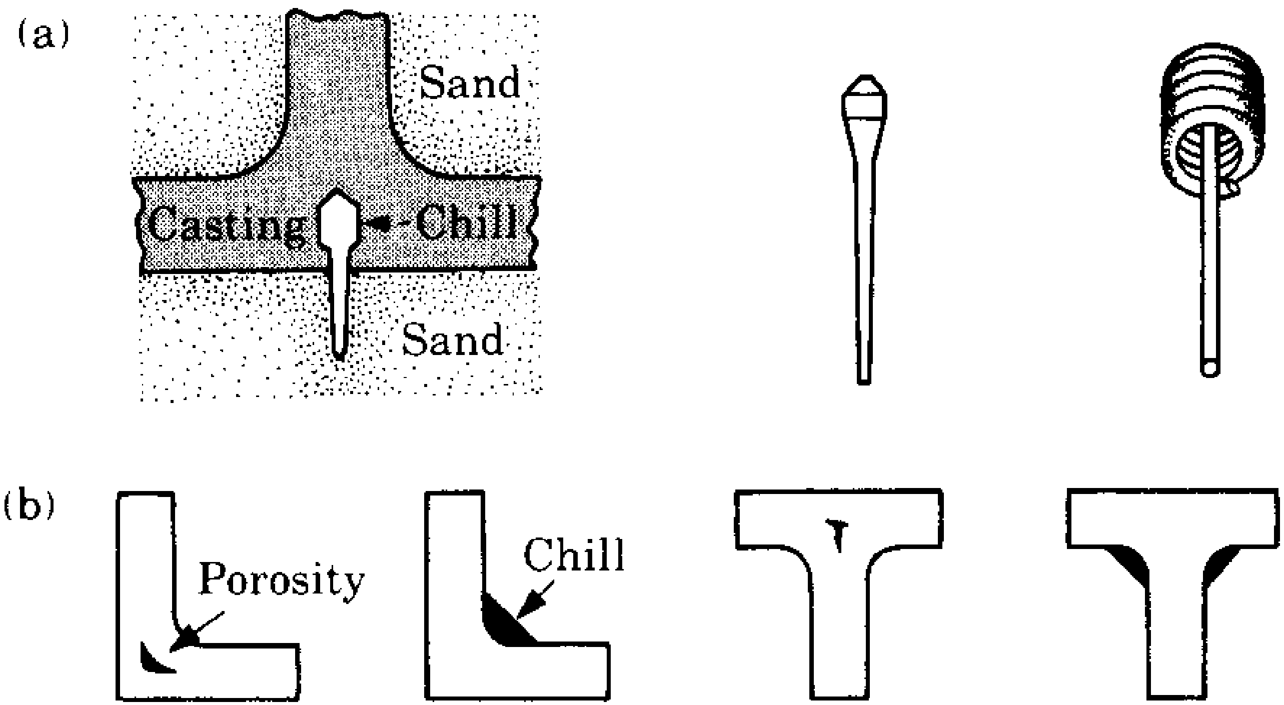


Fig. 5.17, Manufacturing Processes for Engineering Materials, by S. Kalpakjian, Addison Wesley

Sand Casting – Mold Making

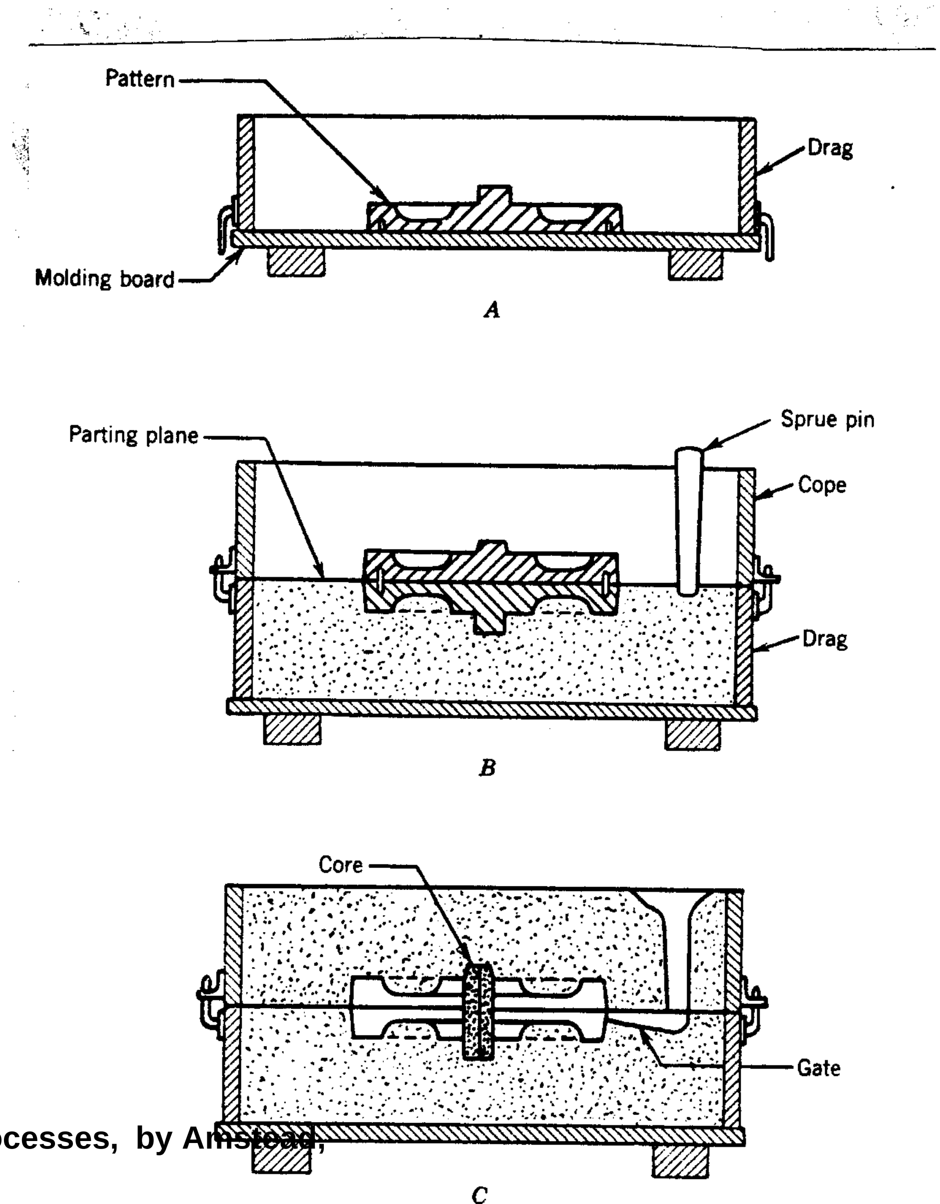


Fig. 5.2, Manufacturing Processes, by Amstead, Ostwald, Begeman, Wiley

Sand Casting – Mold Making

- Flask larger than the mold cavity is used
- Drag part of flask is placed on ram-up board (molding board)
- Drag pattern then placed on the board
- Facing sand is riddled on the pattern and board
  - 1 inch thick (facing sand is fine sand. gives good surface finish)
- Backing sand is then packed into the flask
  - Packing must be uniform backing sand is rougher than facing sand.
- Excess sand is cleaned with a strike bar
- Bottom board is then placed on the drag and clamped with ram-up board

Sand Casting – Mold Making

- Drag is then inverted and ram-up board removed
- Parting material (powder) lightly spread over parting surface (fine sand or silica flour)
- Cope flask then placed on drag flask and aligned with guide pins
- Cope pattern, riser form, and gating system are positioned
- Cope flask is filled with sand and rammed
- On removing cope, gates, risers, etc. are also removed. Pattern is also removed
- Loose cores may be positioned
- Mold is then closed and clamped for pouring

Mold Features

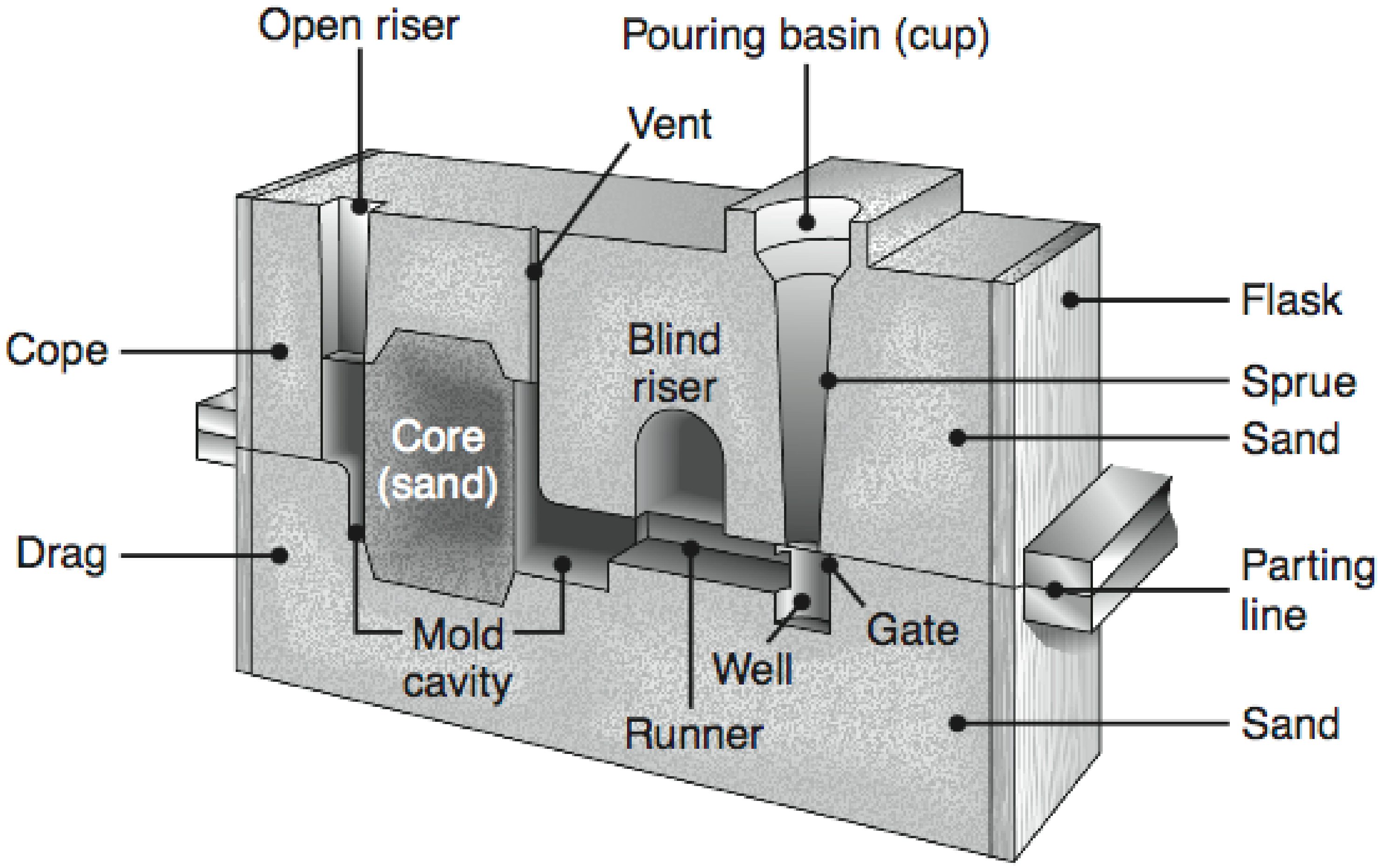


FIGURE 5.10 Schematic illustration of a typical sand mold showing various features.

