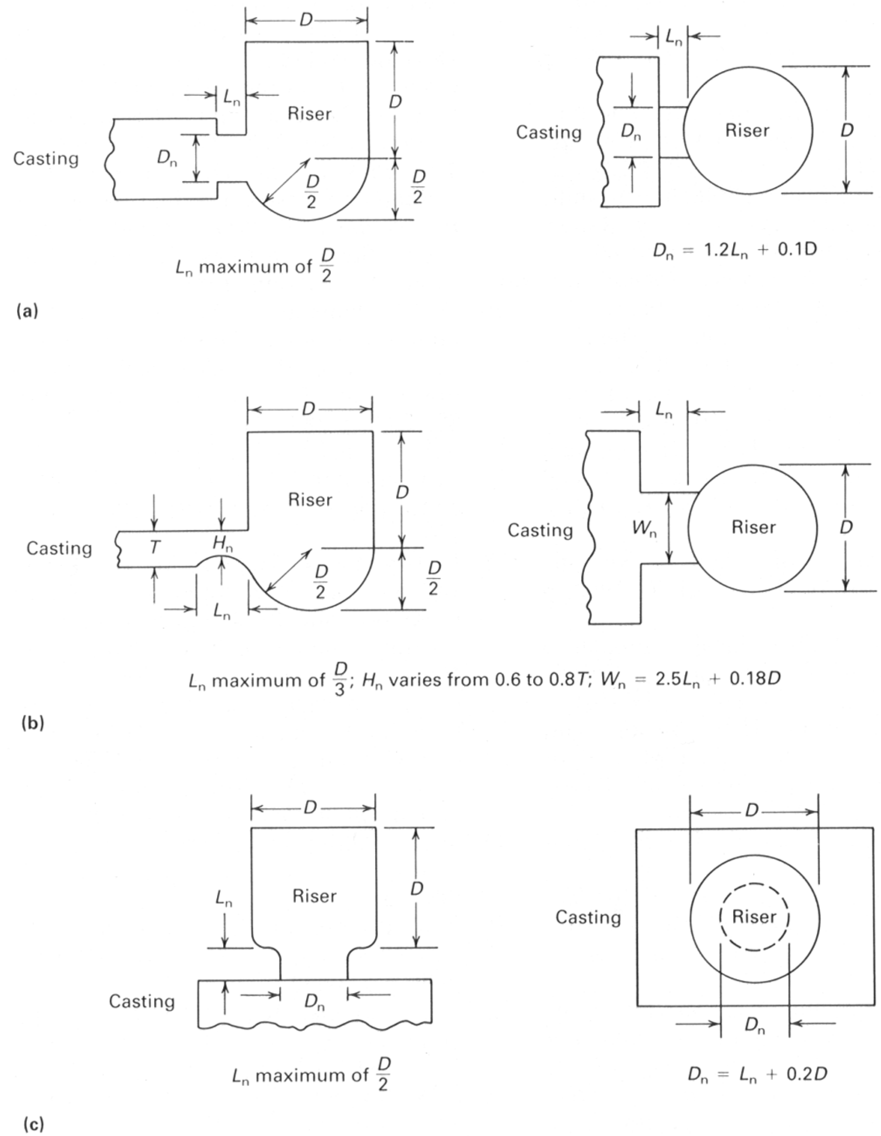
Risers and Riser Design

- General design rules for riser necks used in iron castings;
  a. general riser
  b. side riser for plates
  c. top round riser



Gating System Design

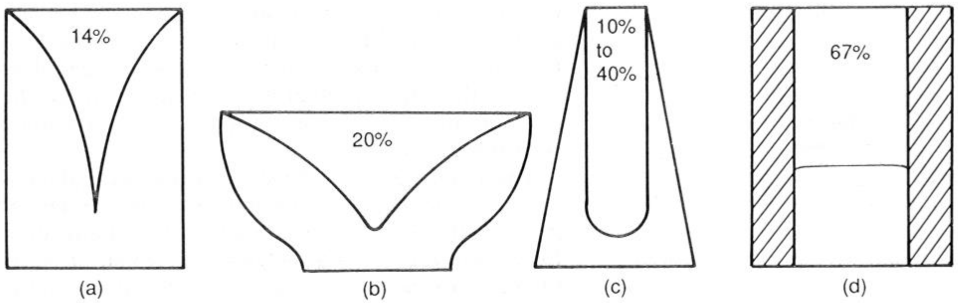


Figure 5.5 *Metal utilization of feeders of various forms moulded in sand. The (a) cylindrical and (b) hemispherical heads have been treated with normal feeding compounds; (c) the efficiency of the reverse taper heads depends on detailed geometry (Heine, 1982, 1983); (d) shows an exothermic sleeve (Beeley, 1972).*

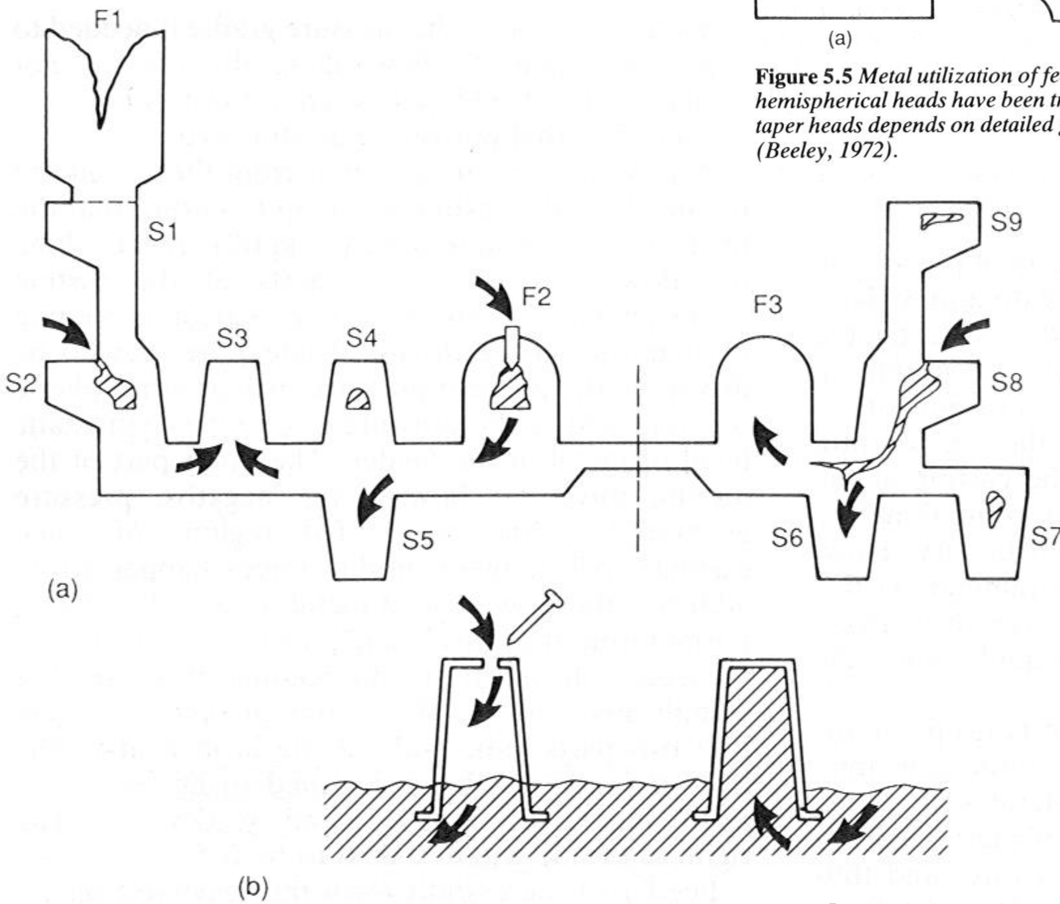
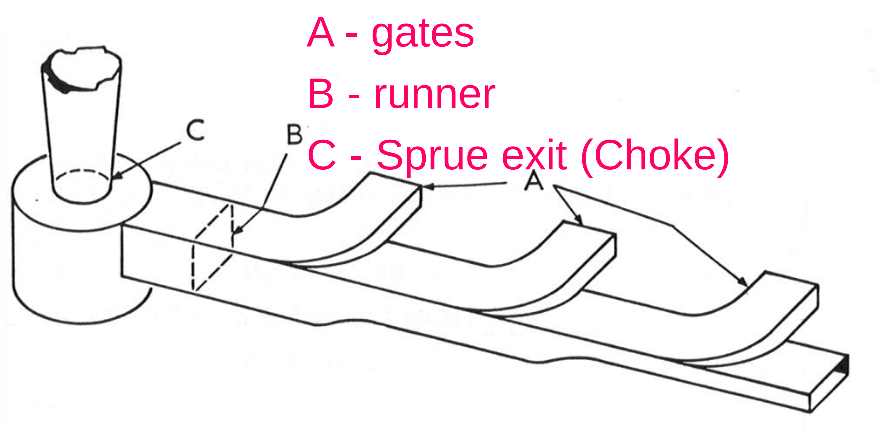


Figure 5.10 *(a) Castings with blind feeders, F2 is correctly vented but has mixed results on sections S3 and S4. Feeder F3 is not vented and therefore does not feed at all. The unfavourable pressure gradient draws liquid from a fortuitous skin puncture in section S8. The text contains more details of the effects. (b) The plastic coffee cup analogue: the water is held up in the upturned cup and cannot be released until air is admitted via a puncture. The liquid it contains is then immediately released.*

Gating System Design



- Un-pressurized system reduces metal velocity and turbulence
- Pressurized systems usually reduce size and weight of gating system (pressure at constriction (gate) causes metal to completely fill runner more quickly)
- System is often designed to follow ratio of (CSA) 1:2:2, or 1:4:4 WRT:
- Sprue exit CSA C : total runner CSA B: total gate CSA A
- Gating system is un-pressurized if area is increasing (e.g. 1:4:4) or pressurized if there is a constriction (4:8:3).

MECH 423 Casting, Welding, Heat Treating and NDT

Time: _ _ W _ F 14:45 - 16:00

Credits: 3.5 Session: Fall

Expendable Mould Casting

Lecture 3

Patterns – Shrink Allowance

- 2 types of Casting Process - Expendable & Reusable Mould
- Expendable mould requires pattern
  - Similar to final product
  - Modified in dimension based on material and process
  - Shrinkage allowance (pattern to be larger than part at room temp)
  - Done by using shrink rules which take into account the shrinkage allowance (1’ will be 1’ 3/16’’ in a shrink rule for brass)

Cast iron	0.8–1.0%	($\frac{1}{10} - \frac{1}{8}$ in./ft.)
Steel	1.5–2.0%	($\frac{3}{16} - \frac{1}{4}$ in./ft.)
Aluminum	1.0–1.3%	($\frac{1}{8} - \frac{5}{32}$ in./ft.)
Magnesium	1.0–1.3%	($\frac{1}{8} - \frac{5}{32}$ in./ft.)
Brass	1.5%	($\frac{3}{16}$ in./ft.)

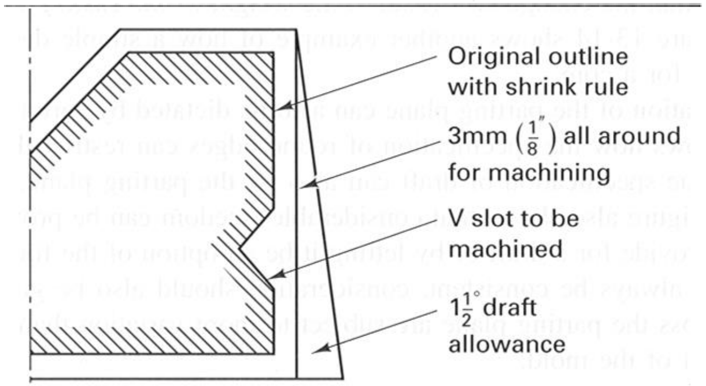


FIGURE 13-12 Various allowances incorporated into a casting pattern.

Patterns – Draft

- Facilitate withdrawal from mould, patterns may be split at parting line
- Location of parting line important - the plane at which 1 section of the mould mates with other section(s)

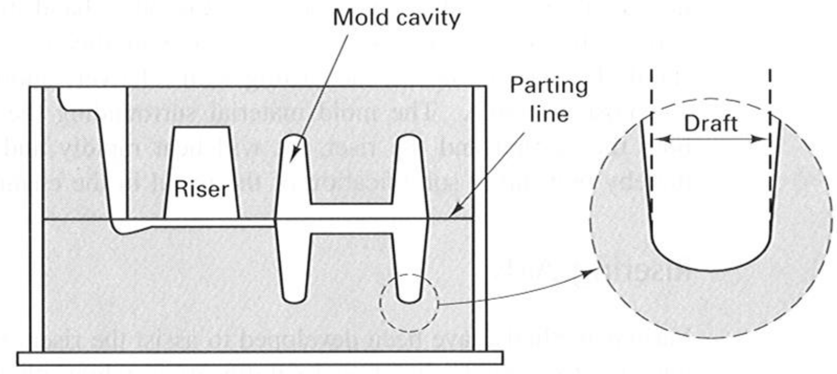
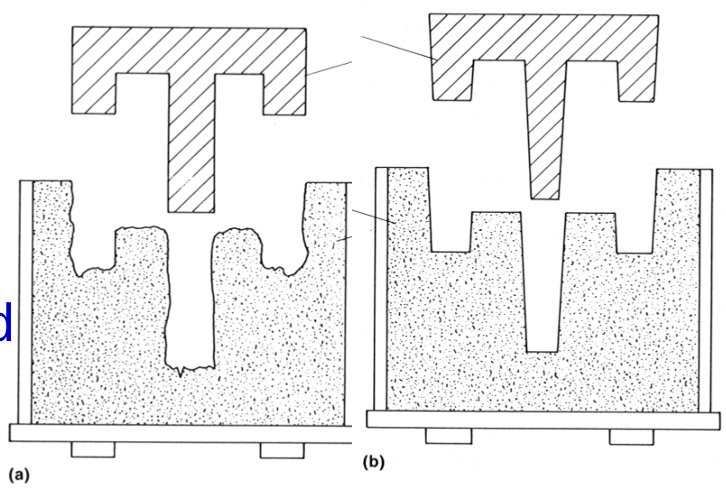


FIGURE 13-11 Two-part mold showing the parting line and the incorporation of a draft allowance on vertical surfaces.

