

Sand Casting

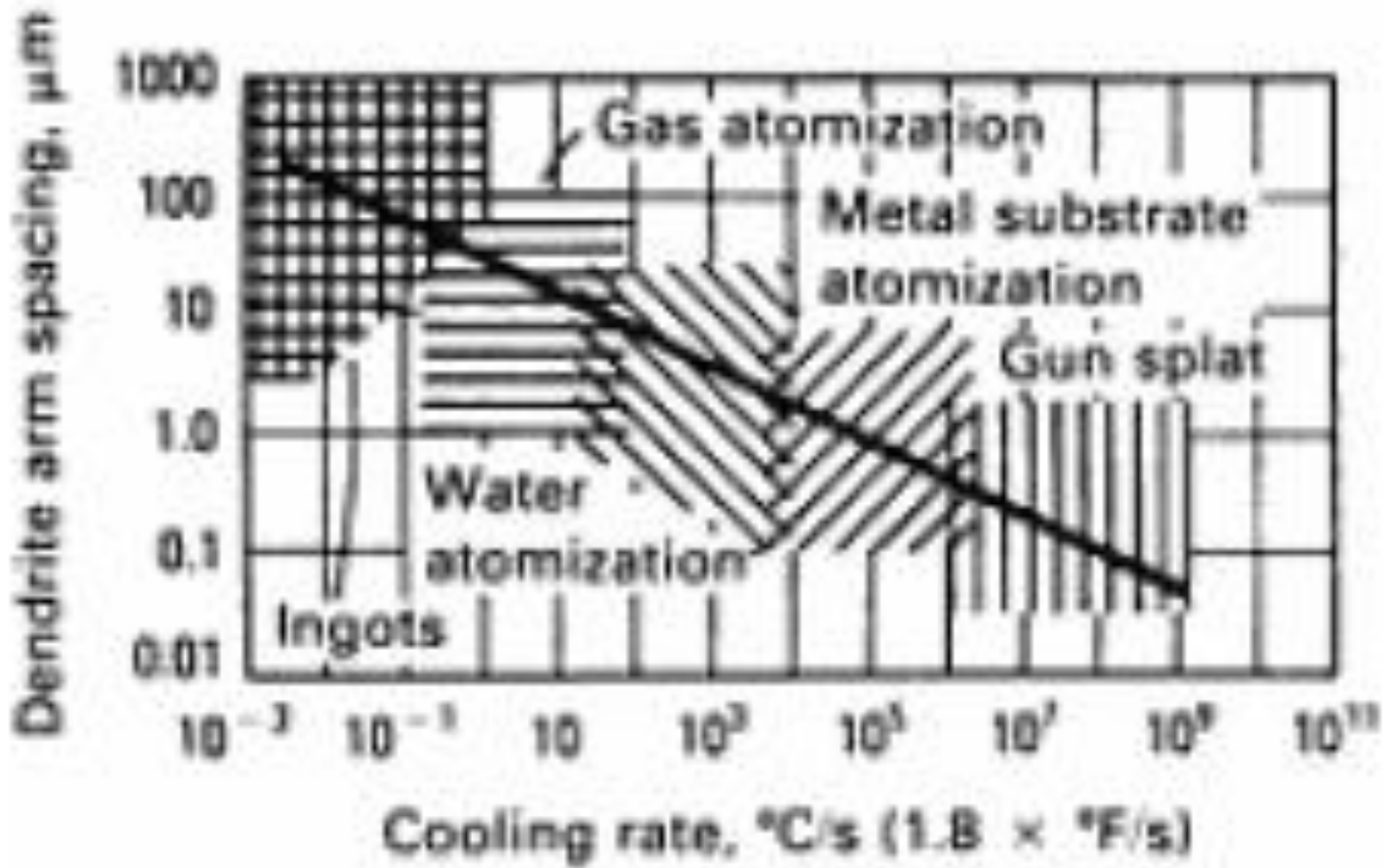
Prof. Dr. Altan Turkeli

MSE-432

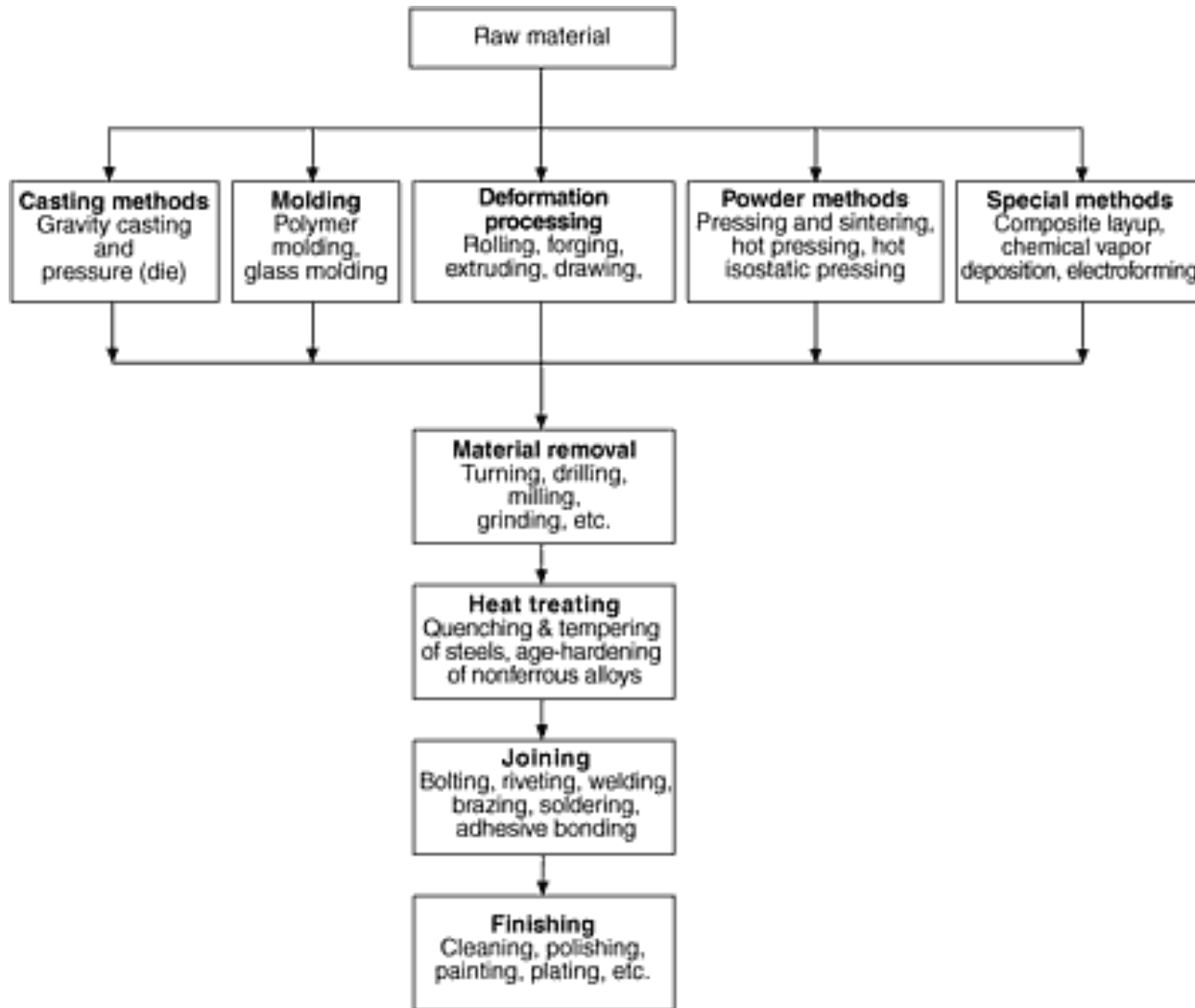
Foundry Technology

- In order to produce an “Alloy”, different metals should melt to obtain right composition.
- This liquid should solidify at the different cooling rates
- At slow cooling rates in the case of ingot casting, component casting
- At the high cooling rates in the case of powder metallurgy, rapid solidification

Dendrite arm spacing versus cooling rate for aluminum alloys.



The nine classes of manufacturing processes. The first row contains the primary forming (shaping) processes. The processes in the lower vertical column are the secondary forming and finishing processes.



Processes

- Sand
- Shell
- Plaster
- Ceramic
- Investment
- Lost foam
- Pressure
- Vacuum
- Die
- Centrifugal
- Squeeze
- Semi-solid
- Single crystal
- Directional solidification
- Slush
- Continuous

Metals processed by casting

- Sand casting – 60%
- Investment casting – 7%
- Die casting – 9%
- Permanent mold casting – 11%
- Centrifugal casting – 7%
- Shell mold casting – 6%

Breakdown of Castings

- Ingots for bulk deformation processing - 85%
- Cast to near net shape - 15%

Ingots

- Iron or steel molds
- Water-cooled molds
- Continuous casting

Shapes

- Permanent mold (cavity)
 - die casting
 - hot chamber
 - cold chamber
- Expendable Molds
 - sand
 - shell
 - slurry
 - investment
 - lost wax
 - lost foam

Shapes

- Centrifugal
 - pipes
 - spinning

Capabilities

- Dimensions
 - sand casting - as large as you like
 - small - 1 mm or so
- Tolerances
 - 0.005 in to 0.1 in
- Surface finish
 - die casting 8-16 micro-inches (1-3 μm)
 - sand casting - 500 micro-inches (10-25 μm)

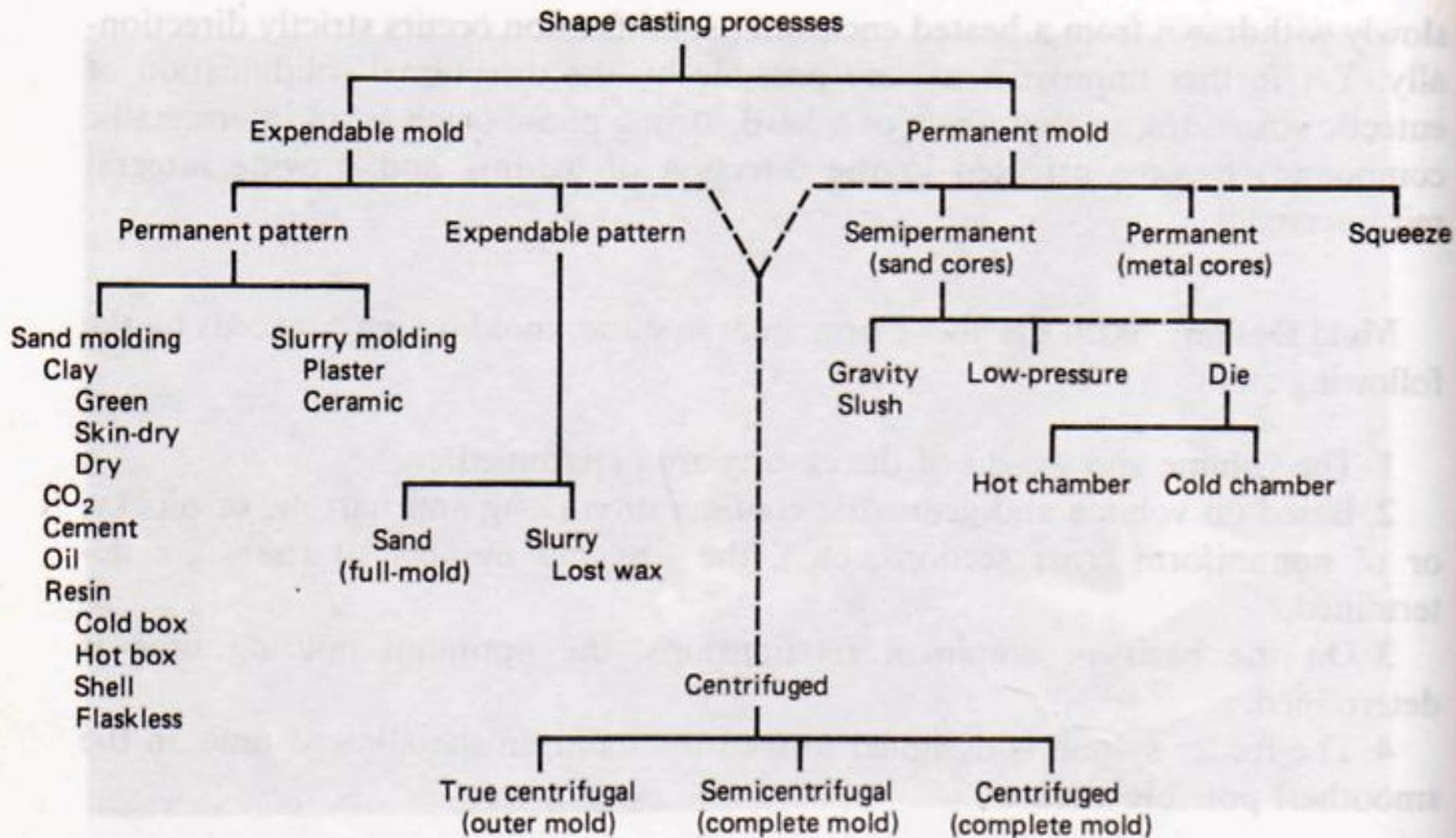
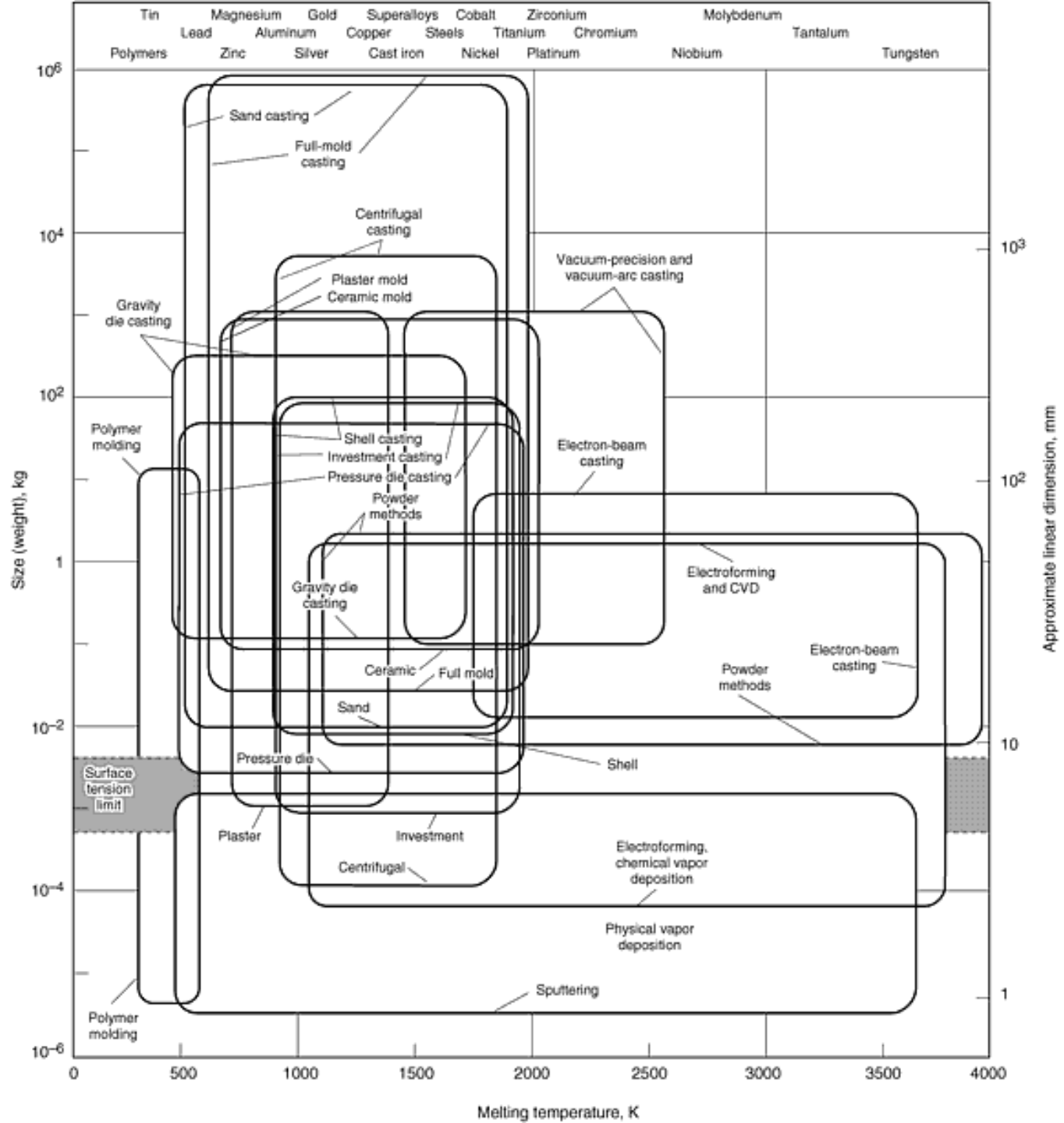
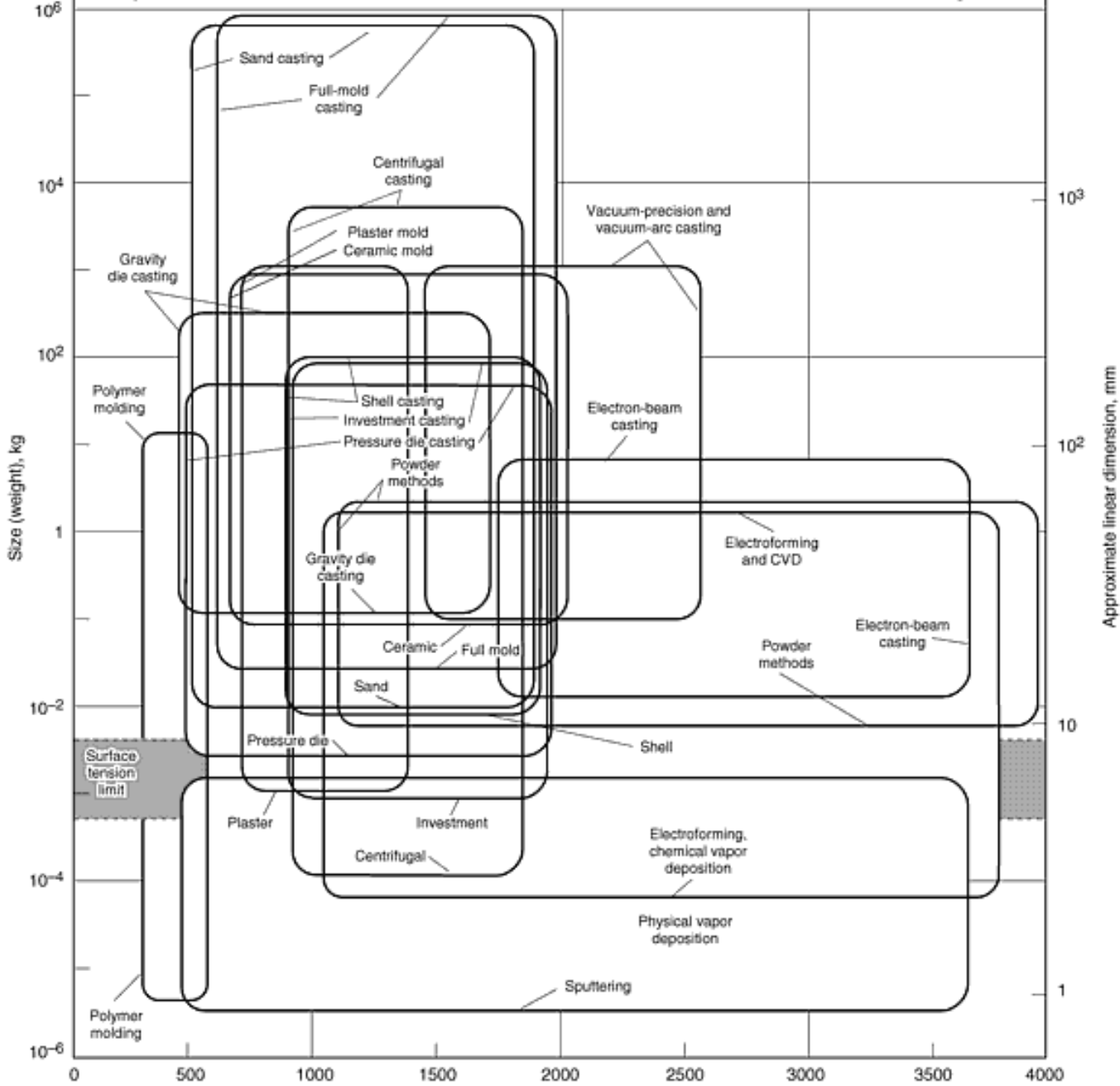


FIGURE 3-33
Classification of shape-casting processes.



Tin Lead Magnesium Aluminum Gold Copper Superalloys Steels Titanium Zirconium Chromium Molybdenum Niobium Tantalum Tungsten



Melting temperature, K

Casting Characteristics

| Process | Typical materials cast | Weight (kg) | | Typical surface finish (micron, Ra) | Porosity* | Shape complexity* | Dimensional accuracy* | Section thickness (mm) | |
|-------------------------|-----------------------------|-------------|----------|-------------------------------------|-----------|-------------------|-----------------------|------------------------|----------|
| | | Minimum | Maximum | | | | | Minimum | Maximum |
| Sand | All | 0.05 | No limit | 5-25 | 4 | 1-2 | 3 | 3 | No limit |
| Shell | All | 0.05 | 100+ | 1-3 | 4 | 2-3 | 2 | 2 | -- |
| Expendable mold pattern | All | 0.05 | No limit | 5-20 | 4 | 1 | 2 | 2 | No limit |
| Plaster mold | Nonferrous (Al, Mg, Zn, Cu) | 0.05 | 50+ | 1-2 | 3 | 1-2 | 2 | 1 | -- |
| Investment | All (High melting pt.) | 0.005 | 100+ | 1-3 | 3 | 1 | 1 | 1 | 75 |
| Permanent mold | All | 0.5 | 300 | 2-3 | 2-3 | 3-4 | 1 | 2 | 50 |
| Die | Nonferrous (Al, Mg, Zn, Cu) | <0.05 | 50 | 1-2 | 1-2 | 3-4 | 1 | 0.5 | 12 |
| Centrifugal | All | -- | 5000+ | 2-10 | 1-2 | 3-4 | 3 | 2 | 100 |

*Relative rating: 1 best, 5 worst.

Note: These ratings are only general; significant variations can occur, depending on the methods used.

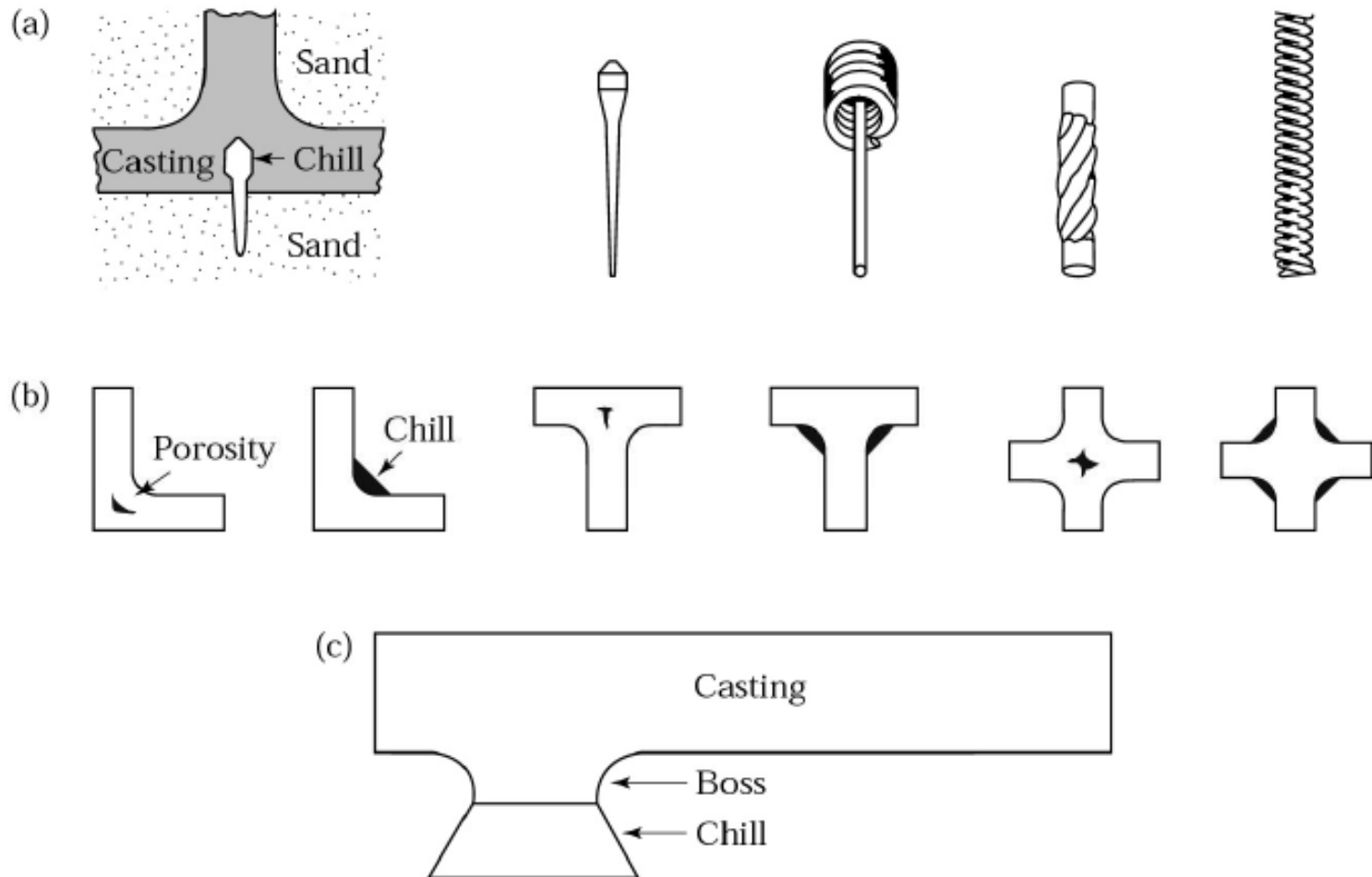
Shrinkage

TABLE 5.1

| Metal or alloy | Volumetric solidification contraction (%) | Metal or alloy | Volumetric solidification contraction (%) |
|-----------------------|--|-----------------------|--|
| Aluminum | 6.6 | 70%Cu–30%Zn | 4.5 |
| Al–4.5%Cu | 6.3 | 90%Cu–10%Al | 4 |
| Al–12%Si | 3.8 | Gray iron | Expansion to 2.5 |
| Carbon steel | 2.5–3 | Magnesium | 4.2 |
| 1% carbon steel | 4 | White iron | 4–5.5 |
| Copper | 4.9 | Zinc | 6.5 |

Source: After R. A. Flinn.