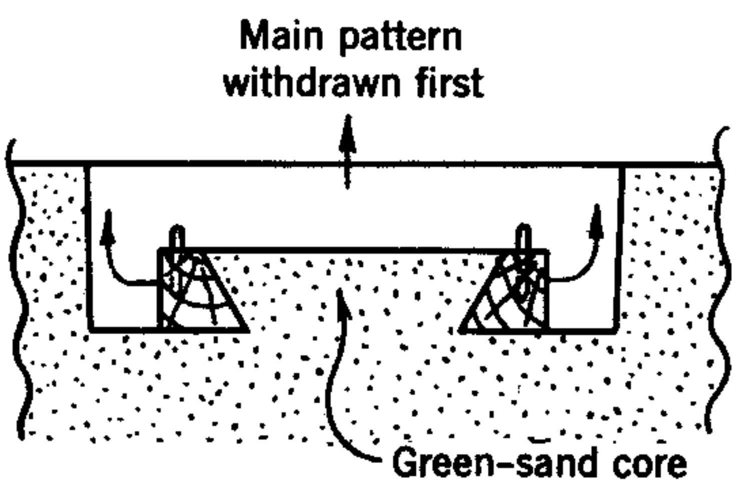
Sand Casting – Cores

- Cores are used for producing cavities in castings
  - Usually made of sand

- Desirable properties
  - Permeability
    - =Permit gases to escape
  - Refractory
    - =Withstand high temperatures
  - Strength
    - =Green strength of mold right after packing
    - =Dry strength of mold after it has been baked to improve strength
  - Collapsibility
    - =Ability to decrease in size as casting cools and shrinks
  - Friability
    - =Ability to crumble and be easily removed from casting

Sand Casting – Core Types

- Green-sand cores
  - Formed by the pattern and made from same sand as rest of the mold
- Dry-sand cores
  - Made separately from green sand, mixed with binder, and dried.
  - Inserted in mold after pattern is withdrawn



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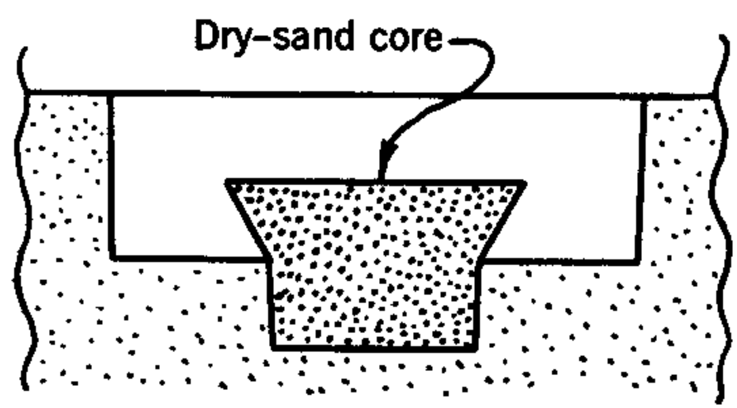

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Fig. 5.8, Manufacturing Processes, by Amstead, Ostwald, Begeman, Wiley

Sand Casting – Patterns

- Used to produce mold cavity
- Pattern types
  - Loose patterns
    - Made up of individual pieces and put together
    - Advantages
      - Cheapest to make
      - Makes pattern removal easier
    - Disadvantages
      - Most time consuming to use
  - Mounted patterns
    - Permanently fastened to board or match plate
    - Advantages
      - Easier to use
    - Disadvantages
      - More expensive

Sand Casting – Pattern Material

- **Wood**
  - ➢ Most common material
    - =e.g. sugar pine
  - ➢ Should have some moisture to avoid warping, shrinking, or expanding of finished pattern
    - =About 5% moisture
- **Metal**
  - ➢ Useful for a large number of castings
  - ➢ Does not warp easily
- **Plaster**
  - ➢ Easy to make, but brittle
    - =Thus not suitable for large number of castings
  - ➢ Used for emergency patterns and for repairing broken patterns

Sand Casting – Shrinkage

- Casting shrinks during solidification and cooling
- Shrinkage allowance provided in pattern
    - Difference between pattern and finished casting
    - Contraction is volumetric, but allowance is given linearly using Shrink Rules
    - Shrink Rules
        - Have scales longer than normal, but in definite proportions
- Shrinkage depends on
    - Material being cast
    - Shape of casting
    - Molding
    - Type of casting

Sand Casting – Other Allowances

- **Machining allowance**
  - **Extra size of casting to be machined**
  - **Included in pattern dimensions**

- **Distortion allowance**
  - **For parts that warp on cooling, e.g.**
    - **Flat plates**
    - **U-shaped castings**

Sand Casting – Other Factors

- **Parting Line – Surface dividing the cope and drag**
  - **Straight line parting is preferable**
    - **=Easier to fabricate**
- **Draft – Taper or slant on side of pattern**
  - **For ease of removing pattern from mold**

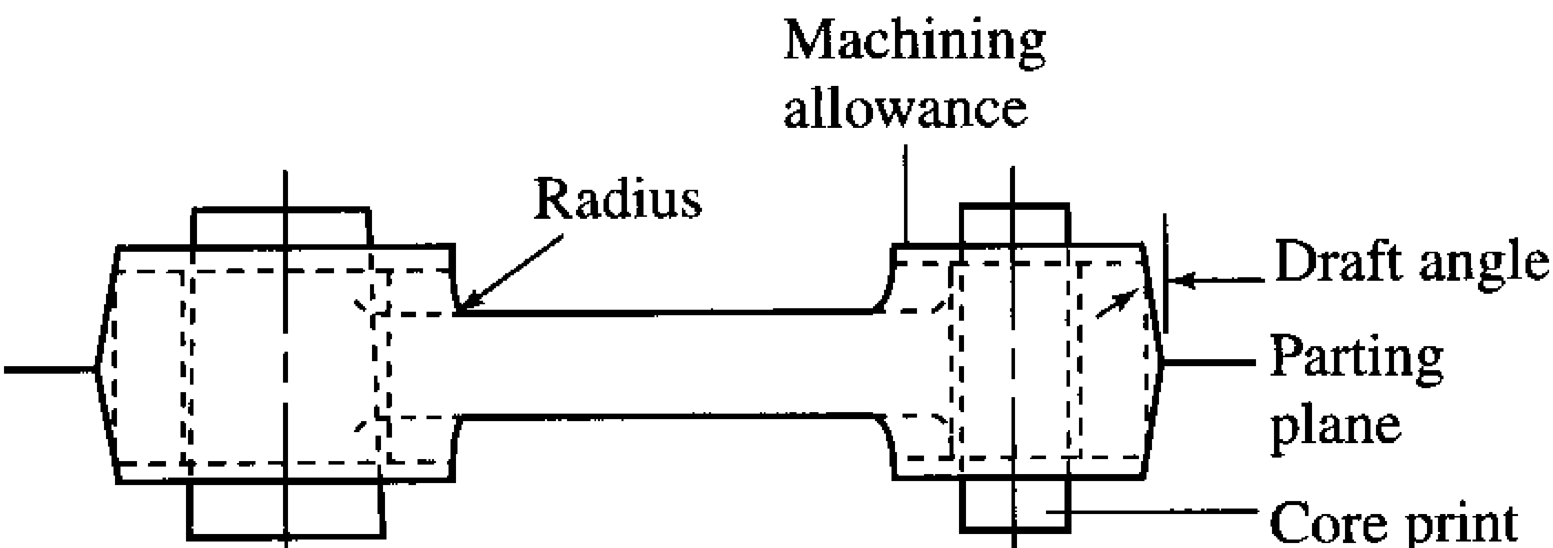
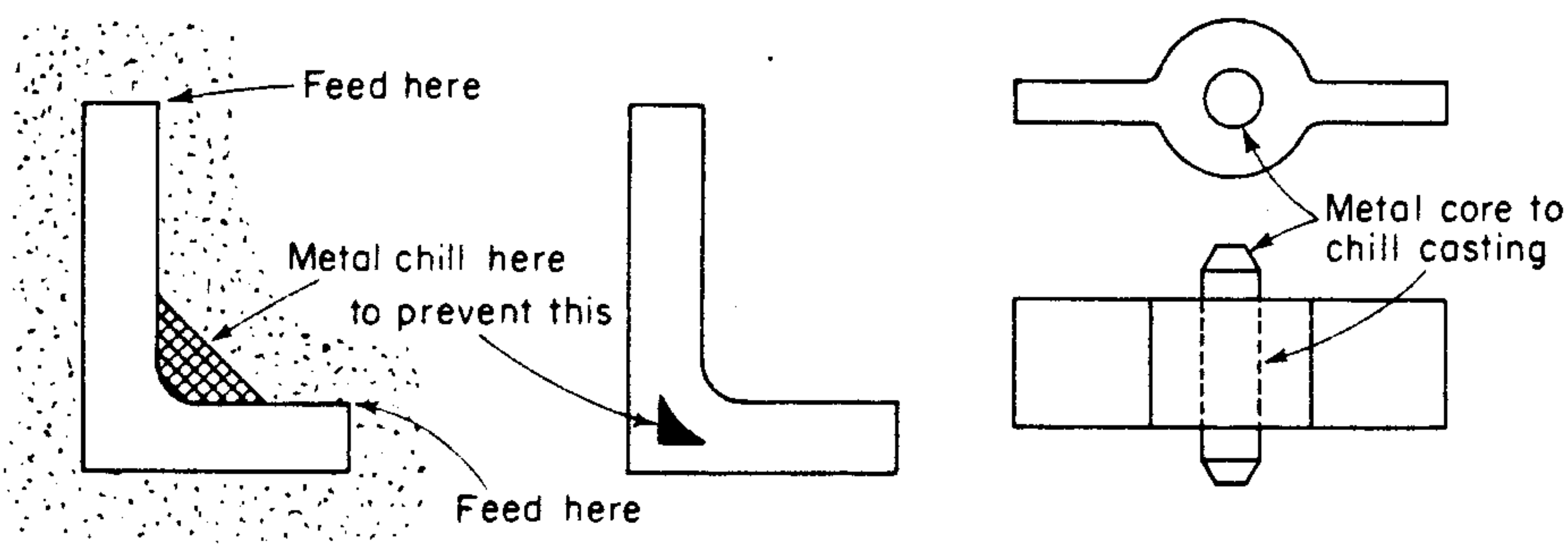


Fig. 7.18, Introduction to Manufacturing Processes, by Schey, McGraw Hill

Sand Casting – Other Factors

- **Fillets – Rounded corners**
  - Make pattern removal easier
  - Enable better flow of molten material
  - Increases strength
  - Can also be made using wax or plastic



Sand Casting – Mold Ingredients

- **Parts of sand molding**
  - **Sand grains**
    - =**Withstand heat**
  - **Bonding material**
    - =**Holds grains together**
      - **e.g. clay, cereal**
  - **Water**
    - =**Coalesces sand grains and binder into uniform material**

Sand Casting – Mold Ingredients

- **Desirable sand properties**
  - **Green permeability**
    =**Permeability of mold right after packing**
  - **Green strength**
    =**Strength of packed sand, ready for molding**
  - **Dry strength**
    =**Strength of baked sand**

- **Depend on**
  - **Grain size** larger grain size, lower strength, higher permeability
  - **Grain shape** regular grain shape, higher strength, lower permeability
  - **Binder content** higher binder content, higher strength, lower permeability
  - **Moisture content** higher moisture content, higher strength (but too much lowers strength) lower permeability

Sand Casting – Mold Ingredients – Green Permeability

- Permeability – Porosity from openings between grains
  - Allows air, gases, and steam to escape during pouring
  - Greater permeability implies greater porosity

- Grain size
  - Finer grains result in
    - =Lower permeability
    - =Smoother casting
  - Optimum value is used
  - Fine sand may be faced on surface of coarse grain mold cavity

Sand Casting – Mold Ingredients – Green Permeability

- **Grain shape**
  - ➢ **Angular**
    - =**Have higher permeability**
  - ➢ **Rounded**
    - =**Pack more closely**
- **Binder**
  - ➢ **Permeability reduces with increasing binder amount**
  - ➢ **Optimum**
    - =**Just coating sand particles without filling pores**
- **Moisture**
  - ➢ **Excess moisture results in lower permeability**
  - ➢ **Optimum**
    - =**Between 2 and 8%**

Sand Casting – Mold Ingredients – Strength

- **Grain size**
  - ➢Green strength decreases as grain size increases
- **Grain shape**
  - ➢Angular
    - =Have lower strength
  - ➢Rounded
    - =Pack more closely
- **Binder**
  - ➢Strength increases with increasing binder amount
  - ➢Compromise between strength and permeability
- **Moisture**
  - ➢Excess moisture results in lower strength

Casting – Analysis

- Two flow principles are useful in the design of gating systems
  - Bernoulli’s theorem
  - Continuity

Casting – Analysis – Bernoulli's Theorem

- This is based on the principle of energy conservation
- Relates
  - ➢Elevation of fluid above a reference plane (h)
  - ➢Pressure at that elevation (p)
  - ➢Velocity of the liquid at that elevation (v)
  - ➢Frictional loss in the liquid as it travels downward through the system (f)

Casting – Analysis – Bernoulli's Theorem

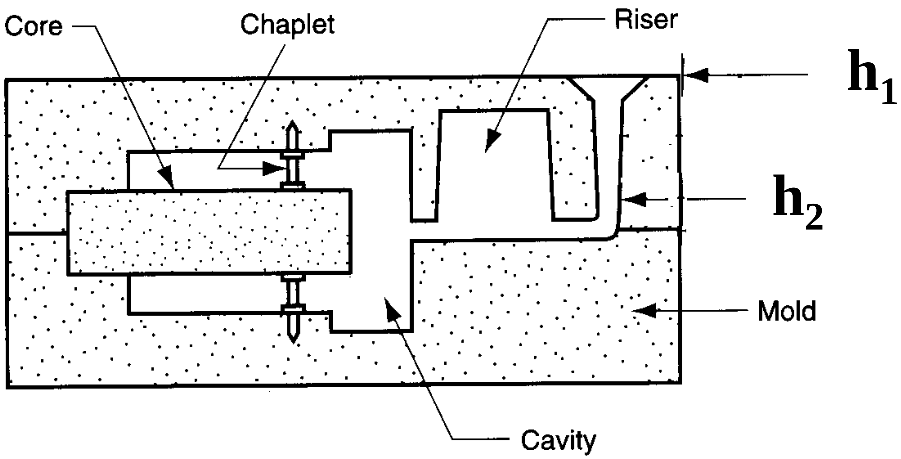
$$h + \frac{p}{\rho g} + \frac{v^2}{2g} = Constant$$

Or for two different elevations,

$$h_1 + \frac{p_1}{\rho g} + \frac{v_1^2}{2g} = h_2 + \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + f$$

Acceleration due to gravity (*g*)

density (ρ)



Casting – Analysis – Continuity

- **The continuity law states:**
  - **For incompressible liquids and in a system with impermeable walls, the rate of flow is constant**

$$Q = A_1 v_1 = A_2 v_2$$

Q **= volumetric flow rate**

A **= cross-sectional area of liquid stream**

- **Assuming constant pressure throughout the fluid and no frictional losses, it can be shown that**

$$\frac{A_1}{A_2} = \sqrt{\frac{h_2}{h_1}}$$

Casting – Analysis – Solidification Time

- The time to solidify is a function of the volume of a casting and its surface area.