- Flat line is preferred, but casting design and mould may require complex parting lines
- To effect withdrawal Draft is given
- Depends on mould material and procedure
- 1/8th to 1/16th of an inch per feet is standard
- Can be reduced by increasing mould strength and automatic withdrawal



Patterns – Parting Line

- Good castings require good design.
- Simple, simple, simple!
- Communicate with foundry.
- Location of Parting Plane - effect:
    - number of cores
    - use of effective gating
    - weight of final casting
    - method of supporting cores
    - final dimensional accuracy
    - ease of moulding.
- Minimize cores if possible.

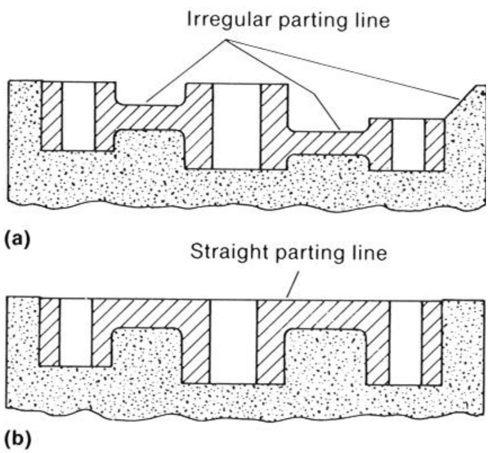


Fig. 28 Designing for a straight parting line reduce pattern and casting costs. (a) regular parting line is a costly design. (b) Straight part line is less expensive.

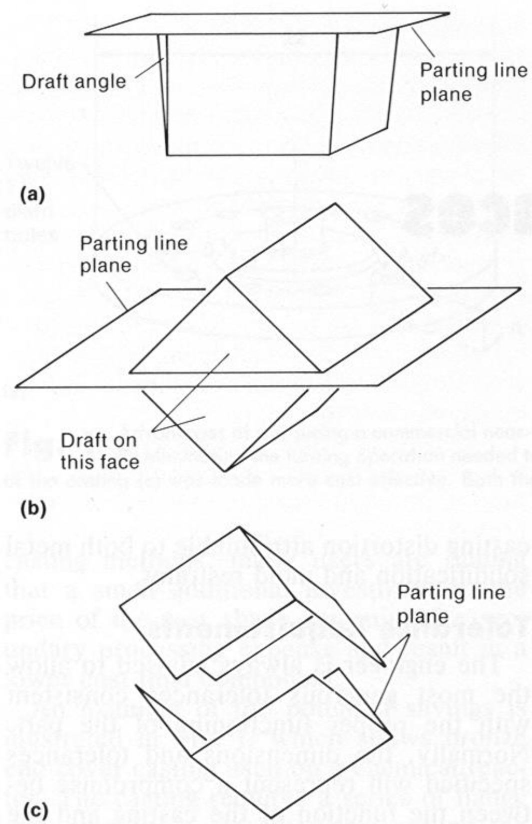


Fig. 29 Parting line options for a cube that must have as many sides as possible parallel and at 90° to each other. (a) Cube parted with four drafted sides is the least expensive option but does not meet design requirements. (b) Parting along the diagonal is a moderate-cost solution that results in four faces in compliance with design requirements. (c) Irregular parting is the most costly option, but is the only one that allows all sides to be parallel and at 90° to each other.

Patterns – Allowance

- Machining Allowance is given on pattern for final finishing operations in casting
- Depends on the mould process and material
- Sand castings rougher than shell castings
- Die, investment castings are smooth, no machining required
- Designer needs to look into these before deciding the final machining allowance required
- Sometimes draft can serve to act as part or whole of machining allowance

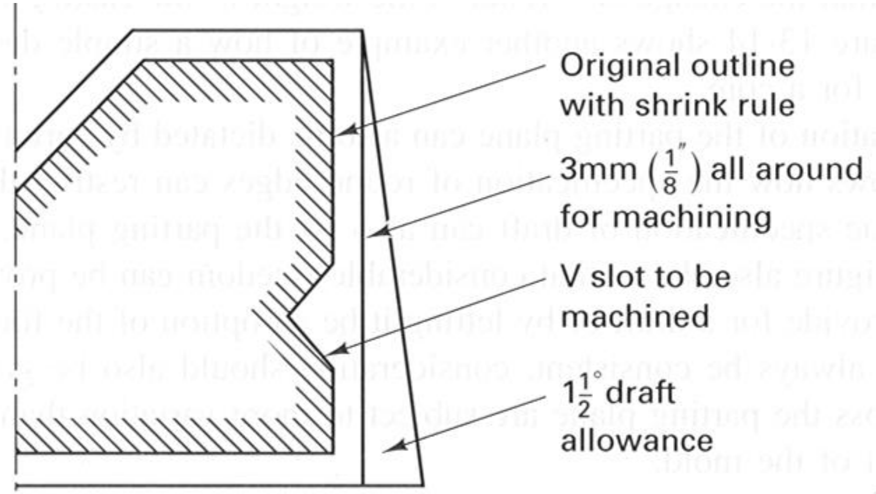


FIGURE 13-12 Various allowances incorporated into a casting pattern.

Patterns – Cores

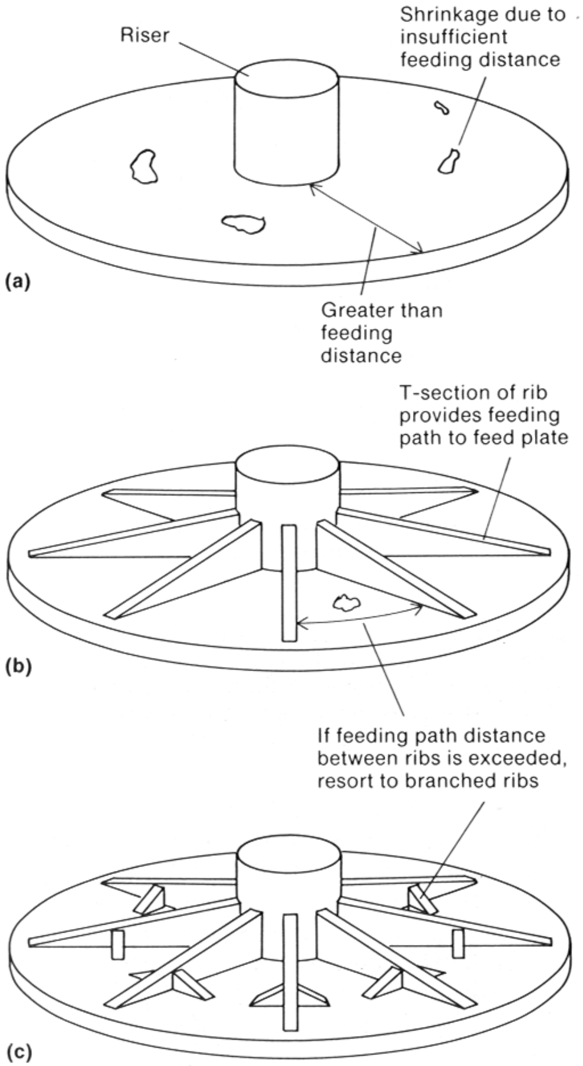


Fig. 16 Feeding path design considerations. (a) Circular flat plate with a single riser. (b) Addition of wedge-shaped ribs to ensure proper solidification. (c) Branched ribs to overcome feeding problems at the circumference of the plate

- Cores to be big to compensate for shrinkage
- Core prints to be added in pattern
- Machining allowance to be reduced from core Size – machining increases hole size

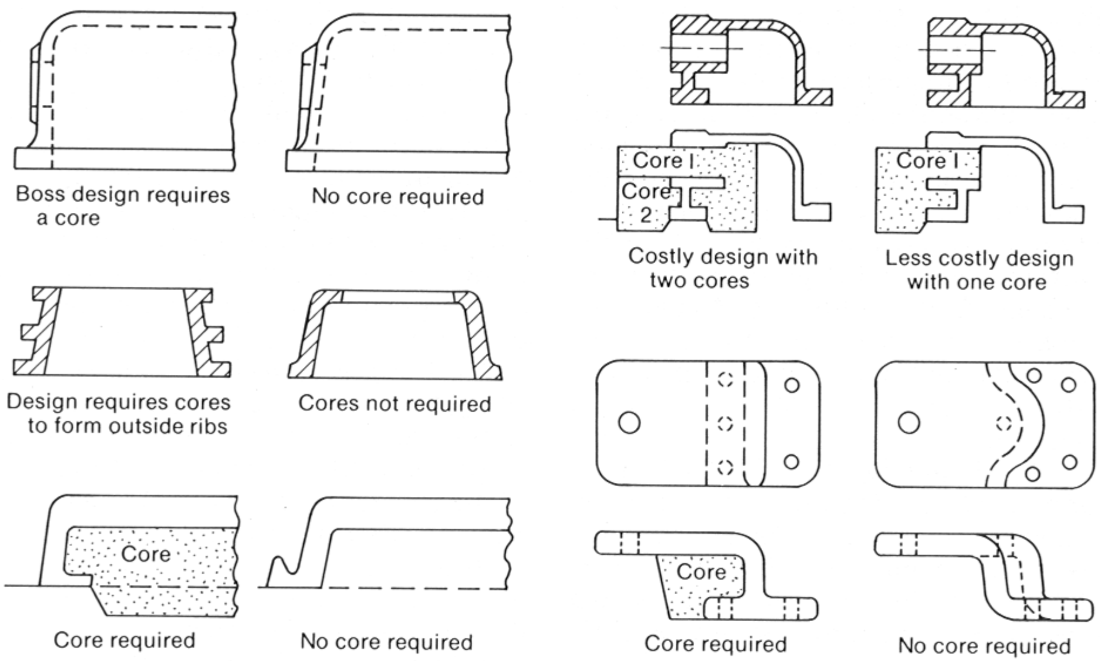


Fig. 27 Restrictions to pattern removal, and some potential solutions

Patterns – Allowances

- Distortion allowance
- U shape castings will distort by bending outside
- To prevent this patterns to be made with an inward angle
- Long horizontal pieces sag in the centre if adequate support not given

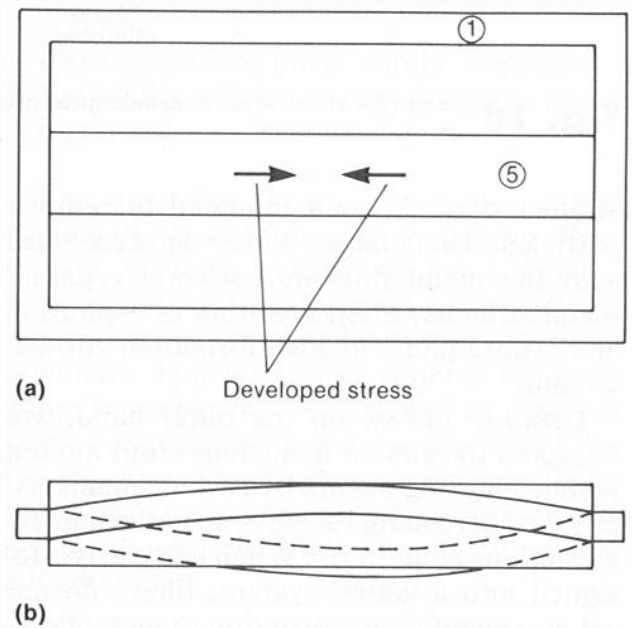
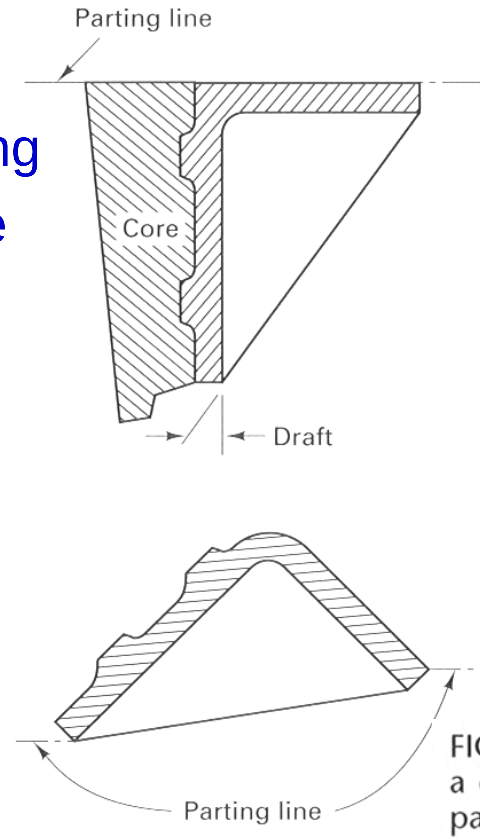


Fig. 1 The effects of design on distortion of castings. (a) Top view of casting; numbers indicate moduli of the two sections. (b) Distortion caused by solidification stresses

- If casting is done directly from reusable mould, all these allowances should go into the mould cavity
- In addition, heating of metal moulds and its expansion while in operation should be taken into account before deciding the final size

Design Consideration in Castings

- Good quality at lowest possible cost.
- Attention to common requirements
- Changes in design to simplify casting example - Location of Parting Plane can affect:
  - number of cores
  - use of effective gating
  - weight of final casting
  - method of supporting cores
  - final dimensional accuracy
  - ease of moulding.
- Minimize cores if possible.



13-13 Elimination of core by changing parting line. Also eliminates draft which reduces weight

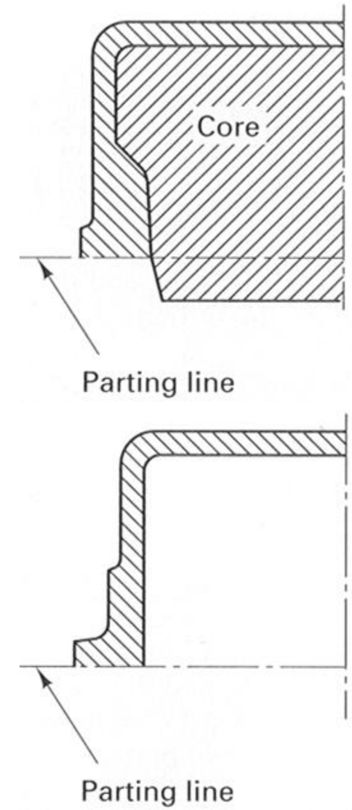
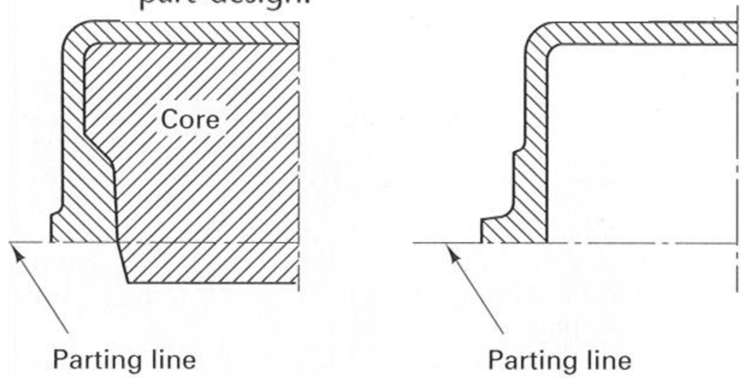


FIGURE 13-14 Elimination of a dry-sand core by change in part design.