Chills



Casting costs

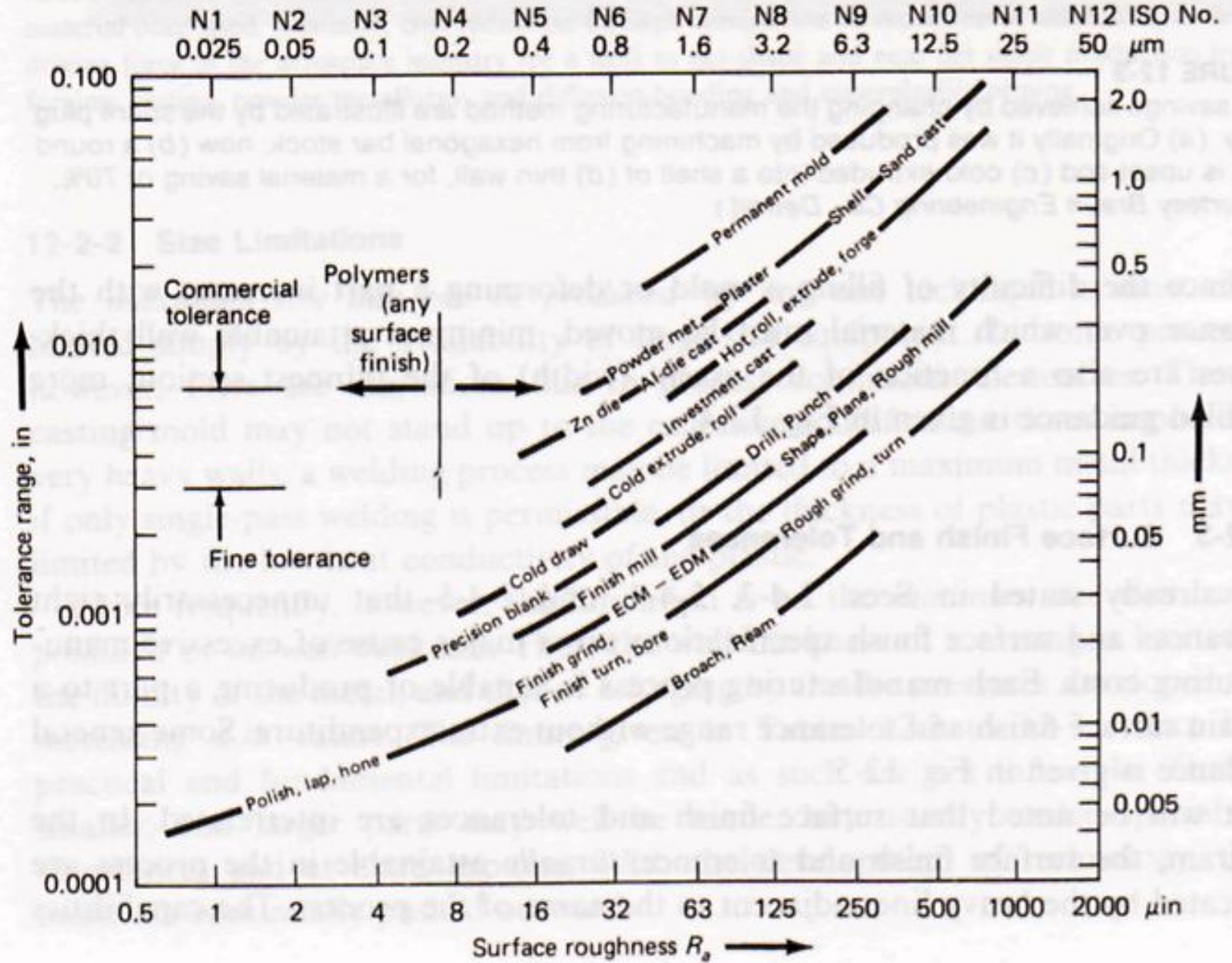
TABLE 5.10

| Process | Cost* | | | Production rate (Pc/hr) |
|----------------|-------|-----------|-------|-------------------------|
| | Die | Equipment | Labor | |
| Sand | L | L | L-M | <20 |
| Shell-mold | 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-M | <200 |
| Centrifugal | M | H | L-M | <50 |

* L, low; M, medium; H, high.

FIGURE 12-5

Under typical conditions, each manufacturing process is capable of producing parts to some characteristic tolerance and surface finish. See text for interpretation of graph.



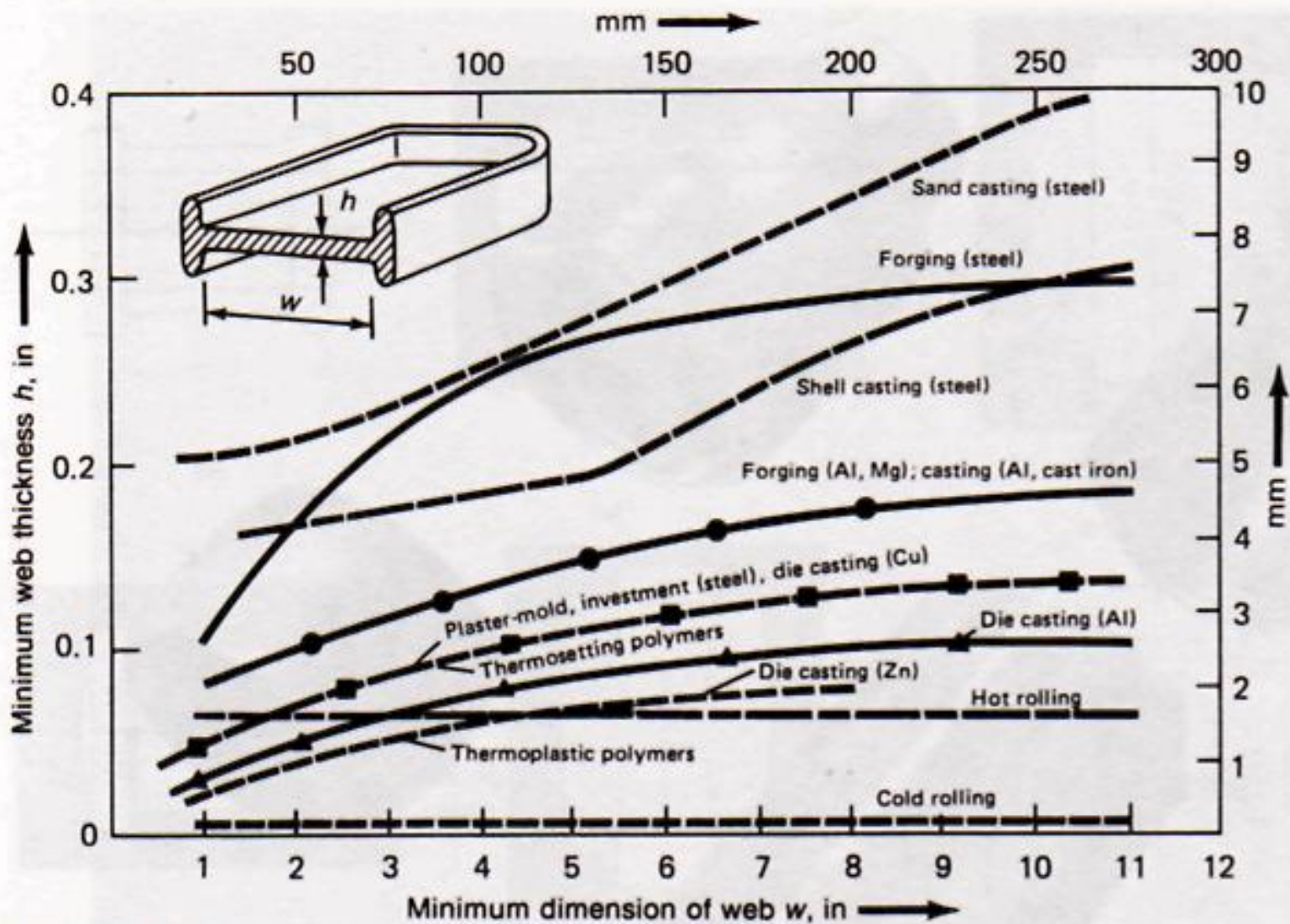


FIGURE 12-4

For a given process, the minimum web thickness increases with the distance over which material must move.

A COMPARISON OF SEVERAL CASTING METHODS

(approximate and depending upon the metal)

| | Green Sand Casting | Permanent Mold Cast | Die Casting | Sand-Shell CO ₂ -Core Casting | Ceramic & Investment Casting |
|--|-------------------------------|--|--|---|------------------------------|
| Relative cost in quantity | low | low | lowest | medium high | highest |
| Relative cost for small number | lowest | high | highest | medium high | medium |
| Permissible weight of casting | unlimited up to approx. 1 ton | 100 lbs. | 30 lbs. | Shell ozs. - 250 lbs. CO ₂ 1/2 lbs. to tons | Ozs. to 100 lbs. |
| Thinnest section castable, inches | 1/10 | 1/8 | 1/32 | 1/10 | 1/16 |
| Typical dimensional tolerance, inches | .012 | 0.03 | 0.01 | .010 | 0.01 |
| Relative surface finish | fair to good | good | best | Shell good CO ₂ fair | very good |
| Relative mechanical properties | good | good | very good | good | fair |
| Relative ease of casting complex design | fair to good | fair | good | good | best |
| Relative ease of changing design in production | best | poor | poorest | fair | fair |
| Range of alloys that can be cast | unlimited | copper base and lower melting preferable | aluminum base and lower melting preferable | unlimited | limited to unlimited |

PARTING LINE INFLUENCE

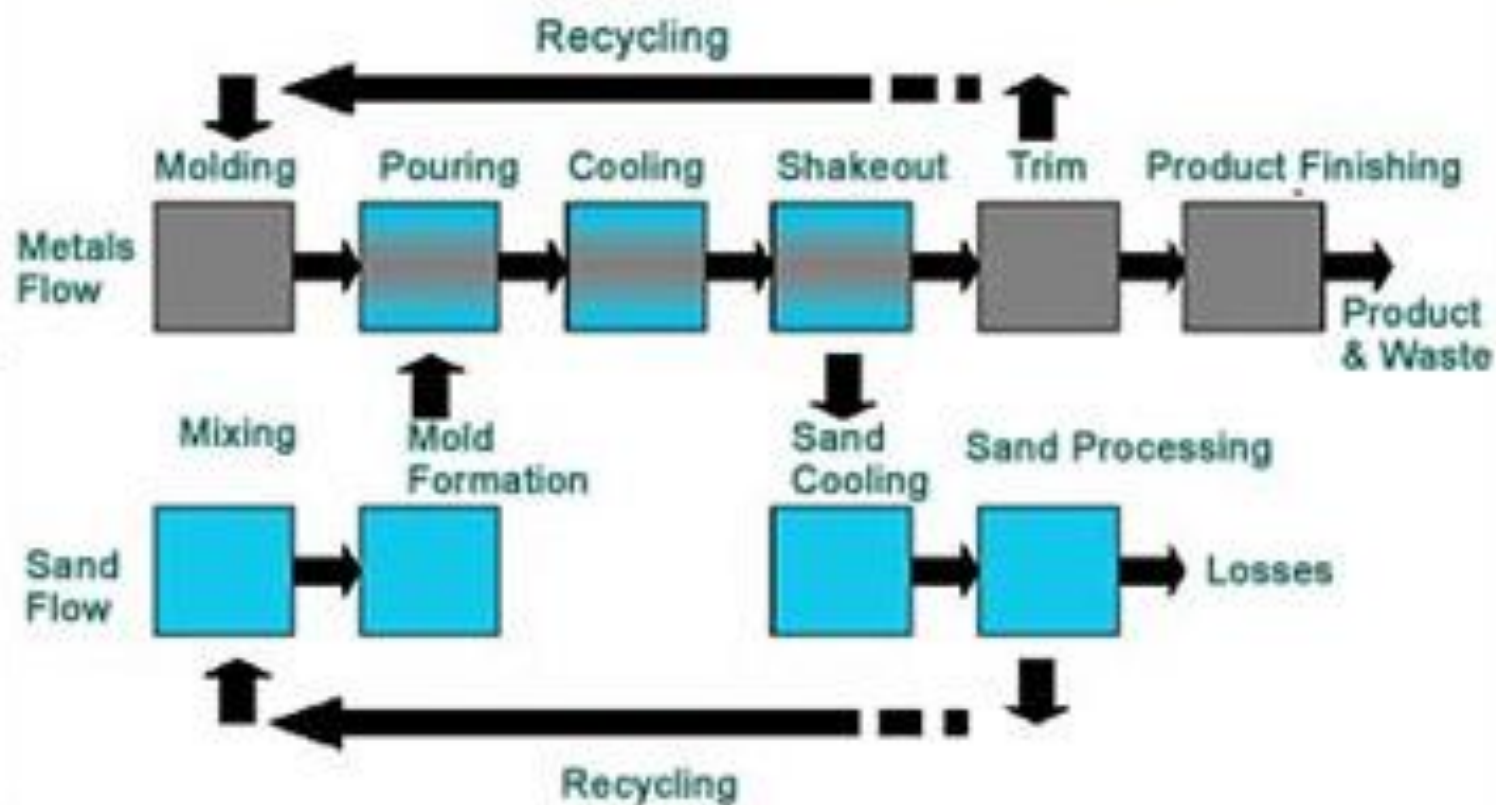
When parting lines are considered, very close tolerances cannot be obtained. Any parting line absorbs many fractions of inches per inch. A foundry is doing well to hold a parting line 0.015 in. Additional measurement is added to the casting tolerance.

Casting Steps

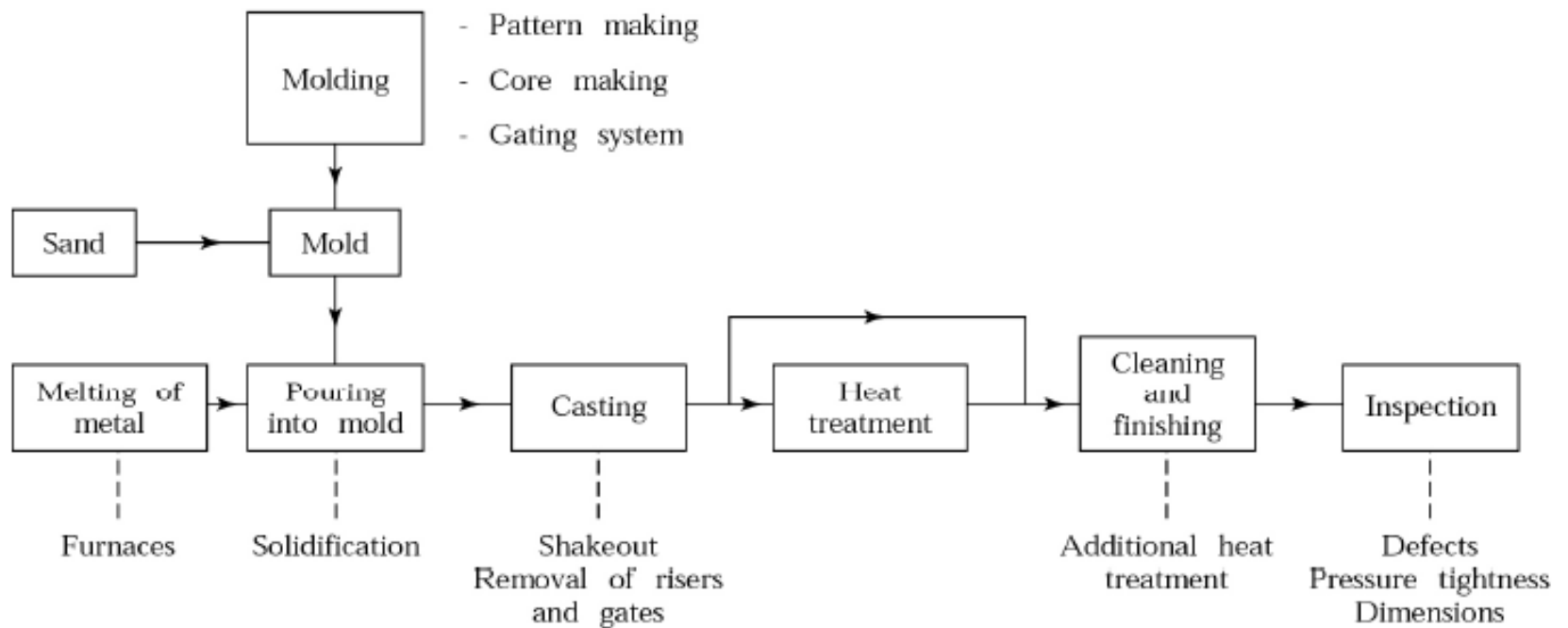
quick route from raw material to finished product

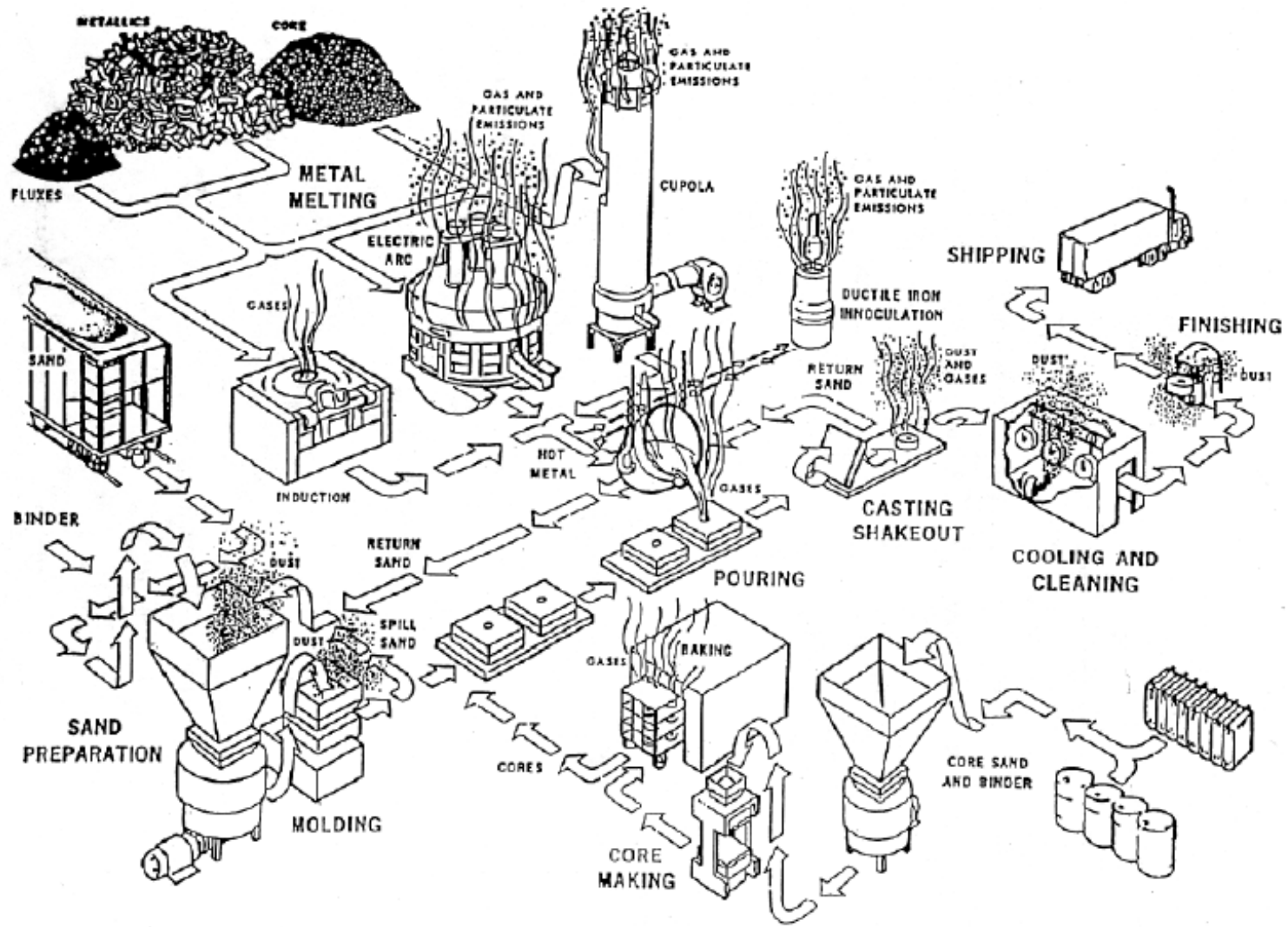
- Melt metals
- Pour / force liquid into hollow cavity (mold)
- Cool / Solidify
- Remove
- Finish

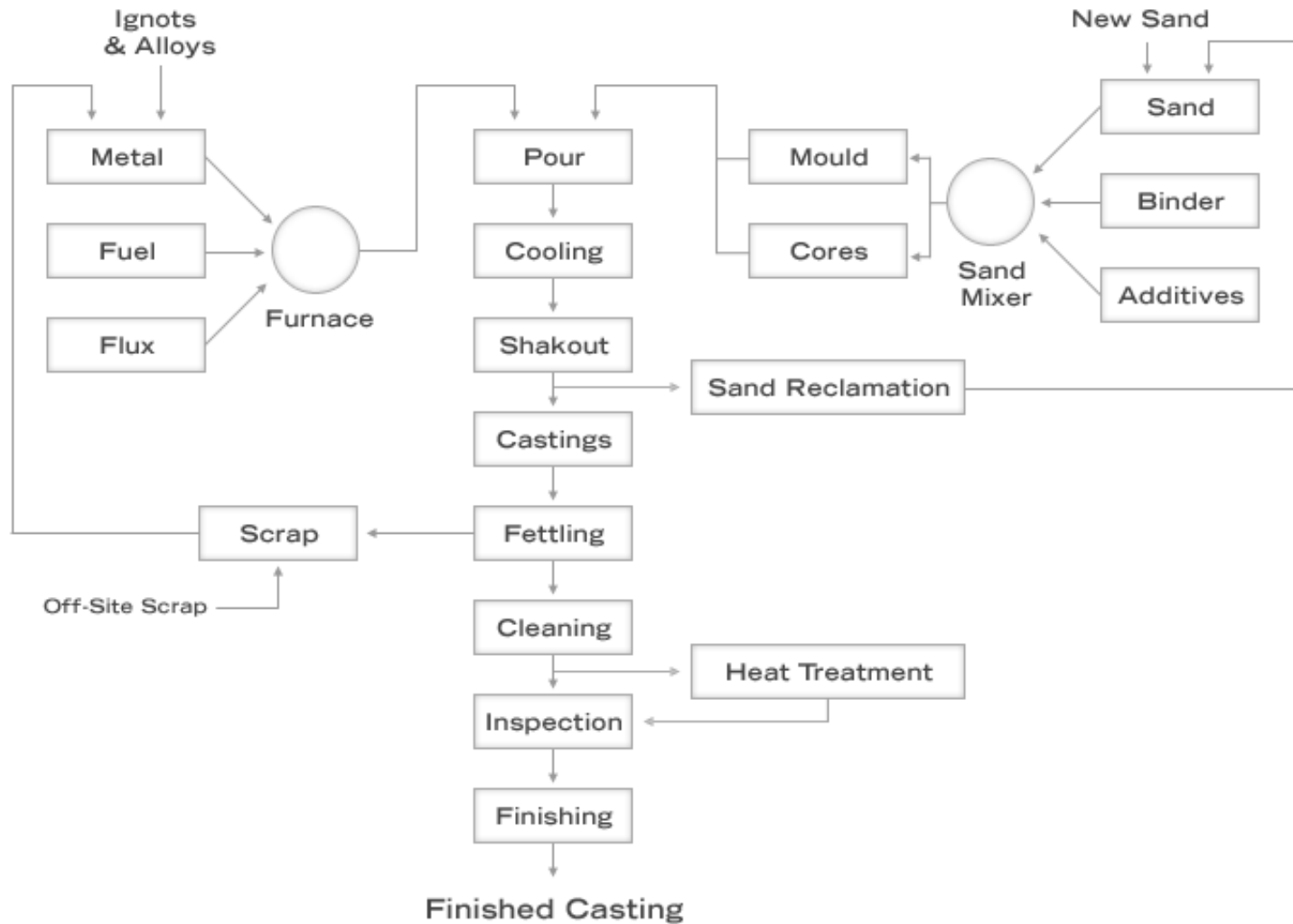
Sand Casting Process Flow Chart



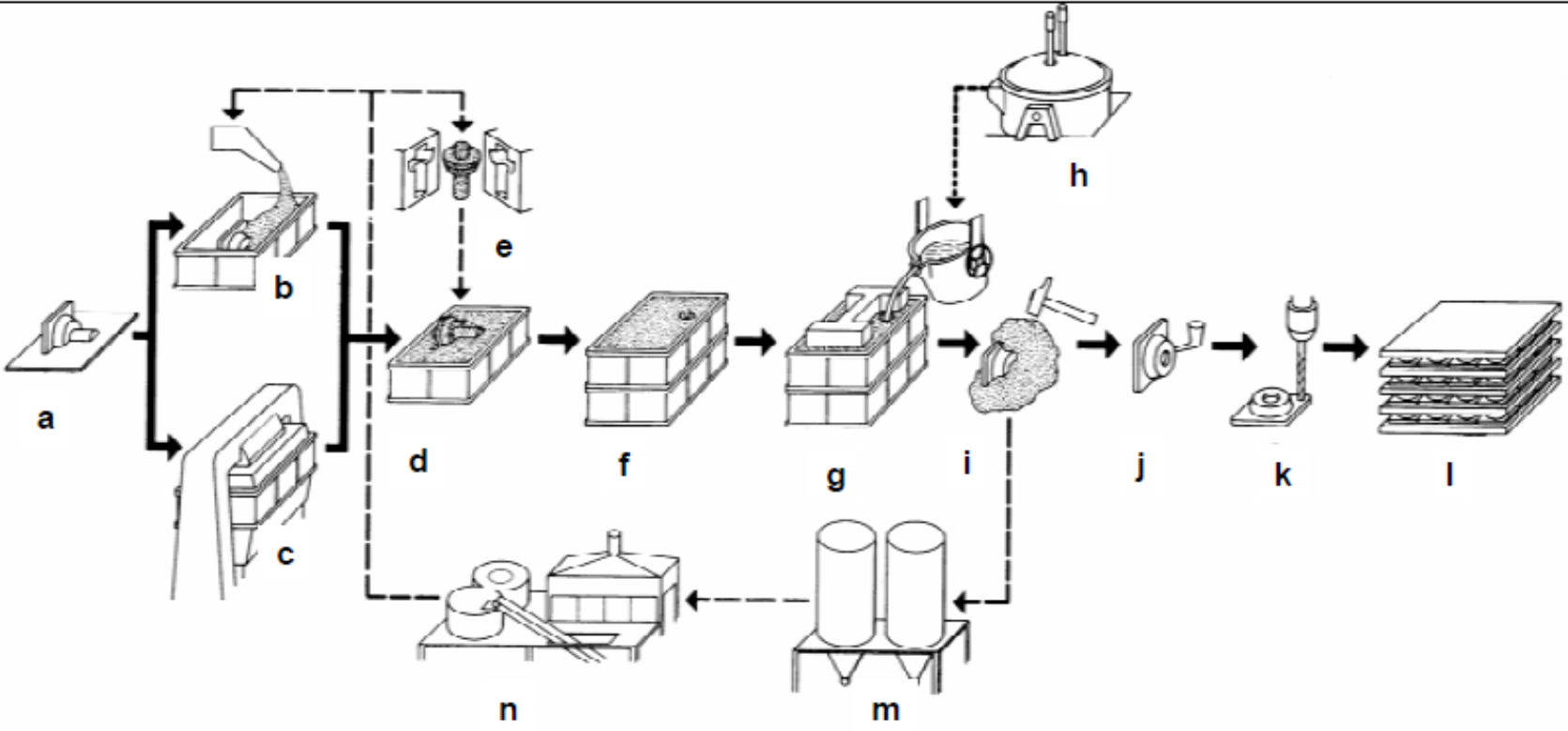
Sand Casting Steps







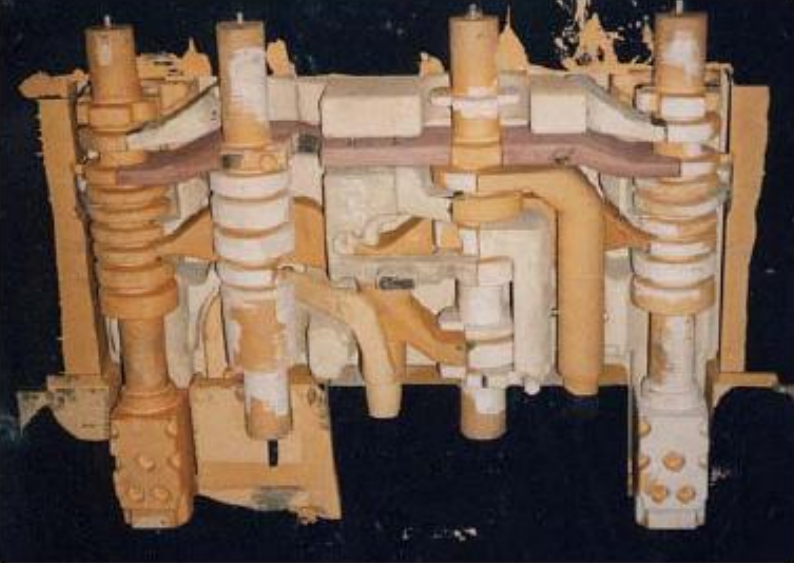
The route to the structural cast part



- | | | | | |
|----------------|----------------------------|--|----------------------------------|-----------------------|
| legend: | a: cast pattern | e: core moulding | i: shaking out | m: sand bunker |
| | b: hand moulding | f: setting the top box of the mould | j: casting cleaning room | n: sand plant |
| | c: machine moulding | g: casting | k: machining of cast part | |
| | d: core setting | h: melting | l: shipping | |