- It is given by Chvorinov's rule:

$$Solidification\ Time = C\left(\frac{Volume}{Surface\ Area}\right)^{2}$$

C = Constant

Casting – Analysis – Example

Starting with Bernoulli's theorem and neglecting frictional losses and assuming that the pressure remains the same throughout, show in 3 or more lines, that the velocity (*v*) and height (*h*) at any two locations of a sprue are related as follows:

$$v = \sqrt{2gh}$$

Casting – Analysis – Solution

$$h_1 + \frac{v^2{}_1}{2g} = h_2 + \frac{v^2{}_2}{2g}$$

Let point 1 be the top of the sprue and point 2 the base. If point 2 is used as the reference plane, then the head at that point is zero ($h_2 = 0$) and h_1 is the height of the sprue.

The initial velocity of the molten metal at the top is zero ($v_1 = 0$).

Which gives

$$h_1 = \frac{v^2{}_2}{2g}$$

Thus we have:

$$v = \sqrt{2gh}$$

Casting – Analysis – Example

A certain mold has a sprue whose height is 8.0 *in.* and the cross-sectional area at the base of the sprue is 0.4 $in.^2$ The sprue feeds a mold cavity whose volume is 100 $in.^3$ The acceleration due to gravity is $g = 386.6\ in/sec^2$. Determine:

a. Velocity of the molten metal at the base of the sprue
b. Volume rate of flow
c. Time to fill the mold.

Casting – Analysis – Solution

a. Velocity of the molten metal at the base of the sprue

$$v = \sqrt{2gh} = \sqrt{2 \times 386.6 \times 8} = 78.65 in./\sec$$

b. Volume rate of flow

$$Q = A_1 v_1 = 0.4 \times 78.65 = 31.5 \ in.^3/sec$$

c. Time to fill the mold.

The time required to fill a mold cavity of 100 in.^{3} at this flow rate is

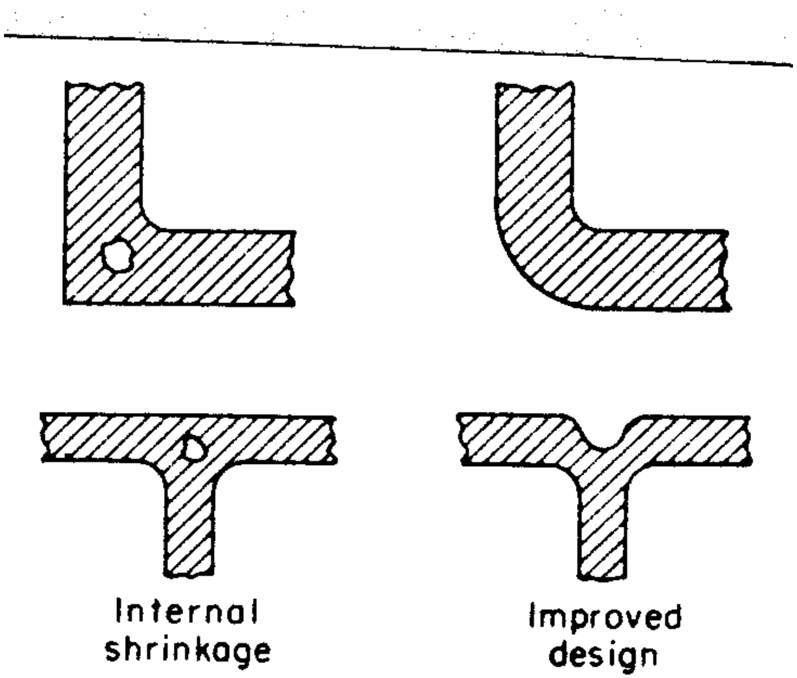
$$t = 100/31.5 = 3.2 \ sec$$

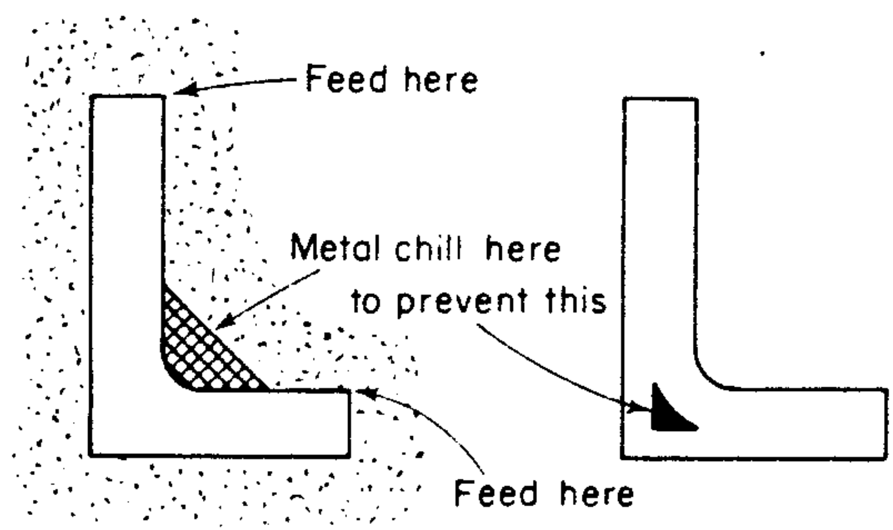
Casting – Behavior of Cast Metal

- Molten metal starts cooling from mold surface towards interior of casting
  - ➢ Faster cooling on casting surface
    - =Finer grain structure
  - ➢ Interior cools slowly
    - =Coarse grain structure

Casting – Behavior of Cast Metal

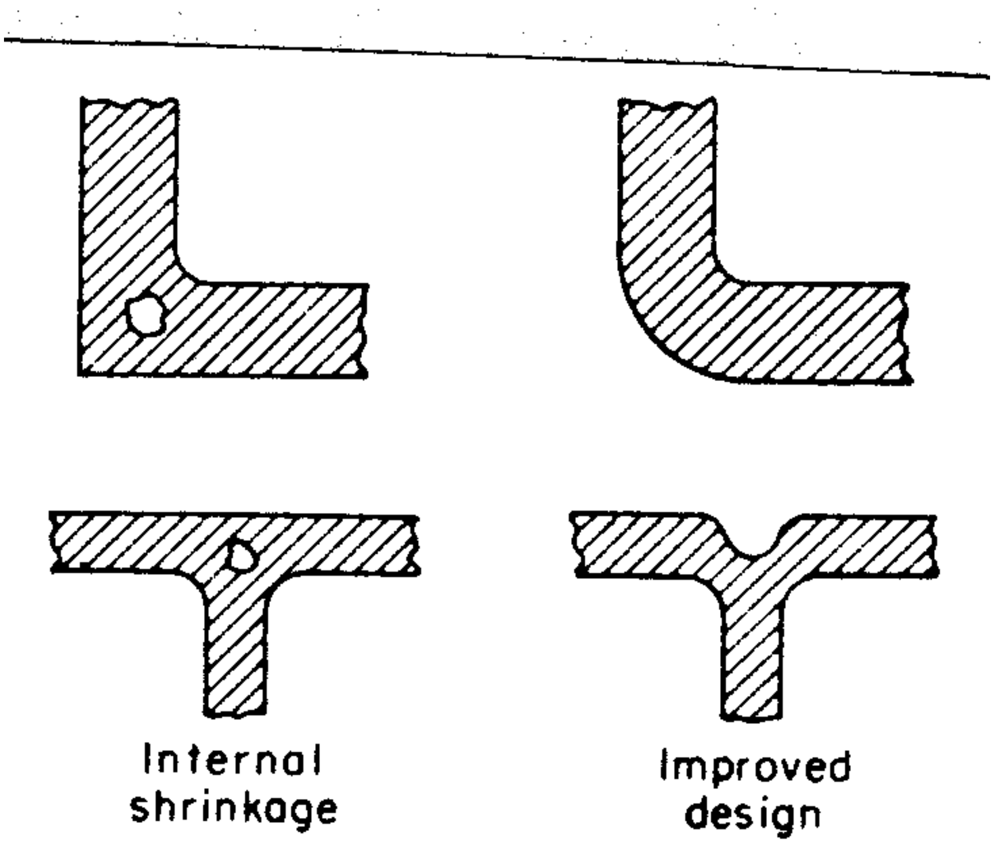
- Thick sections may have interior cavity as they cool and shrink – Hot Spots
  - Prevented by
    - =Design modification
    - =Riser
    - =Chill





Casting – Behavior of Cast Metal

- **Hot Spots**
  - ➢Thick sections that are far from the riser
  - ➢Develop voids or tears
- **Prevention**
  - ➢Uniform sections
  - ➢Chills



Casting – Behavior of Cast Metal

- **Thin sections cool faster**
  - **Finer grains and stronger**
  - **However, melt may freeze in passageway and prevent complete filling of mold**
  - **Minimum thickness:**
    - **Iron – 1/8″**
    - **Steel – 3/16″**

Casting – Behavior of Cast Metal

- **Non-uniform sections create problems** tubulence may be experienced by flowing molten metal
  - ➢ **Different cooling rates create residual stresses**
- **Prevention**
  - ➢ **Gradual tapers or changes in thickness**

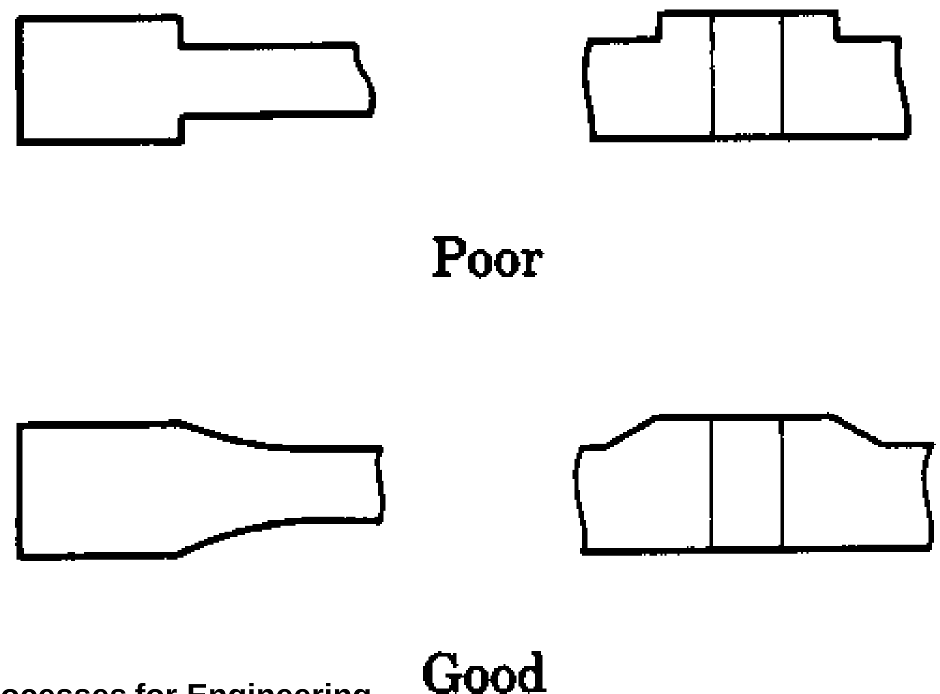


Fig. 5.42, Manufacturing Processes for Engineering Materials, by S. Kalpakjian, Addison Wesley

Casting – Shell Mold Casting

- Molding material
  - Fine sand with phenolic resin binder
- Mixture placed on heated metal pattern (450ºF)
- Layer about ¼” thick forms around pattern
- Resin then cured and shell hardened by baking
- Mold may be reinforced to withstand hydrostatic pressure