Design Consideration in Castings

- Cores can also be eliminated by design change
- Design dictates location of patterning plane - cannot be on the plane of round edges
- Draft also can determine the parting plane – giving it as a note provides more options in foundry

FIGURE 13-14 Elimination of a dry-sand core by change in part design.



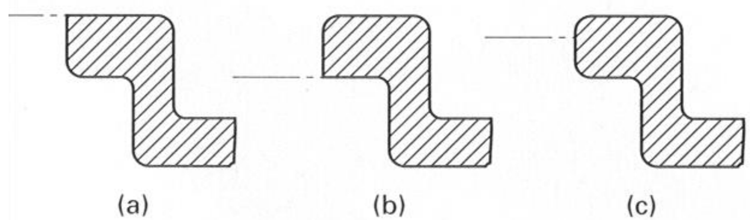


FIGURE 13-15 Parting planes should not intersect rounded edges. Three alternative designs are presented.

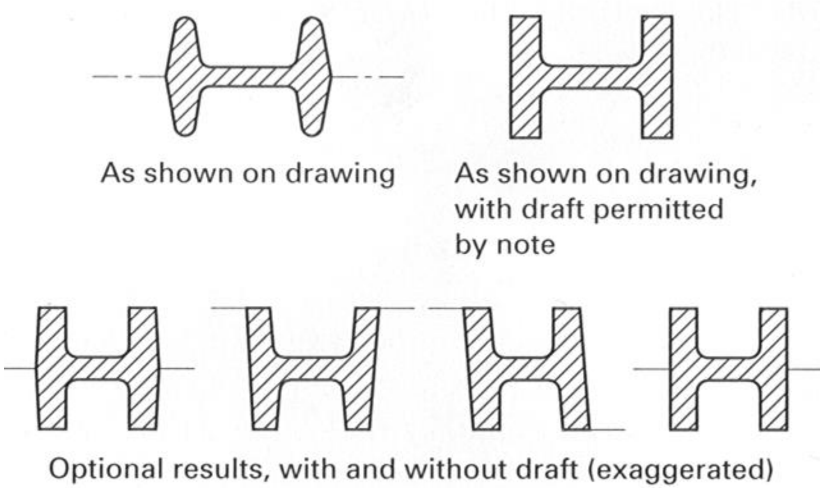


FIGURE 13-16 (*Top left*) Design where the location of the parting plane is specified by the draft. (*Top right*) Part with draft unspecified. (*Bottom*) Various options in producing that part, including a no-draft design.

Design Consideration in Castings

- Sections with high area to volume ratio will cool faster.
- Heavier sections cool slower - more potential for void formation on solidification, and large grains.
- Try for uniform wall thicknesses.
- If not possible use gradual changes in section

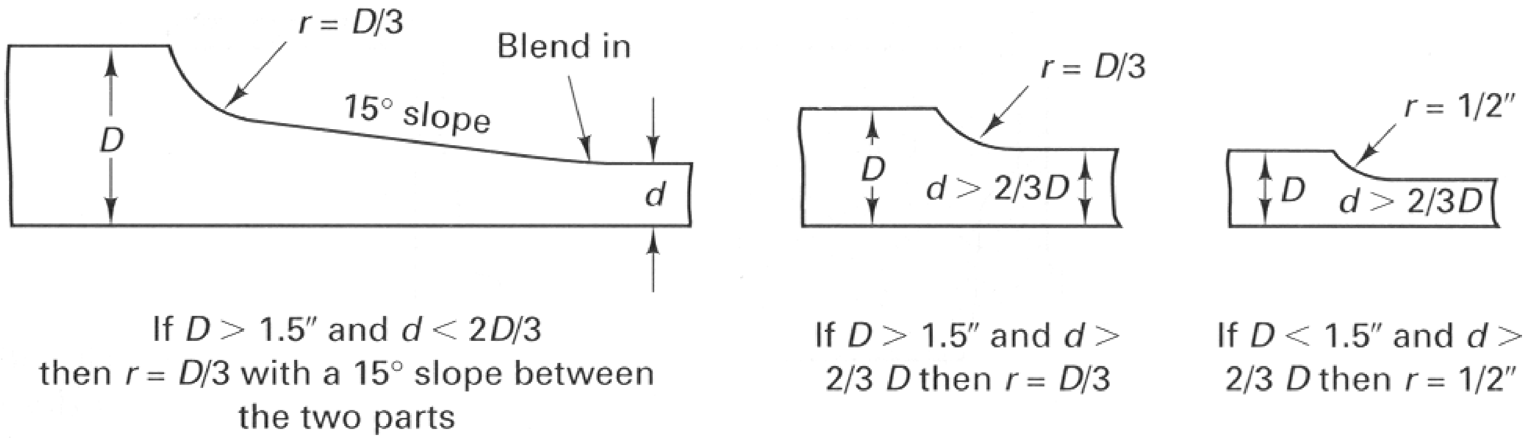


FIGURE 13-17 Guidelines for section changes in castings.

Design Consideration in Castings

- Where walls/sections intersect - problems.
  - Stress concentrations (use fillets)
  - Hot spots. Localized thick section at intersection (especially if fillets too big!). These regions cool slower and often contain voids.
- Try to avoid hot spots and voids in castings.
  - Sometimes use cores to make deliberate, controlled “voids” in heavy sections.
  - Place risers to feed heavy sections/hot spots.
  - Stagger ribs on plates to avoid high stresses/cracking.

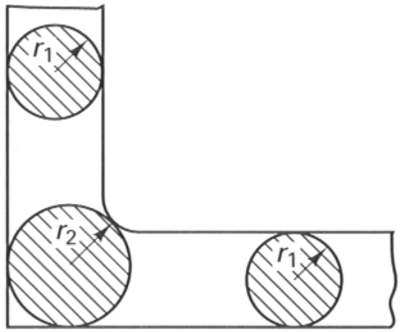
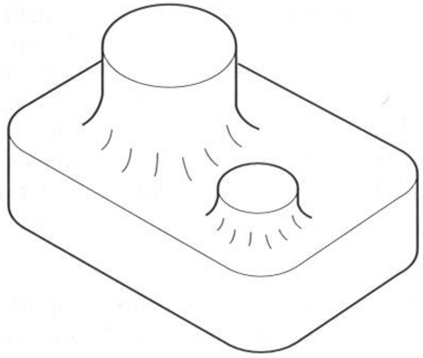


FIGURE 13-18 “Hot spot” at section r_2 caused by intersecting sections.



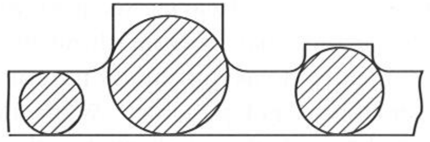


FIGURE 13-19 Hot spots resulting from intersecting sections of various thickness.

Design Consideration in Castings

- Use risers near heavy sections.
  - Adjacent riser feeds these sections
  - Shrinkage will be in the riser that will be cut off rather than in the casting
- Intersecting Sections crack.
  - When ribs are placed, due to shrinkage, material cracks at the intersection
  - Possible solution is to use staggered ribs arrangement.

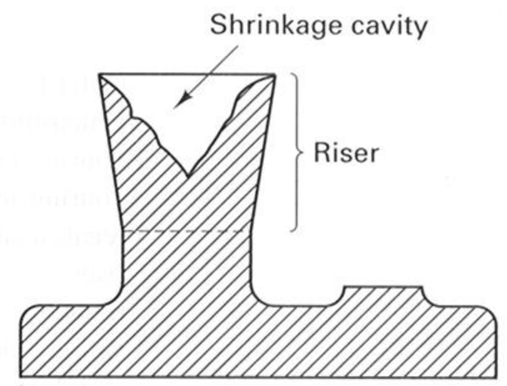


FIGURE 13-21 Use of a riser to keep the shrinkage cavity out of a casting.

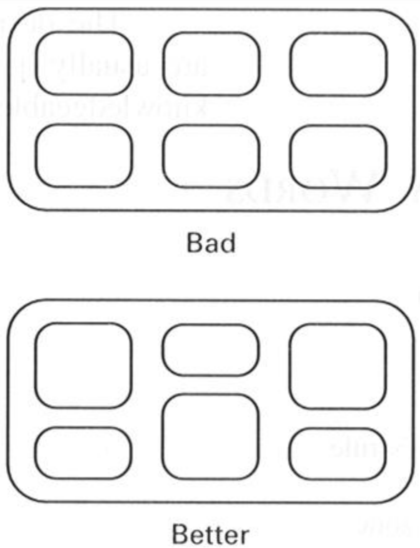


FIGURE 13-22 Method of using staggered ribs to prevent cracking during cooling.

Design Consideration in Castings

TABLE 13-2. Recommended Minimum Section Thicknesses for Various Engineering Metals and Casting Processes

Material	Minimum mm	Minimum in.	Desirable mm	Desirable in.	Casting Process
Steel	4.76	$\frac{3}{16}$	6.35	$\frac{1}{4}$	Sand
Gray iron	3.18	$\frac{1}{8}$	4.76	$\frac{3}{16}$	Sand
Malleable iron	3.18	$\frac{1}{8}$	4.76	$\frac{3}{16}$	Sand
Aluminum	3.18	$\frac{1}{8}$	4.76	$\frac{3}{16}$	Sand
Magnesium	4.76	$\frac{3}{16}$	6.35	$\frac{1}{4}$	Sand
Zinc alloys	0.51	0.020	0.76	0.030	Die
Aluminum alloys	1.27	0.050	1.52	0.060	Die
Magnesium alloys	1.27	0.050	1.52	0.060	Die

- Avoid large, unsupported areas - tend to warp on cooling disrupts smooth surface (especially if reflective)
- Consider location of parting line
  - Flash often appears at parting line
  - Locate parting line at corners/edge rather in middle
- Consider minimum thickness. Use common sense and ask advice

Expendable Mould Casting

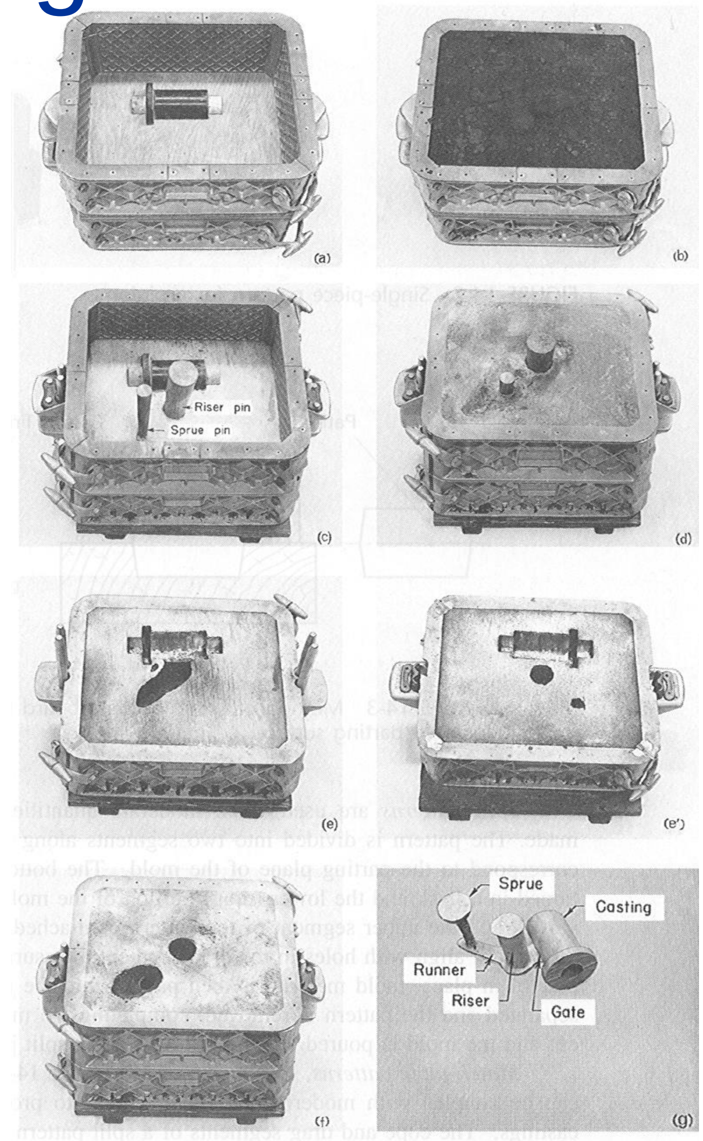
Introduction

1. Single use moulds made from the same pattern (multiple-use pattern)
2. Single use moulds made from single-use patterns (one-off).

- These two are called expendable mould casting processes
- Mould material usually made from sand, plaster, ceramic powder mixed with binder.
- Metals often cast this way are: iron, steel, aluminum, brass, bronze, magnesium, some zinc alloys, nickel-based alloys.
- Cast iron and aluminium are most common:
  - Cheap, good fluidity
  - low shrinkage, good rigidity,
  - Good compressive strength and hardness

Sand Casting

- Most common casting technique
- Sand (mixture of sand + clay + water) is packed around pattern.
- Pattern removed to give cavity, sprue, runners added
- Mould closed, metal poured in.
- After solidification, sand broken out and casting removed. Casting fettled.
- New mould required for next casting (Expendable moulding).