source: Spur

Example of application: Moulding shop

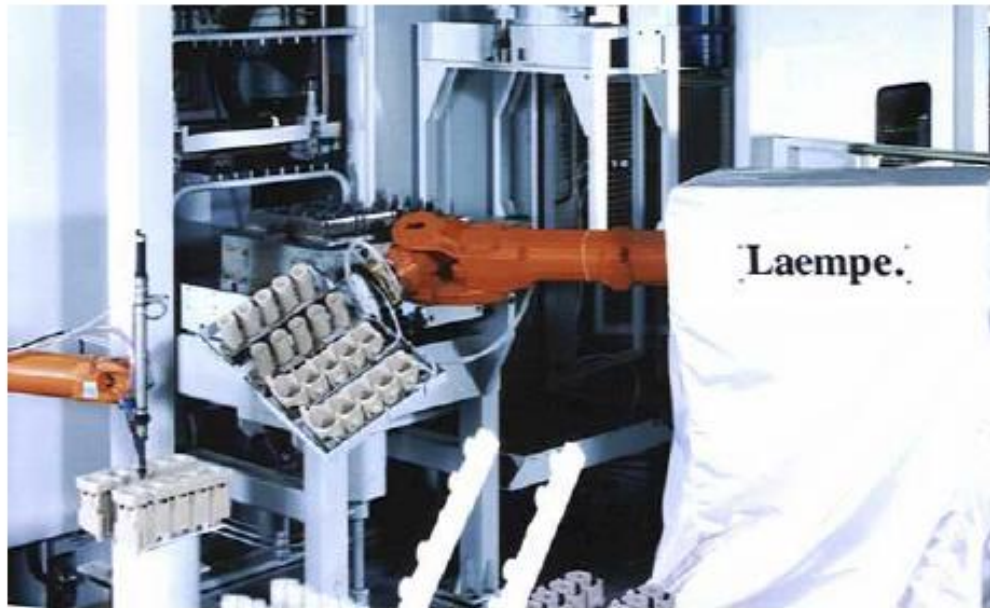


Example of application: Hand core moulding



Example of application: Automatisatisation at core production

unloading the cores out of the core shooter



core setting

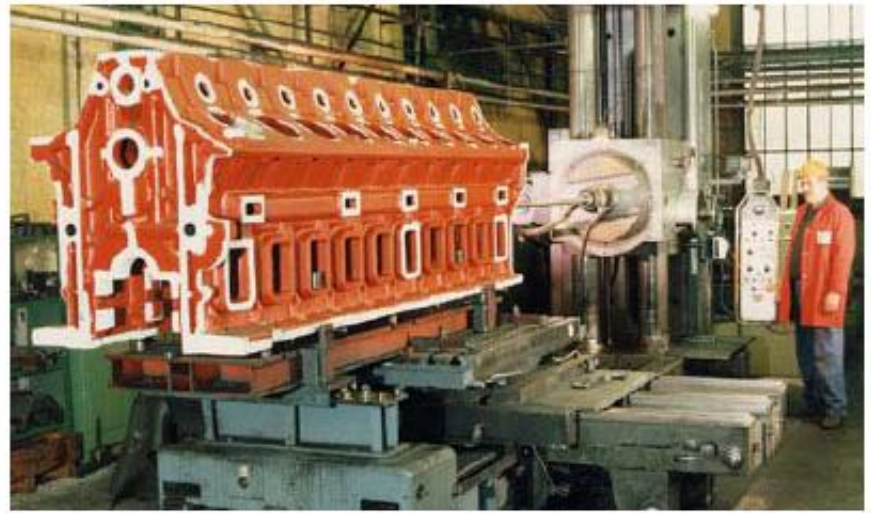


Example of application: Machining of cast parts

machining



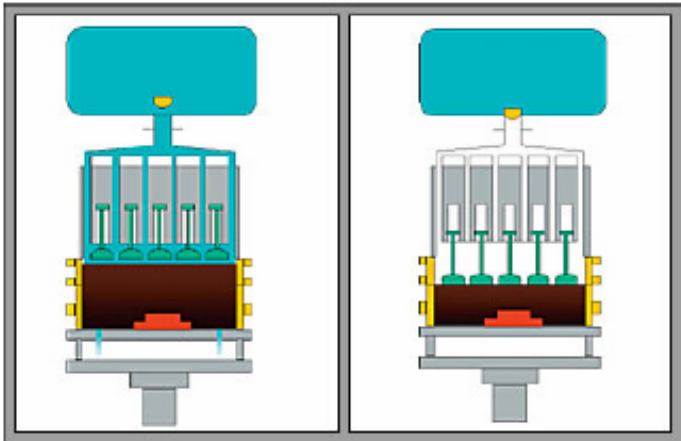
deep-hole drilling



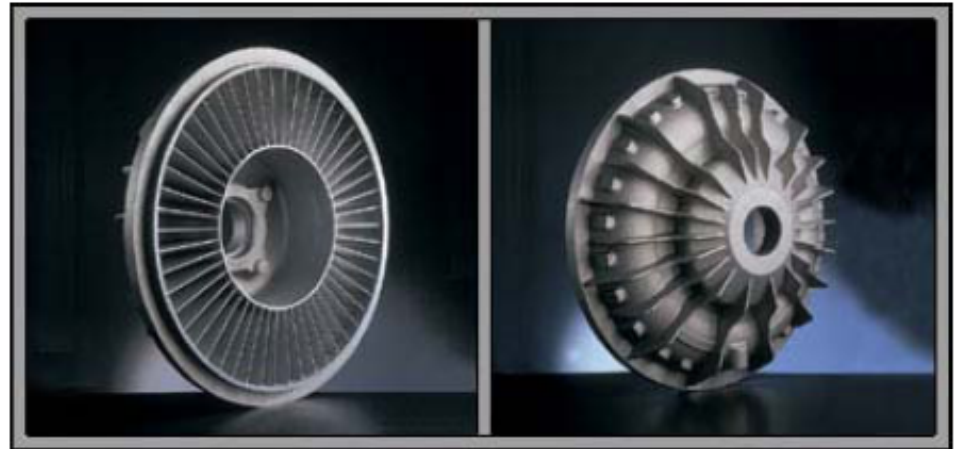
Production of sand moulds using the SEIATSU™-process

principle

SEIATSU™ Airflow Squeeze technology



example of application: cast part



Process characteristics:

The loose moulding sand is filled into the mould area formed by pattern plate/pattern bolster, mould box and filling frame. An air current is passed through and then the mould is compacted.

The air current flows through the sand from the back of the mould in the direction of the pattern and escapes through vents in the pattern plate. The air current moves the sand into the less accessible regions of the pattern and greatly improves and optimises compaction.

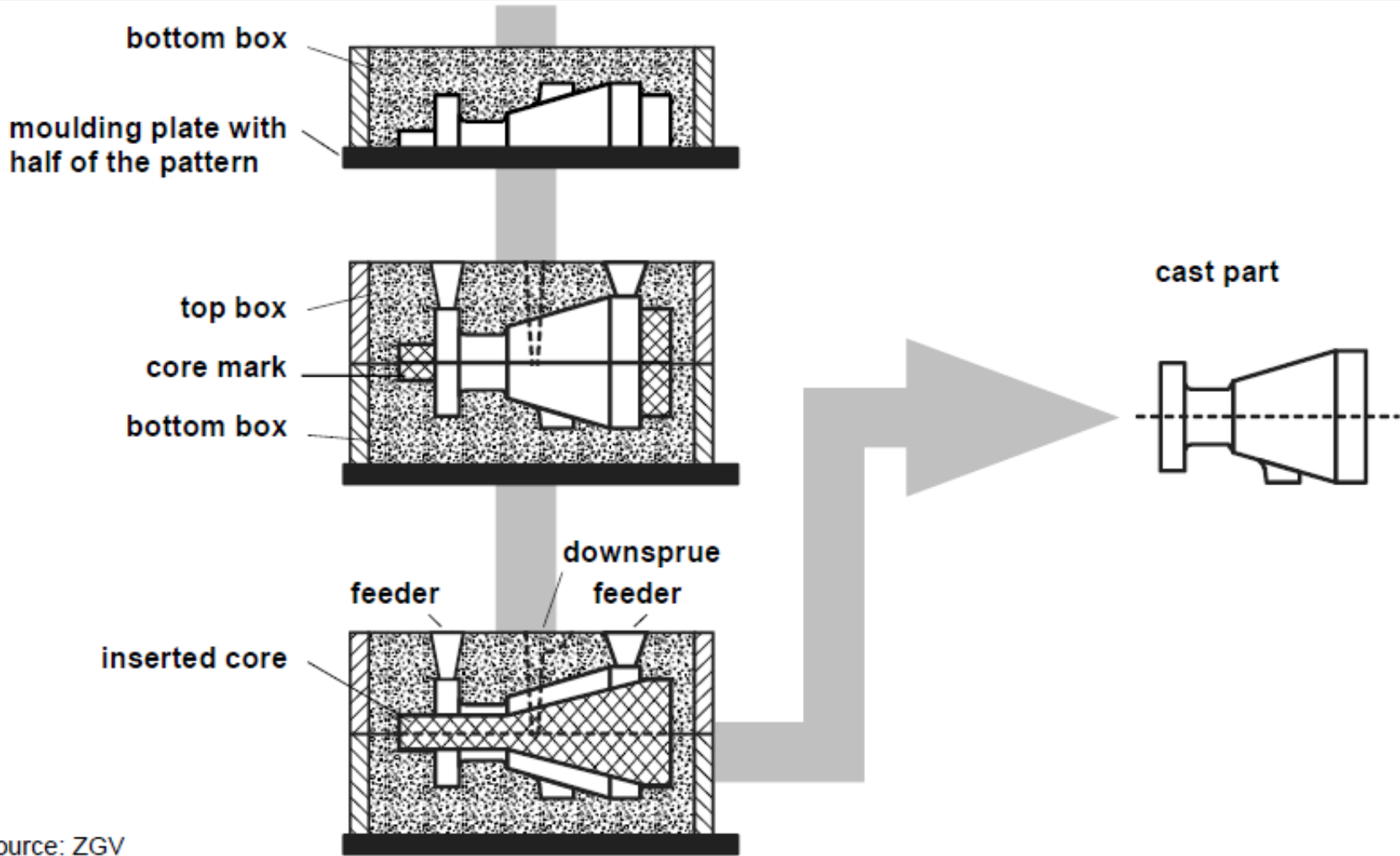
The final strength in the mould is built up in an after-pressing stage, using a fixed or a flexible pressure plate, a water cushion or a multi-platen press. The magnitude of the press pressure, as well as the pressure and duration of the air current can be controlled. This enables optimum mould strengths to be achieved to suit the individual application.

Survey: Casting in consumable moulds with permanent patterns

| Process | Hand moulding | Machine moulding | Shell casting | Shaw-process |
|---|---|---|--|---|
| Possible materials | all metals | all metals | all metals | all metals |
| Weights (mass) rough values | no restriction, available transportation equipment and melting capacity determine the upper limit | up to several tons, restricted by the size of the machinery | up to 150 kg | up to 1000 kg |
| Quantities, rough values | single parts, small batch series | small batch series up to large-batch production | medium batch series up to large-batch production | single parts, small batch up to medium batch series |
| tolerance range for 500 mm nominal size (*) | 2,5% up 5% | 1,5% up 3% | 1% up 2% | 0,3% up 0,8% |
| typical part | pump case | piston rings | ribbed cylinder head | hip-joint implate |

(*) : The specified tolerances are rough values for a nominal size of about ca. 500 mm; they depend on the grade of accuracy, the part size and the material.
 Material related tolerance specification see also DIN1680 and DIN 1683 up to DIN 1688.

Work flow of the sand casting process



source: ZGV

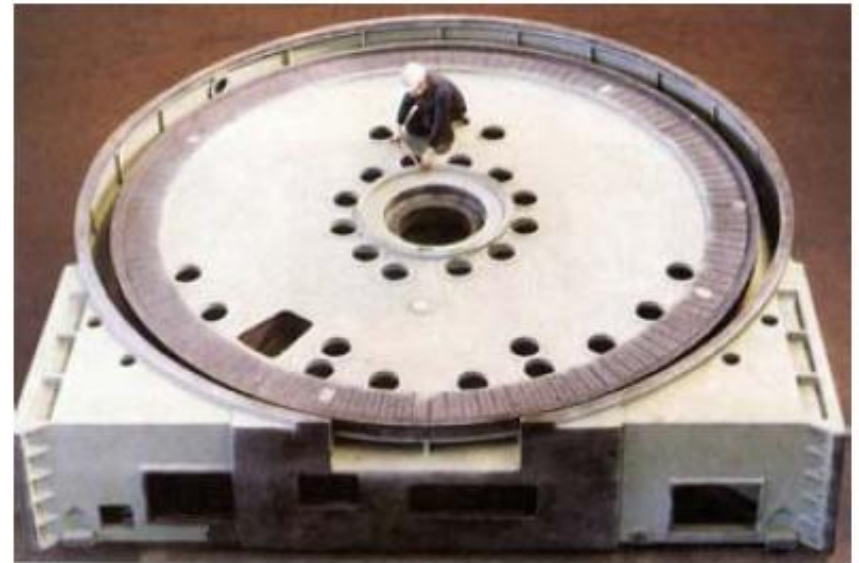
Examples for application - Sand casting (hand moulding)



Driving wheel for a belt drive

material: GJL-300

diameter: 2850 mm



Base of a vertical boring and turning mill

material: **GJL-200**

diameter: 5800 mm

weight: 44 t

Example of application - Components of a ship's propolsion



process: sand casting
material: CuAl9Ni7
CuAl10Fe5Ni5
weight: 1 propeller blade ca. 1300 kg
hub ca. 3000 kg

blade

hub

source: Zollem

Casting in sand at a semi-automatic moulding facility



Example of application: Pump case - sand casting



Pump case made of low alloy GJL-300

single weights: 362 resp. 144 kg

Example of application: Power transmission - sand casting



Truck wheel hub
(light weight design)
nodular cast iron
GJS-400-15
weight: 17.6 kg



Differential casting
nodular cast iron



Crankshaft
nodular cast iron
GJS-600-3
weight: 13.4 kg

Example of application: Aluminium sand casting



Suction inlet

Al - sand casting, G-ALSiCu3
weight: 16.8 kg



Oil pan

Al - sand casting / G-ALSiMg(wa)
weight: 4.5 kg



Clutch housing

Al - sand casting / G-ALSi9Cu3
weight: 44.6 kg

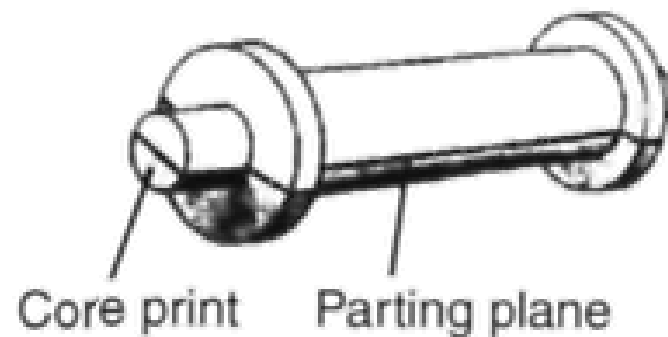


Figure 1.4 (a) A pattern, normally made of wood, is prepared as two halves. It is equipped with a so-called core print at the ends as dowels. Reproduced with permission from Gjuterihistoriska Sällskapet.

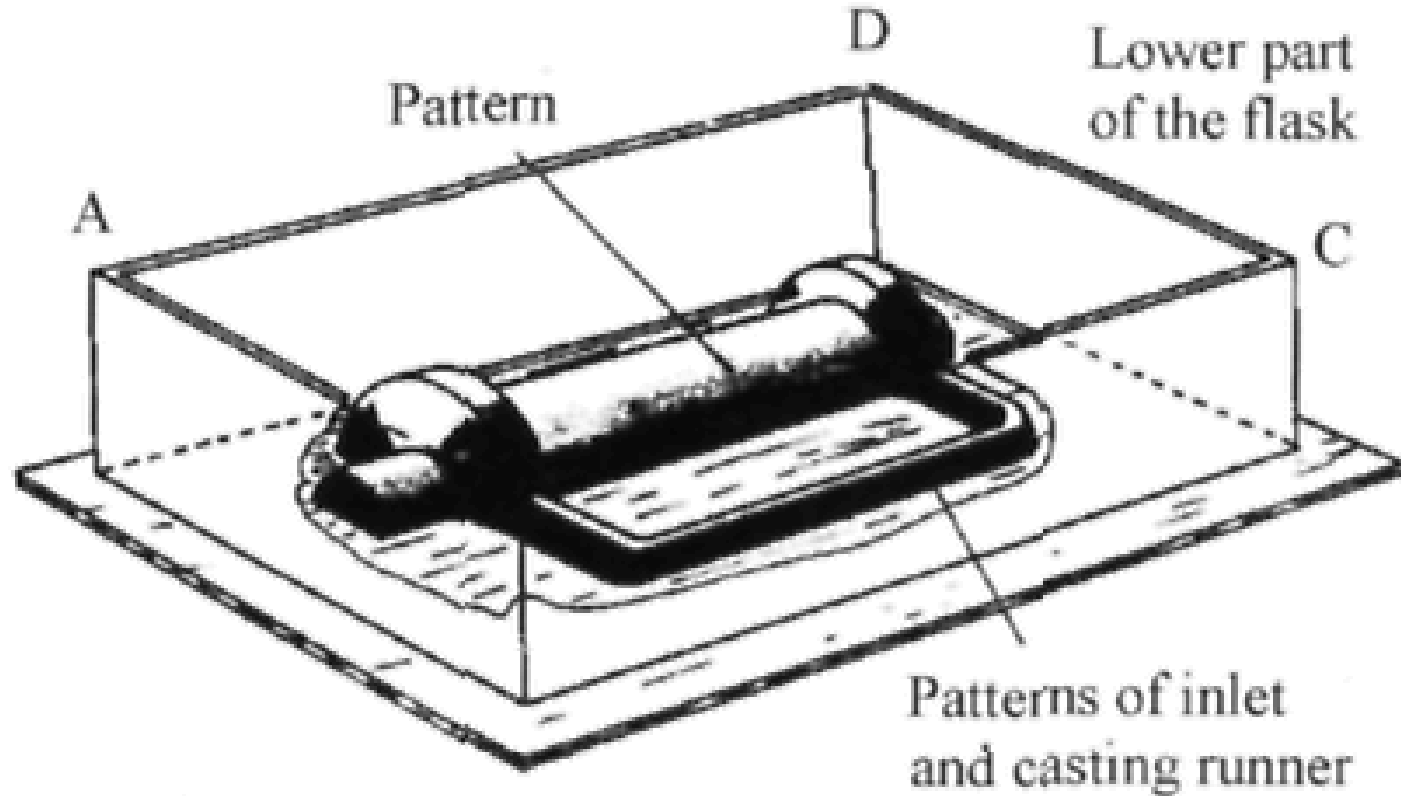


Figure 1.4 (b) Half the pattern and the patterns of inlet and casting runner are placed on a wooden plate in half a flask. A fine-grained powder, for example lycopodium powder or talc, is distributed over the pattern to facilitate the future stripping of the pattern [see Figure 1.4 (d)]. Reproduced with permission from Gjuterihistoriska Sällskapet.

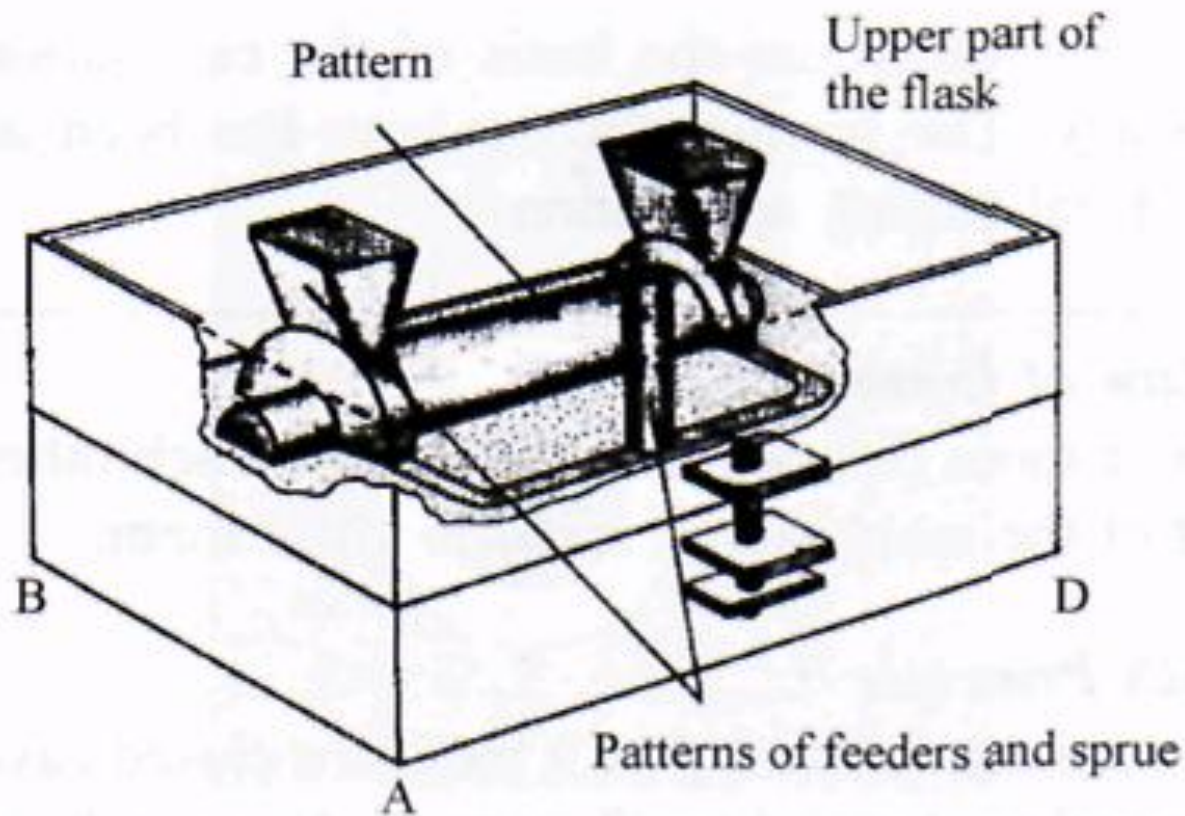


Figure 1.4 (c) The upper pattern half and the upper part of the mould flask are placed on the corresponding lower parts. A thin layer of fine-grained dry sand, so-called parting sand, covers the contact surfaces. Special patterns of the future sprue and the feeders are placed exactly over the inlets in the lower parts of the tube flanges. Reproduced with permission from Gjuterihistoriska Sällskapet.

Interface between
upper and lower
mould sections

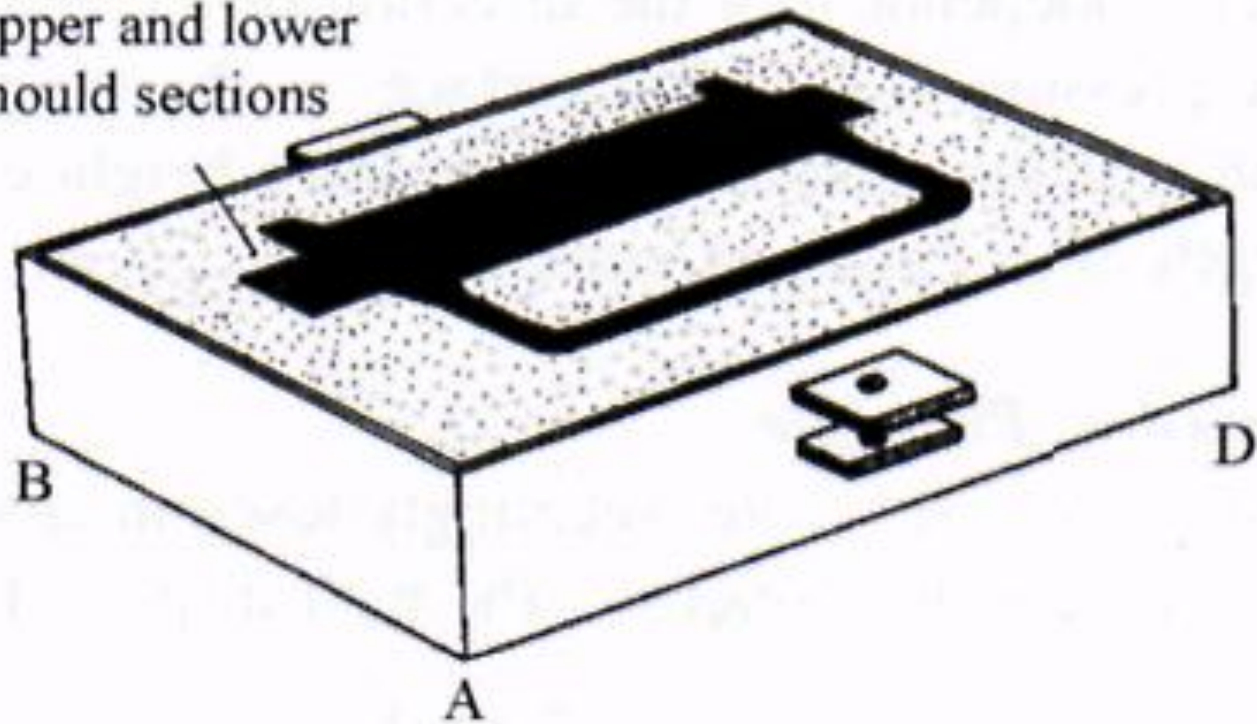


Figure 1.4 (d) The mould parts are separated and the pattern parts are stripped, i.e. lifted off the upper and lower parts of the mould. The patterns of the inlet, sprue and feeders are also removed. The figure shows the lower part of the mould after the pattern stripping. Reproduced with permission from Gjuterihistoriska Sällskapet.