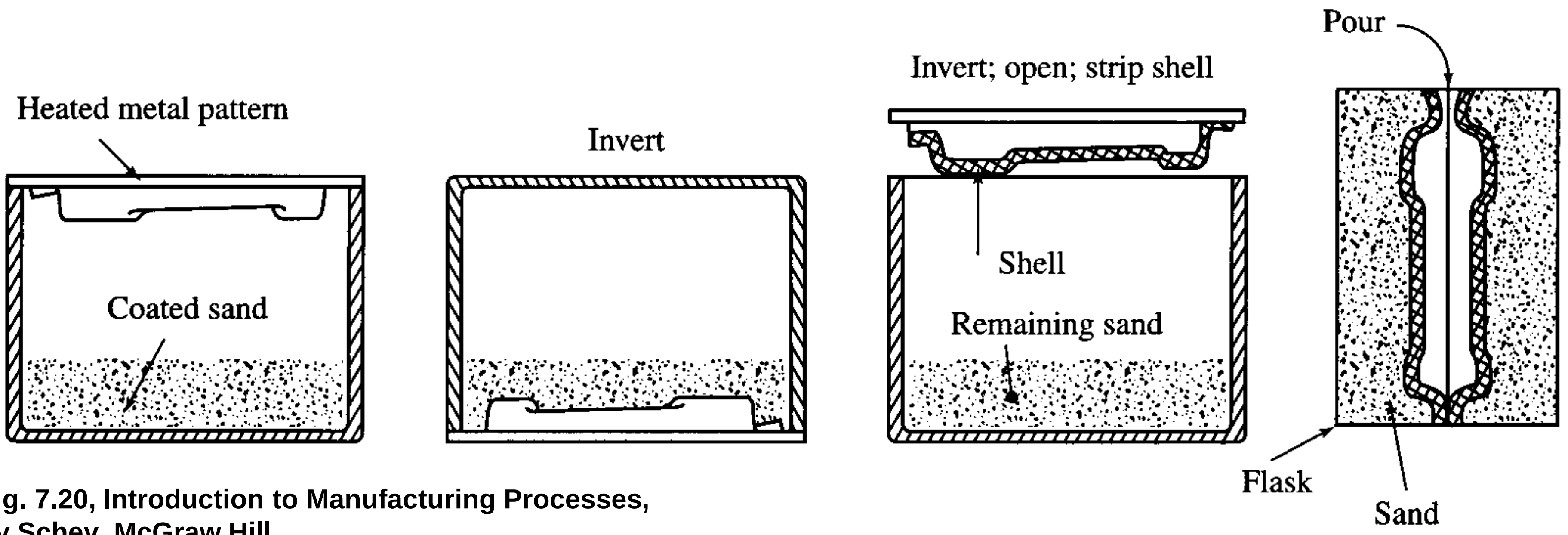


Fig. 7.20, Introduction to Manufacturing Processes, by Schey, McGraw Hill

Casting – Shell Mold Casting

- **Advantages**
  - Less sand is used
  - Mold is light and easy to handle
  - Gas venting better
  - Less scrap of castings
  - Easily mechanized
  - Better finish and closer tolerances
  - More complex shapes
  - Less chill effect

- **Disadvantages**
  - More expensive

Casting – Full Mold (Lost Foam) Casting

- Uses polystyrene pattern which stays in mold
  - ➢It is vaporized by the molten material as it is poured
- Mold material
  - ➢Sand, binder, water
- Advantages
  - ➢More complex parts - undercuts
  - ➢No need for drafting

disadvantage
foam has to be chemically inert to metal

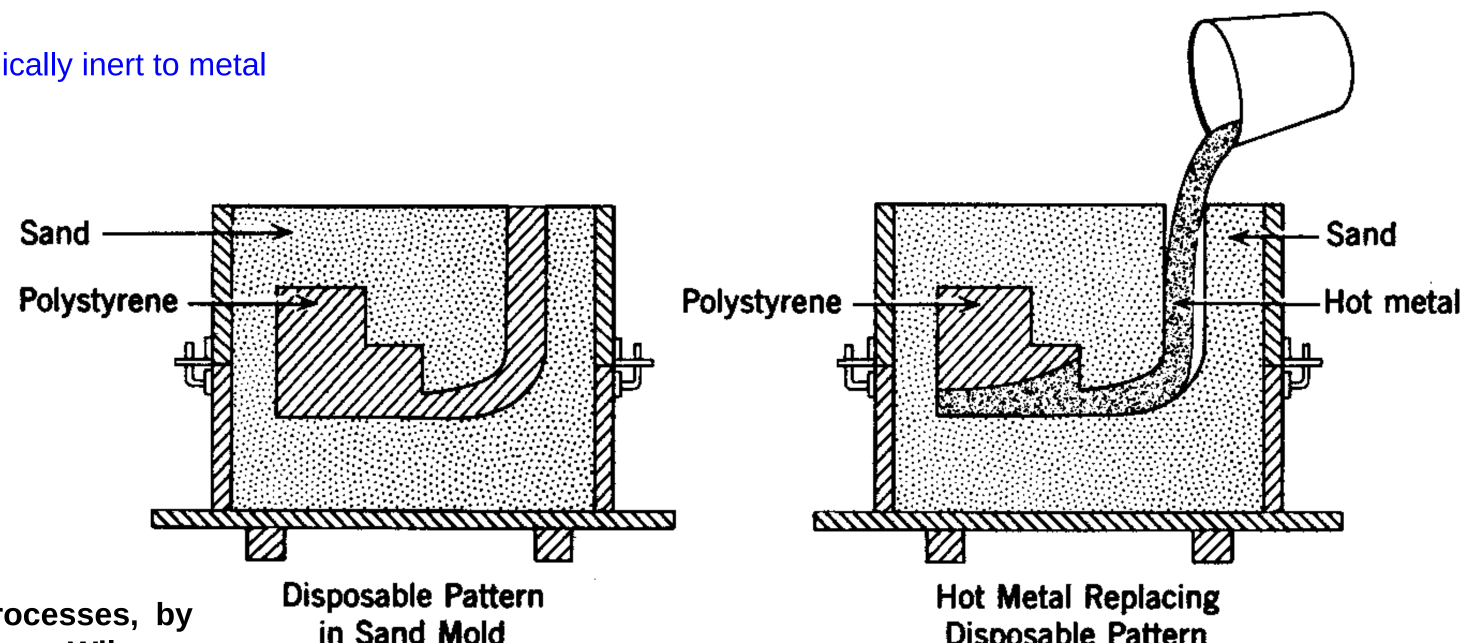


Fig. 5.3, Manufacturing Processes, by Amstead, Ostwald, Begeman, Wiley

Casting – Plaster Mold Casting

- Mold material
  - Plaster of paris (hydrated calcium sulfate) (gypsum)
  - Talc – magnesium silicate
  - Silica flour

- Slurry of material is poured over the pattern and allowed to harden
- Mold is then dried
- Process is used mainly for
  - Al, Mg, Zn, and some copper-base alloys

Casting – Plaster Mold Casting

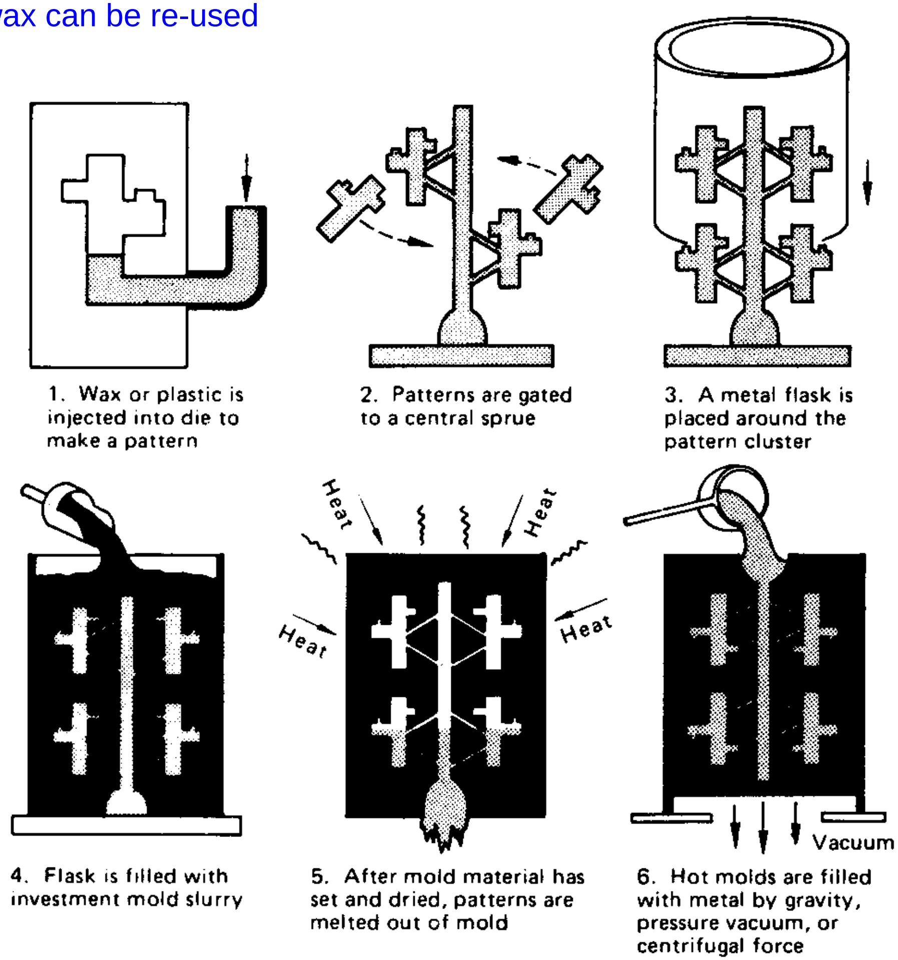
- **Advantages**
  - Complex shapes with thin walls
  - Better accuracy than sand casting
  - Smoother surfaces

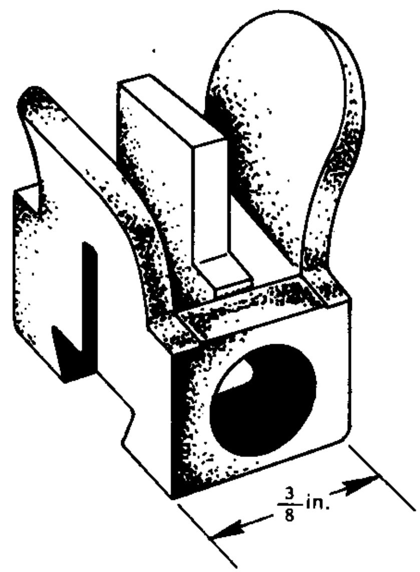
- **Disadvantages**
  - More expensive
  - Coarse and more uniform grain structure
    - =Slow cooling due to low thermal conductivity of mold material
  - More time consuming
    - =Because of long baking

Casting – Precision Investment Casting

- **Also called**
  - **Lost Wax Process**

wax can be re-used





(b)

Fig. 5.18, Processes and Materials of Manufacture, by Lindberg, Allyn and Bacon

Casting – Precision Investment Casting

- Pattern is prepared by injecting wax or plastic into a die
- Patterns may be joined by an adhesive
- Metal flask then placed around pattern
- Mold then poured into flask to cover pattern
    - Investment
- Pattern may also be dipped in a slurry to form a mold (about ¼" thick) around it
    - No flask used for this method
- Mold is then cured
- Then heated to melt the pattern to leave mold cavity
    - About 2000°F
- Molten material is then poured into the mold
- Mold is broken off after the casting solidifies

Casting – Precision Investment Casting

- Die material
  - Rubber, plaster, wood, or metal
- Pattern material
  - Wax or plastic
- Mold material
  - Silica sand
- Binder
  - Plaster or organic silica (ethyl silicate)

Casting – Precision Investment Casting

- **Advantages**
  - ➢Good for metals with good fluidity, uniform shrinkage, chemical inertness
  - ➢Small tolerances, fine details, thin sections

    =Better than sand casting
  - ➢No parting surface or draft
  - ➢Readily automated
  - ➢Complex parts and smaller quantities and sizes
  - ➢Can be used for higher melting metals not suitable for metal mold casting

- **Applications**
  - ➢Tooth fillings, surgical instruments, jewelry
  - ➢Turbine blades and vanes
  - ➢Cutting tools

Casting – Permanent Mold Casting

- Molds can be used a number of times
  - Usually made of metal
- Mold held together during casting by clamps
- Mold is washed with refractory slurry
  - Graphite or clay
    - =Prevents casting from sticking in the mold
- Molten material poured into mold and hydrostatically pressed
- Example materials that are cast
  - Pb, Zn, Al, Mg alloys, bronze, cast iron

Casting – Permanent Mold Casting

- **Mold material**
  - ➢ Alloy cast iron
  - ➢ Bronze
    - =For Pb, Sn, Zn
  - ➢ Wrought alloy steel
    - =For bronzes

- **Core material**
  - ➢ Generally alloy steel
  - ➢ Sand
  - ➢ Plaster

Casting – Permanent Mold Casting

- **Applications**
  - Refrigerator compressor parts
    - =Cylinder blocks
    - =Heads
    - =Connecting rods
  - Automobile
    - =Cylinder blocks
    - =Heads
    - =Connecting rods
  - Gear blanks for appliances
  - Kitchenware

Casting – Semi-Permanent Mold Casting

- Uses metal molds and sand cores
  - Cores cheaper and easier to remove
  - Poorer accuracy and surface finish