Patterns and Pattern Materials

- For most expendable mould casting techniques a pattern is required
- Material depends on No. of castings to be made, metal being cast, process being used, size and shape, dimensional precision required
- Multiple - Use Patterns
  - **Wood -** Cheap, easily machined but prone to warping, swelling (moisture), unstable, wears. Used for small runs.
  - **Metal -** more expensive but stable, accurate, durable. Typically aluminium, cast iron or steel. Either cast then machined or machined directly (e.g. NC-machining). Large runs and elevated pressure and/or temperature moulding process

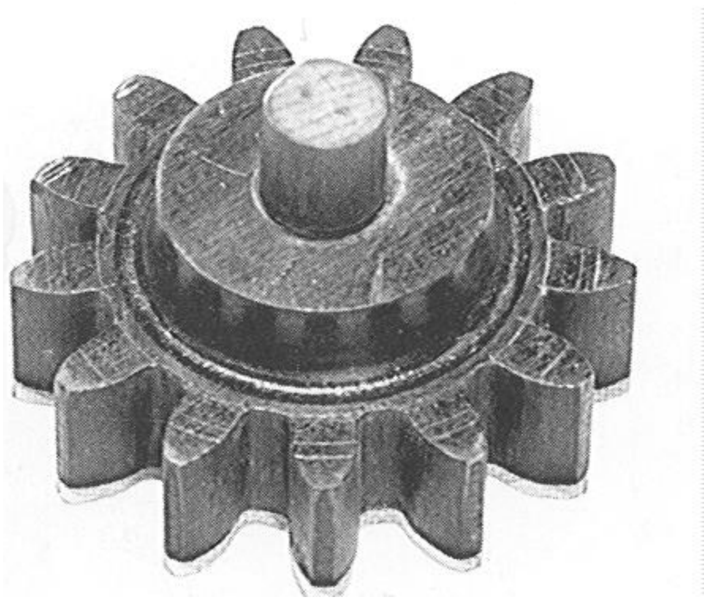
Patterns and Pattern Materials

- **Plastic -** Epoxy and Polyurethane. More common now. Easy preparation, stable and durable relative to wood. Cast & machined, easily repaired, can be reinforced/backed
- Expendable (single-use) patterns:
  - **Wax -** used for investment casting. Wax formulated for melting point, viscosity, ash residue etc. Melted out (mostly) before casting
  - **EPS -** Expanded PolyStyrene. Pre-expanded beads blown into mould, heated (steam) to completely fill mould and bond beads. Pattern is burnt out by molten metal. Carbon film possible.

Types of Pattern

- Type of pattern depends on number of castings and complexity.
- **One Piece (Solid) Patterns -** simplest, cheapest, slowest moulding. For simple, low number of castings.
- Only allowances and core prints

FIGURE 14-2 Single-piece pattern for a pinion gear.



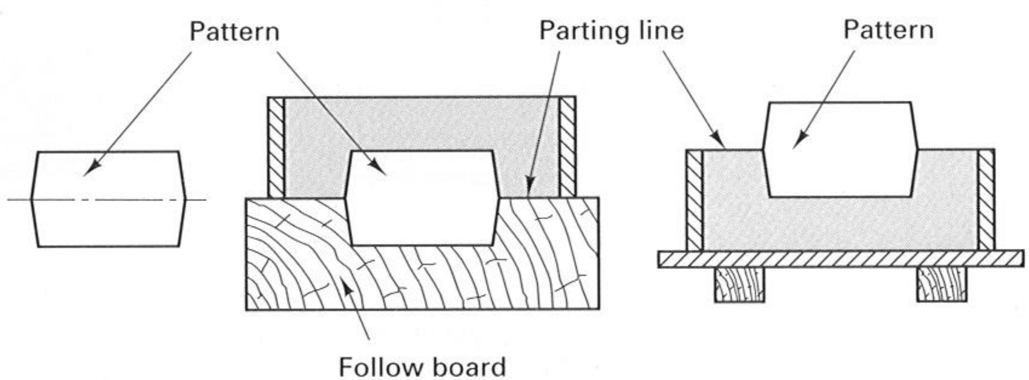
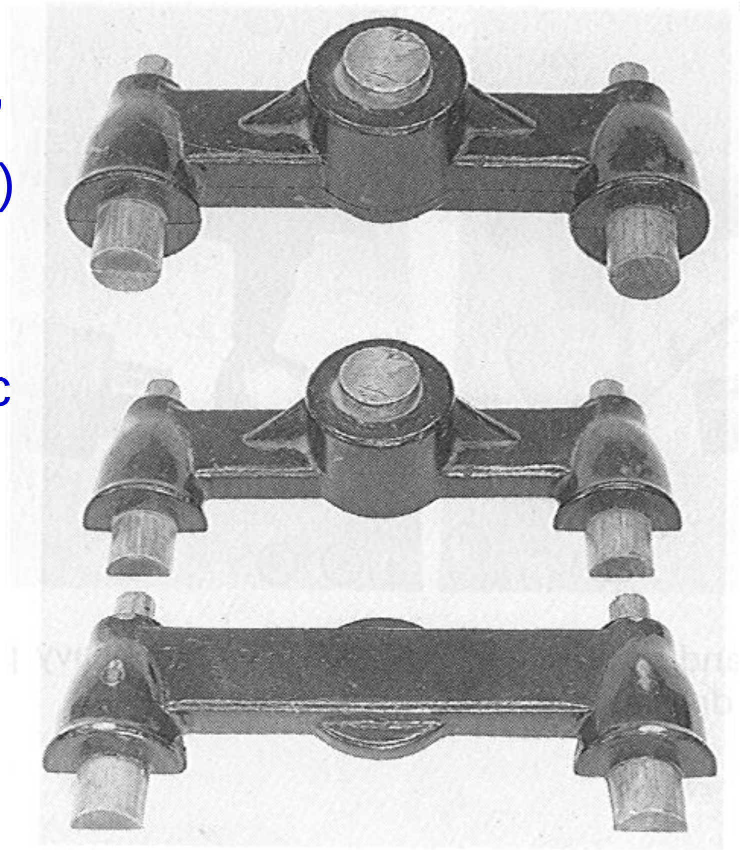


FIGURE 14-3 Method of using a follow board to position a pattern and locate a parting surface.

Types of Pattern

- **Split Patterns -** splits into two parts where parting line will be.
- Mould drag first with bottom part of pattern, invert, add top half of pattern (locating pins) then mould cope.
- Remove pattern, close, cut runner, riser etc and ready to pour.
- OR each part of the mould (Cope & Drag) can be moulded separately then joined
- High volume and large castings

FIGURE 14-4 Split pattern, showing the two sections together and separated. Light-colored portions are core prints.



Types of Pattern

- **Match-Plate Patterns -** a plate with the cope pattern on one side and the drag pattern on the other side (with locating pins and holes respectively).
- Can include runners and gates. Made from wood and joined or machined/cast from metal. (higher volumes, small to medium size castings).

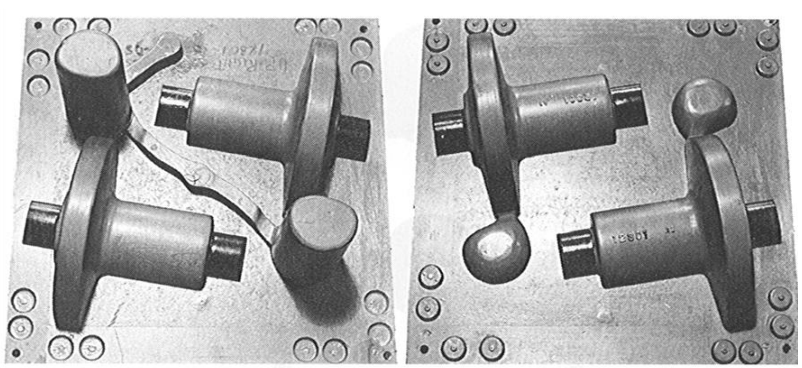


FIGURE 14-6 Cope-and-drag pattern for molding two heavy parts. (*Left*) Cope section; (*right*) drag section.

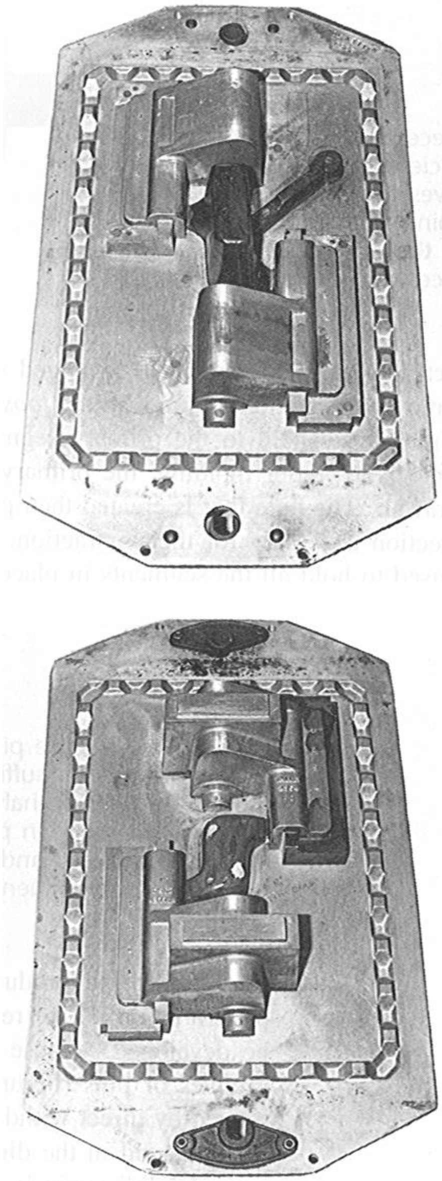


FIGURE 14-5 Match-plate pattern to produce two identical parts in a single flask. (*Left*) Cope side; (*right*) drag side.

Types of Pattern

- **Loose Piece Patterns -** Special patterns can be made for very complex shapes. Pattern is assembled from different pieces held together with pins. Pieces are withdrawn sequentially after pin removed. Expensive.
- All patterns should have a small radius on internal corners to prevent stress concentrations in the casting, avoid shrinkage cracking and make pattern easier to remove without mould damage (3-7mm is good). Machined in for NC patterns; added to patterns using wax, plastic strips.

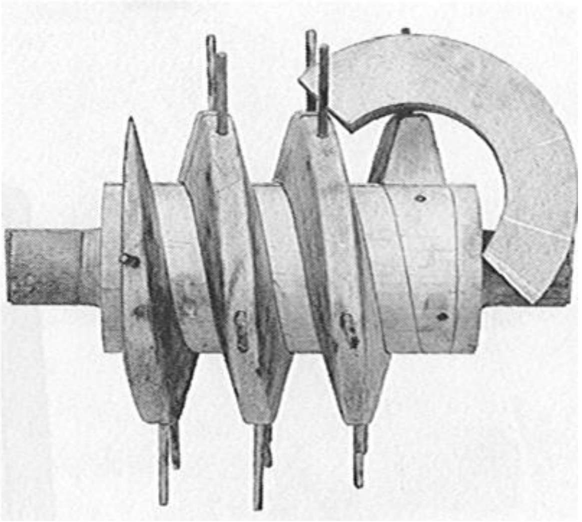


FIGURE 14-7 Loose piece pattern for molding a large worm. After sufficient sand is packed around the pattern halves to hold the pieces in position, the wooden pins are withdrawn. The mold is completed and the pieces of the pattern are removed in sequence.

Sand and Sand Conditioning

- SAND - very important part of sand-casting. Require following properties.
- Refractoriness - ability to withstand high temperatures.
  - Silica (“sand”)- cheap, lower temps (Al, Mg possibly cast iron).
  - Zircon ($ZrO_2.SiO_2$) - more expensive, higher temps. Steels. Investment casting.
  - Others
- Cohesiveness - how well the sand bonds together to give shape.
  - Controlled by adding binder, clays (bentonite, kaolinite) + water.

Sand and Sand Conditioning

- Permeability - ability to allow gas to pass through/escape as metal fills cavity. Denser packing - stronger, better surface finish but less permeability.
    - Depends on size and shape of sand particle, amount of clay and water, compacting pressure.
- Collapsibility - ability to permit metal to shrink after solidification and also to disintegrate during “knock-out”.

- Usually trade-off in properties: more clay means stronger bond but less permeability and refractoriness etc.
- 88% Silica, 9% clay, 3% water; typical for green-sand cast.
- Blended and mixed; uniform, flows easily into mould (Fig 14-8)
- Tested for grain size, moisture content, permeability, strength etc.

Sand Testing

- Grain Size – tested by shaking in 11 sieves of decreasing mesh size and the weight in each of them gives an idea of grain size.
- Moisture – electrical conductivity, or weigh 50g sample of sand after heating for sometime at 110°C for water to evaporate
- Clay – wash 50g of sample sand with alkaline water (NaOH) to remove clay, dry the sand and weighed to find the clay content
- Permiability – measure of escape gases – done by standard ramming of sand and passing air through it at known pressure. Pressure loss between orifice and sand gives permiability (12-9)
- Compressive Strength – also mould strength. Use the prepared sample and compressively load it find when it fails
- Hardness – Resistance of sand to spring loaded steel ball (12-10)
- Compactibility – 45% is good. Amount of height change from loose sand to application of standard load

Sand Properties and Defects

TABLE 14-1. Desirable Properties of a Sand-Based Molding Material

1. Is inexpensive in bulk quantities
2. Retains properties through transportation and storage
3. Uniformly fills a flask or container
4. Can be compacted or set by simple methods
5. Has sufficient elasticity to remain undamaged during pattern withdrawal
6. Can withstand high temperatures and maintains its dimensions until the metal has solidified
7. Is sufficiently permeable to allow the escape of gases
8. Is sufficiently dense to prevent metal penetration
9. Is sufficiently cohesive to prevent wash-out of mold material into the pour steam
10. Is chemically inert to the metal being cast
11. Can yield to solidification and thermal shrinkage, thereby preventing hot tears and cracks
12. Has good collapsibility to permit easy removal and separation of the casting
13. Can be recycled

- Round grains - better permeability, minimize clay required.
- Angular grains - better strength due to interlocking.
- Large grains - better permeability, better high temps.
- Smaller grains - better surface finish.
- Uniform particle size - better permeability.
- Wide PSD - better strength & surface finish.
- Sand expands on heating; (also phase transformation in silica). Expands next to cavity but not elsewhere, sometimes get sand expansion defects especially on long flat surfaces.

Sand Properties and Defects

- Sand expands on heating; (also phase transformation in silica). Expands next to cavity but not elsewhere, sometimes get sand expansion defects especially on long flat surfaces.
- Voids can be formed if gas cannot escape ahead of molten metal (short run). Either low permeability or too much gas produced (volatiles/steam). May need vent passages.
- Penetration if sand too coarse, fluidity too high.
- Hot tears or cracks can occur in long freezing range alloys especially if casting is restrained by mould/cores during cooling (poor collapsibility) Add cellulose.