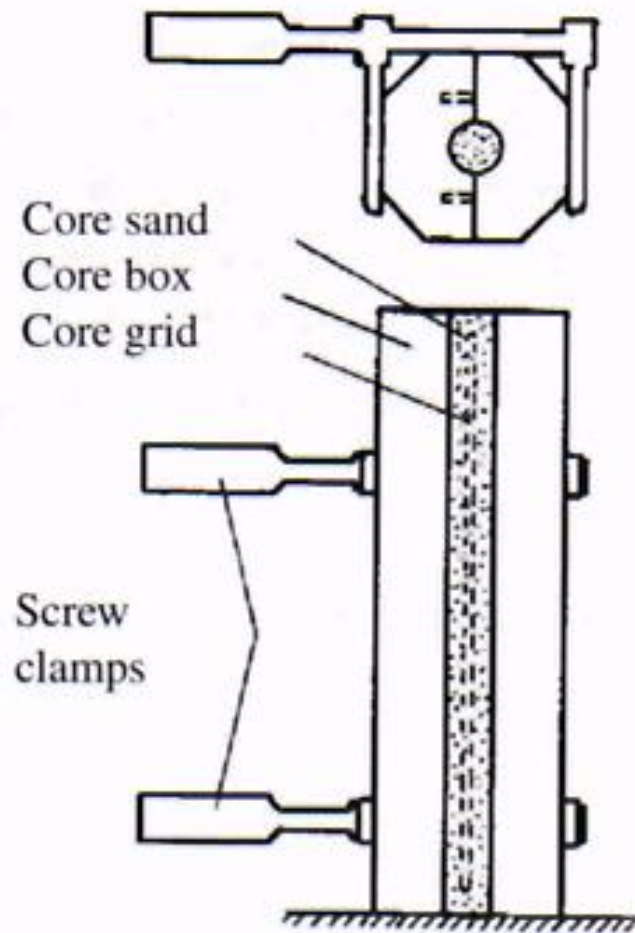


Figure 1.4 (e) The cavity in what will become the tube is formed by a sand core, produced in a core box. The two halves of the core box are kept together by screw clamps while the sand is rammed into the mould. A cylindrical steel bar is placed as core grid in the lengthwise direction of the core to strengthen the future core. Reproduced with permission from Gjuterihistoriska Sällskapet.

Sand core



ready for use

Figure 1.4 (f) The core is lifted out of the parted core halves. The core is often baked in an oven to achieve satisfactory strength. Reproduced with permission from Gjuterihistoriska Sällskapet.

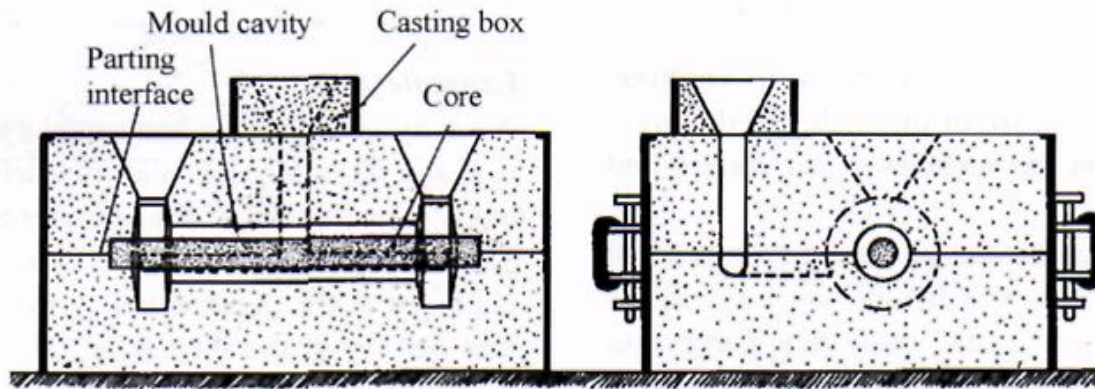


Figure 1.4 (g) The core is placed in the lower part of the mould. The parts of the mould are joined with the parting surfaces towards each other. The dowels through the holes in the outer walls of the flask parts guarantee the exact fit of the corresponding cavities in the upper and lower halves of the mould. A so-called casting box, which insulates the upper surface of the melt and prevents it from solidifying too early, is placed exactly above the sprue and the parts of the mould are kept together by screw clamps. The mould is ready for use. Reproduced with permission from Gjuterihistoriska Sällskapet.

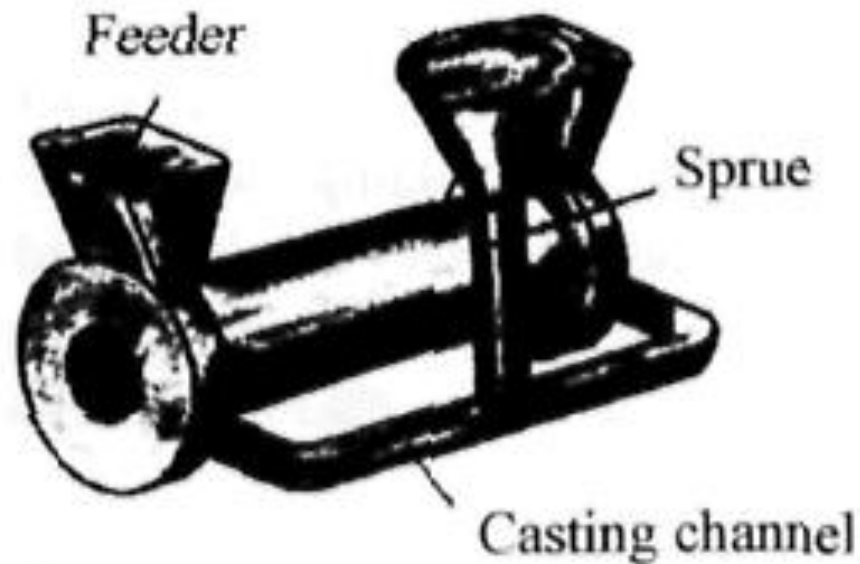


Figure 1.4 (h) When the casting has solidified and cooled after casting, the mould is knocked out. The casting is cleaned from remaining sand. The feeders and inlet are removed through cutting or oxygen shearing. The section surfaces are ground smoothed. Reproduced with permission from Gjuterihistoriska Sällskapet.

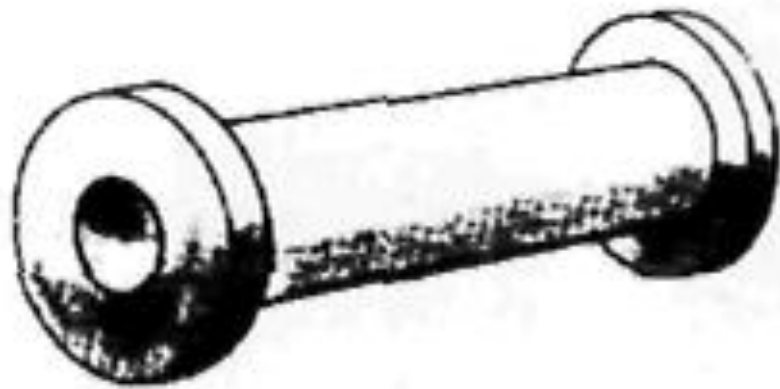


Figure 1.4 (i) The complete steel tube.

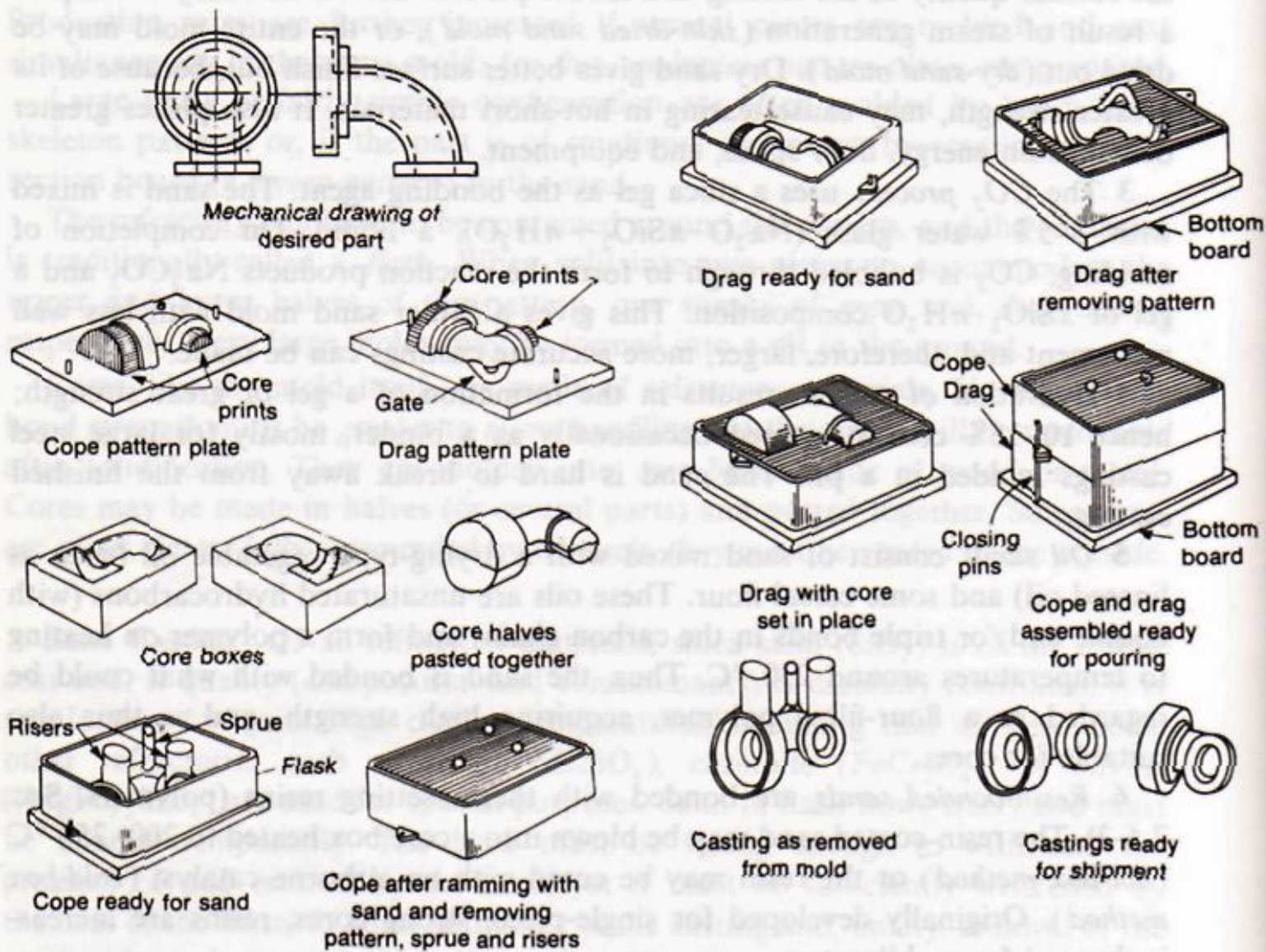


FIGURE 3-36

A typical sand molding sequence. (From *Steel Castings Handbook*, 5th ed., Steel Founder's Society of America, Des Plaines, Ill., 1980. With permission.)

TABLE 1.1 The sand mould casting method.

| Advantages | Disadvantages |
|--|---|
| Most metals can be cast | Relatively poor dimensional accuracy |
| Relatively complicated components can be cast | Poor surface smoothness |
| Single components can be produced without too high initial costs | |



BOT STICK

TAPPING STICK

11

DRAW SCREW

BELLOW

12

FLASK

MOULDING WEIGHT

FLAT BLADE SHOVEL

LADLE

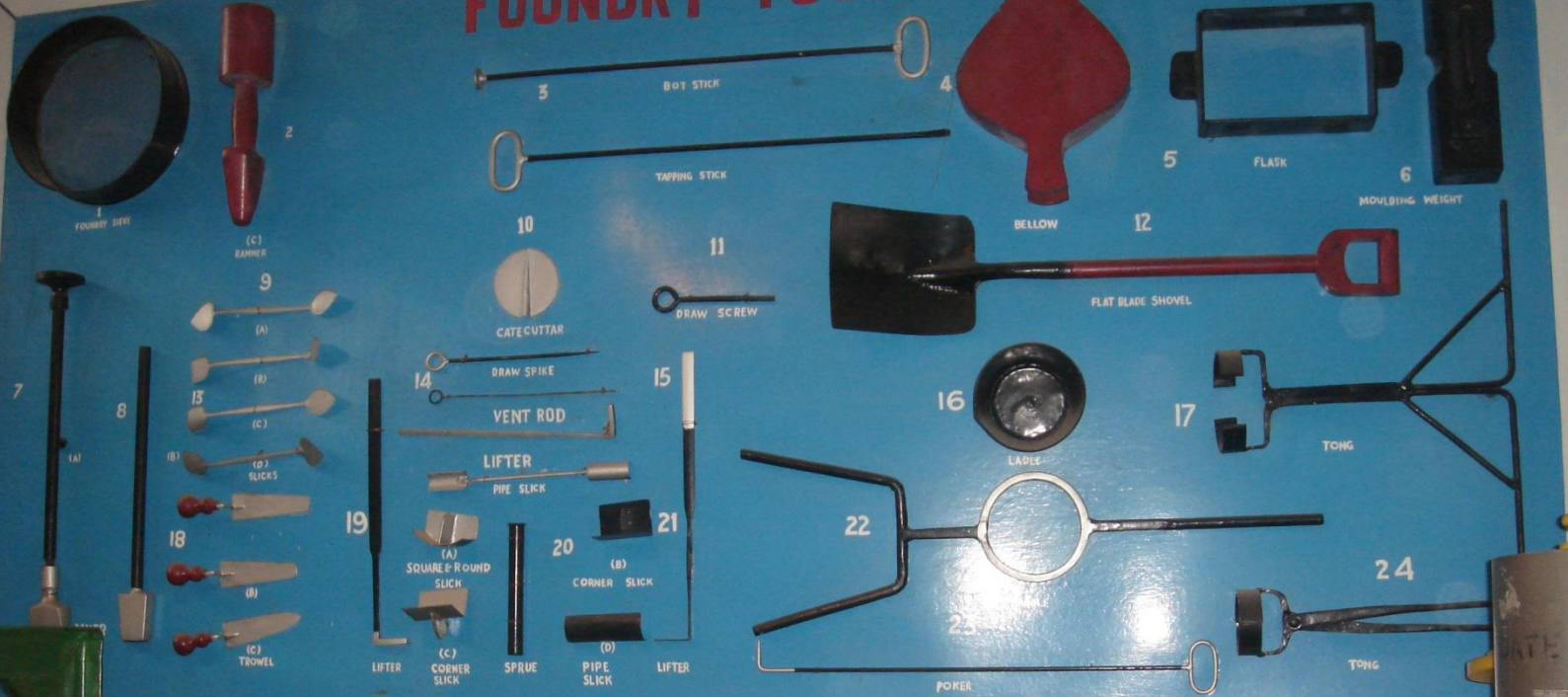
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HANDLE

POKER

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FOUNDRY TOOLS



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FOUNDRY TOOLS



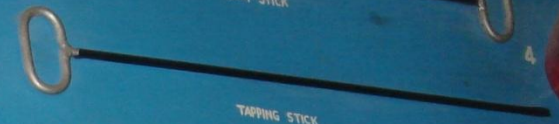
1
FOUNDRY SIEVE



2
(C)
RAMMER



3
BOY STICK



4
TAPPING STICK



7

(A)

HAMMER



8

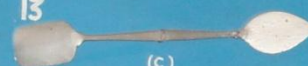


9

(A)



(B)



13

(C)



(B)

(D)

SLICKS



18

(B)



(B)



(C)
TROWEL



19

LIFTER



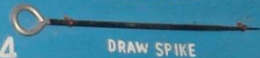
10

CATECUTTAR



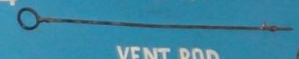
11

DRAW SCREW



14

DRAW SPIKE



VENT ROD

15



LIFTER

PIPE SLICK



(A)
SQUARE & ROUND
SLICK



(C)
CORNER
SLICK

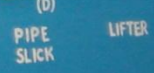


20

SPRUE



(B)
CORNER SLICK



(D)
PIPE
SLICK

LIFTER



21

(B)
CORNER SLICK

(D)
PIPE
SLICK

LIFTER



22

6 1 2008

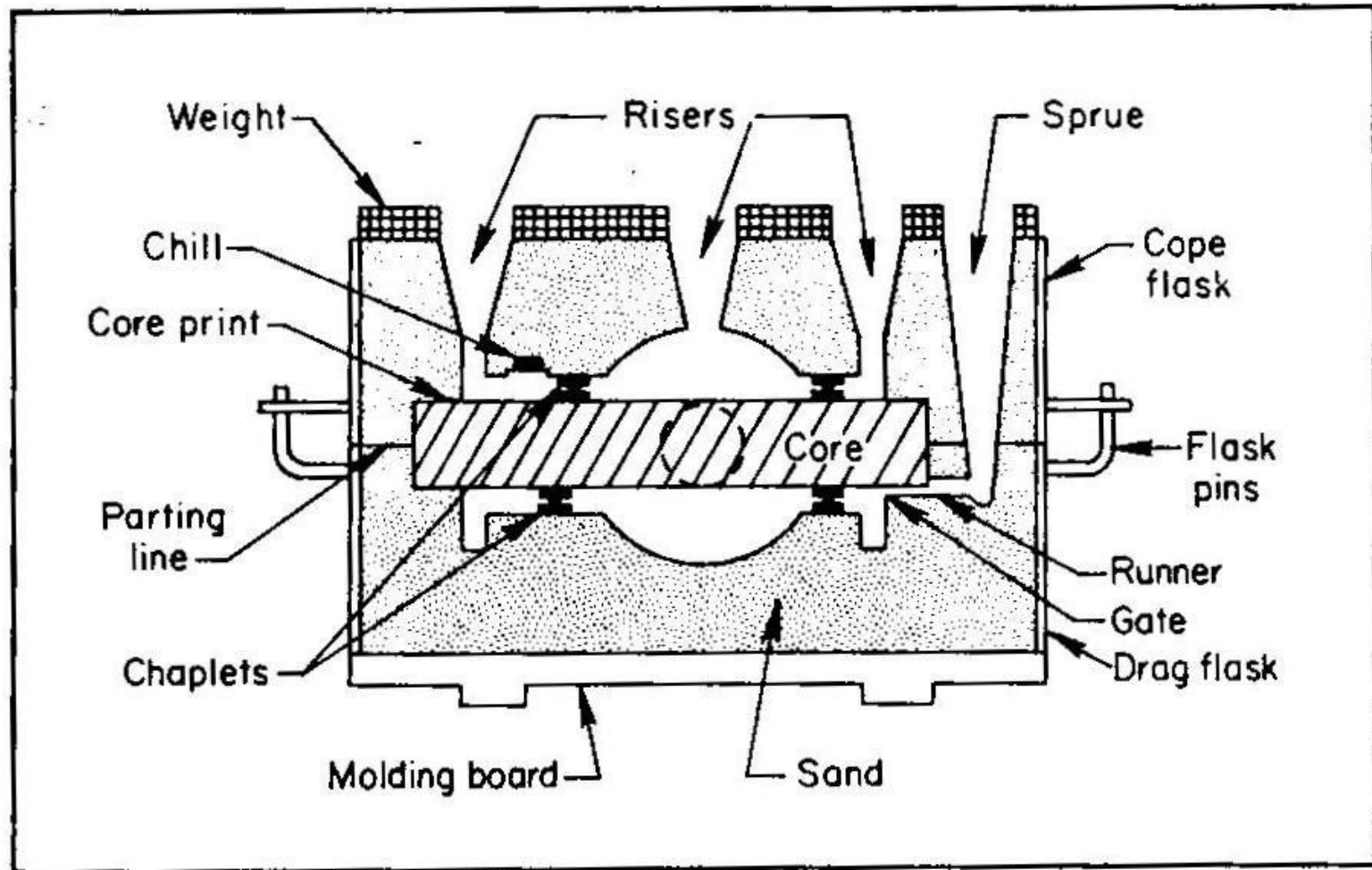
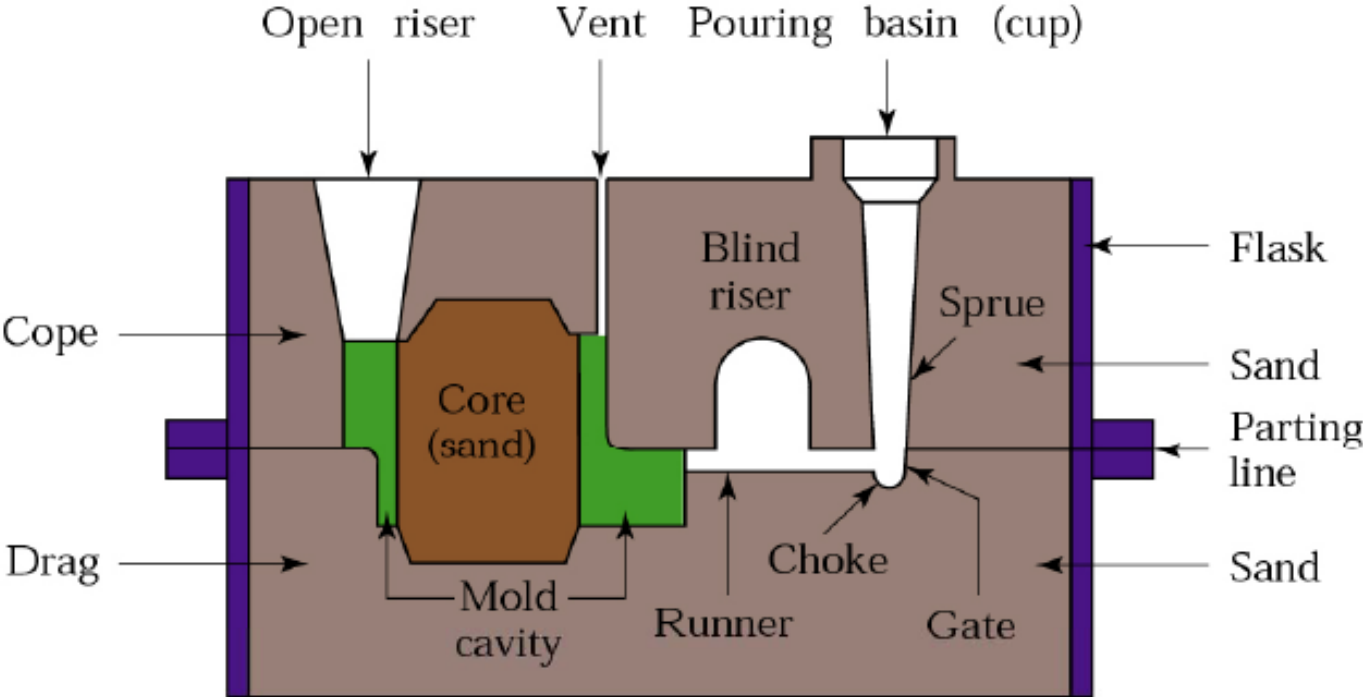
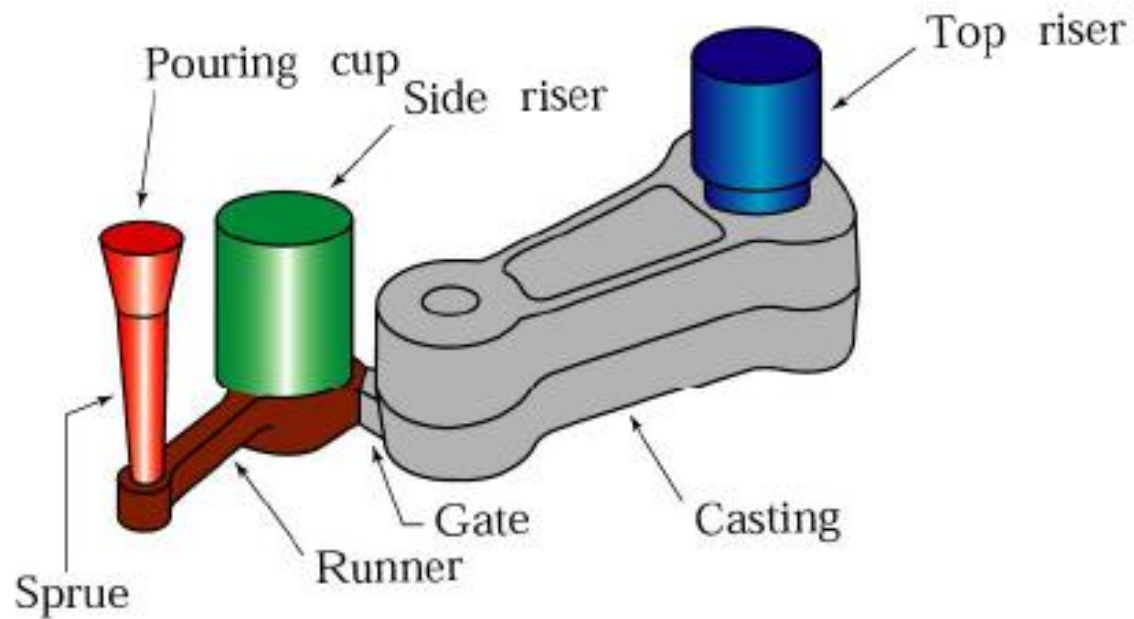


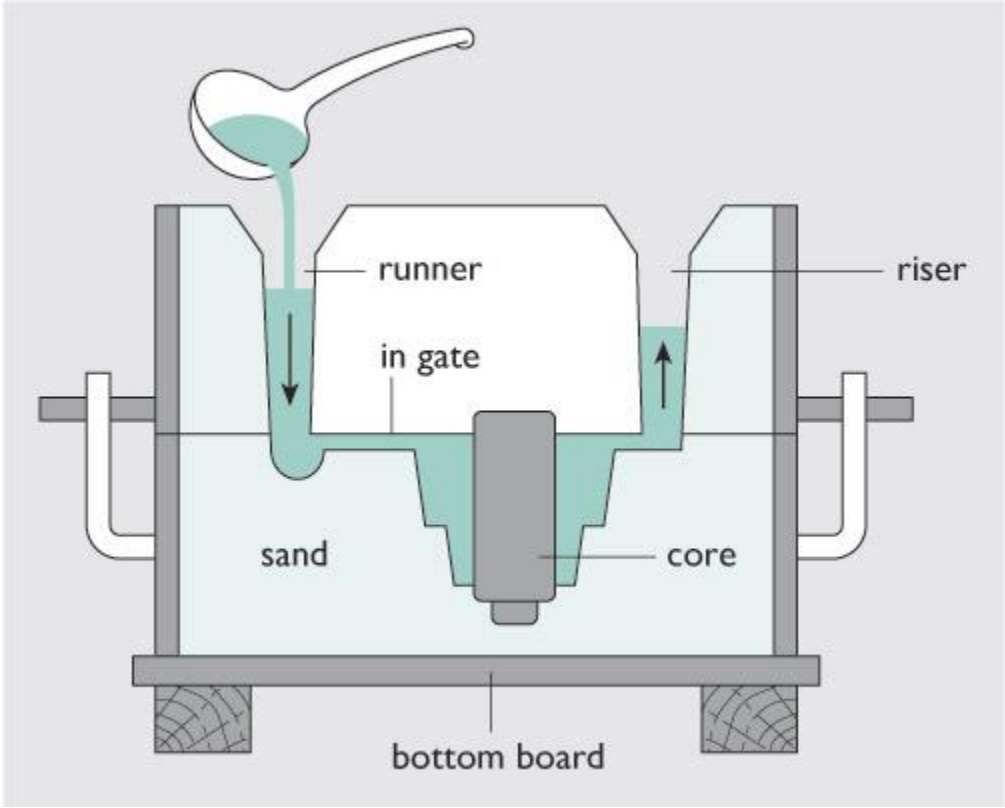
Fig. 2—Typical sand mold for ferrous and nonferrous castings.