Casting – Permanent Mold Casting – Low Pressure Casting

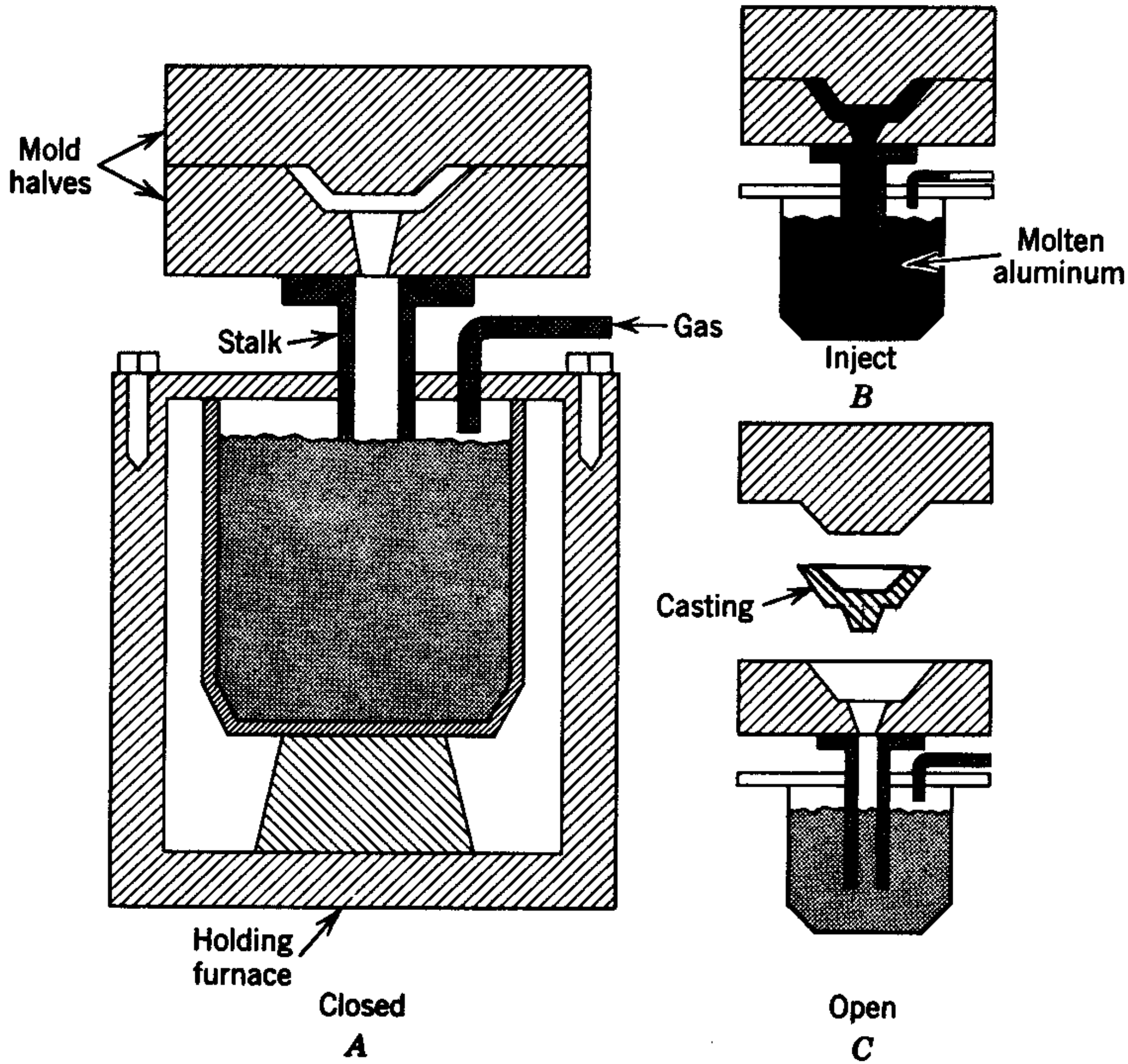


Fig. 6.8, Manufacturing Processes, by Amstead, Ostwald, Begeman, Wiley

Casting – Permanent Mold Casting – Low Pressure Casting

- Molten material is forced upwards to fill the mold
- Pressure is released after solidification
- Used mainly for aluminum
- Gives moderately thin sections and intermediate accuracy and finish

Casting – Permanent Mold Casting – Slush Casting

- Useful for hollow castings with thin walls
- After a thin section of material solidifies, the remaining molten metal is poured out
- Good for small production runs
- Also good for plating
- Applications
  - Toys and ornaments
- Materials cast
  - Zn, Pb, Sn alloys

Casting – Permanent Mold Casting – Die Casting

- Molten material is forced into die using moderate to high pressures
  - Up to about 150 MPa or higher
- Dies may be water-cooled to hasten solidification
- Pressure is usually provided by a plunger
- Pressure is held until molten material solidifies
- Dies are then forced open and die casting ejected
- Usually used for high production applications

Casting – Permanent Mold Casting – Die Casting

- **Applications**
  - Transmission housings
  - Valve bodies
  - Carburetors
  - Hand tools
  - Toys

- **Range of part sizes**
  - 90 g to 25 kg

- **Process Types**
  - Hot-Chamber Process
  - Cold-Chamber Process

Casting – Die Casting – Hot-Chamber Process

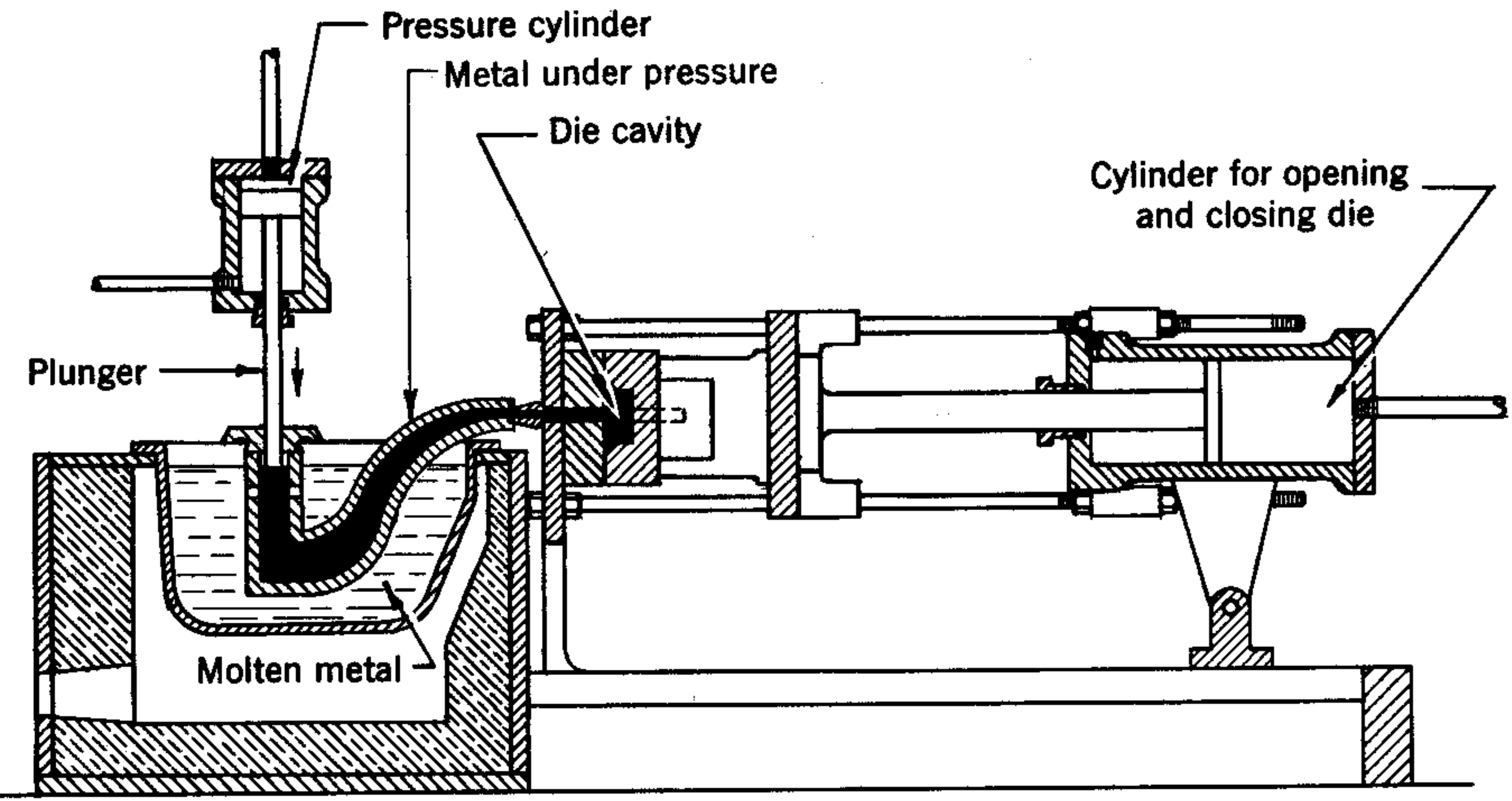


Fig. 6.4, Manufacturing Processes, by Amstead, Ostwald, Begeman, Wiley

Casting – Die Casting – Hot-Chamber Process

- Uses a piston and cylinder arrangement
- Metal flows into container by gravity with piston in upper position
- Trapped melt then forced into die by piston on downward stroke
- Typical pressures
  - 10-35 MPa
- Rate
  - About 900-18,000 parts per hour
- Materials cast
  - Low melting point alloys - Zn, Sn, Pb

Casting – Die Casting – Cold-Chamber Process

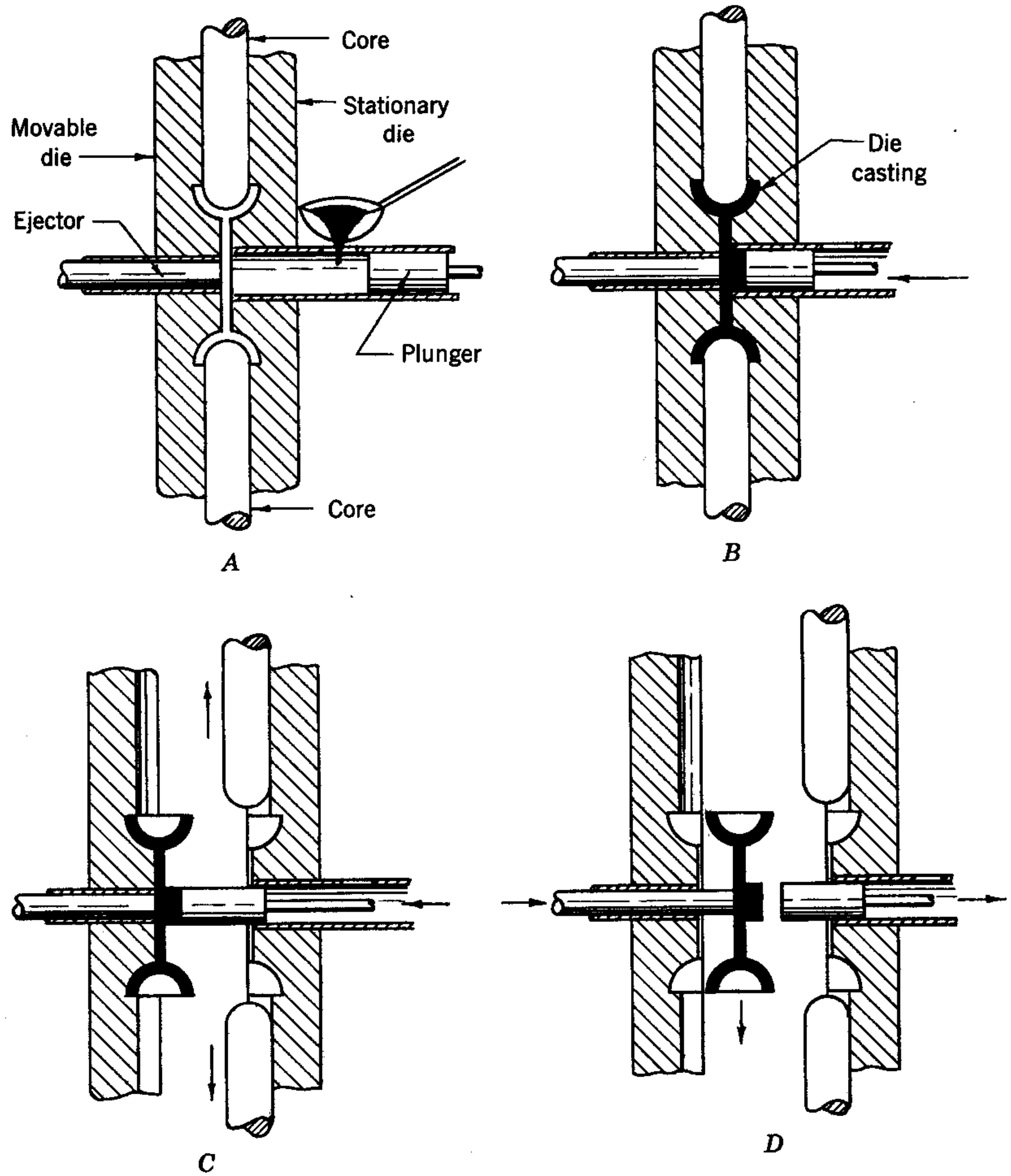


Fig. 6.5, Manufacturing Processes, by Amstead, Ostwald, Begeman, Wiley

Casting – Die Casting – Cold-Chamber Process

- Molten metal is introduced into an un-heated shot chamber (injection cylinder)