Making Sand Moulds

- Hand ramming. For small number of castings. Pneumatic hand rammer as well.
- **Moulding Machines**
- Jolting - sand on pattern then drop flask several times to pack sand.
- Squeezing - platen/piston squeezes sand against pattern. Non-uniform sand density.
- Combined Jolt & Squeezing - Uniform density.

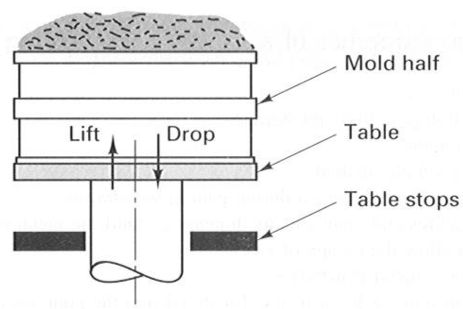


FIGURE 14-12 Jolting a mold half.

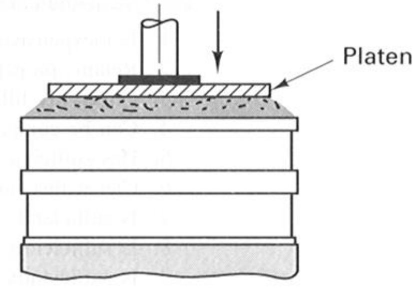


FIGURE 14-13 Squeezing operation

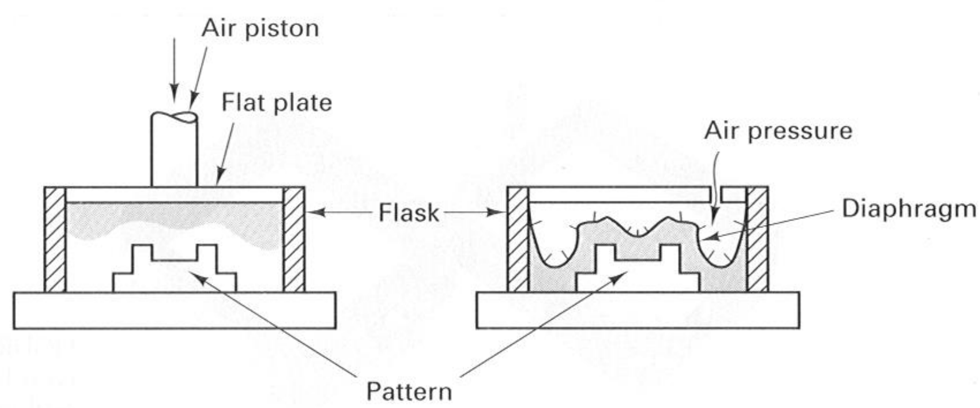
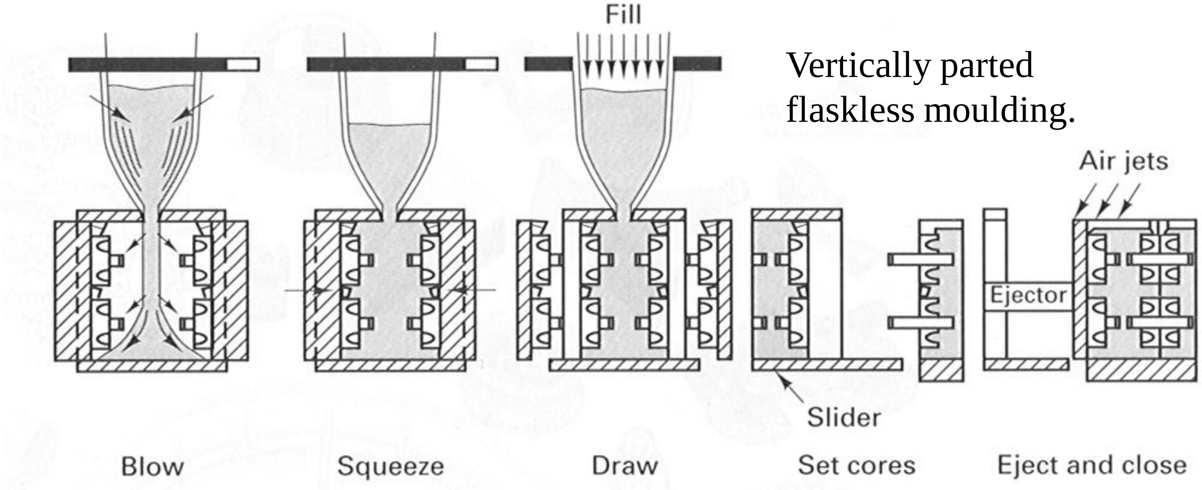


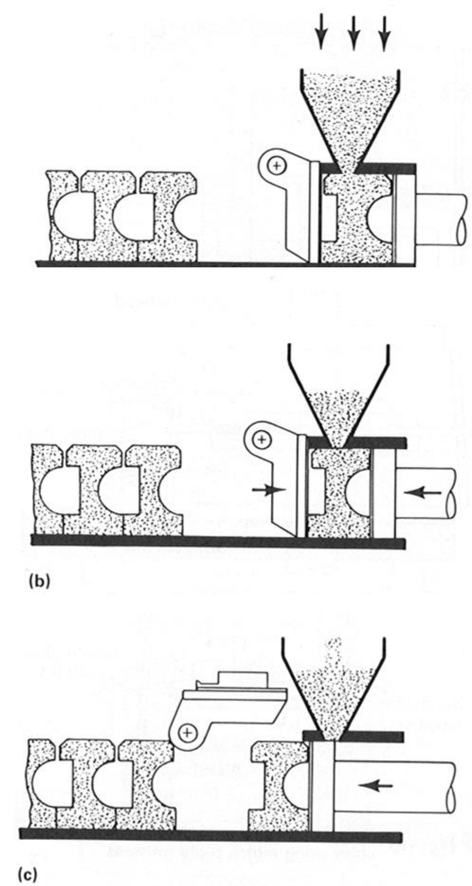
FIGURE 14-14 Schematic diagram showing relative sand densities obtained by flat-plate squeezing (*left*) and by flexible-diaphragm squeezing (*right*).

Making Sand Moulds



Vertically parted
flaskless moulding.

- Automatic mold making (eg. Disamatic Process)
- Vertically parted, flaskless moulding machine. Block of sand is pressed with RHS of casting pattern on the left side and LHS of pattern/casting on the RHS. Stacked in a line to give multiple moulds (refer back to H-process). Good for mass production



Blow-fill pressure squeeze molding machine making vertically parted molds. (a) Molding chamber filled with sand. (b) Sand compacted by squeeze pressure. (c) Finished sand mold pushed out of molding chamber

Sand Cast Parts-Examples

FIGURE 14-16 Some aluminum products produced by conventional sand casting. *(Courtesy of Bodine Aluminum Inc.)*

Sand Moulds

TABLE 14-2. Green-Sand Casting

Process:	Sand, bonded with clay and water, is packed around a wood or metal pattern. The pattern is removed and molten metal is poured into the cavity. When the metal has solidified, the mold is broken and the casting is removed.
Advantages:	Almost no limit on size, shape, weight or complexity; low cost; almost any metal can be cast.
Limitations:	Tolerances and surface finish are poorer than in other casting processes; some machining is often required; relatively slow production rate.
Common metals:	Cast iron, steel, stainless steel, and casting alloys of aluminum, copper, magnesium, and nickel
Size limits:	1 oz to 6000lb
Thickness limits	As thin as $\frac{3}{32}$ in., with no maximum
Typical tolerances:	$\frac{1}{32}$ in. for first 6 in., 0.003 in. for each additional inch; additional increment for dimensions across the parting line
Draft allowance:	1–3°
Surface finish:	100-1000 µin. rms

- Dry sand moulds are durable
- Long time required for drying and increased cost of operation
- Compromise is skin dried mould
  - Commonly used for large castings
  - Binders (linseed oil etc) added in the sand face to improve the strength of the skin

- Disadvantages of green sand can be reduced.
- Improved surface and casting by drying mould before casting.
  - Bake mould (150°C) - expensive, time consuming.
  - Skin-dried mould - just dry area near to cavity e.g. using gas torch.

Sand Moulds

- Sodium Silicate - CO_2 molding
  - Sand mixed with 3-4% liquid sodium silicate to add strength.
  - Soft and mouldable until exposed to flow of CO_2 gas
  - Has poor Collapsibility (difficult to remove by shakeout)
  - Heating (due to metal pour) makes it more stronger
  - Additives that burn during pour increases collapsibility
  - Can use this material close to cavity upto 1” thickness and then back-filed with regular moulding sand
  - If CO_2 is introduced only sand close to mould is hardened without affecting the mould

Sand Moulds

- No-Bake, Air-Set or Chemically-bonded sands.
  - Alternative to sodium silicate
  - Use organic resin binders that cure at room temperature.
  - Binders mixed with sand just before moulding and curing begins immediately
  - Limited working time before curing – operation to be fast
  - After some time (depending on binder) the sand cures and pattern can be withdrawn. After some more time to cure, metal can be poured
  - Offers high dimensional accuracy, good strength and high resistance to mould related casting defects
  - Patterns can have thinner section with deeper draws
  - Easy to shakeout as they decompose after metal pour

Shell Moulding

- Becoming increasingly popular; Better surface finish and dimensional accuracy, higher production rate and reduced labour costs. Possible to mechanize for mass production.
- Make shell of sand+binder on hot metal pattern, bake, strip and clamp.
- Less fettling as resin binder burns out due to heat from molten metal

TABLE 14-3. Shell-Mold Casting	
Process:	Sand coated with a thermosetting plastic resin is dropped onto a heated metal pattern, which cures the resin. The shell segments are stripped from the pattern and assembled. When the poured metal solidifies, the shell is broken away from the finished casting.
Advantages:	Faster production rate than sand molding; high dimensional accuracy with smooth surfaces.
Limitations:	Requires expensive metal patterns. Plastic resin adds to cost; part size is limited.
Common metals:	Cast irons and casting alloys of aluminum and copper
Size limits:	1 oz minimum; usually less than 25 lb; mold area usually less than 500 in^2
Thickness limits:	Minimums range from $\frac{1}{16}$ to $\frac{1}{4}$ in., depending on material
Typical tolerances:	Approximately 0.005 in./in.
Draft allowance:	$\frac{1}{4}-\frac{1}{2}°$
Surface finish:	50–150 µin. rms

Shell Moulding

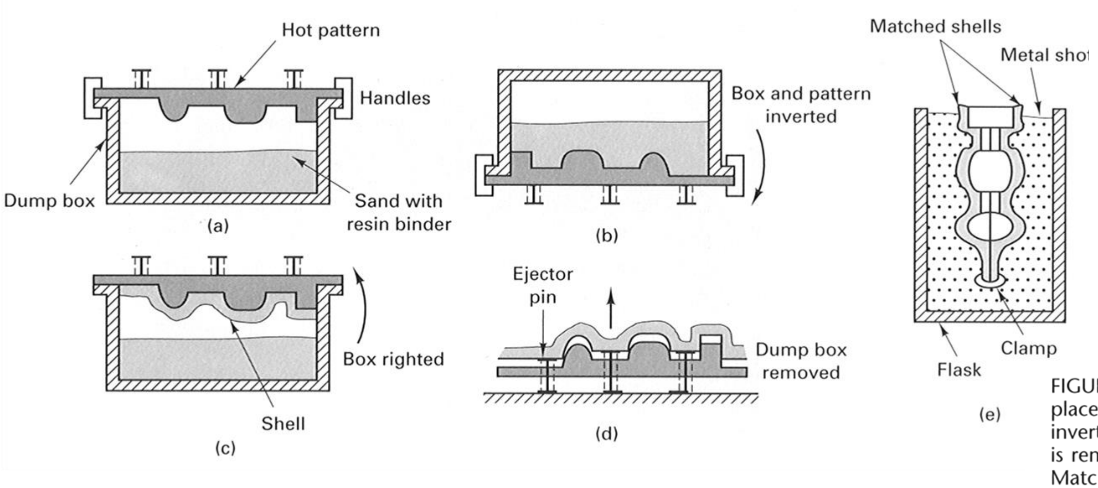
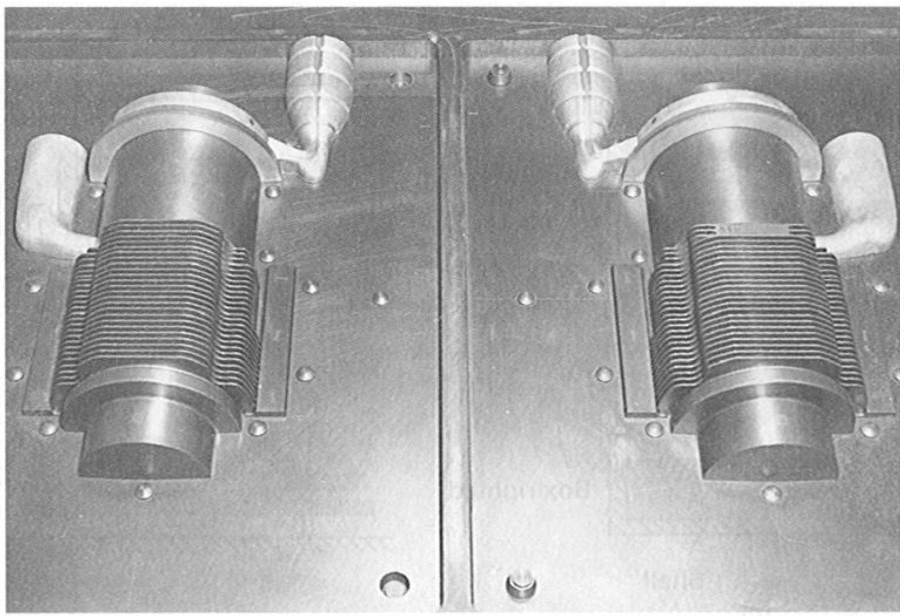


FIGURE 14-17 Schematic of the shell-molding process. A heated pattern is placed over a dump box containing a sand and resign mixture. The box is inverted and a shell partially cures around the pattern. The box is righted, the top is removed, and the shell is further cured and is finally stripped from the pattern. Matched shells are then joined and supported in a flask ready for pouring.