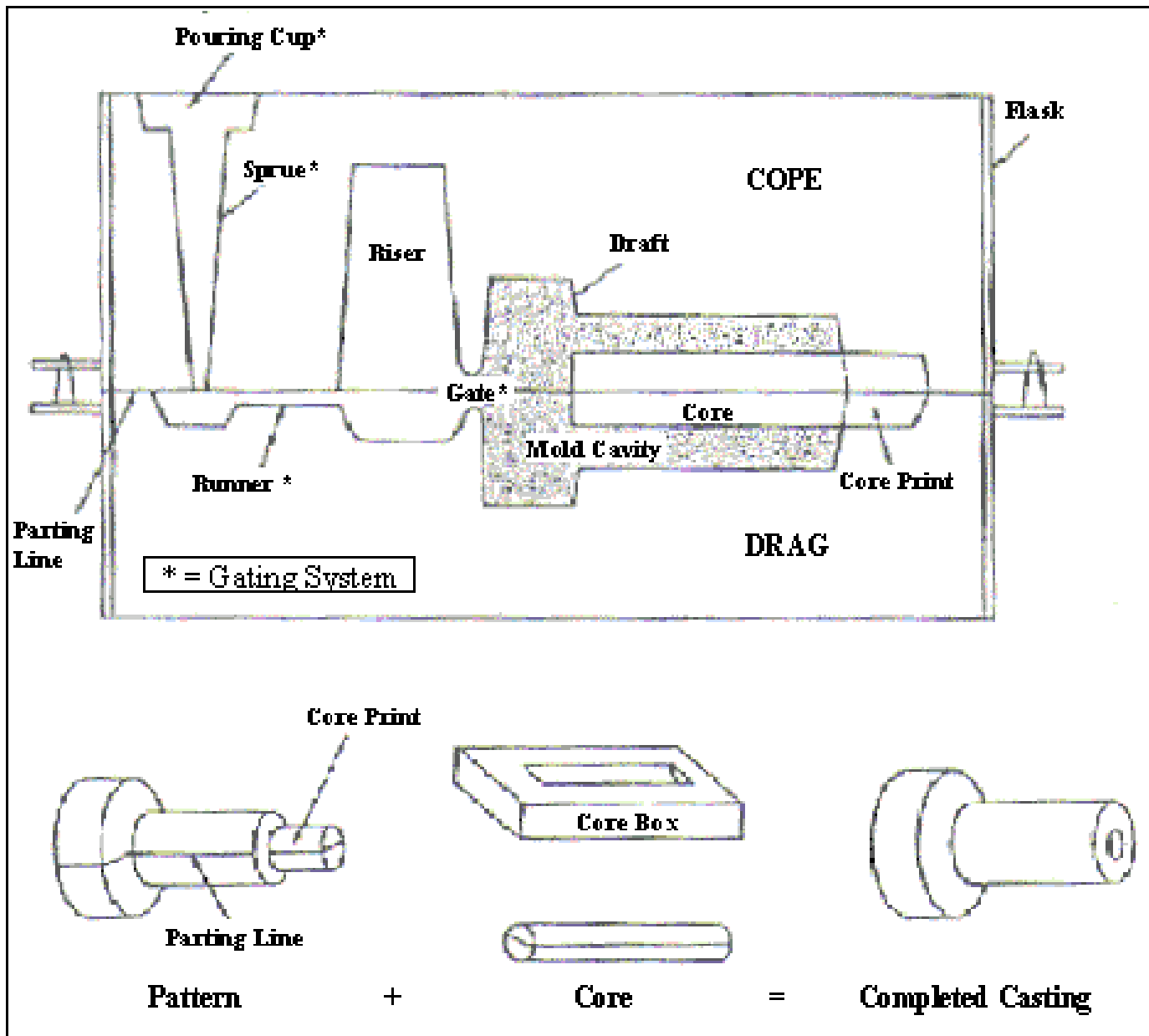
Sand Casting

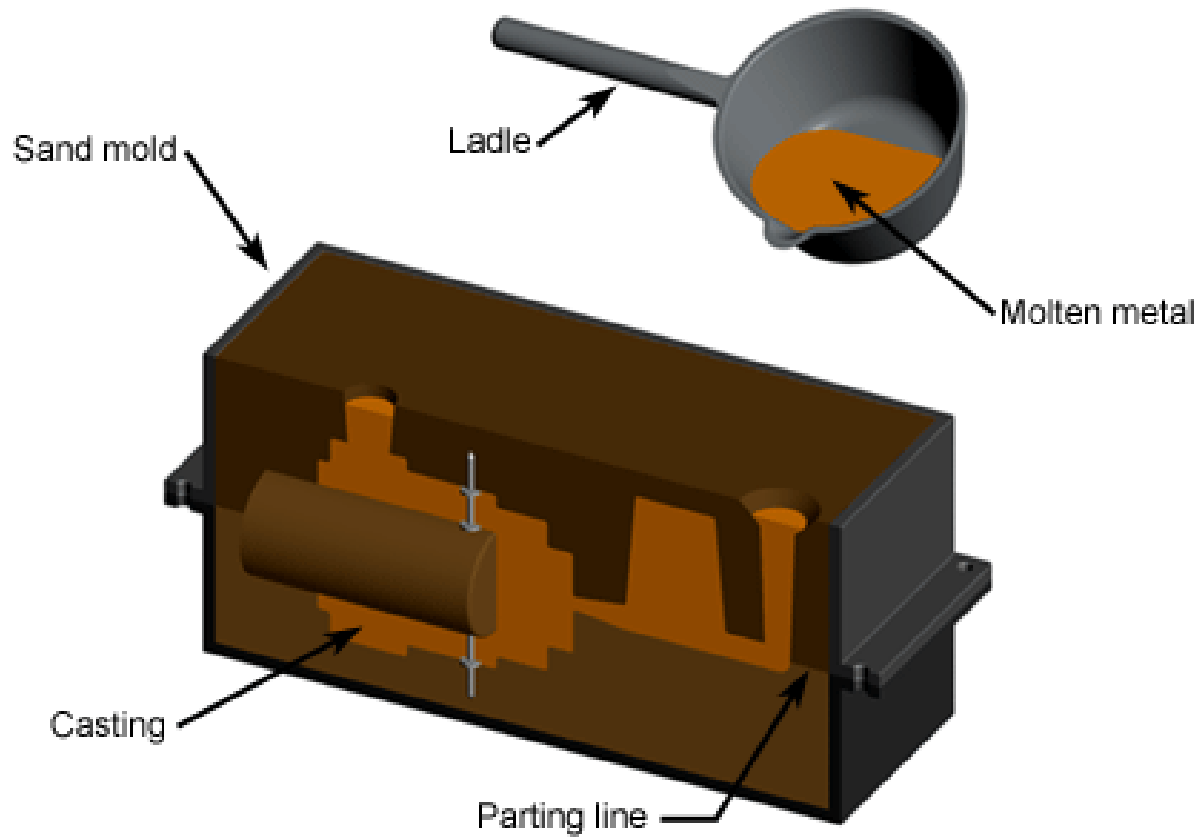


Sand Casting

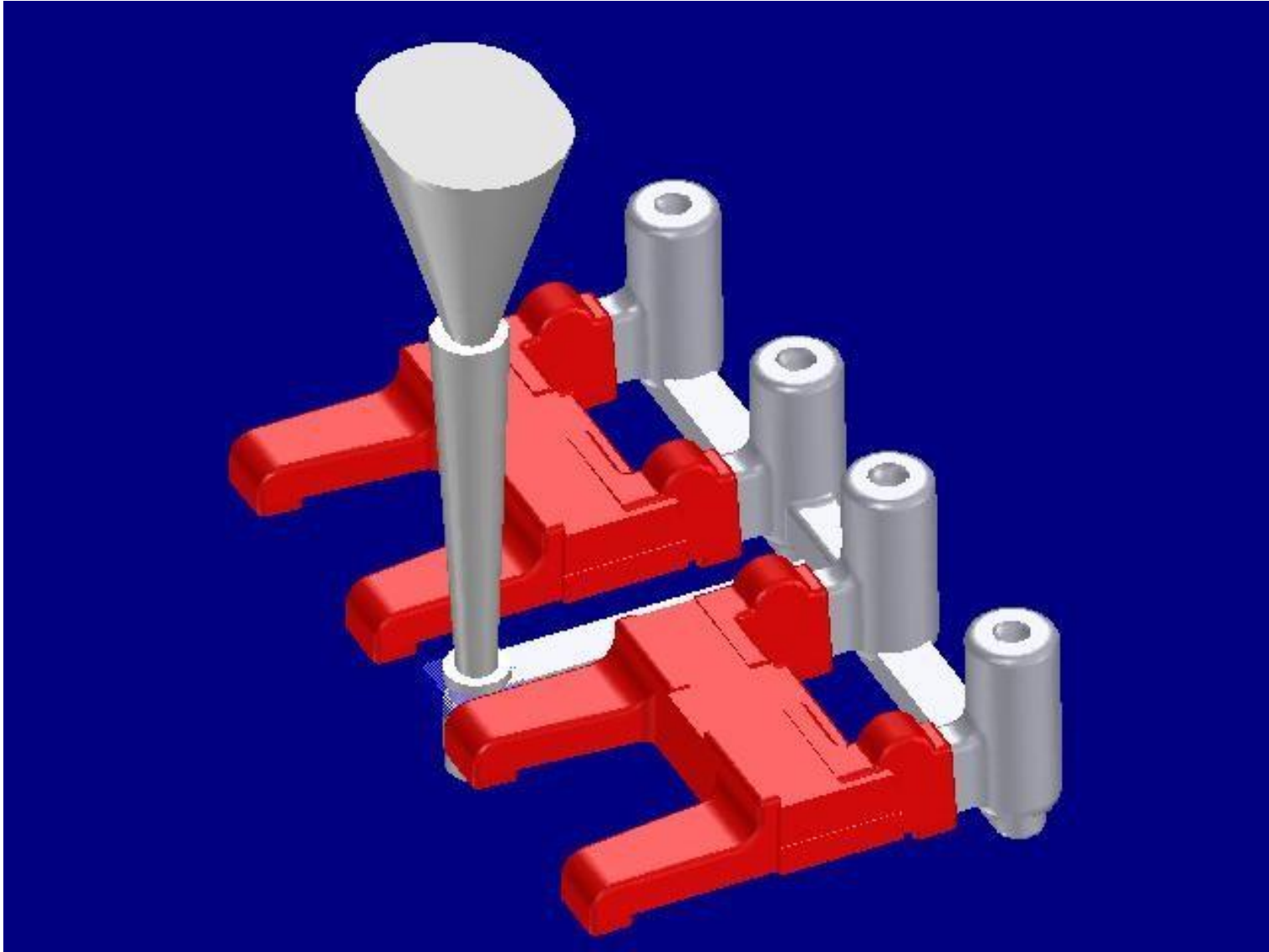




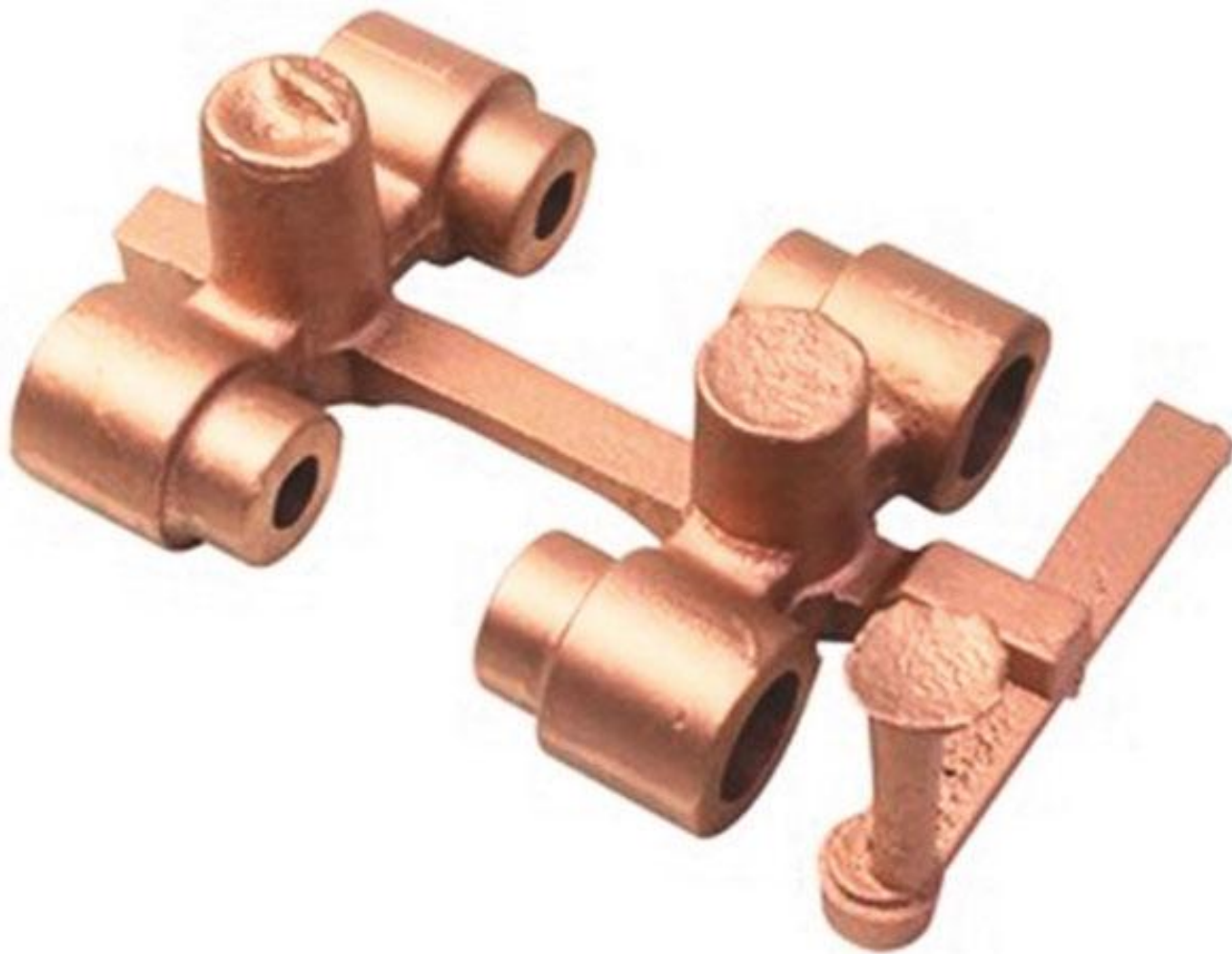




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Copper Alloy Casting



Sand Casting

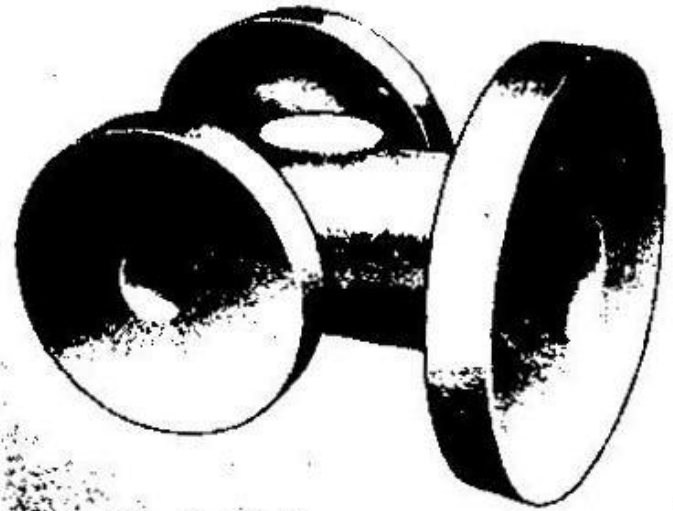


Green Sand Molds

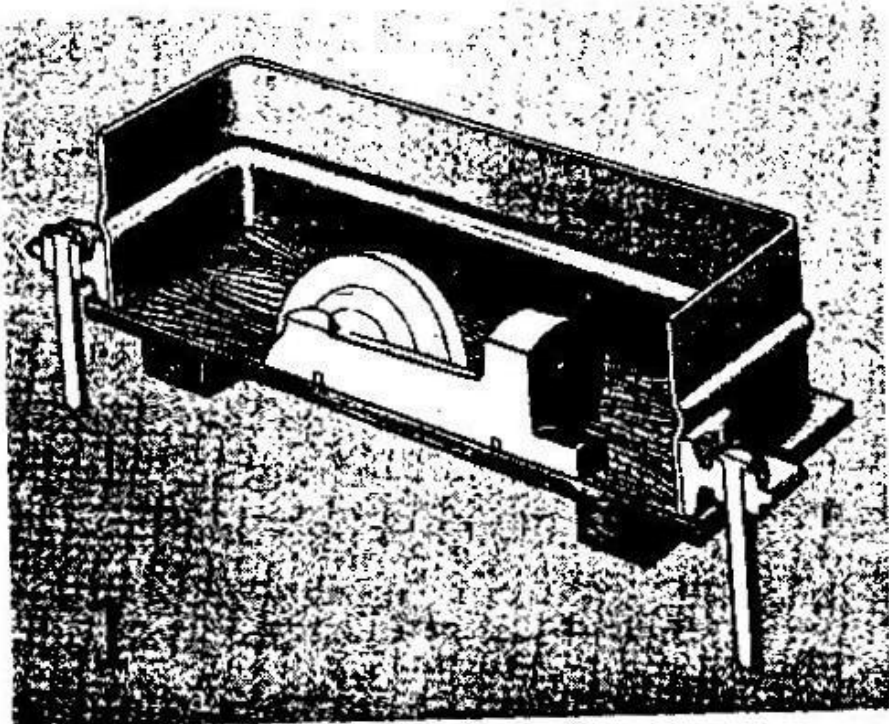
- This is the most widely used molding method for small to medium castings in all metals.
- The process utilizes a mold made of compressed or compacted moist sand. The term green denotes the presence of moisture in the molding sand, and indicates that the mold is not baked or dried.
- The advantage of green sand casting is that the process can be of short time cycle; e.g. sand preparation, mold making; closing, pouring and shakeout are ideally suited to a mechanized, continuous process.

- Green sand is the best known of all the sand casting molding methods, as the molds may be poured without further conditioning. This type molding is most adaptable to light, bench molding for medium sized castings or for use with production molding machines.
- The majority of all small, repetitive, medium and medium-heavy castings are made in green sand molds. Automotive castings, farm machinery, household equipment, valves, fittings, internal combustion engines, pumps, compressors, railroad parts, mining parts, construction machinery and castings for general industrial usage are made from green sand molds.

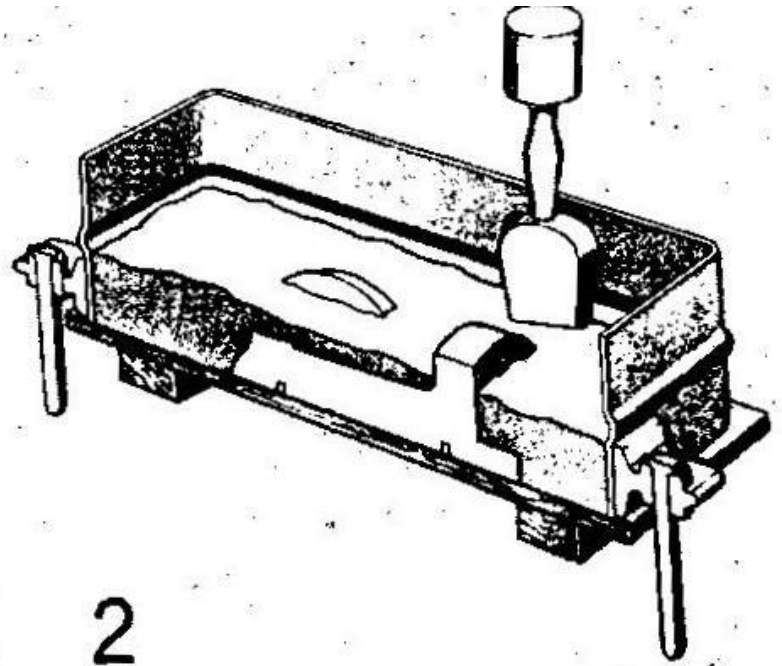
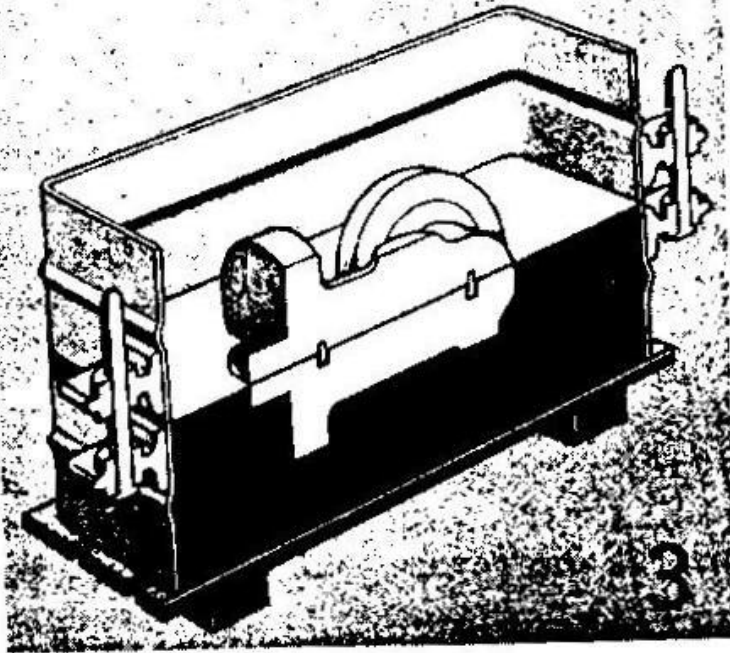
Iron casting to be produced
in the subsequent
illustrations of molding.



Cross section of the first step
in making a green sand
mold. Bottom half of the
pattern is on the mold
board and surrounded by
the bottom or drag half
of the flask.

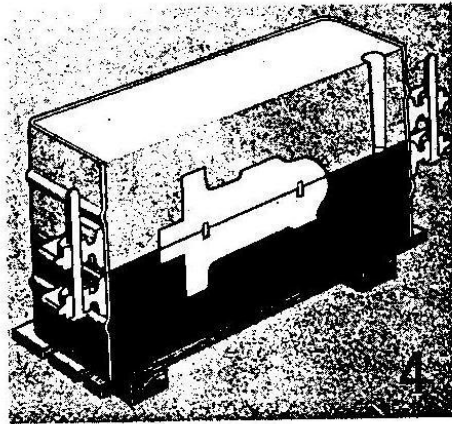


Molding sand is rammed
around the pattern in
multiple steps to provide
uniform density.



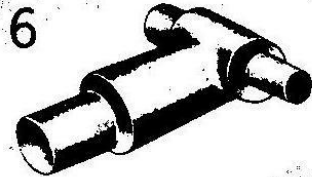
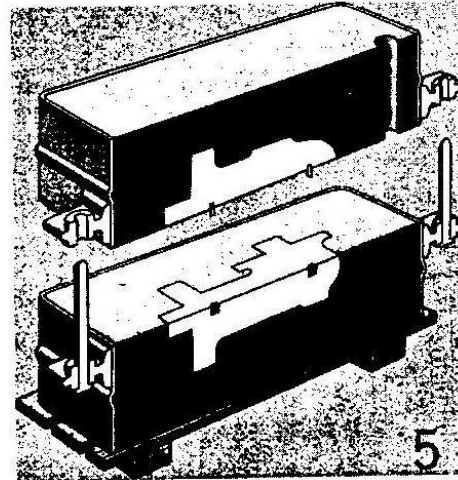
After the bottom half of the
mold is filled, it is rolled
upright and the top half of
the pattern and flask are
put in place to
complete the mold.

Fig. 1



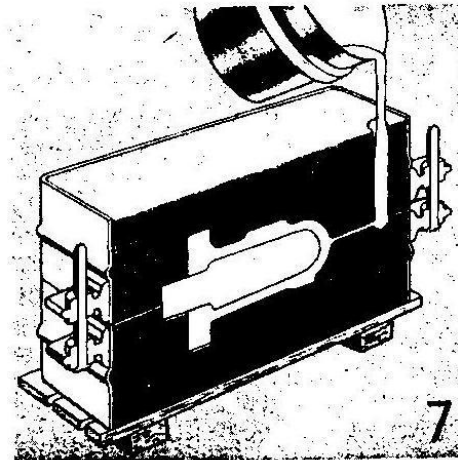
Section through the completed mold with pattern still in place and the sprue hole formed for entrance of molten metal.

Cope and drag halves of mold are separated in order that the pattern may be removed. The gate channel is then cut from the sprue to the mold cavity.



The core of bonded sand is made separately to form the internal passages of the casting.

After placing core in the mold, it is closed and clamped to resist the pressure exerted by the molten metal when it is poured in the mold.



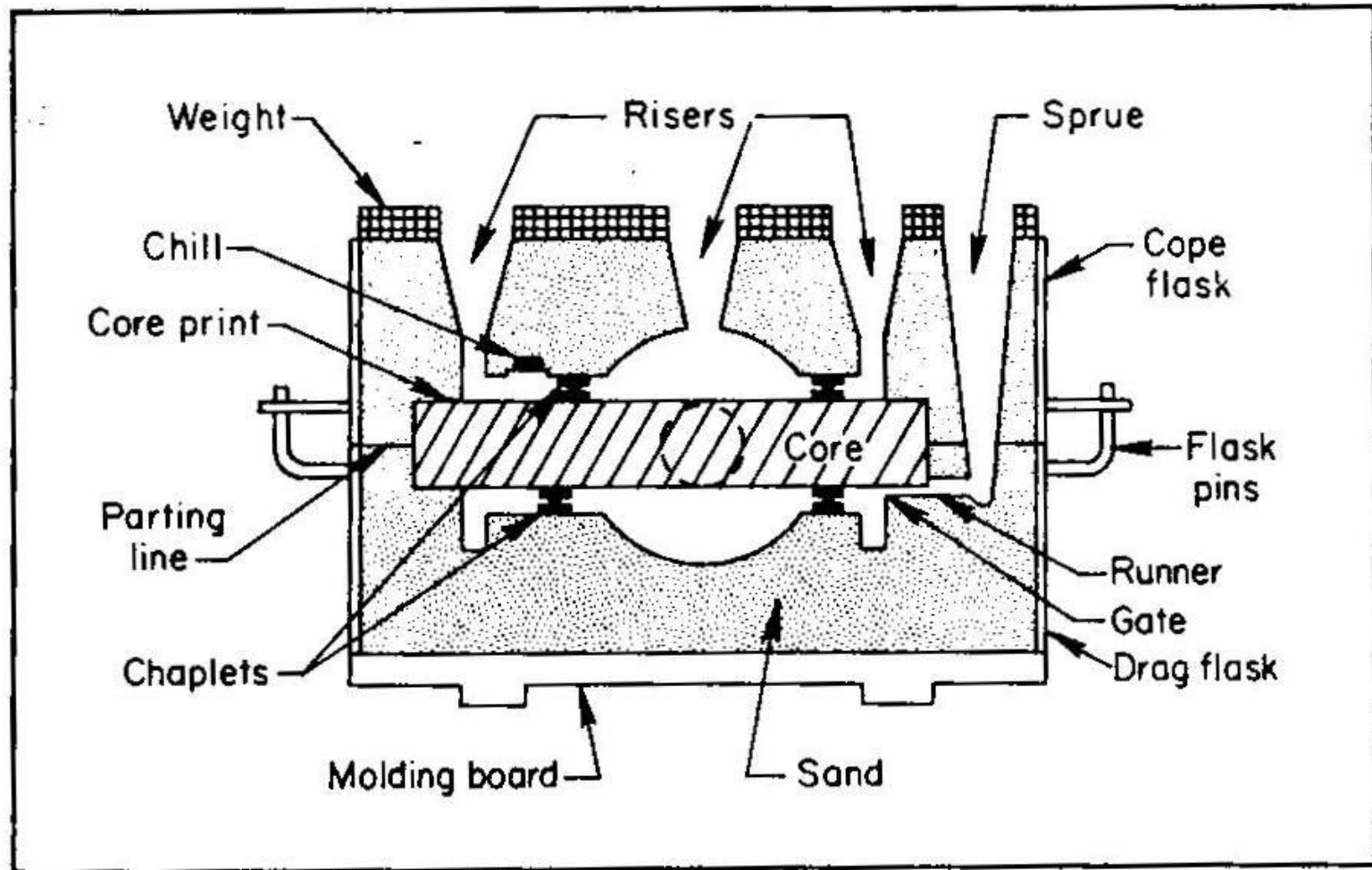


Fig. 2—Typical sand mold for ferrous and nonferrous castings.