- Machine may be horizontal or vertical

- Typical pressures
  - 20-150 MPa

- Materials cast
  - High melting point alloys – Al, Mg, Cu

Casting – Die Casting – Dies

- Generally consist of 2 parts
  - Front cover portion – stationary
  - Ejector portion – movable
  - 2 parts aligned by the machine and dowel pins

- Types of Dies
  - Single cavity dies
    - =Produce one casting for each cycle
  - Multiple cavity dies
    - =Have several cavities in a die – All fed by one sprue
      - Good for large scale production
  - Combination dies
    - =Have several differently shaped cavities in a die
      - Different castings produced at one time
  - Unit dies
    - =Holder in which several dies may be placed

Casting – Comparing Metal Mold and Plaster Mold Casting

- Accuracy and finish
  - About the same
- Patterns for plaster molds
  - Less expensive
- Operation cost
  - More expensive for plaster molds
- Plaster molds
  - Better for high melting non-ferrous metals

Casting – Comparing Metal Mold and Sand Casting

- Accuracy, finish, strength, appearance
  - Better for metal molds
- Cost
  - More expensive die costs for metal molds
- More draft is required for metal molds

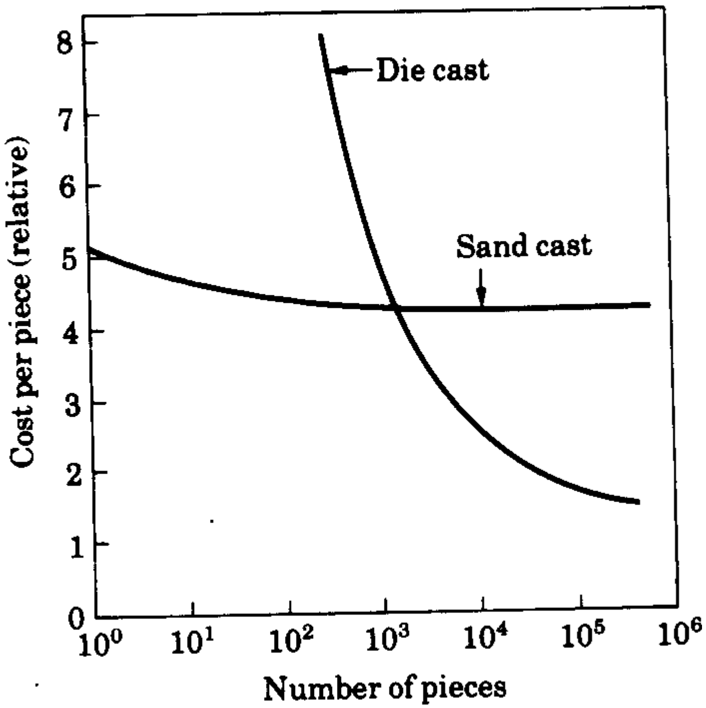
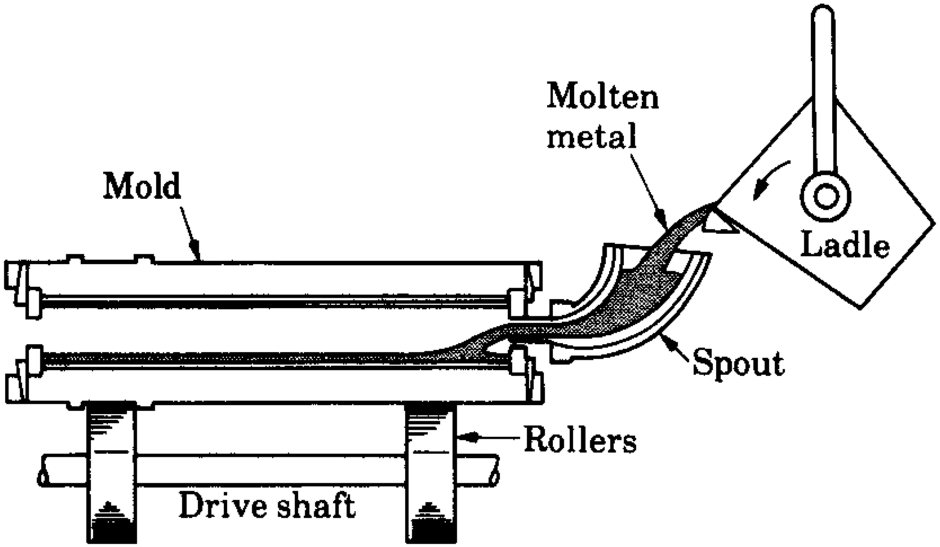


Fig. 5.45, Manufacturing Processes for Engineering Materials, by S. Kalpakjian, Addison Wesley

Casting – Centrifugal Casting

- Molten material is poured into revolving cylindrical mold or flask
- Mold
  - ➢Metal, graphite or sand



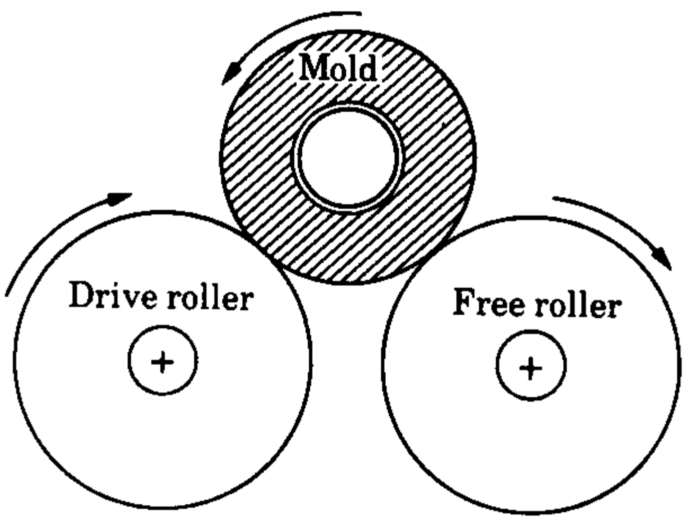


Fig. 5.33, Manufacturing Processes for Engineering Materials, by S. Kalpakjian, Addison Wesley

Casting – Centrifugal Casting

- Gates and risers are not necessary
    - Eliminates waste
- Produces good quality and accurate castings
- Impurities are segregated and may be machined off later
- Dense castings with fine-grained structure and uniform and high physical properties
- Outside surface may also be polygonal
- Centrifugal castings without holes may be porous and weak and contain inclusions in the center
- Types
    - Horizontal
    - Vertical – Usually for short pieces

speed affects quality of casting.

Casting – Centrifugal Casting

- Molten material is poured into revolving cylindrical mold or flask
- Mold
  - ➢Metal or sand

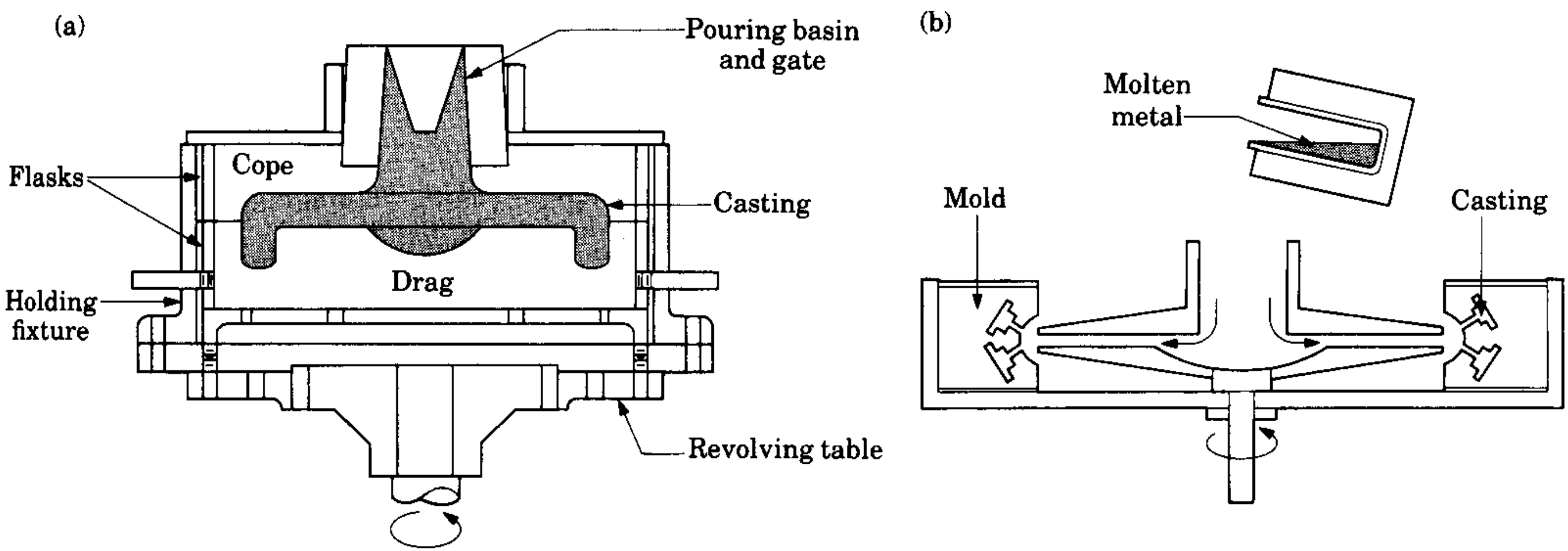


Fig. 5.33, Manufacturing Processes for Engineering Materials, by S. Kalpakjian, Addison Wesley

Casting – Centrifugal Casting

- **True centrifugal**
  - **For hollow cylindrical parts**

- **Semi-centrifugal**
  - **For parts with rotational symmetry**
    - **=e.g. wheel with spokes**

Casting – Continuous Casting

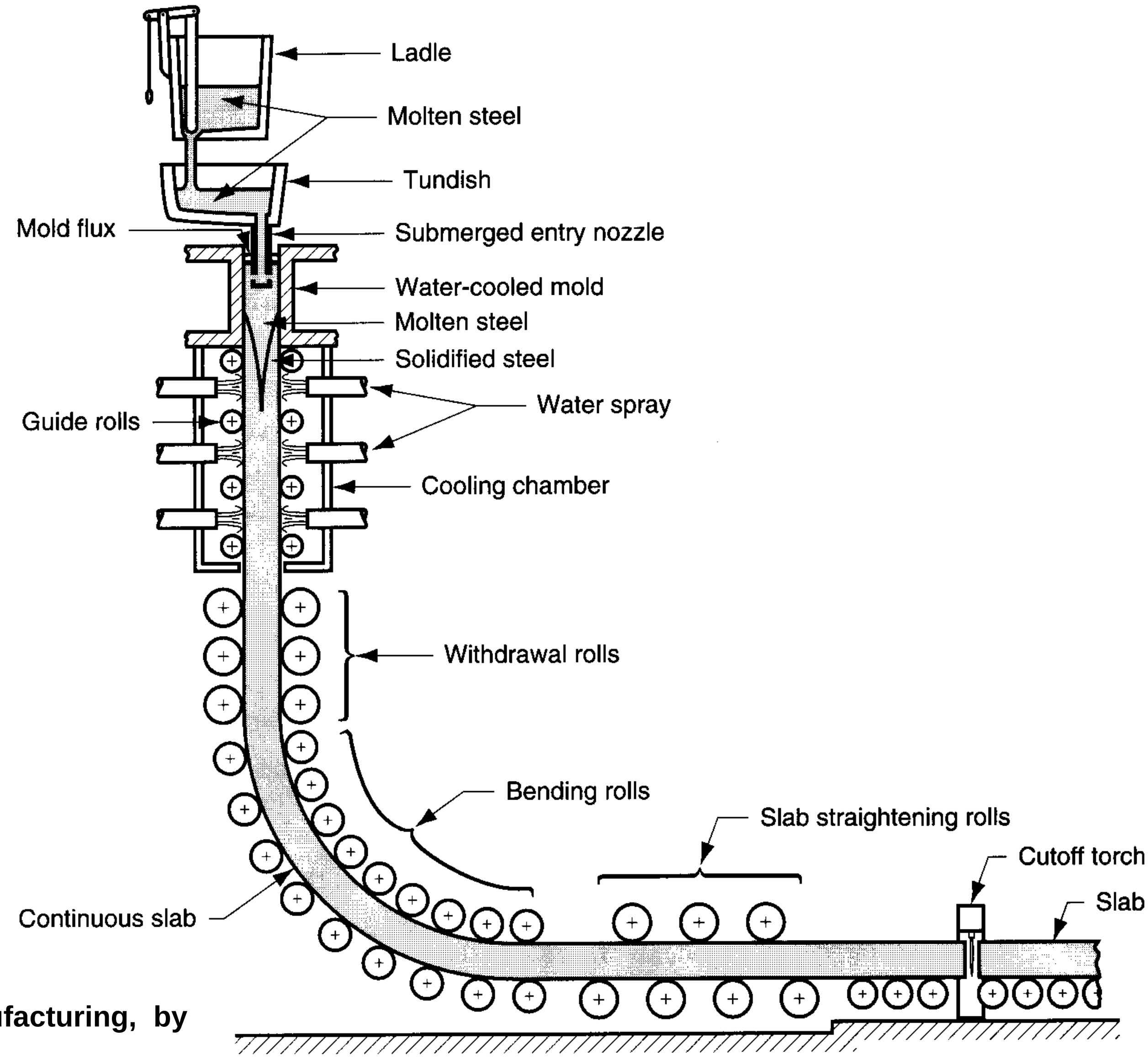


Fig. 7.11, Fundamentals of Modern Manufacturing, by M. P. Groover, Prentice Hall

Casting – Continuous Casting

- Uses a mold that is open at both ends
- Molten material is poured in at one end, and the casting removed continuously from the other end in one piece
- Mold is cooled
- The mold may be vibrated to avoid sticking of the casting
- Common metals cast by this method
    - Cu, Al, Fe, brass, bronze, steel
- Dies
    - Cu or graphite