- Use of metal pattern and finer sand (with smooth resin) gives smoother surface and high dimensional accuracy (0.08 - 0.13mm).
- More consistent casting. Thin shell increases permeability but gas evolution is less due to less moisture in sand
- Metal pattern (including runner & gates) cost is high & cost of binder, BUT only thin shell produced (5-10mm).
- High productivity etc economical for many cases (small to medium)

Shell Moulding



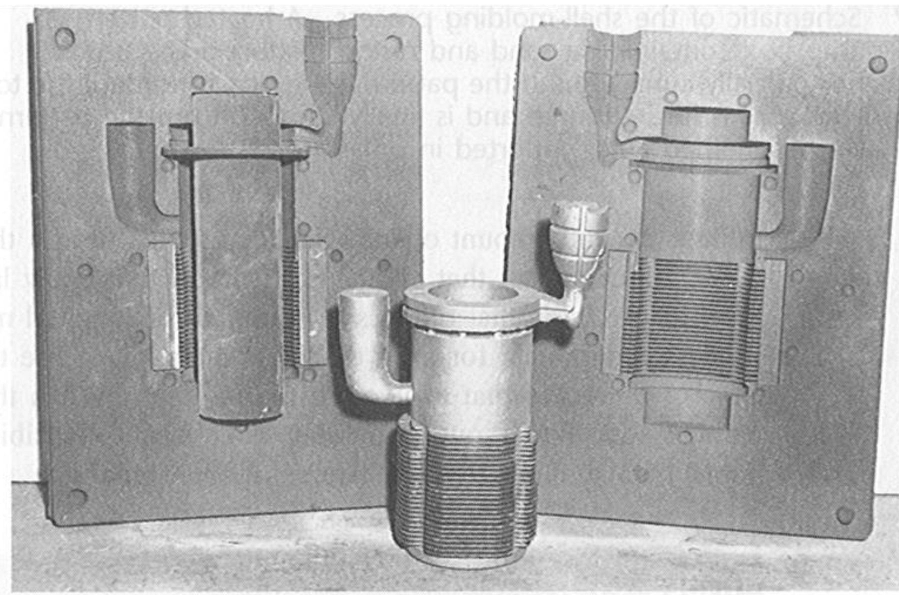
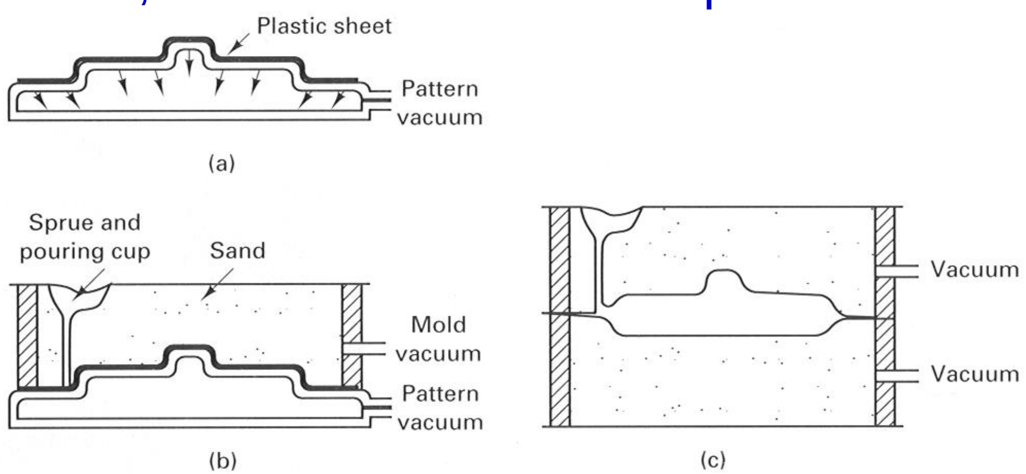


FIGURE 14-18 (*Top*) Two halves of a shell-mold pattern. (*Bottom*) The two shells before clamping, and the final shell-mold casting. (*Courtesy of Shalco Systems, an Acme-Cleveland Company.*)

Other Sand Moulding Processes

- Processes proposed to overcome limitations of traditional methods
- V-process or vacuum molding - Draping a thin sheet of heat-softened plastic over a special vented plastic pattern
- The sheet is then drawn tightly to the pattern surface by a vacuum
- A vacuum flask is then placed over the pattern, filled with sand, a sprue and pouring cup are formed, and a second sheet of plastic is placed over the mold



- Vacuum is used to compact the sand
- The pattern vacuum is released, and the pattern is withdrawn.

FIGURE 14-19 Schematic of the V-process or vacuum molding. A) A vacuum is pulled on a pattern, drawing a plastic sheet tightly against it. B) A vacuum flask is placed over the pattern, filled with sand, a second sheet placed on top, and a mold vacuum is drawn. C) The pattern vacuum is then broken and the pattern is withdrawn. The mold halves are then assembled, and the molten metal is poured.

Other Sand Moulding Processes

- Repeat for other segment, and the two mold halves are assembled.
- Metal is poured while maintaining vacuum. Plastic film vaporizes instantaneously. Vacuum is still sufficient to hold the sand in shape until metal cools.
- When the vacuum is released, the sand reverts to a loose, unbonded state, and falls away from the casting.
- No moisture-related defects. No binder cost. Dry sand is reusable.
- Better surface finish since there is no clay, water, or other binder to impair permeability, finer sands can be used,
- Excellent Shakeout characteristics, since the mold collapses when the vacuum is released.
- Unfortunately, the process is relatively slow because of the steps required

http://www.mccannsales.com/book/vprocess.pdf#search=%22v-process%20moulding%22

Cores and Core Making

- For making internal cavities or reentrant sections (undercuts)
- Increase moulding cost but reduce machining cost, wastage, allow design versatility
- 14 -21 shows 4 methods of making the pulley
- Machining out the hole, making as 2 piece pattern (also called green sand cores)
- Green sand cores have low strength and difficult to do long or complex sections

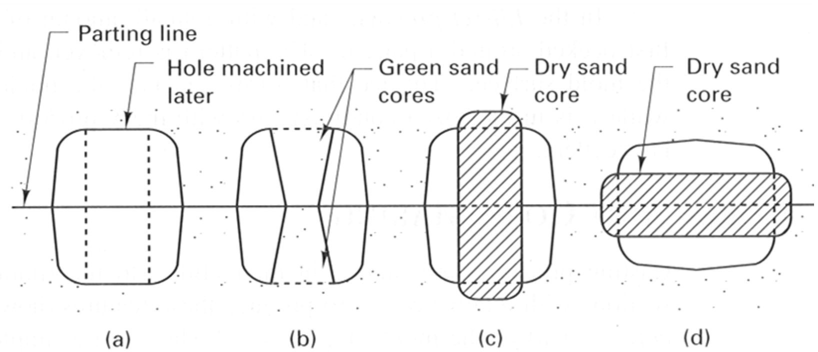


FIGURE 14-21 Four methods of making a hole in a cast pulley.

This part cannot be cast without use of cores

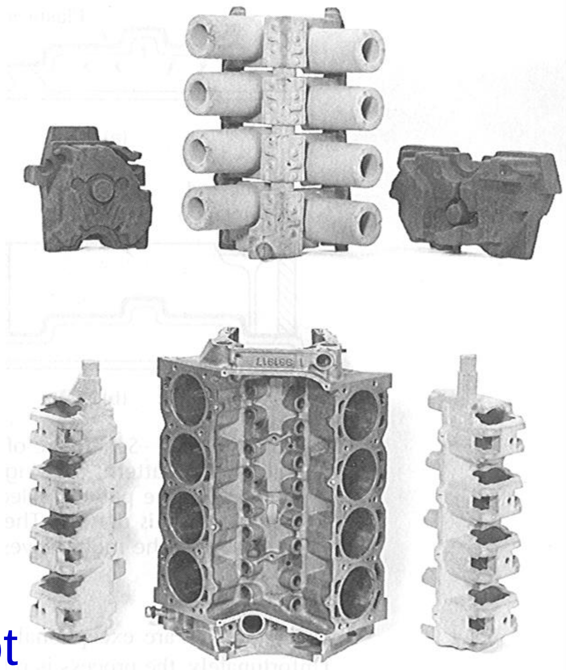


FIGURE 14-20 V-8 engine block (*bottom center*) and the five dry-sand cores that are used in its construction. *(Courtesy of Central Foundry Division of General Motors Corporation.)*

Cores and Core Making

- Dry-sand cores – independent to mould cavity. Make sand block that fits inside cavity (resting in core-prints). Cast around core. Remove core as crumbled sand. 14-21 C & D
- Dump core box approach -
  - Mould sand + binder in core-box, baked and removed. Joined with hot melt glue and fettled if necessary.
  - Coated with heat resistant material and to get smooth surface (graphite, silica etc)
  - Simple cores can be pressed or extruded.
  - Complex cores can be done in core making machines similar to injection moulding

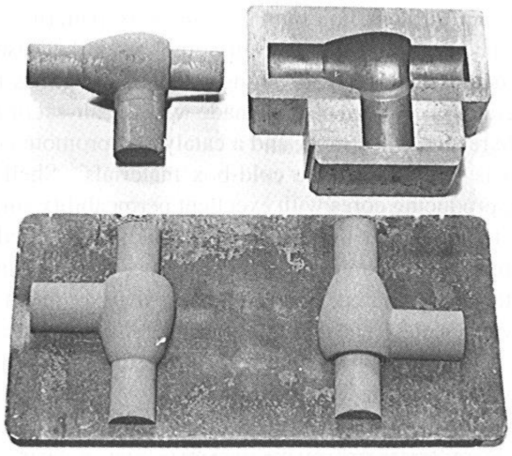


FIGURE 14-22 (*Clockwise from upper right*) Core box, two core halves ready for baking, and the completed core made by gluing the two halves together.

Cores and Core Making

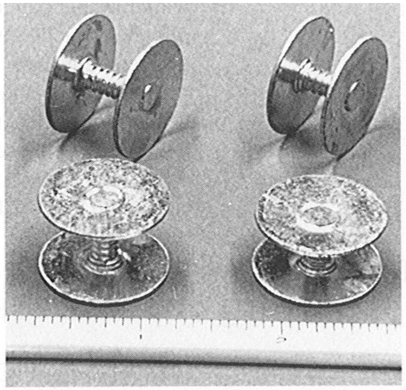
- Cores are fragile and the core making process should provide the required strength for the cores.
  - Hot-Box method - A liquid thermosetting binder is added to sand and blown into hot (230°C) core-box. Cures quickly (10-30s) & removed.
  - Cold-Box method - Binder + sand blown into core-box and gas (e.g. SO_2) passed through to cure resin without heat. (gases are toxic).
  - Air-set and no-bake sands (cold curing binder) and shell process can also be used to make cores.
    - The advantages of these approaches include curing in room temperature and in shell moulding hollow cores can be formed

Cores and Core Making

- Cores require:
  - Sufficient strength before hardening for handling
  - Sufficient hardness and strength after hardening to withstand handling and molten metal. (wires may be added) 100-500psi
  - Good permeability to gases. (charcoal centre or venting)
  - Collapsibility. After pouring, core must be weak enough to allow shrinkage, and also be easily removed on knock-out. (increase this by using straw centre)
  - Adequate refractoriness. Usually surrounded by hot metals.
  - Smooth surface.
  - Minimum gas generation during pour.

Cores and Core Making

- Cores located/supported by:
  - Core prints in cavity (from pattern)
  - Extra supports (Chaplets) can be added. Like internal chills these will become part of casting (possible cause of defects - to be avoided).
  - Large enough to prevent full melting, and small enough for surface to melt and fuse



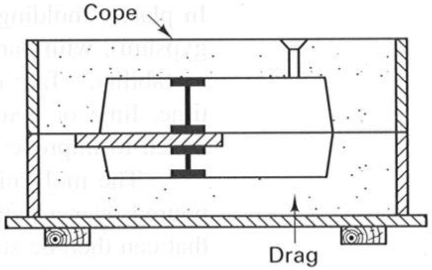


FIGURE 14-24 (*Top*) Typical chaplets. (*Bottom*) Method of supporting cores by use of chaplets (relative size of the chaplets is exaggerated).

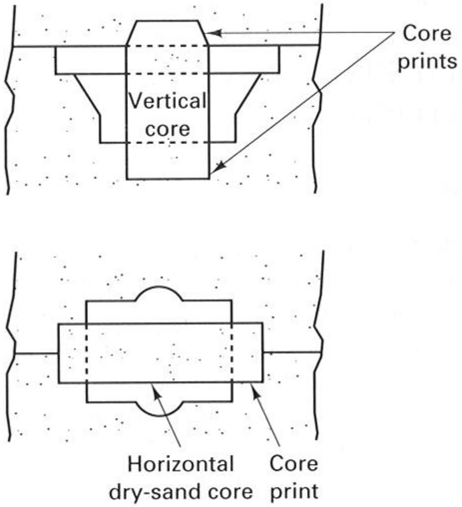
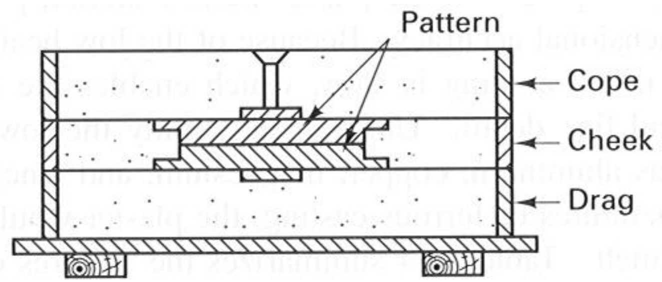


FIGURE 14-23 Molds cavities containing core prints to hold and position cores. (*Left*) Vertical core; (*right*) horizontal core.

Cores and Core Making

- A pulley with recess on sides has reentrant angles and can be made by two approaches:
  - 14-25 use of 3 piece process. Adding an additional parting line enables use of withdrawable patterns
  - No cores (green sand cores) – good for small runs
  - 14-26 use of cores. Use simple green sand mould together with ring shaped cores
  - Reduced moulding time – good for large runs

FIGURE 14-25 Method of making a reentrant angle using a three-piece flask.



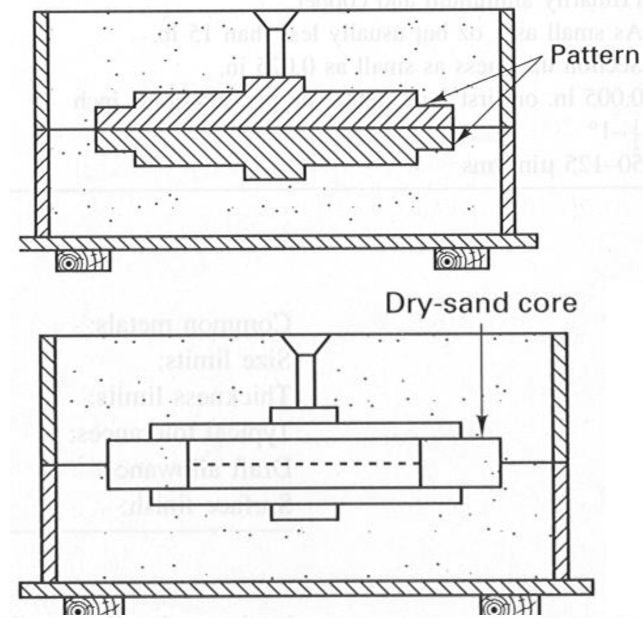


FIGURE 14-26 Molding a reentrant section using a dry-sand core.