- Green sand is used in both the ferrous and nonferrous industries to a far greater degree than all other molding processes combined.
- About 90 per-cent of the approximately 20 million tons of castings produced annually in the US are produced in green sand molds.

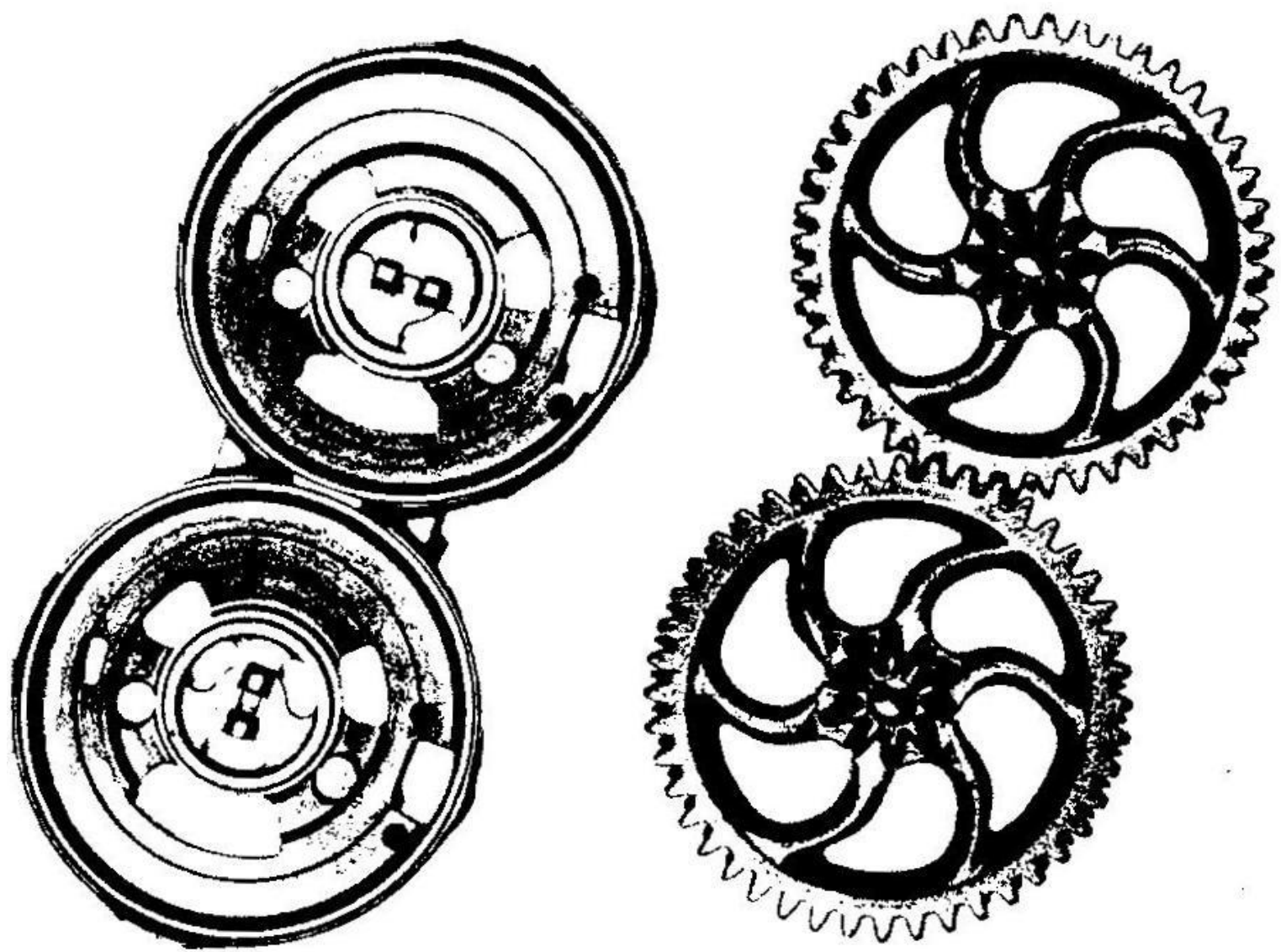


Fig. 4—All cast in green sand molds.

High Pressure (High Density) Molding

- There have been dramatic changes in foundry molding systems in the past decade.
- 20 years ago, a foundry producing 3000 or 4000 molds in a day could have 20 or more molding machines. This volume of production is being produced today in many foundries on one automatic molding line in two shifts. It is not uncommon for a foundry to depend on one or two auto-matic molding machines for almost all of their production.

- In recent years automatic high pressure or high density molding has been widely adapted for the casting of most metals. High pressure (high density) molding has virtually eliminated the past problems of mold-wall movement. Mold-wall movement has been markedly aggravated by the moisture content of the molding sand, the density of the molds and the mold surface hardness.
- High pressure molding practices have allowed lower moisture contents in the molding sand, so that higher mold densities can be achieved with higher capacity molding machines. Thus, castings have considerably better dimensional accuracy are produced. In general, the surface finish of the castings is improved and they are closer to pattern accuracy

- There is no known limit to the size of castings which can be made by high-pressure (high density) molding. Molds can be 5-6 feet wide, up to 10 feet long with depths of 2 feet or more, and there does not seem to be a restriction on mold cycle speed. Speeds are a factor of degree of automation rather than pressure, yet cycle speeds at less than 10 sec are a reality.
- Most known alloys are being poured in high-density molds. Gray, ductile and malleable iron, steel, high alloy steel, brasses, bronzes, aluminum and magnesium castings are being produced daily.

- The advantages of high pressure molding are castings with closer dimensional tolerances, consistently uniform casting weight, better surface finish, increased productivity and lower costs.
- Other advantages which can be derived from high pressure (high density) molding are reduced feed metal and improved casting soundness, reduced cleaning costs and minimum setup operations for machining because of casting dimensional accuracy.

THE IMPORTANCE OF MOLD HARDNESS

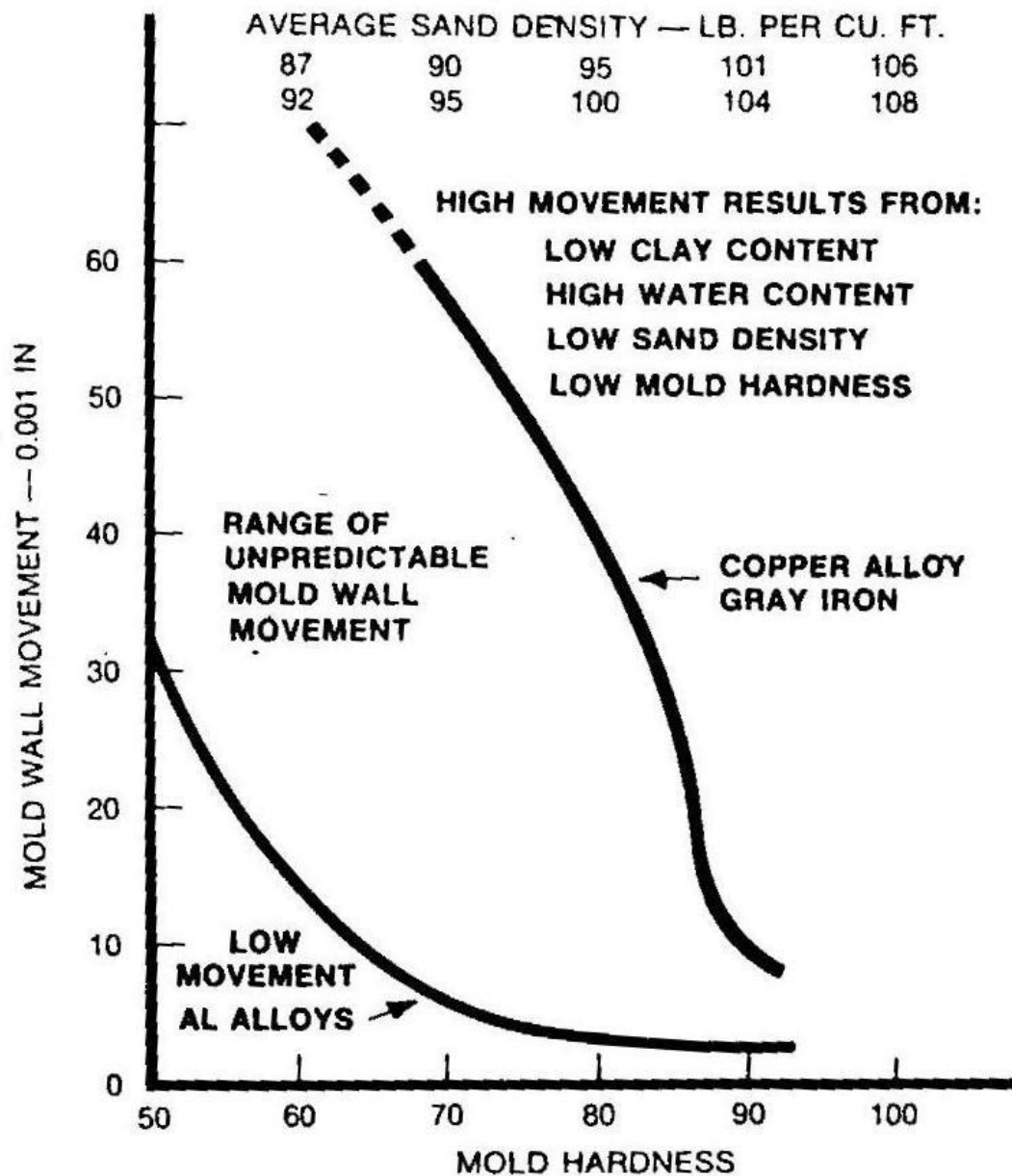


Fig. 5—How mold hardness controls to a large degree expected casting accuracy. Note that the mold hardness is most significant for the heavy alloys such as those in the copper and iron families.

Flaskless Molding

- One of the latest innovations in green sand molding methods and concepts has been the introduction of flaskless molding-with both vertical as well as horizontal partings.
- Contrary to any misconceptions, a flask must be used on all green sand molding primarily for containment of sand while it is firmed about the pattern.
- In flaskless molding (whether vertical or horizontal) instead of using "tight" individual flasks for each mold produced, the master flask is contained as an integral unit of the totally mechanized mold producing system.

- Flaskless molding has been in use since about the turn of the century and, with the introduction of the jolt squeezer in about 1920, removable flasks have been widely used in the production of hundreds of thousands of molds.
- In 1957 Professor V.A. Jeppesen of the Copenhagen Technical Institute invented one of the first production machines. The emphasis and potential of the vertically parted concept was soon realized as a vital contribution to increased productivity in the production of molds.

- Through advanced engineering techniques as well as constant modification and improvements, vertical flaskless molding has achieved notable production as well as casting quality and has attained new heights of casting dimensional tolerance and accuracy.
- The vertical flaskless system is suited to gray, malleable and ductile iron as well as steel, aluminum and brass.
- In the vertical flaskless system, the completely contained molding unit blows and squeezes a mold against a pattern (or multiple patterns) which has been designed for a vertical gating system.
- Molds of this type can be produced in very high quantities per hour, and of high density (mold hardness ranging from 85-95 B scale) with excellent dimensional reproducibility. The production efficiencies of vertical flaskless molding which may be realized are impressive. **Some of these are listed below:**

- Uniform preliminary blown mold density.
- Uniform dense final squeezed mold with over 85 mold hardness.
- Highly dense mold allows maximum effective use of mold surface for intricate castings.
- Adjustable draw-both speed and lengths.
- Adjustable mold thickness, blow pressure and squeeze pressure.
- Maximum output (up to 600 molds per hour) with minimum man-power and floor space.

- Mold shift is eliminated by the use *of* extremely rugged rams, platens and guides which maintain pattern impressions accurately opposite during closing and pouring so that flask requirement is reduced or eliminated.
- Pour conveyor and cooling conveyor are an integrated part of the system.
- No flasks are required and, therefore, need for an involved return system is eliminated.
- No regular check on flask parts is necessary.
- Labor costs are reduced because the molding operation is entirely automatic.
- Produces a dimensionally accurate casting because of the high compaction pressures used.

- Economies effected with vertical flaskless molding:
- Elimination of flasks, cost of bushings and pins and maintenance required for flask conditioning.
- Elimination of flask handling equipment.
- Elimination of clamps or weights.
- A rapid molding cycle.
- Excellent utilization of productive floor space.
- Minimum manpower requirements.
- Rapid pattern change.

- The high density (high pressure) mold hardness minimizes mold wall movement, thus allowing accurate casting wall dimensions and increasing accuracy across the parting line.
- Fins are also essentially eliminated and shift is significantly reduced from that previously experienced in cope and drag tight flask molding.

Advantages of Flaskless Molding

- No flask storage problem.
- No continual flask repair.
- Working area noise is reduced. Handling, transferring and stacking of flasks causes much excessive noise during the various sequences of mold and casting processing.
- The one necessary snap or slip flask which must be used can be made stronger, more durable and more precise than is practical with *a* multiflask system. (Some "flaskless molds" may be poured with the use of slip flasks.)

Advantages of Flaskless Molding

- Mold gas ignition at the parting is more spontaneous.
- Cleaning of flasks as they return from shakeout is no longer necessary.
- Flaskless molding offers an easier mold dump, shakeout or knock-out.
- The need for handling of flasks returning from the shakeout is eliminated.
- Flaskless molding incurs less total capitalization costs.
- Lower total cost per mold is obtainable.

Disadvantages of Flaskless Molding

- Location of the casting cavity. When castings are crowded and very close to the outside mold wall, flaskless molding may be impractical to use. Mold handling may be more difficult as flasks provide convenient "handles" for lifting or pushing.
- The cope and drag are more likely to shift if the mold is bumped or jostled during handling.
- Jackets and weights are re-quired with certain types of flaskless molds. If jackets are required, it presents a problem of proper placement over the mold.

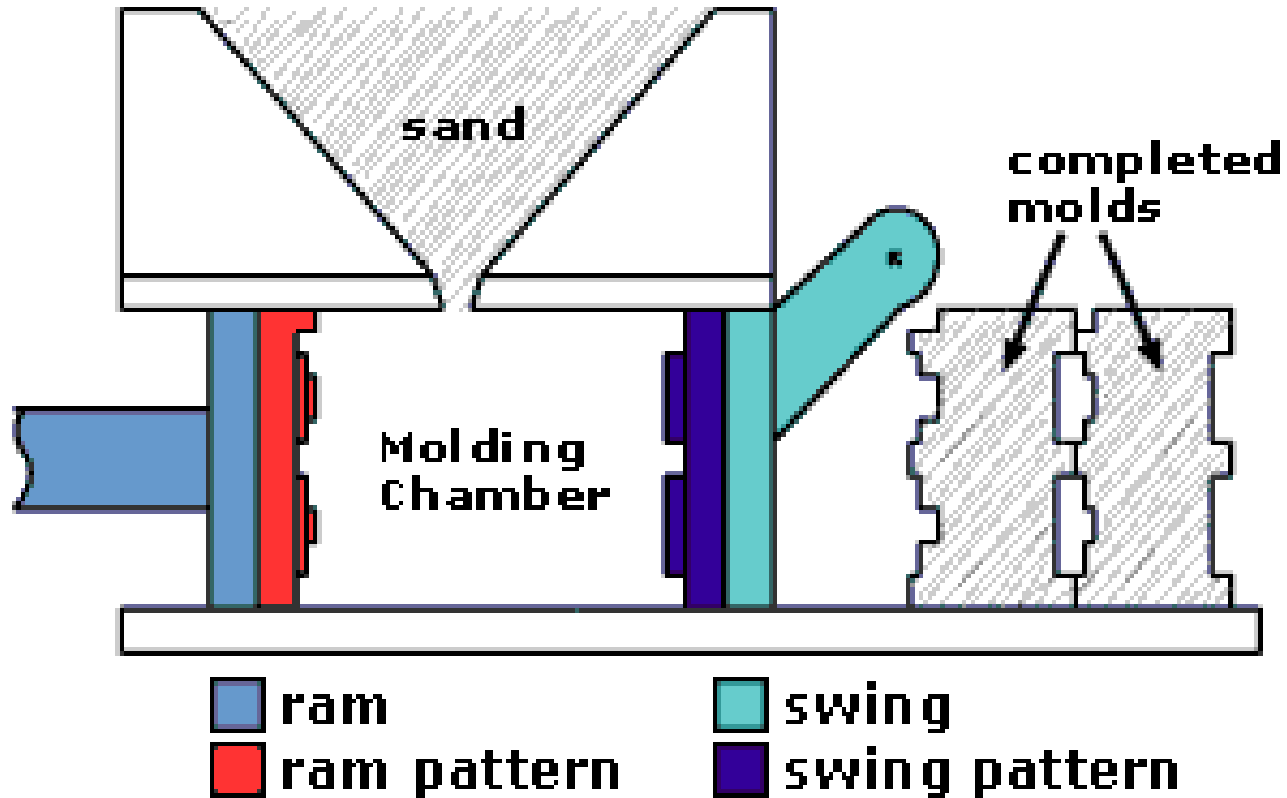
Disadvantages of Flaskless Molding

- In some cases, more castings per mold can be obtained using larger flasks. The size of the castings produced is limited by the size of the mold.
- Complicated coring-up is impossible because of the nature of the high pressure compaction of this sand.

Disamatic Molding

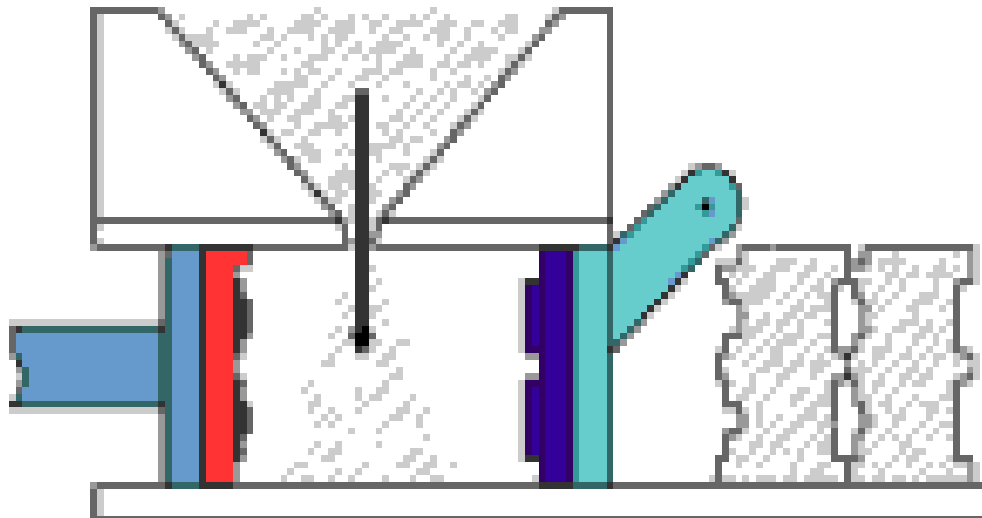
- Currently, all Metal Technologies foundries utilize Disamatic Molding Machines to produce molds for our castings. Disamatics offer a highly efficient means of rapidly and automatically creating a string of flaskless molds. These molds are built for vertical casting and are created in a vertical molding environment. For an explanation of the process, read through the text below and click on the thumbnail images to see illustrations.

Disamatic Molding



Disamatic Molding

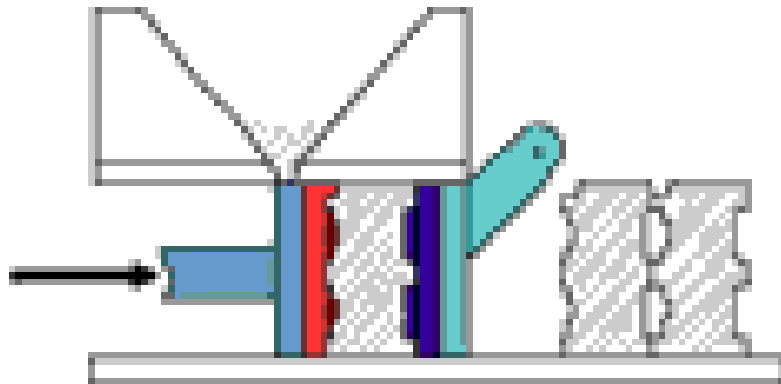
Step 1. Sand is blown into the Molding Chamber from above.



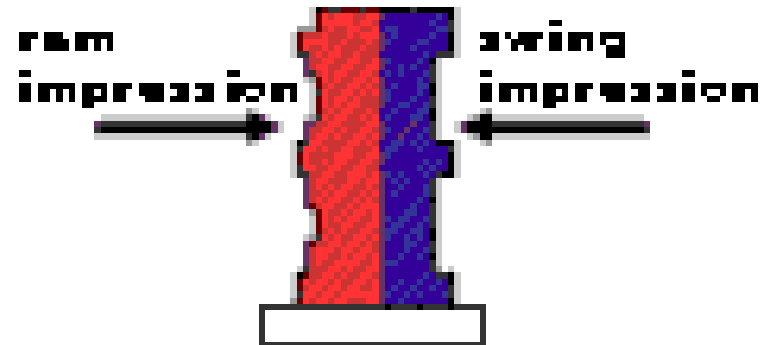
Sand fills the Molding Chamber from above.

Disamatic Molding

Step 2. The Ram advances, pushing the Ram Pattern. This compresses the sand in the Molding Chamber to form mold impressions. Then compression creates opposite halves of consecutive molds to be placed in the mold string.



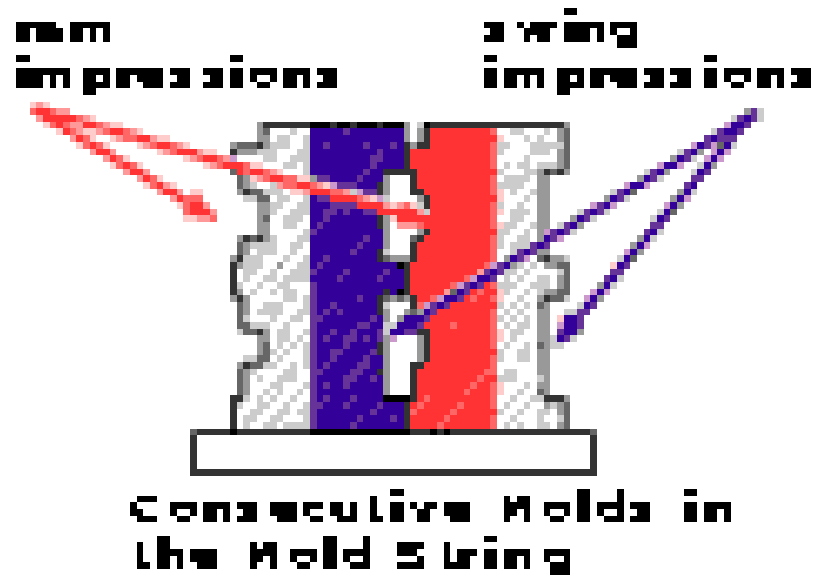
Ram pattern compresses sand to form mold impressions.



Single Mold inside the Molding Chamber

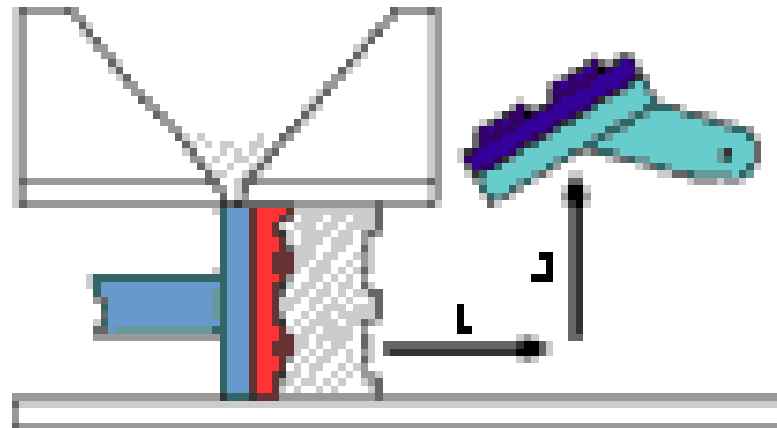
Disamatic Molding

Step 2. (cont) Castings cannot be formed using a single mold, but when a new mold is placed in the mold string, its leading edge meets the trailing edge of the previous mold to create a completed mold cavity.



Disamatic Molding

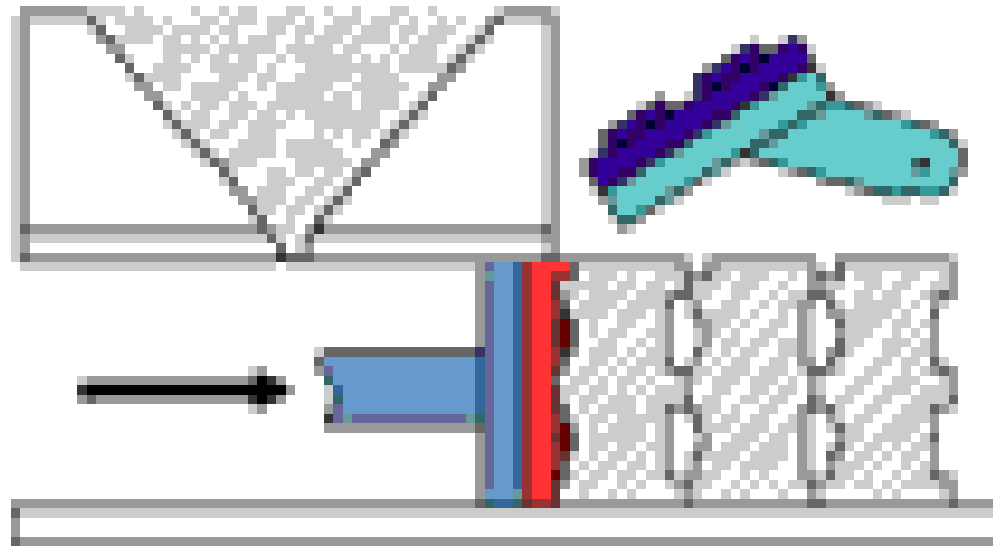
Step 3. The Swing Pattern moves back and up to allow the mold to exit the Molding Chamber.