Casting – Continuous Casting

- **Advantages**
  - **Uniform shapes of any cross-section**
    =**Round, polygonal, gears, solid, hollow**
  - **Can produce blooms, billets, etc. for rolling**
    =**Cheaper than rolling from ingots**
- **Disadvantage**
  - **Hollow center due to shrinkage**
    =**Remedied after rolling**

Casting – Comparing Different Casting Processes

GENERAL COST CHARACTERISTICS OF CASTING PROCESSES

PROCESS	COST*			PRODUCTION RATE† (Pieces/hr)
	DIE	EQUIPMENT	LABOR	
Sand	L	L	L–M	< 20
Shell	L–M	M–H	L–M	< 50
Plaster	L–M	M	M–H	< 10
Investment	M–H	L–M	H	< 1000
Permanent mold	M	M	L–M	< 60
Die	H	H	L	< 200
Centrifugal	M	H	L–M	< 50

*L, low; M, medium; H, high.
†Depends greatly on casting size.

Table 5.10, Manufacturing Processes for Engineering Materials, by S. Kalpakjian, Addison Wesley

Casting – Comparing Different Casting Processes

Table 7-3 General Characteristics of Shape Casting Processes

	Casting Process						
	Sand						
Characteristics	**Green**	**Resin-Bonded**	**Lost Foam**	**Plaster**	**Investment**	**Permanent Mold**	**Die**
Part							
Casting alloy	All	All	Al to cast iron	Zn to Cu	All	Zn to cast iron	Zn to Cu
Shape*	All	All	All	All	All	Not T3, 5, F5, U1, 5, 7 with solid core	Not T3, 5, F5, U1, 5, 7
Surface detail†	C	B	C	A	A	B–C	A–B
Mass, kg	0.01–300 000	0.01–100	0.01–100	0.01–100	0.001–100	0.1–100	<0.01–50
Min. section, mm	3–6	2–4	2–4	1	0.75	2–4	0.5–1.5
Min. core diam., mm	4–6	3–6	4–6	10	0.5–1	4–6	3 (Zn: 0.8)
Porosity†	C–E	D–E	C–E	D–E	E	B–C	A–C
Cost							
Equipment†	C–E	C	B–C	C–E	C–E	B	A
Die (or pattern)†	C–E	B–C	B–C	C–E	B–C	B	A
Labor†	A–C	C	C	A–B	A–B	C	E
Finishing†	A–C	B–D	C–D	C–D	C–D	B–D	C–E
Production							
Operator skill†	A–C	C	C	A–B	A–B	C	C–D
Lead time†	Days	Weeks	Weeks–months	Days	Hours–weeks	Weeks	Weeks–months
Rates (piece/h·mold)	1–20	5–50	1–20	1–10	1–1000	5–50	20–200
Min. quantity	~1–100	~100	~500	~10	~10–1000	~1000	~10 000

*From Fig. 3–1.

†Comparative ratings, with A indicating the highest value of the variable, E the lowest. For example, investment casting produces excellent surface detail, gives very low porosity, involves moderate to low equipment cost, medium to high pattern cost, high labor cost, medium to low finishing cost, and high operator skill. It can be used for low or high production rates and requires a minimum quantity of 10 to 1000 to justify the cost of the pattern mold.

Table. 7.3, Introduction to Manufacturing Processes, by Schey, McGraw Hill

Casting – Design for C

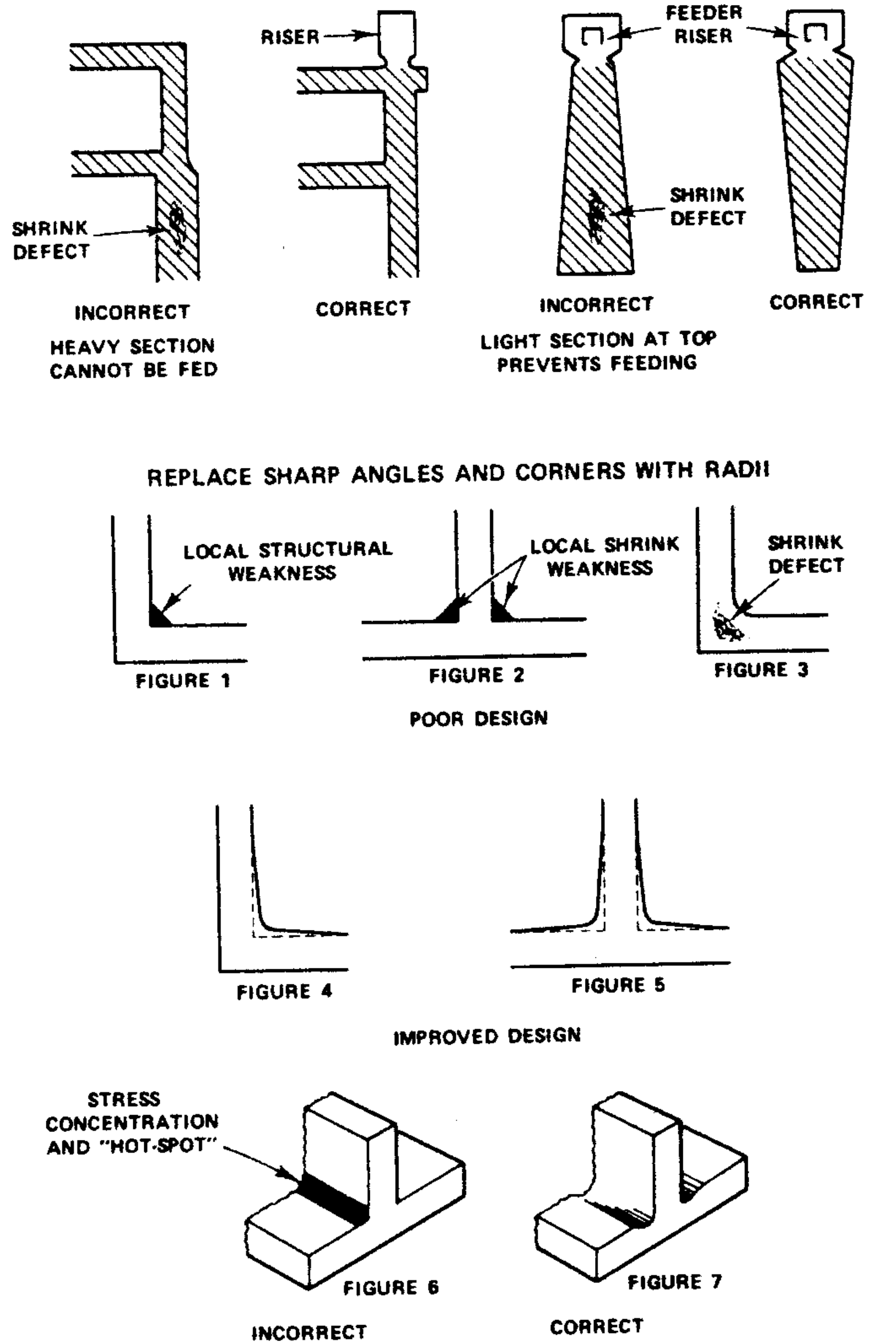
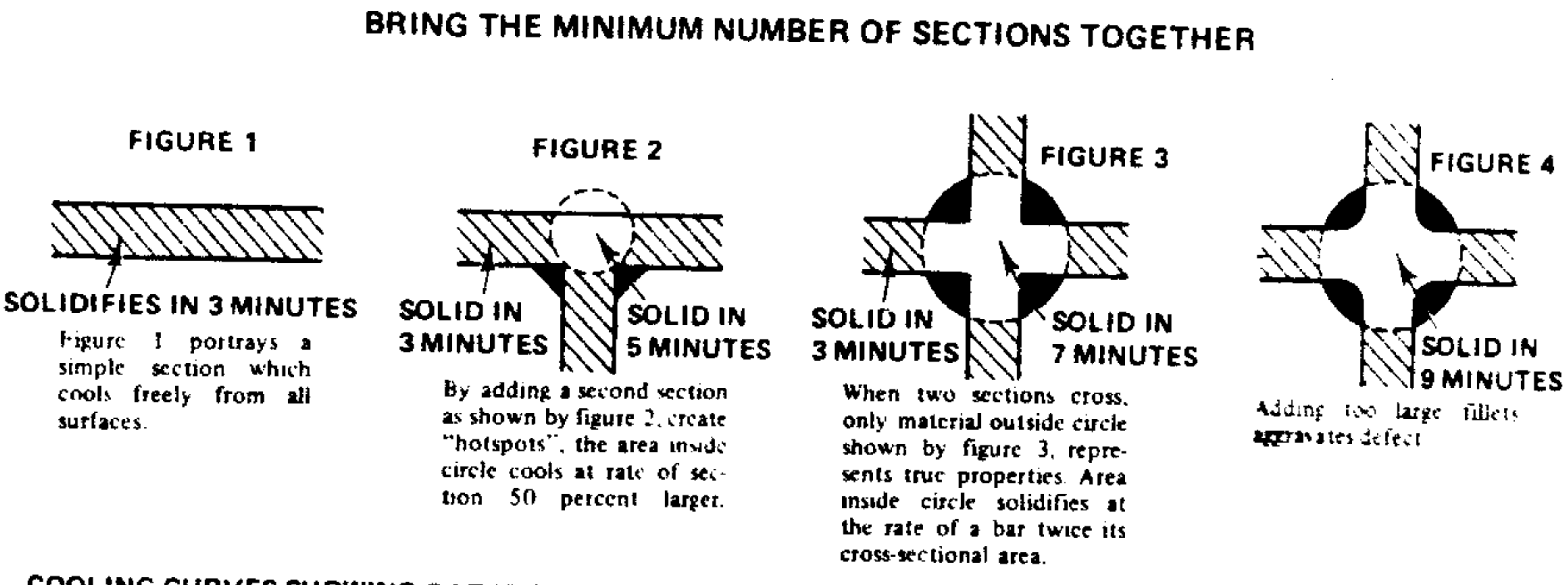


Fig. 8-49. Rules for the design of castings.

Casting – Design for Casting



Casting

Casting – Design for Casti

DESIGN RIBS AND BRACKETS FOR MAXIMUM EFFECTIVENESS

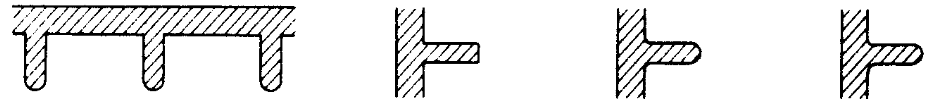
Ribs have two functions:
(1) to increase stiffness
(2) to reduce weight
If too shallow in depth, or too widely spaced they are ineffectual.

A
INCORRECT
RIBS TOO SHALLOW

B
INCORRECT
TOO WIDELY SPACED

Thickness of ribs should approximate 0.8 casting thickness

Correct rib depth and spacing is a matter of engineering design.



C
CORRECT

D
INCORRECT
Thin ribs should be avoided when joined to a heavy section. Otherwise, they will lead to high stresses and cracking.

E
INCORRECT
As far as possible, junction between ribs and main casting should prevent any local accumulation of metal.

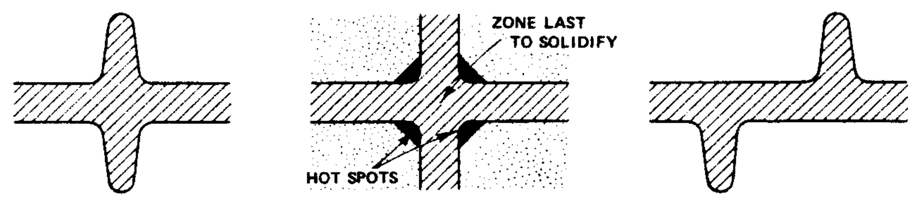
F
CORRECT
Ribs should solidify before the casting section they adjoin.