Other Processes – Multi use patterns

- Plaster Mould Process – also known as Plaster of Paris is the mold mat'l
- Mixed with additives

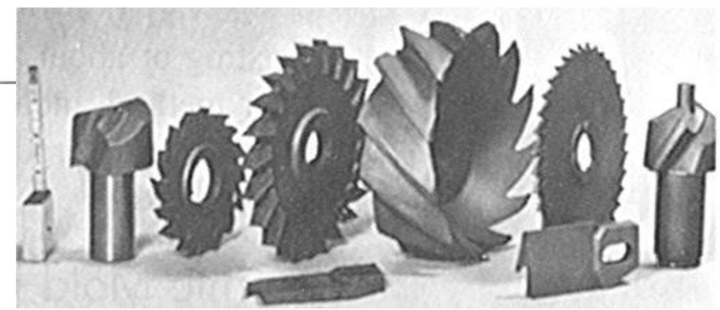
Process:	A slurry of plaster, water, and various additives is poured over a pattern and allowed to set. The pattern is removed and the mold is baked to remove excess water. After pouring and solidification, the mold is broken and the casting is removed.
Advantages:	High dimensional accuracy and smooth surface finish; can reproduce thin sections and intricate detail to make net- or near-net-shaped parts.
Limitations:	Lower-temperature nonferrous metals only; long molding time restricts production volume or requires multiple patterns; mold material is not reusable; maximum size is limited.
Common metals:	Primarily aluminum and copper
Size limits:	As small as 1 oz but usually less than 15 lb.
Thickness limits:	Section thickness as small as 0.025 in.
Typical tolerances:	0.005 in. on first 2 in., 0.002 in. per additional inch
Draft allowance:	$\frac{1}{2}$–1°
Surface finish:	50–125 μin. rms

  - Talc (MgO_2) is added to prevent cracking, lime controls expansion, glass fibers add strength and sand is used as filler.

- Mould material added with water and additives poured over pattern and allowed to cure. Mould is then removed from metal pattern (complex patterns can be rubber too for easy removal)
- Advantage - Good surface finish. Limitation – Low MP metals/alloys

Other Processes – Multi use patterns

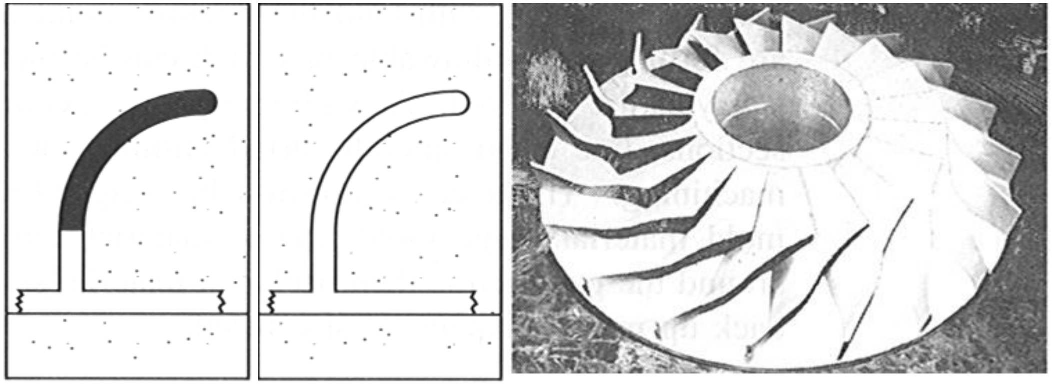
Process:	Stable ceramic powders are combined with binders and gelling agents to produce the mold material.
Advantages:	Intricate detail, close tolerances, and smooth finishes.
Limitations:	Mold material is costly and not reusable
Common metals:	Ferrous and high-temperature nonferrous metals are most common; can also be used with alloys of aluminum, copper, magnesium, titanium, and zinc.
Size limits:	Several ounces to several tons
Thickness limits:	As thin as 0.050 in.; no maximum
Typical tolerances:	0.005 in. on the first inch, 0.003 in. per each additional inch
Draft allowance:	1° preferred.
Surface finish:	75–150 μin. rms



- Ceramic Mould Process – similar to plaster but can withstand higher temp good for casting high MP metals/alloys
- Cope and drag moulds are formed using ceramic slurry as mould
- Thin sections can be done and good surface finish possible
- Mould material is expensive. Can use a thin layer of ceramic material backed with sand for large castings to reduce cost.

Other Processes – Multi use patterns

FIGURE 14-28 Method of combining ceramic mold casting and wax pattern casting to produce the complex vanes of an impeller. A wax pattern is added to a metal pattern. After the metal pattern is withdrawn *(**Left**)*, the wax pattern is melted out, leaving a cavity as shown *(**Center**), to produce the casting (**Right**).*



- Expendable graphite moulds - for metals like titanium (reactive when hot) graphite mixed binder is used around the pattern and cured at 1000°C. The pattern is removed and after casting, mould is broken.
- Rubber-mould casting - artificial elastomers are cast around pattern. Stripped from pattern (semi-rigid) to form mould. Good for low melting point materials and metals (<260°C) and for small castings.

Expendable Mould and Pattern

1. Investment casting - Produce a master pattern. (metal, wood, plastic).
2. From master pattern, produce a master die. (low-MP metal, steel, wood). If low-MP metal or rubber molds are used, the die can be cast from the master pattern. Steel dies may be machined without step 1
3. Produce wax patterns. Injecting molten wax into the master die. Cores can be made with soluble wax and removed before ceramic coating.
4. Assemble the wax patterns onto a common wax sprue to produce a pattern cluster, or tree to get better re entrant angles.
5. Coat the cluster with a thin layer of investment material. (dipping into a watery slurry of finely ground refractory).

Investment Casting

6. Produce the final investment around the coated cluster. (cluster is re-dipped, but wet ceramic is coated with a layer of sand - process repeated until desired thickness reached, or the single-coated cluster can be placed upside down in a flask and liquid investment material poured around it)
   - Vibrate the flask to remove entrapped air and settle the investment material around the cluster. (performed when the investment material is poured around the cluster)
7. Allow the investment to harden.
8. Melt or dissolve the wax pattern to remove it from the mold. (place molds upside down in an oven - wax melts and runs out, any residue subsequently vaporizes.

Investment Casting

9. Preheat the mold in preparation for pouring. Heating to 1000 to 2000°F (550 to 1100°C) complete removal of wax, cures the mold to give added strength, and allows the molten metal to retain its heat and flow more readily to all thin sections. It also gives better dimensional control because the mold and the metal will shrink together during cooling.
10. Pour the molten metal. Various methods, beyond simple pouring, can be used to ensure complete filling of the mold, especially when complex, thin sections are involved. Among these methods are the use of positive air pressure, evacuation of the air from the mold, and a centrifugal process.
11. Remove casting from mould

Investment Flask Casting

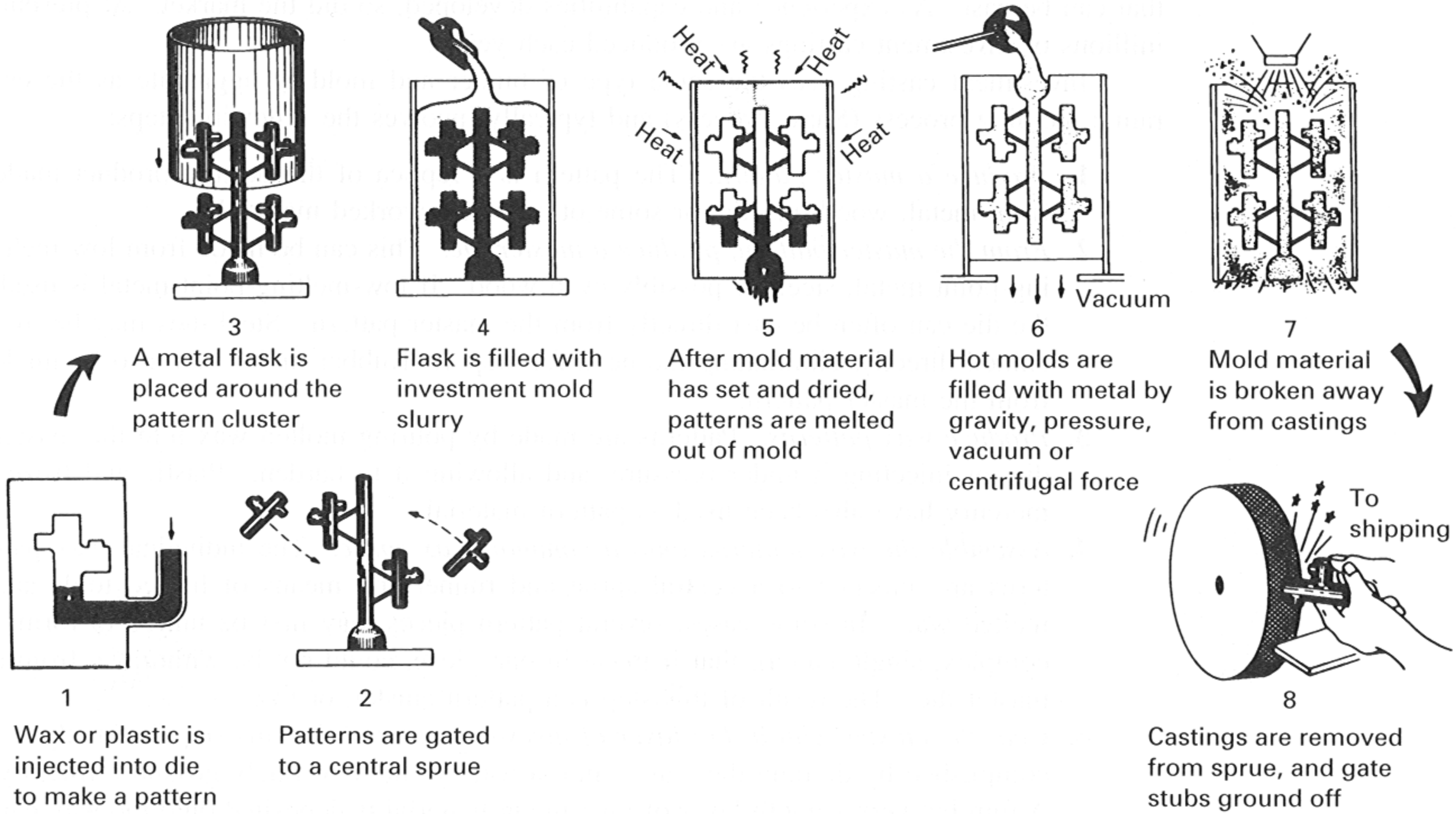


FIGURE 14-29 Investment flask-casting procedure. *(Courtesy of Investment Casting Institute, Dallas, Texas.)*

Investment Shell Casting

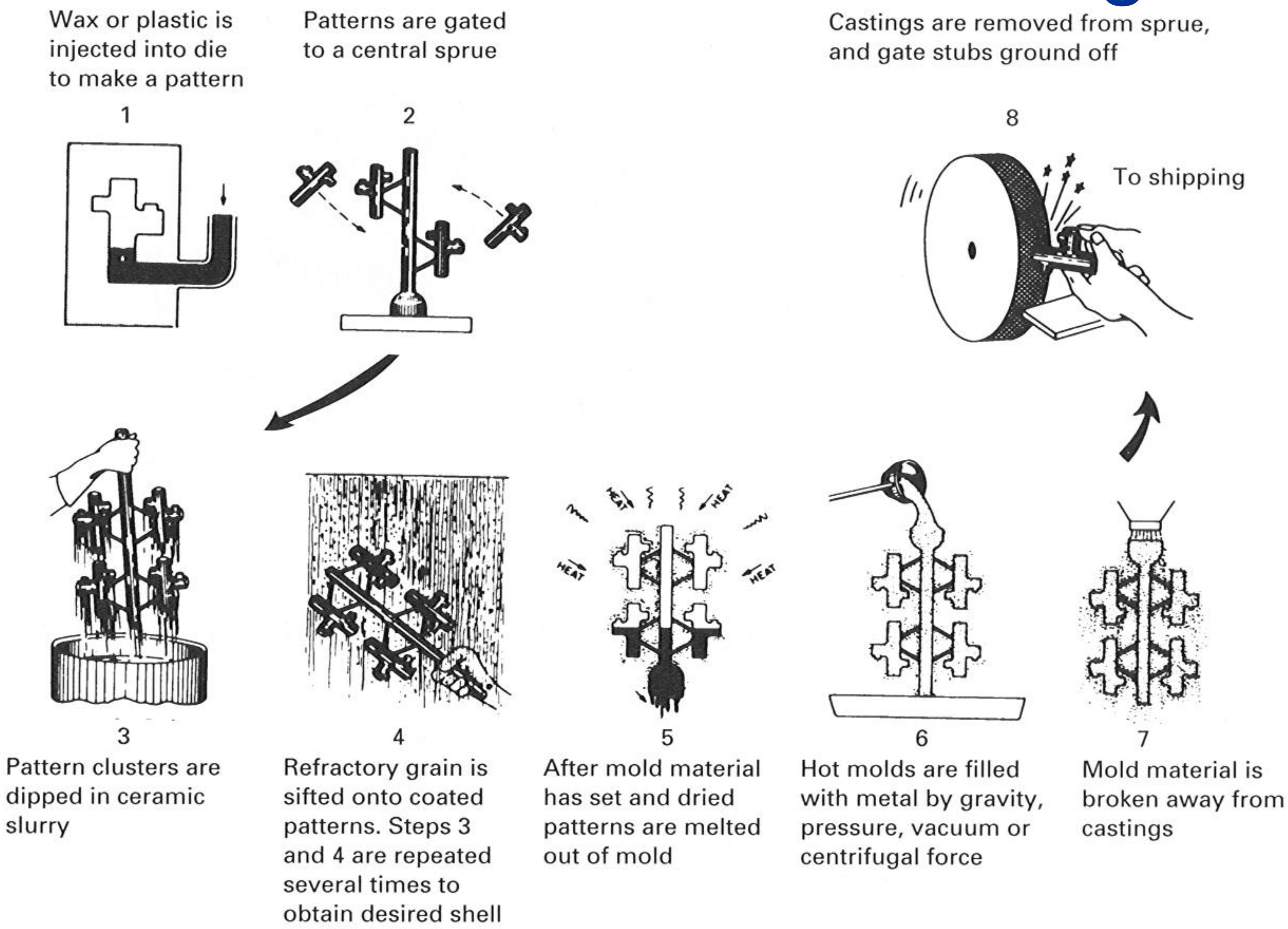


FIGURE 14-30 Investment shell-casting procedure. *(Courtesy of Investment Casting Institute, Dallas, Texas.)*