1. Swing arm moves back
2. Swing arm moves up to allow mold to exit.

Disamatic Molding

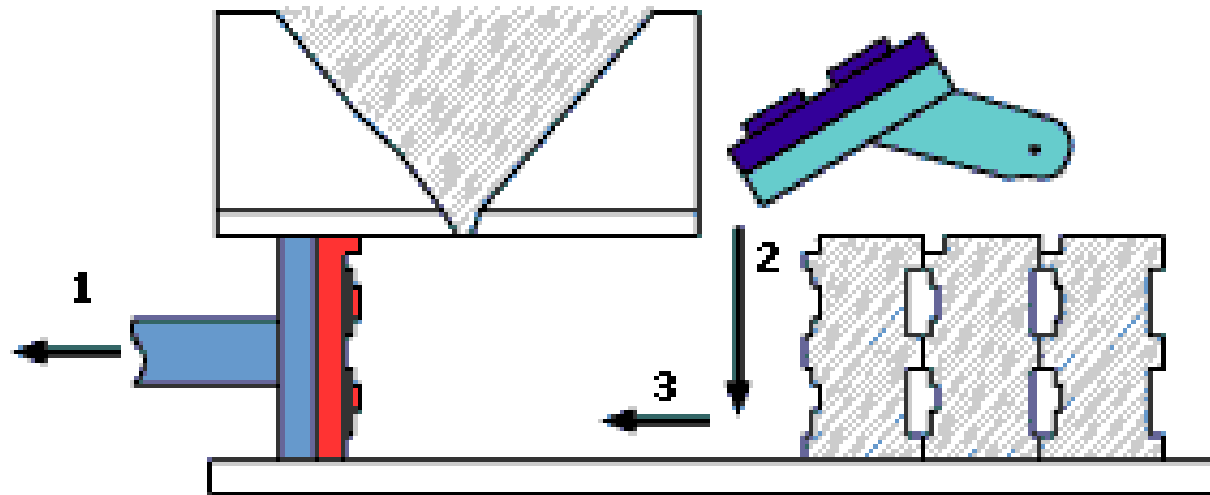
Step 4. The Ram extends, pushing the new mold into the existing mold string.



Ram extends, pushing the new mold into the existing mold string.

Disamatic Molding

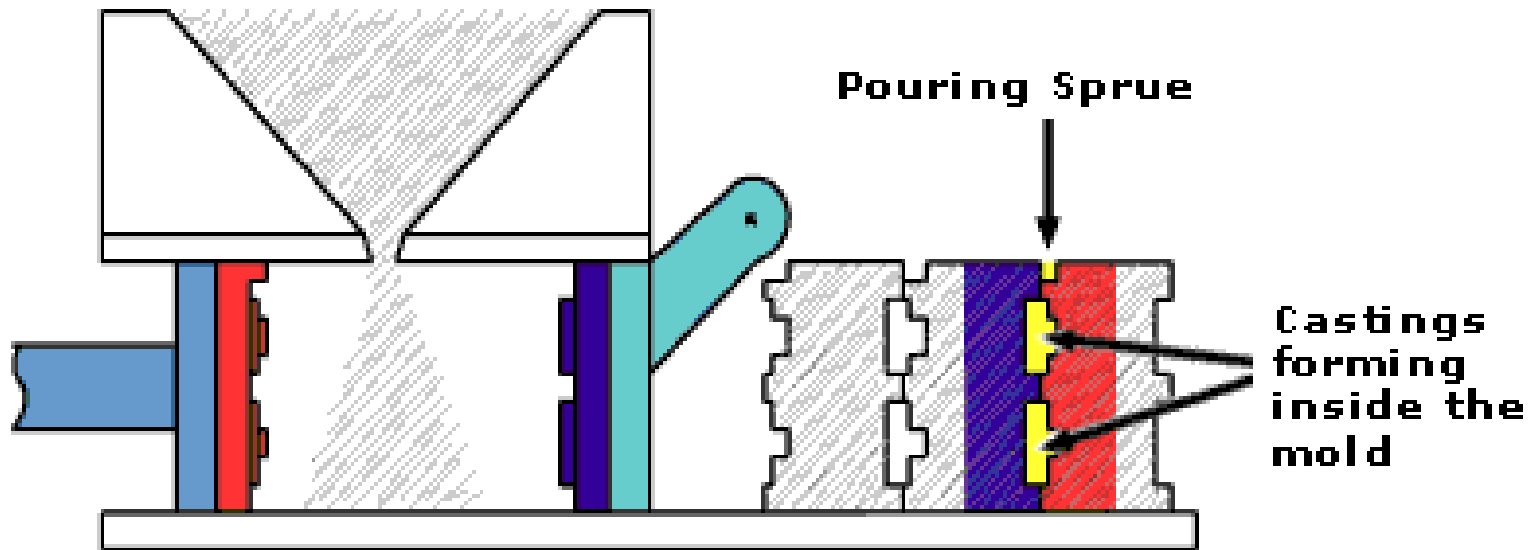
Step 5. The Ram and Swing patterns return to their original position to begin the process again.



1. Ram arm returns to original position.
2. Swing arm descends.
3. Swing arm returns to original position.

Disamatic Molding

Step 6. Sand is blown into the Molding Chamber for the next mold. A little further down the mold string, iron is poured into the top of a formed mold via the pouring sprue left by the pattern impressions.



Sand enters the Molding Chamber for the next mold. Iron is poured into the pouring sprue on top of the formed molds.

Skin-Dried Molds

- Skin-dried or air-dried molds are sometimes preferred to green sand molds where assurance is desired that the surface moisture and other gas-forming materials are removed.
- By skin drying the face of the mold after special bonding materials have been added to the sand molding mixture, a firm mold face is produced similar to that obtained in dry sand practice.
- Skin-dried molds possess certain properties of green sand. Collapsibility of the mold is almost as good as that obtained with green sand molding. Skin-dried molds are commonly employed in making medium-heavy and heavy castings.

- Many methods of drying are used, the most common being hot air drying or gas and oil flame drying.
- Skin-drying can be accomplished with the aid of torches, a bank of radiant-heating lamps or electrical heating elements directed at the mold surface.
- Other apparatus can be used, such as the infrared lamp. Electrical devices have been satisfactory, provided the mold is free of deep cavities.

- Most generally the surface of the mold is washed or sprayed with a refractory mold coating, either before or after drying, in order to prevent metal penetration and to effect a surface hardness in order to resist any possible erosion caused by impingement of the metal stream during pouring.
- It is important to observe caution when closing molds which have been skin-dried. Allow the mold sections to cool to room temperature before closing in order to avoid condensation reactions with the metal.

Dry Sand Molds

- Since intricate large parts are very difficult to cast to exact size and dimensions, some foundries must use dry sand molds to produce them. Dry sand molding is the green sand practice modified by baking the mold at 204C to 316C.
- Molds are generally dried (or baked) in large mold drying ovens, or with large mold heaters. Castings of large or medium size, and of complex configuration such as frames, engine cylinders, rolls, large gears and housings are often made utilizing the dry sand technique.
- Both ferrous and nonferrous metals are cast in this type of mold.

- Essentially a dry sand mold is prepared in the same manner as a green sand mold. The same tools and procedures apply to each. With dry sand molding, consideration must be given to selecting the sand mixture, making certain joints, choosing the type of mold and core refractory coatings/assembling the core and the mold and also the gating and drying method employed.
- In dry sand molding the foundryman will usually select pitch or replacements for pitch, and can use molasses, dextrin, glutrin or other forms of organic binders in the tempering water added.
- Moisture and clay additions are both usually higher in dry sand molding than in other forms of molding requiring water—first for workability and then to impart properties upon drying which ensure good dimensional tolerances as cast sur-faces.

- This type of molding is much more expensive than green sand molding but does have several advantages. Dry sand molds are generally stronger than green sand molds and therefore can withstand much additional handling. Because of the hard surface of these molds after baking, only a small amount of water vapor or gas evolves.
- The castings usually possess more exactness of dimension than if they were molded in green sand. The improved quality of the sand mixture due to the removal of moisture can result in a much smoother finish on the castings than if made in green sand molds. Where the molds are properly washed and sprayed with refractory coating compounds the casting finish is further improved

Sand Slings

- Slings of sand is a rapid method of mechanically filling the flask with sand. The invention of this innovative method of sand compaction was the joint effort of E. O. Beardsley and W. F. Piper at their Oregon Works in 1912.

- The sand is thrown with a propelling force similar to that of a slingshot thus the reference to it as a sand slinger. Sand slingers generally used are of three types stationary, portable and mobile. The latter is subdivided into two specific categories locomotive and monorail or cantilevered. The slinger units can be hand-operated (Fig. 7) or where the operation is an in-tegral part of the production cycle of filling a number of large flasks ar-ranged on a conveyor loop the slinger can be a large operator-controlled unit. With this type unit, the operator is seated high above the floor over the position of sand ejection. Separate cope and drag molding can also be accomplished with the sand slinger.

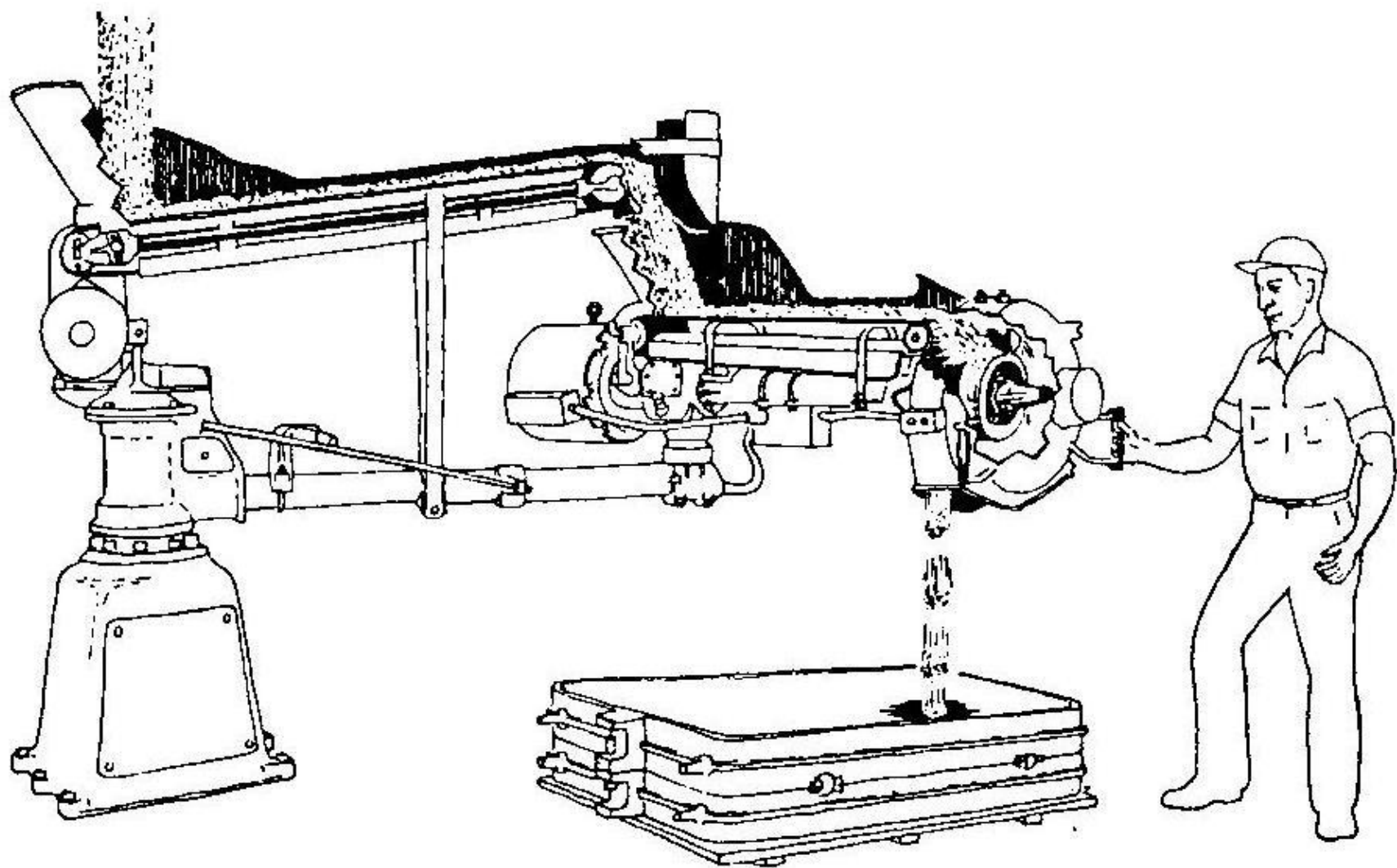


Fig. 7—Filling a flask with a sand slinger.

Loam (killi toprak-kil) Molds

- This process was used a great deal in the past for the production of large bronze castings such as huge manganese bronze ship propellers and bells. The technique of loam molding consists of the preparation of a substructure (made of bricks, wood and other material) to the approximate contour of the required casting. A very viscous slurry of water, clay and sand is daubed (trowelled) over the framework and worked to proper shape with sheet steel or wooden sweeps, In the U.K., loam mofding is also referred to as strickle molding. This technique was used for generations by U.K. iron founders. It was originally used in the manufacture of cannon, and at a later date in the **production** of early steam-engine cylinders.

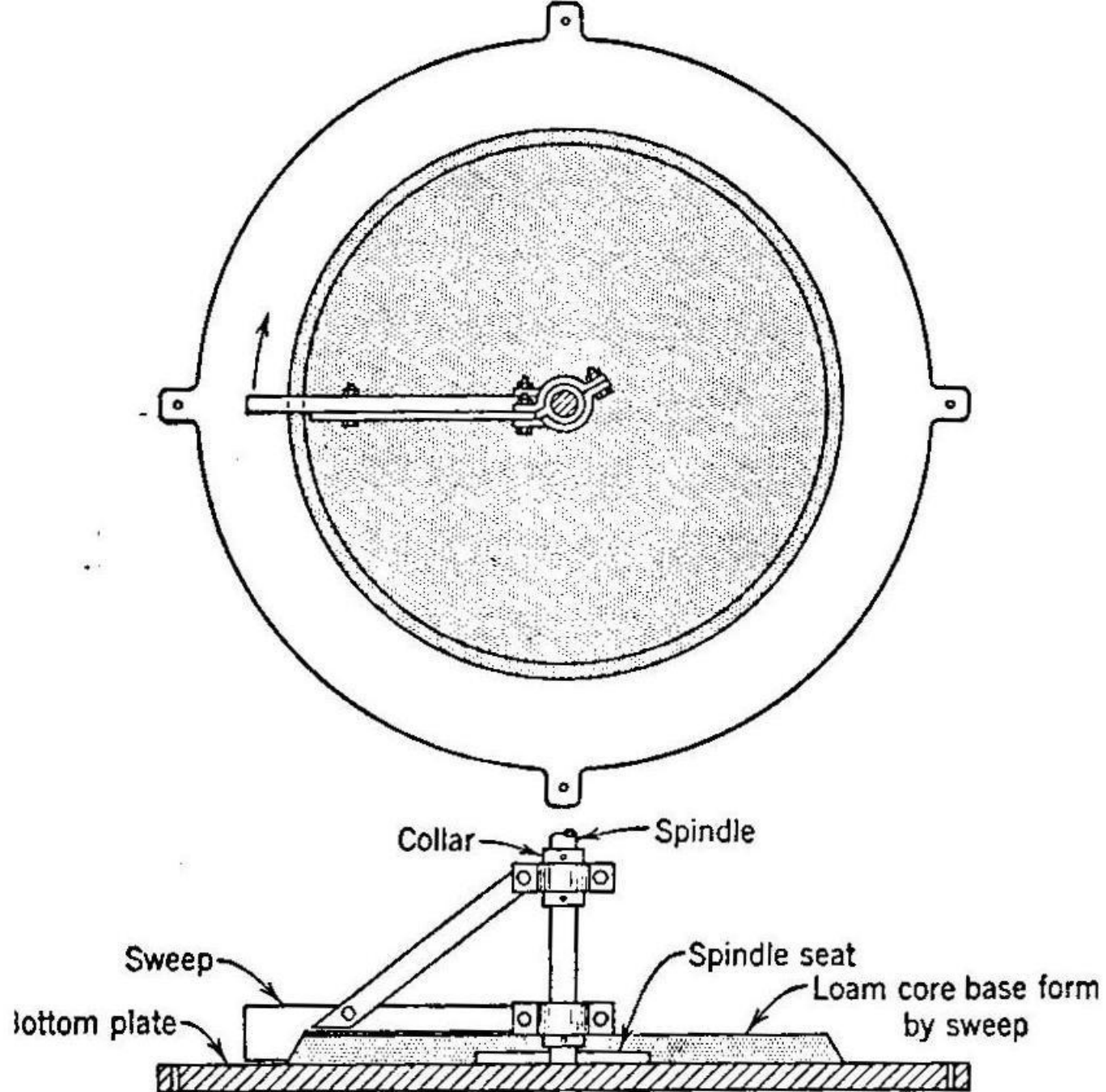


Fig. 9A.—Construction of base for a loam sand core with a sweep.

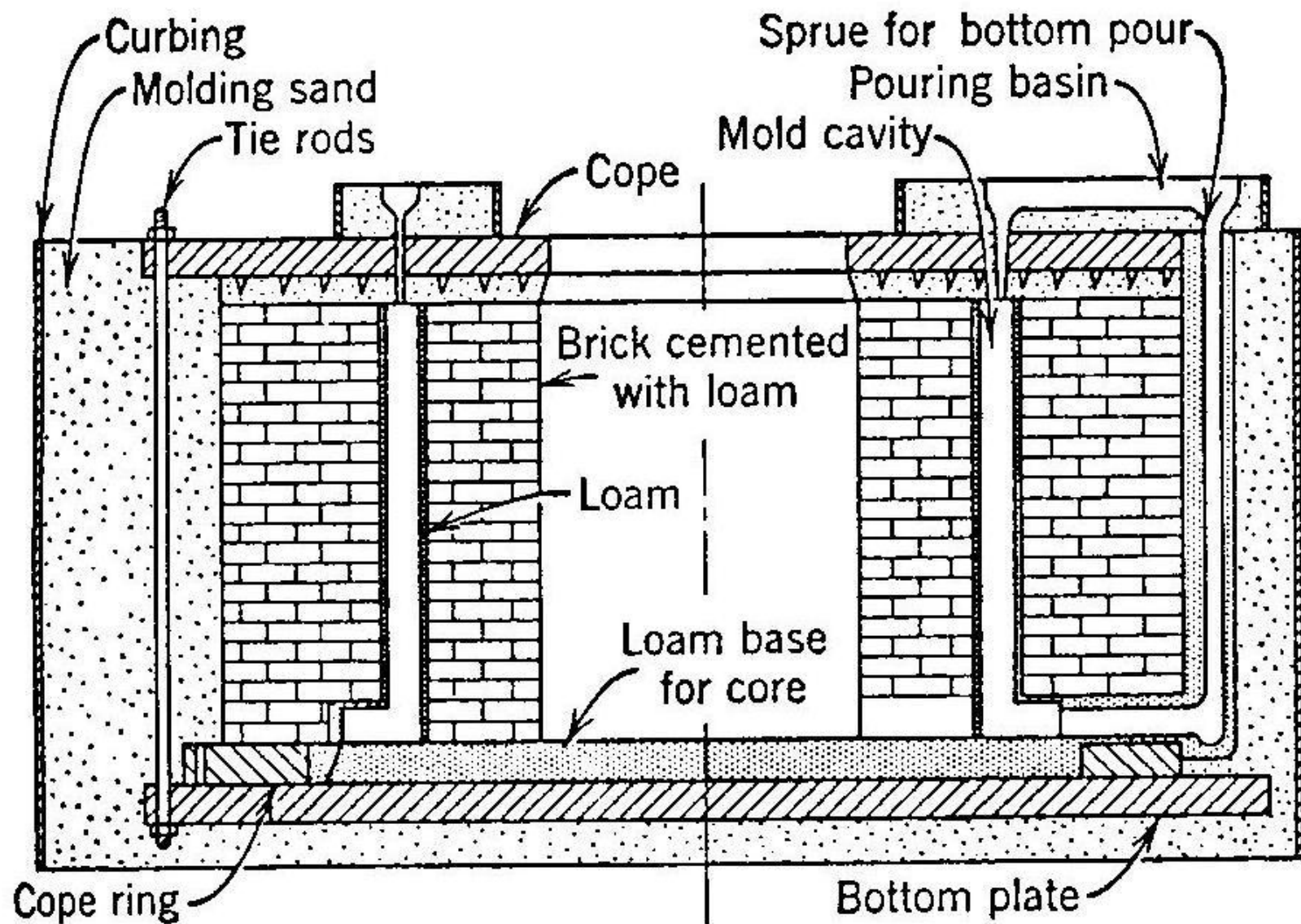


Fig. 9B.—Sectional view of a loam mold.

Chamotte Molds

- Chamotte is a calcined flint-clay refractory aggregate used to a great extent by European foundries. Some U.S. foundries utilized the process and the domestic calcined refractory grog proved highly adequate. By being a calcined material, chamotte replaces the unstable silica sand in molding sand mixtures. It is a very coarse (open) material since it is crushed in pans, rollers or jaws. The general formulation is to add 10 to 12 percent of a highly refractory plastic fireclay to the chamotte at a moisture of approximately 8 to 10 percent.

- The coarseness of the chamotte necessitates a skilled mold-finisher who literally tamps and swabs a high viscosity graphite and fireclay ceramic coating into the mold face voids. The mold is then oven-dried at 550F (288C) to 600F (316C) after which it must be fired by subjecting the mold surfaces to torch temperatures of HOOOF to 1200F (593C to 649C). The extensive mold finishing requirements in time and labor negate the great advantage of this highly temperature stable molding aggregate.

Compo Molds

- Compo molding is sometimes confused with loam molding and chamotte molding. Compo is sometimes referred to as the oldest form of a synthetic molding sand mixture. It consists of a crushed refractory material which generally is used firebrick, crucibles or ganister which is mixed with fire-clay. Formulas vary with the European countries which still use compo.
- One of the formulations notes approximately 70 percent of crushed fire-brick, 15 percent crushed chamotte grog, 15 percent ground plastic fireclay and 1 percent foundry blacking (graphite). To this is added a high percentage of tempering water.

- The compo mixture is generally used on large castings weighing several tons. Refractory coatings are applied as with dry sand molding, etc. and the molds are oven dried.

Cement-Bonded Sand Molds

- Many favorable claims are made for large cement molds that stand in storage for a period of time. Molds that require long periods of assembly before the casting is finally poured are best made by this process. This innovative process for the making of large-dimensioned heavy-section castings (particularly of ferrous metals) was originally named the Randupson process.

- One of the major uses for the cement-bonded molding practice is the making of large ingot molds and stools. This process produces air-dried molds of unusual properties. It develops such great dry strength that cranes can handle molds without damage. Cement molding is used in nonferrous foundries particularly in intricately designed pressure bronzes which may leak or sweat.

- Cement is used because of its low gas forming rate and the moisture can be held below one percent. Cement molds also chill the metal faster, the same as in gray iron or steel practice, and thereby impart deeper and denser skin to the castings. Cement is selected as a binder because the cores can be stored for a longer length of time. Large propellers and marine castings are made in this process.(Figs. 10 and 11)

- The cement mixture is mulled as in green sand molding. This molding aggregate is generally a mixture of sand, 8 to 12 percent high-early strength hydraulic cement and 5 to 6 percent water. The cement mixture is molded the same as is the mixture for green sand molding. The mixture develops extreme hardness and strength by the setting action of the portland cement. The mixture must be allowed to set or harden before the pattern can be withdrawn. Cement-bonded molds are air-dried (cured) over lengthy predetermined cycles which may be for periods as long as 72 hours before the mold may be closed for pouring.

- When the mold is poured, heat causes the water of crystallization of the ce-ment to be driven off. The highly permeable quality of the mold and suitable vents allow the developed steam to pass through the sand. Reclamation is rather expensive **for** cement-bonded molds. Ingot mold manufacturers are presently investigating the newer chemically bonded self-setting sand mixtures in order to overcome the major production disadvantage of the long cycle drying (curing) period.



Fig. 10—Single blade pattern produces a three-blade propeller by cement molding method.



Fig. 11—Bronze propeller at shakeout—cast in a cement bonded mold.

- Some of the advantages and disadvantages of cement molding are:

Advantages

- Molds can be air-dried.
- No costly drying equipment necessary.
- Molding bonds develop very high dry strengths.

Disadvantages

- Possibility of molds freezing in winter.
- Molding materials are usually more costly.
- Difficult shakeout.
- Rapid use of materials to prevent setting.
- Lacks flexibility.
- Usually cement molds or molding material cannot be reused

Floor and Pit Molds

- When molds are medium to large in size, considerable heavy equipment, floor space and time must be allocated to the molding operation. Floor molding is done on the floor in sections of the molding bay which are set aside for the handling of large patterns, etc. so that the long mold-making time requirements will not interfere with other operations. If the pattern being molded is too large to be handled in flasks, the molding is done in pits.

- Molding pits are concrete lined, boxed-shaped holes in the molding floor. The pattern is lowered into the pit in the position in which the casting is to be poured. The sand is tamped and rammed under and around the sides of the pattern. The cope of the completed mold, resting on the drag above floor level may be bolted with long tie rods to the drag plate in the base of the pit, or it may be weighted down to prevent a run-out at the parting line. Bedding-in practice is also adapted to floor molding, especially when the flask is so large that routine molding is likely to distort the mold.

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Sweep Molds (*Loam Molding*)

- Many large castings which have surfaces of revolution may be cast by the sweep-molding practice. Sweeps are used to avoid the expense of making detailed pattern equipment and are especially economical if only a few castings of one part are required.

- A sweep can be used with green sand, dry sand, loam, chamotte, compo or other similar type mixtures. In making a mold using a sweep, the spindle base and spindle are well seated in the bottom of the mold. The mold is filled with sand and rammed until the cavity contour approximates the size and shape of the required casting. A sweep holder is placed on the spindle and the sweep is attached with bolts. The cutting edge of the sweep has the desired contour. As the sweep is rotated, the sand is literally sculptured to the desired configuration. After sweeping, the spindle is removed and the hole in the center is filled with sand so that the surface is even and smooth.

- There are several forms of sweep moldings including vertical and horizontal. Horizontal sweeps are used extensively for the production of castings for rolling mills.

Open Sand Molds

- Most open-mold foundry practice is limited to low-priced castings. The principal reason for open-sand molding is to avoid the added expense of ramming copes. Loam plates, crossbars, waterworks castings, sewer and street castings are typical of this molding, as well as the production of clamps and core arbors. This type of molding operation is simple as there is neither cope nor head of metal. The beds must be rammed only hard enough to support the actual weight of the metal. To ensure uniform thickness in the casting, the bed must be absolutely level.

- Sometimes cinders or coke are placed under the bed of sand in order to act as a venting area. Two or three inches of molding sand (either naturally-bonded sand, a loam mixture or a synthetic sand mixture) are placed over these cinders. The bottom of the casting should be about 2 to 3 in. above the cope bed. A pouring basin is cut in the open sand and an overflow is made to regulate the thickness of the plate or casting being made. This is quite common in the casting of sewer covers.

- Metal is never poured directly into an open mold, but rather into the pour-ing basin which, in turn, overflows into the mold cavity, furnishing a steady stream with the least amount of turbulence.