THICKNESS OF RIBS SHOULD EQUAL 80% OF CASTING THICKNESS. SHOULD BE ROUNDED AT EDGE AND CORRECTLY FILLETED.

G

T AND H SHAPED RIBBED DESIGNS HAVE THE ADVANTAGE OF UNIFORM METAL SECTIONS AND HENCE UNIFORM COOLING.

Design preference in average design is for ribs to have a greater depth than thickness. Ribs in compression in general offer a greater factor of safety than ribs in tension. However, castings having thin ribs or webs in compression may require design changes to give necessary stiffening to avoid buckling.



INCORRECT
RIBBING ON BOTH SIDES OF CASTING IS UNDESIRABLE FROM A FOUNDRY VIEWPOINT. IT INCREASES CASTING DEFECTIVES AND COSTS.

THESE CORNERS OF SAND REACH TEMPERATURE OF MOLTEN IRON AND HOLD THIS TEMPERATURE LONG AFTER CASTING IS SOLID.

INCORRECT
CROSS RIBBING CREATES HOT SPOTS, RENDERS FEEDING SOLID DIFFICULT, AND CAUSES LOCAL WEAKNESS AND POROSITY.

CORRECT
CROSS COUPLED RIBS SHOULD PREFERABLY BE DESIGNED AS DOUBLE T FORMS.

Avoid complex ribbing. It simplifies molding procedure, assures more uniform solidification conditions and eliminates "hot spots." Casting stresses and stress distribution favor omission of ribbing if the casting wall itself can be made of ample strength and stiffness.

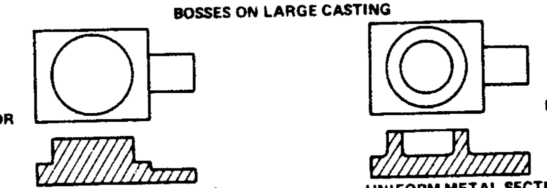
Casting

Casting – Design for Casting

BOSSES, LUGS AND PADS SHOULD NOT BE USED UNLESS ABSOLUTELY NECESSARY

BOSSES ON LARGE CASTING

A POOR



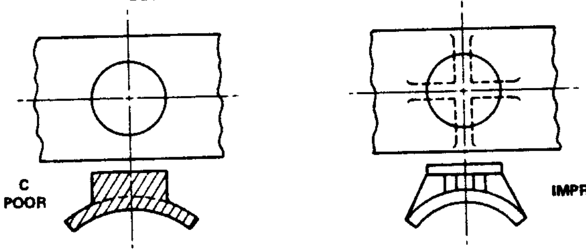
B IMPROVED

METAL SECTION TOO HEAVY AT BOSSES. DIFFICULT TO FEED SOLID.

UNIFORM METAL SECTION ASSURES SOUND CASTING, LESS WEIGHT, LOWER MACHINING COSTS

DESIGN FOR BOLTING OR BEARING BOSSES

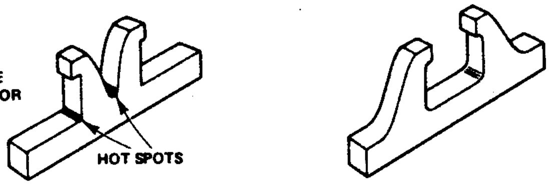
C POOR



D IMPROVED

SPREAD LUGS TO AVOID HOT SPOTS

E POOR



F CORRECT

Bosses and pads increase metal thickness, create hot spots and cause open grain or draws. Blend into casting by tapering or flattening the fillets. Bosses should not be included in casting design when the surface to support bolts, etc., may be obtained by milling or countersinking.

FIGURE 1 INCORRECT

FIGURE 2 CORRECT

A continuous rib instead of a series of bosses permits shifting hole location.

Thickness of bosses and pads should preferably be less than the thickness of the casting section they adjoin, but thick enough to permit machining without touching the casting wall. Where the casting section is light and does not permit use of this rule, then the following minimum recommended heights can serve as a guide.

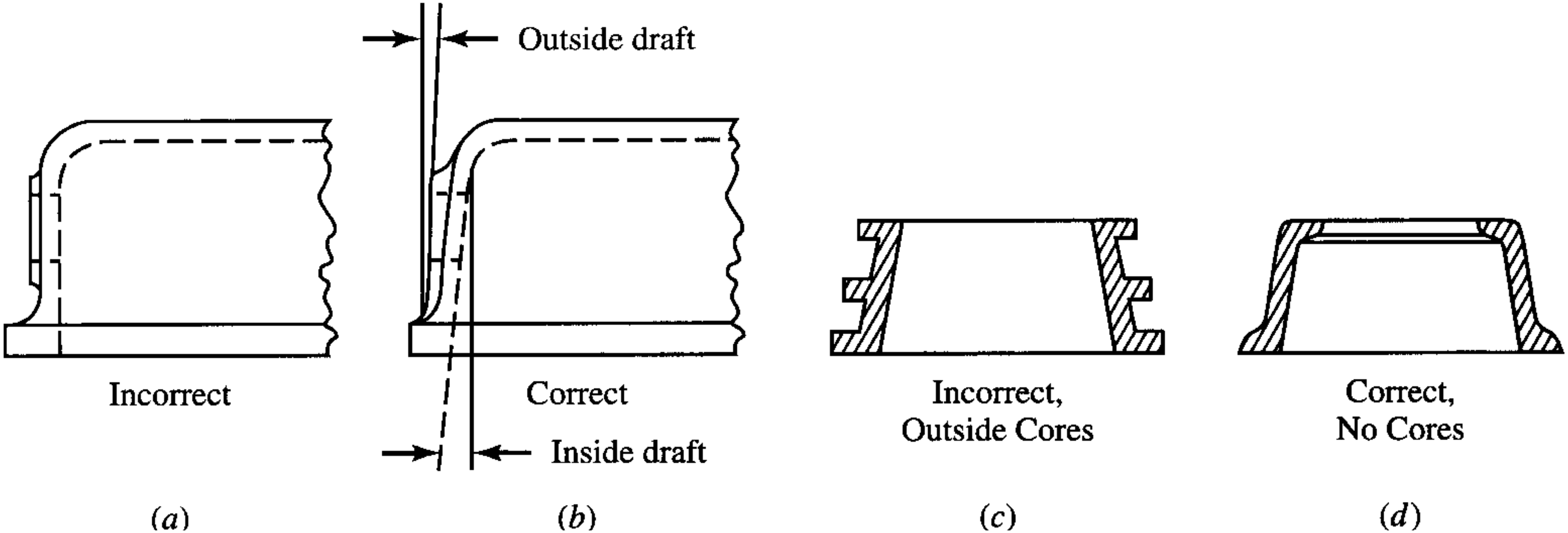
APPROXIMATE CASTING LENGTH–FEET	HEIGHT OF BOSS–INCHES
Up to 1½	0.25
1½ to 6	0.75
Over 6	1.0

FIGURE 3 INCORRECT

FIGURE 4 CORRECT

Continuous rib instead of a series of bosses permits shifting hole location.

Casting – Design for Casting



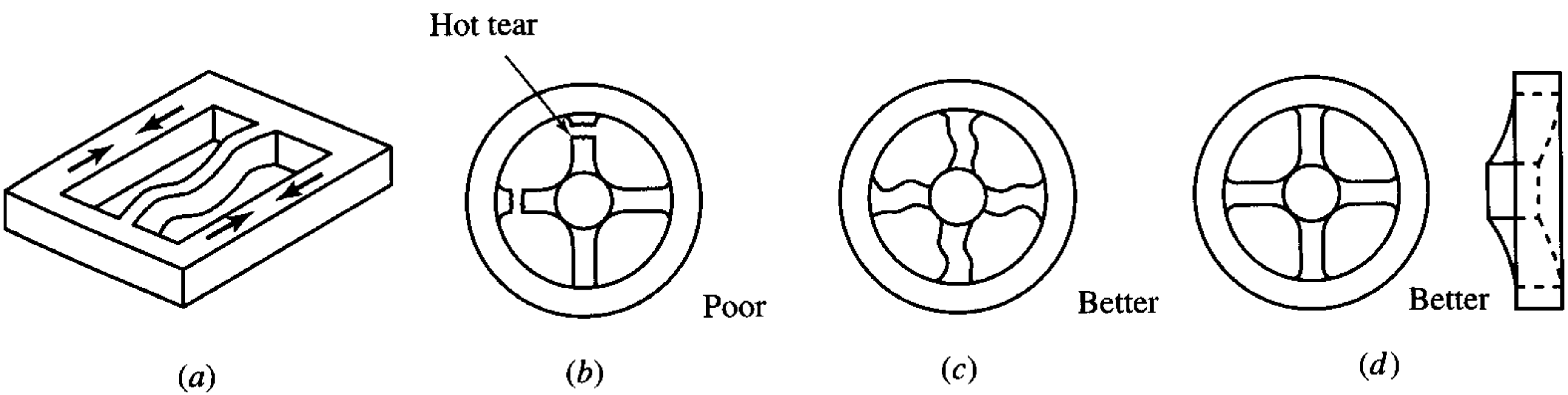


Fig. 7.29, 31, Introduction to Manufacturing Processes, by Schey, McGraw Hill

Casting – Design for Casting

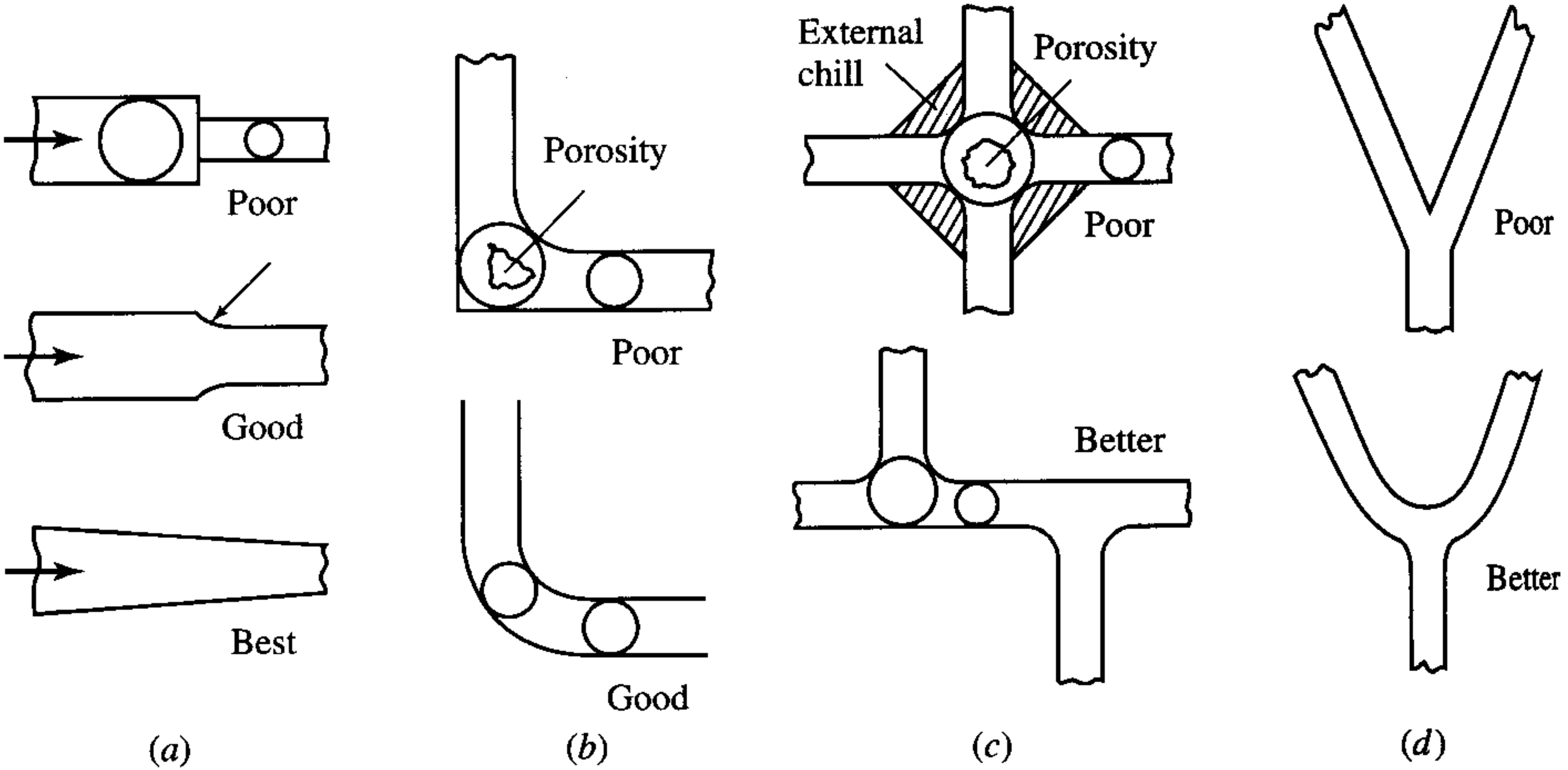


Fig. 7.30, Introduction to Manufacturing Processes, by Schey, McGraw Hill