Investment Casting

TABLE 14-6. Investment Casting

Process:	A refractory slurry is formed around a wax or plastic pattern and allowed to harden. The pattern is then melted out and the mold is baked. Molten metal is poured into the mold and solidifies. The mold is then broken away from the casting.
Advantages:	Excellent surface finish; high dimensional accuracy; almost unlimited intricacy; almost any metal can be cast; no flash or parting line concerns.
Limitations:	Costly patterns and molds; labor costs can be high; limited size.
Common metals:	Aluminum, copper, and steel dominate; also performed with stainless steel, nickel, magnesium, and the precious metals.
Size limits:	As small as $\frac{1}{10}$ oz but usually less than 10 lb
Thickness limits:	As thin as 0.025 in., but less than 3.0 in.
Typical tolerances:	0.005 in. for the first inch and 0.002 in. for each additional inch.
Draft allowance:	None required
Surface finish:	50 to 125 μin. rms

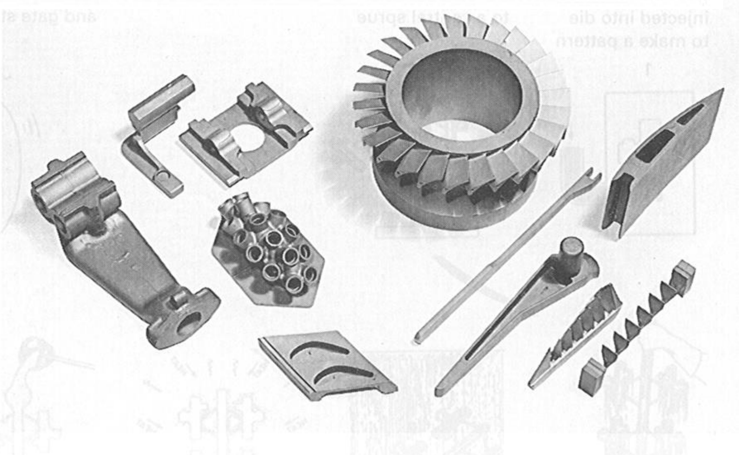


FIGURE 14-31 Typical parts produced by investment casting. *(Courtesy of Haynes Stellite Company.)*

Evaporative Pattern Casting

1. EPS casting - Produce a pattern made of expanded polystyrene. For small quantities, pattern can be cut by heated wires. Runners and risers can be added by glue.
2. If large quantities are required, a metal mould is used to do single use pattern. Beads of PS injected into the mould cavity and heated where the expanded PS bonds together to form a complex bond. For more complex patterns can be made in multiple sections and glued
3. After patterning and gating attached, mould is done by
   - Full Mould method – green sand with chemical additives 14-32
   - Lost Foam Method – dipping in water based ceramic and powder 14-33

Evaporative Pattern Casting

4. Mould metal poured inside the cavity without removing the pattern. During the pour the metal vaporizes and replaces the EPS pattern.
5. After cooling the sand is dumped and the casting is taken out for finishing.
6. Can make complex castings of both ferrous or non-ferrous metal economically. No draft is required as well.

TABLE 14-7. Full-Mold Casting

Process:	A Pattern containing a sprue, runners, and risers is made from single or multiple pieces of foamed plastic, such as polystyrene. It is dipped in a ceramic material, dried, and positioned in a flask, where it is surrounded by loose sand. Molten metal is poured directly onto the pattern, which vaporizes and is vented through the sand.
Advantages:	Almost no limits on shape and size; most metals can be cast; no draft is required and no flash is present (no parting lines).
Limitations:	Pattern cost can be high for small quantities; patterns are easily damaged or distorted because of their low strength.
Common metals:	Aluminum, iron, steel, and nickel alloys; also performed with copper and stainless steel.
Size limits:	1 lb to several tons
Thickness limits:	As small as 0.1 in. with no upper limit
Typical tolerances:	$\frac{1}{32}$ in./ft or less
Draft allowance:	None required
Surface finish:	100–1000 μin. rms

Evaporative Pattern Casting

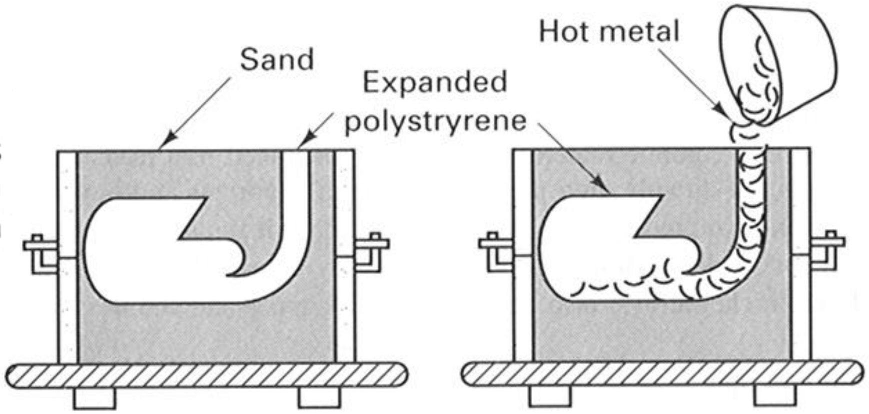


FIGURE 14-32 Schematic of the full-mold process. (*Left*) Uncoated polystyrene pattern is in a bonded sand mold. (*Right*) Hot metal vaporizes the pattern and fills the resulting cavity.

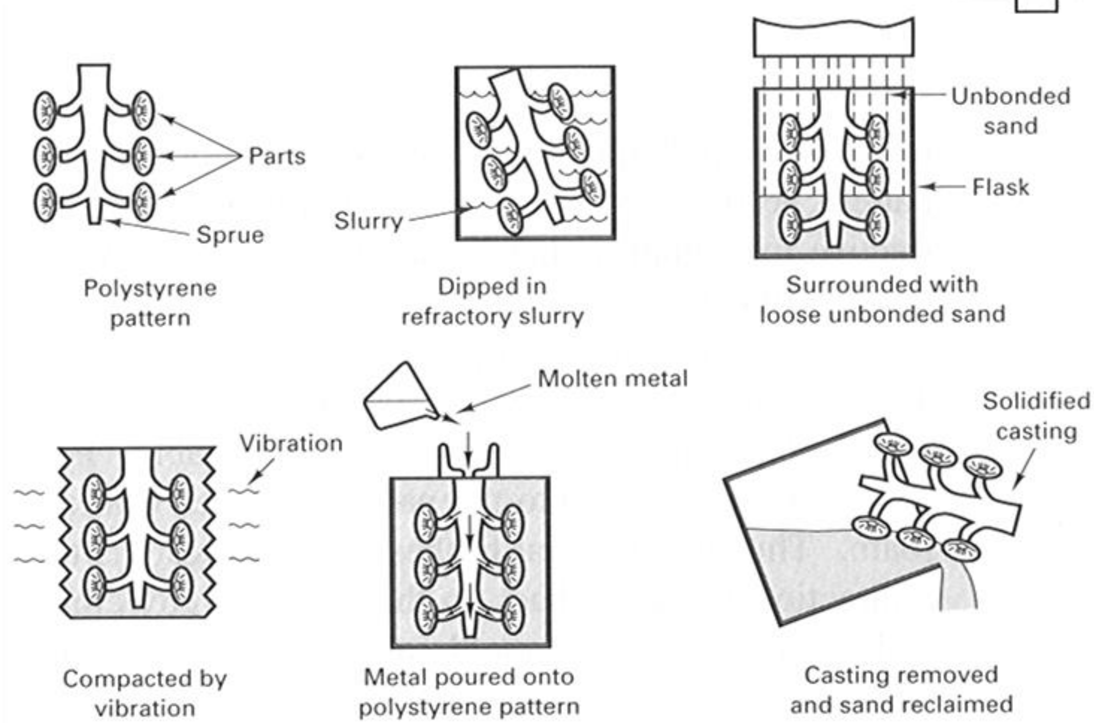


FIGURE 14-33 Schematic of the lost-foam casting process. In this process, the polystyrene pattern is dipped in a ceramic slurry, and the coated pattern is surrounded with loose, unbonded sand.

Evaporative Pattern Casting

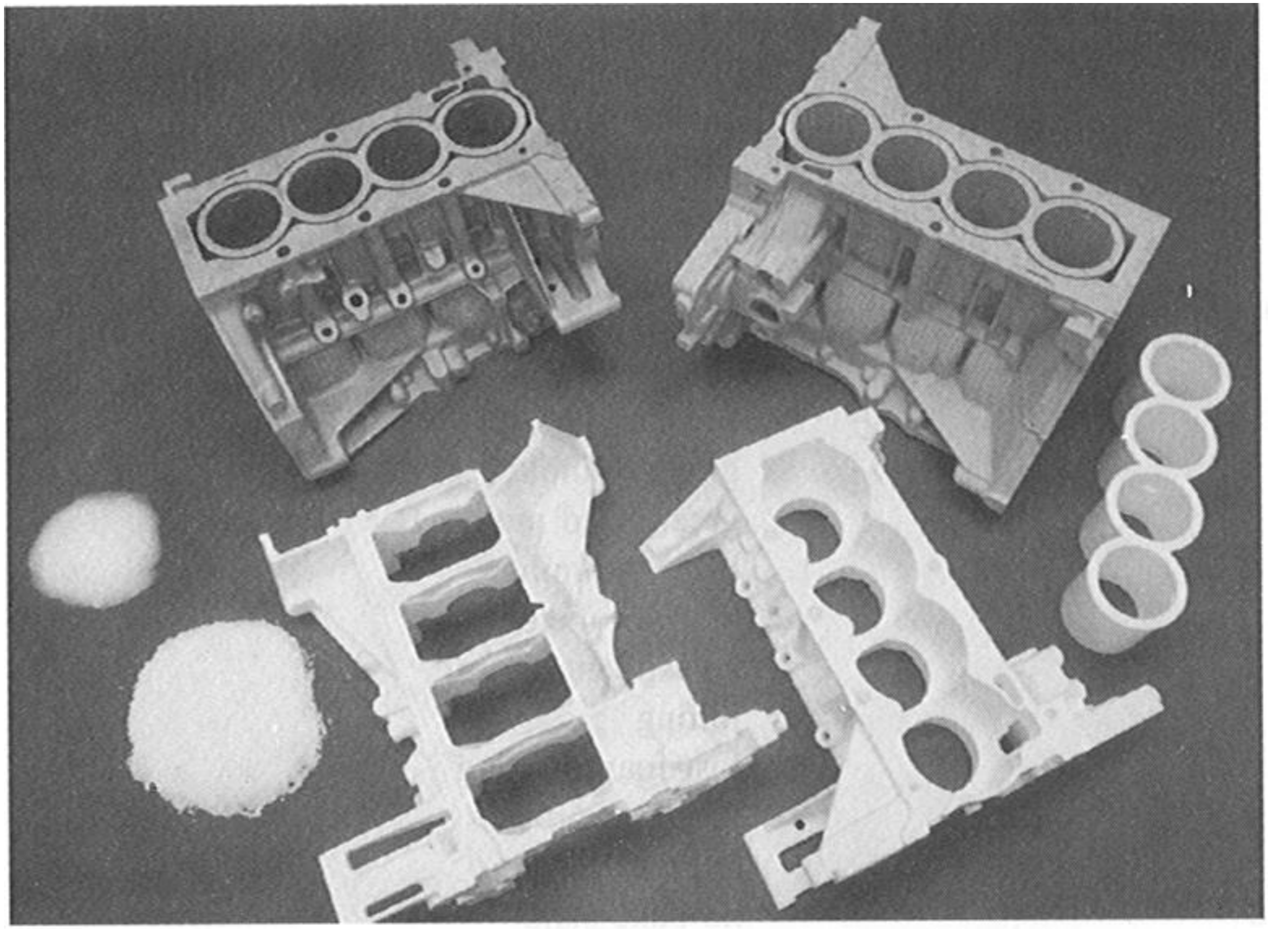


FIGURE 14-34 The stages of full-mold casting, counterclockwise from the left: polystyrene beads, expanded polystyrene pellets, foam pattern segments, assembled and dipped polystyrene pattern, and the finished metal casting. *(Courtesy of Saturn Corporation, Spring Hill, TN.)*

Shakeout, Cleaning and Finishing

- Final operation in casting is to separate casting from mould.
- Shakeout is designed to do
  - Separate the moulds and remove casting from mould
  - Remove sand from flask and cores from cast
- Punch out or vibratory machines are available for this task
- Blast cleaning is done to remove adhering sand from casting, or remove oxide scale and parting line burs.
- Final finishing operations include Grinding, Turning or any forms of machining

Types of Pattern

Table 5–2. Types of molds/dies, mold materials, patterns, and pouring principles classified in four basic process groups

Grouping	Type of mold	Mold material	Pouring principle	Pattern material	Process name
Sand casting	Nonpermanent (single-purpose)	Sand (green)	Gravity	Wood, metal, plastics	Green sand, dry sand, core sand casting
Permanent (metallic) mold casting	Permanent	Alloy steels	High pressure	—	Die casting
		Graphite, steel, cast iron	Low pressure	—	Low pressure (permanent mold casting)
		Cast iron, steel	Gravity		Nonpressure gravity permanent mold casting
Precision casting	Nonpermanent (single-purpose)	Nonmetallic (sand, plaster, ceramics, etc.)	Gravity (low pressure)	Metal	Shell mold casting
Investment or precision casting				Wax, plastic, (rubber, metal)	Plaster mold casting
Investment or precision casting				Wax, plastic, (rubber, metal)	Ceramic shell mold casting
Investment or precision casting				Wax, plastic, (rubber, metal)	"Lost wax" casting (investment casting)
Centrifugal casting	Nonpermanent/ permanent	Nonmetallic/ metallic	Centrifugal forces	—	Centrifugal casting