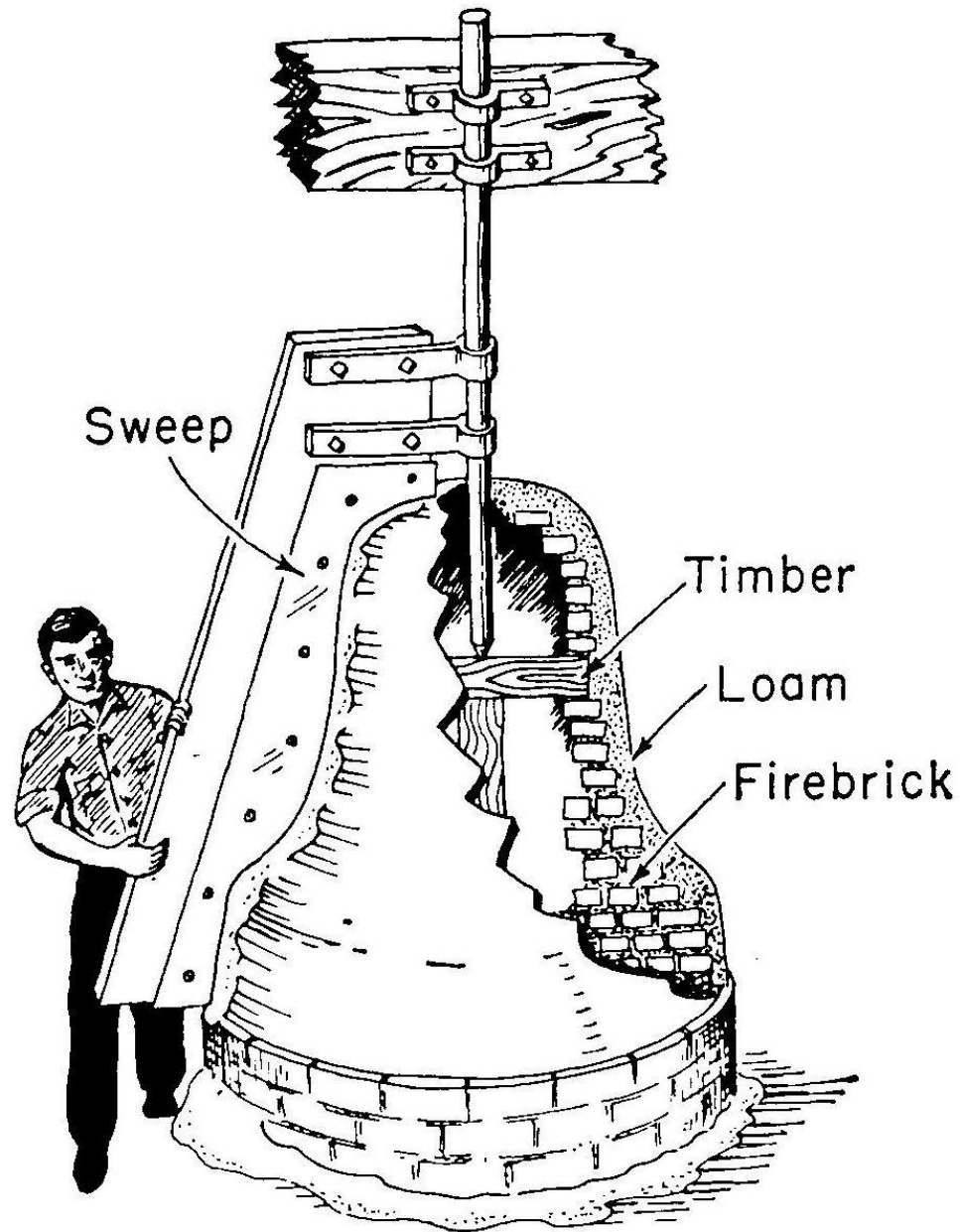


Fig. 13—Sweep molding of a loam mold for a bell casting.

Waterless Bonded Sand Molds

- Waterless binders and water-free molding sands were developed to eliminate the disadvantages inherent in molding sands containing water. Many problems arise from the fact that properties of conventional molding sand and the subsequent casting quality depend greatly upon the variabilities of the sand's moisture content.

- To avoid disadvantages of molding sands requiring water, numerous re-search projects have developed a variety of waterless binders for foundry use. Oil has been the primary lubricating agent. Oil is believed to be superior to water because of its higher boiling temperature. Oils chill metal less than water and certain oils create less evolved gases.
- Efforts had been made for a long time to convert a water-swelling bentonite into an oil-swelling bentonite. The first attempts to develop swelling of a bentonite in oil were made using organic salts. The study of the effect of certain organics on bentonite dates back several decades. The ability of these organic salt-treated western bentonites to swell and jell in some solvents developed into the commercial Bentone.

- The Mellon Institute received credit for its past work in this field and the Illinois Institute of Technology, formerly Armour Research Foundation. was involved in the research and development of one of the first bentones. Most bentones are organic ammonium compounds that first found their use in paints, fabrics, etc. These modified western bentonites evidenced southern bentonite properties in most foundry use and were usually low in dry and hot properties. The theory was that the structural layers of the bentonites were able to absorb more oil, thus creating greater spacing between the layers of the typical western bentonite structure.

- A waterless molding sand mixture is generally one that consists of a washed, dried, fine silica sand. AFS GFN Number 100-180. Approximately 5 percent (by weight) waterless binder and 2 percent (by weight) coastal oil (SAE 40) appears to be the best formulation. Other materials such as iron oxide or other similar additives can be used at the discretion of the individual foundry. Experience dictates the mechanical properties but most waterless binder foundries work with approximately 8-12 psi green compression strength. Dry compression strengths are usually over 50 psi and hot compression strengths at 1650F (900C) are over 100 psi.

- Coarser sands require less binder and oil to produce the sand strengths required while finer sands, although requiring more binder and oil will produce improved casting surfaces.
- It is important that the waterless binder be mullied. Mixing does not coat the sand grains properly. Proper mulling develops maximum bond strength and thoroughly distributes the jell-like mass throughout the sand grains

- Shakeout is important. The ratio of sand in the mold to the volume of metal poured, plus the time allowed before shakeout, will determine the amount of bond retained and the frequency of rebonding of the sand for proper workability. As long a time as is practical between pouring and shakeout is advantageous as the oil has a chance to recondense in the sand rather than be drawn off by the exhaust system as vapor. However, it is important that molds do not stand for a long period after casting as the oil burns away and the binder is progressively destroyed. The rebonding cycle and the amount of additives required are dependent upon several factors. The Btu input into the mold is one factor.

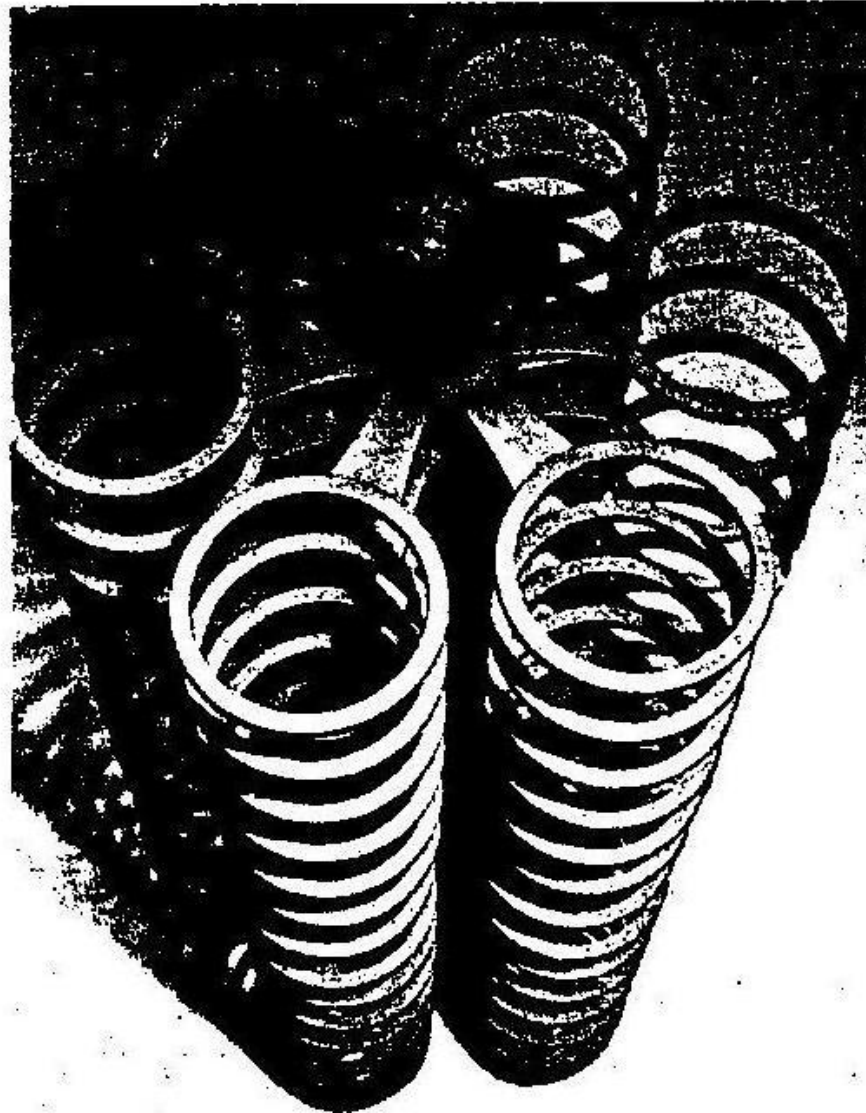
- High Btu input can affect the binder as well as the burn-out of the oil. Strength is lost when higher Btu input occurs into the mold from long standing of the castings before shakeout; another factor is the amount of burnt, unbonded core sand entering the system. The more sand from the cores, the more binder and oil will be required. However, if castings are shaken out too fast and the flash-point of the oil is at the proper temperature to ignite, more bond and oil will be required after flaming.

- Many nonferrous metalcasters have found waterless binders to be a highly successful medium for casting production. In the case of the production of magnesium castings, although the binder is waterless by its nature it may still be advisable to incorporate the addition of an inhibitor in the sand mix-ture.

Stack Molding

- Stack molding is another high production green sand molding process. The principle of stack molding is not new. The piston ring industry has used this method of molding rings for years to maintain production at a high level and at a very low cost per casting. (Fig. 14) The method is economical because it is possible to produce one complete mold per flask section. A series of flasks are stacked to make a complete mold. (Stack molding is sometimes referred to as multiple molding.)

Stack molded cast iron piston rings.



- In this molding process, pattern impressions are made in both sides of the mold. The bottom of a given flask in a stack provides the cope of the flask below and the top provides the drag of the next layer. (Fig. 15) The mold section can be made on squeezer, jolt-squeeze or mold-blow-squeezer machines. The stack-molding technique is now being applied very successfully

- to shell-molded mold components and sodium silicate/CO₂ where the completely engineered stack molding unit utilizes an automatic gassing cycle. As long as the pattern geometry will allow the use of the multiple moldin| concept there is no limit as to the ingenuity to which today's binder technology can be utilized in producing the stack molded components.

- The successful use of this method of molding is dependent on a number of factors such as accuracy of pattern alignment, rigidity and alignment of molding machines, proper gating and spruing (turbulence must be avoided and good venting practice must be heeded), mold hardness, pouring methods and proper temper of the sand used (when using green-sand stack molding).

Schematic of an arrangement of stacked molds displaying gating system and both faces of molded parts to be cast.

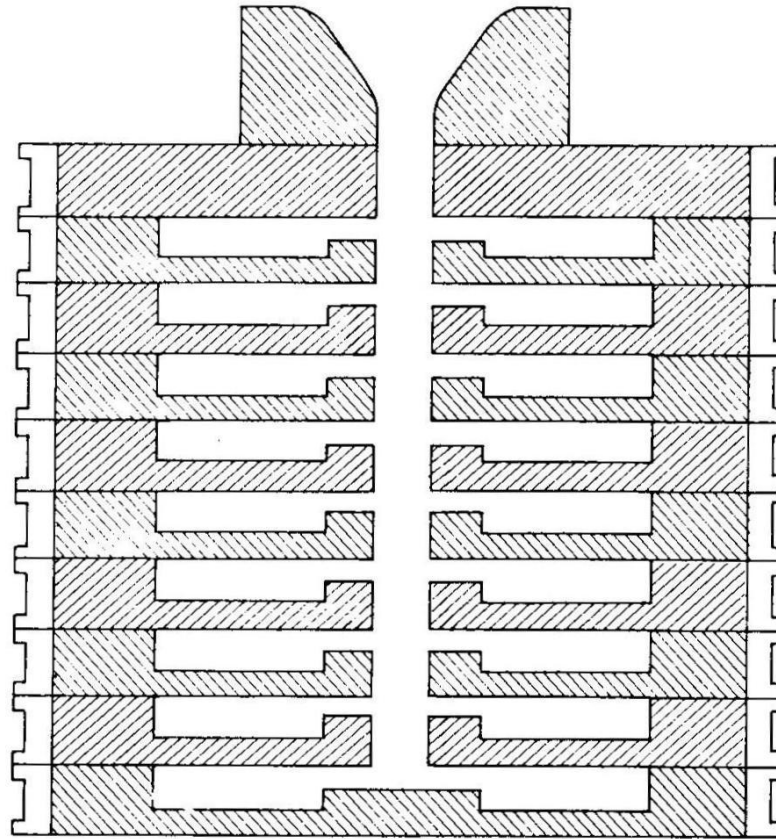


Fig. 15— Schematic of an arrangement of stacked molds displaying gating system and both faces of molded parts to be cast.

Dry or Baked Sand Core Molds

- For years intricate automotive and agricultural castings have been made with core or dry mold assemblies. Although today's technology has offered other alternatives such as shell molding, many foundries still resort to the aforementioned techniques.

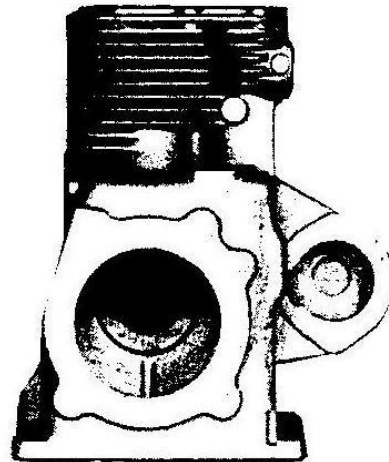
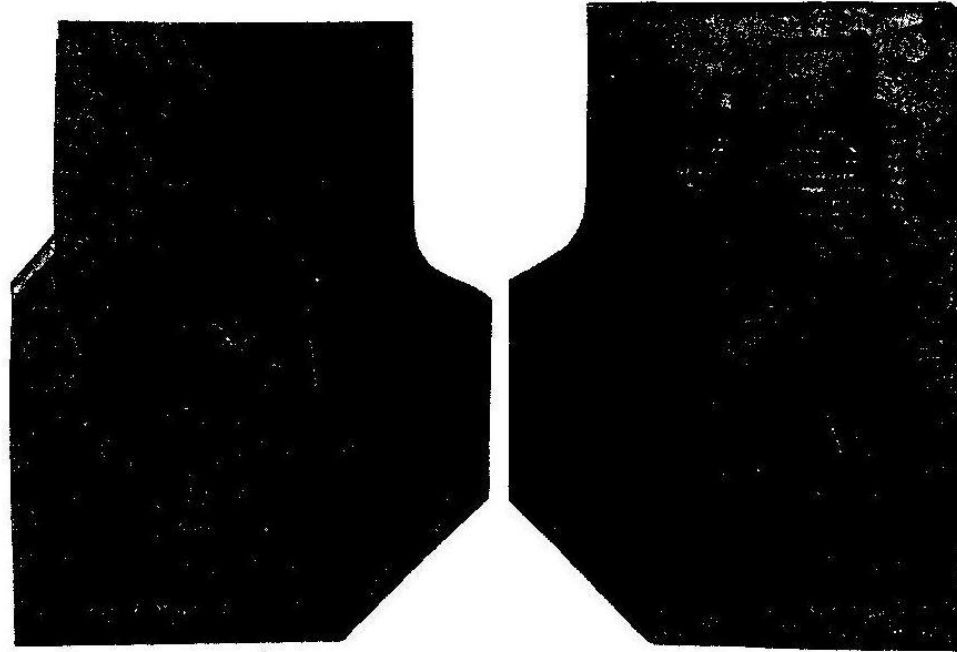
- Molding with dry or baked sand molds is one of the oldest forms of mold-ing where accuracy is required. Where close tolerances are desired, baked core molds are often recommended. This type of molding is more suitable for castings with deep fins, edges or difficult green sand pattern draws. (Fig. 16) Conventional gating and heading practices are used with this method. Some believe that gating into a core permits more flexibility, since after assembly the hard baked core may be turned into any position for pouring.

- Baked molds have the same composition as oil sand cores: Various binders are available such as compounded core oil, linseed oil, dextrin, cereals, clay bonds, resin, pitch, organic binders, lignin sulfite, sugar binders, as well as other synthetic binders. After properly mixing the binder with an unbonded sand, the mixture is formed and shaped to the pattern or core box used and baked. Every baked mold mixture is composed differently due to the type of equipment available for baking or forming. The assembly of these molds requires careful gaging since accuracy is one of the prime reasons for resorting to this method of casting production. The expense of preparing them is considered worth the accuracy obtained in the casting.

- Each metal has special characteristics to be considered when one selects certain mixtures for best application. Many of the mixtures are composed of approximately one percent linseed oil by weight and one percent cereal binder, blended into a washed and dried silica sand containing approximately three percent moisture. This mixture is baked at temperatures between 250F (121C) and 400F (204C) for approximately one hour per cross-sectional inch of the core. Actual baking temperatures will depend upon the manufacturer's recommendation for the particular binder being used. The mold can be sprayed with a refractory coating to ensure better dimensional stability as well as improved cast surfaces.

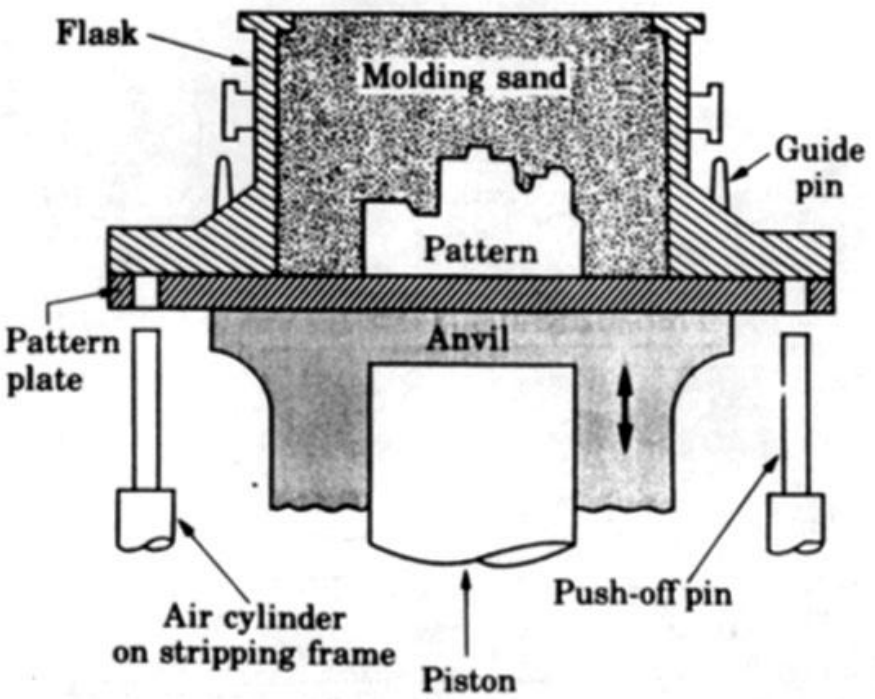
- If a considerable amount of metal is poured into such molds, the foundry-man has a choice of adding iron oxide, pitch or gilsonite. Each of these materials provides hot plastic deformation and will aid in minimizing some of the typical expansion type defects which occur at elevated temperatures. Since some metals are not compatible with carbonaceous materials, non carbon type additives must be selected. Bentonites and clays are used singly or in combination for certain dry mold mixtures that are baked into sintered assemblies. The amount will vary from less than one percent to as much as 10 percent by weight depending on the metals poured, the pouring temperature and the metal section thickness.

Oil-bonded core mold and casting.





(a)



(b)

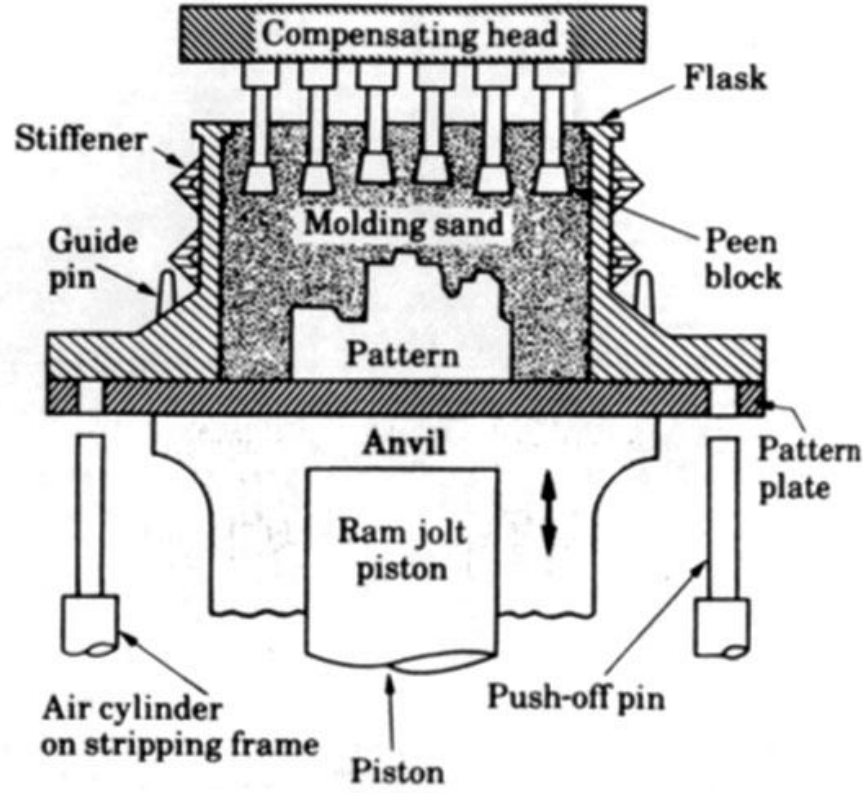


FIGURE 11.8

(a) Schematic illustration of a jolt-type mold-making machine. (b) Schematic illustration of a mold-making machine which combines jolting and squeezing.











Al-sand-casting



Al-sand-casting



Al-sand-casting



Al-sand-casting



Al-sand-casting



Al-sand-casting



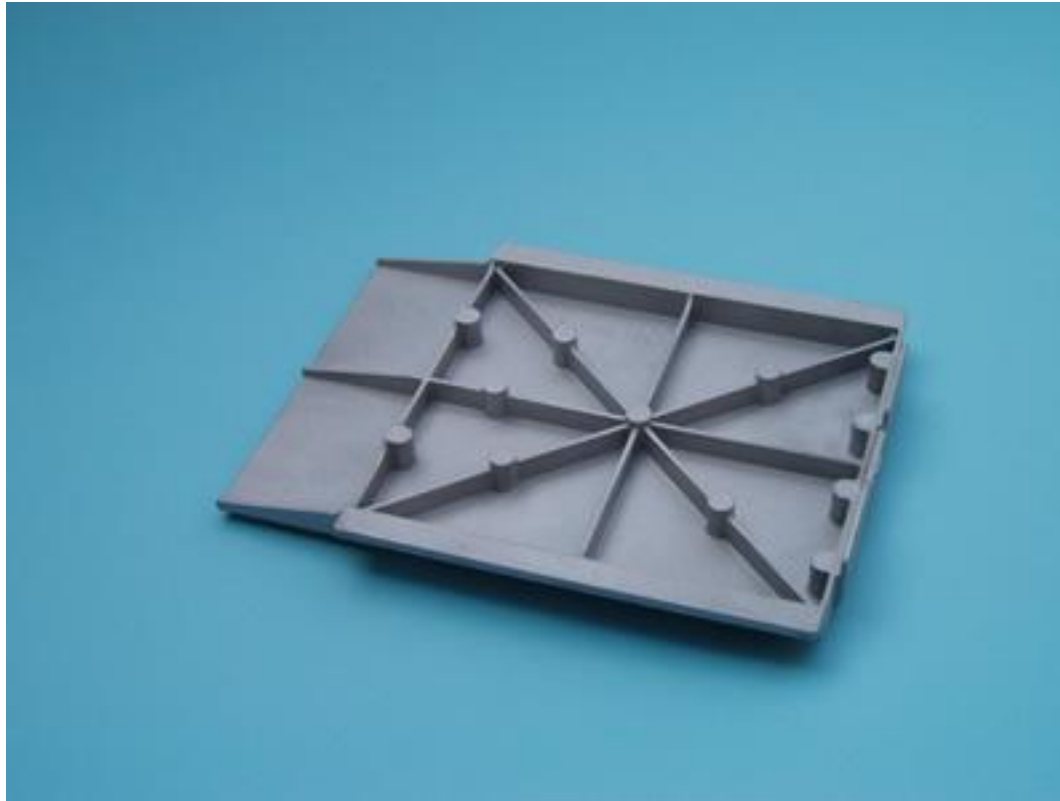
Al-sand-casting



Al-sand-casting



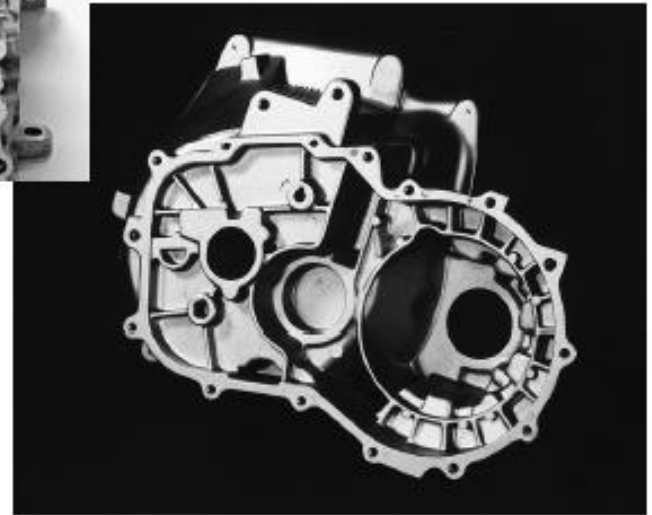
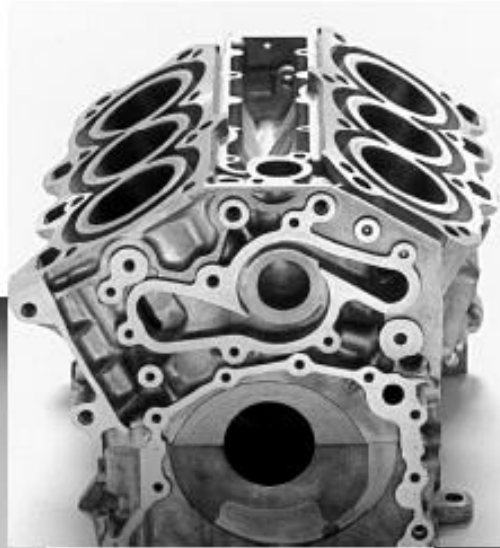
Al-sand-casting



Al-sand-casting



Sand Cast Parts



Al-sand-casting



Cast iron Sand Casting

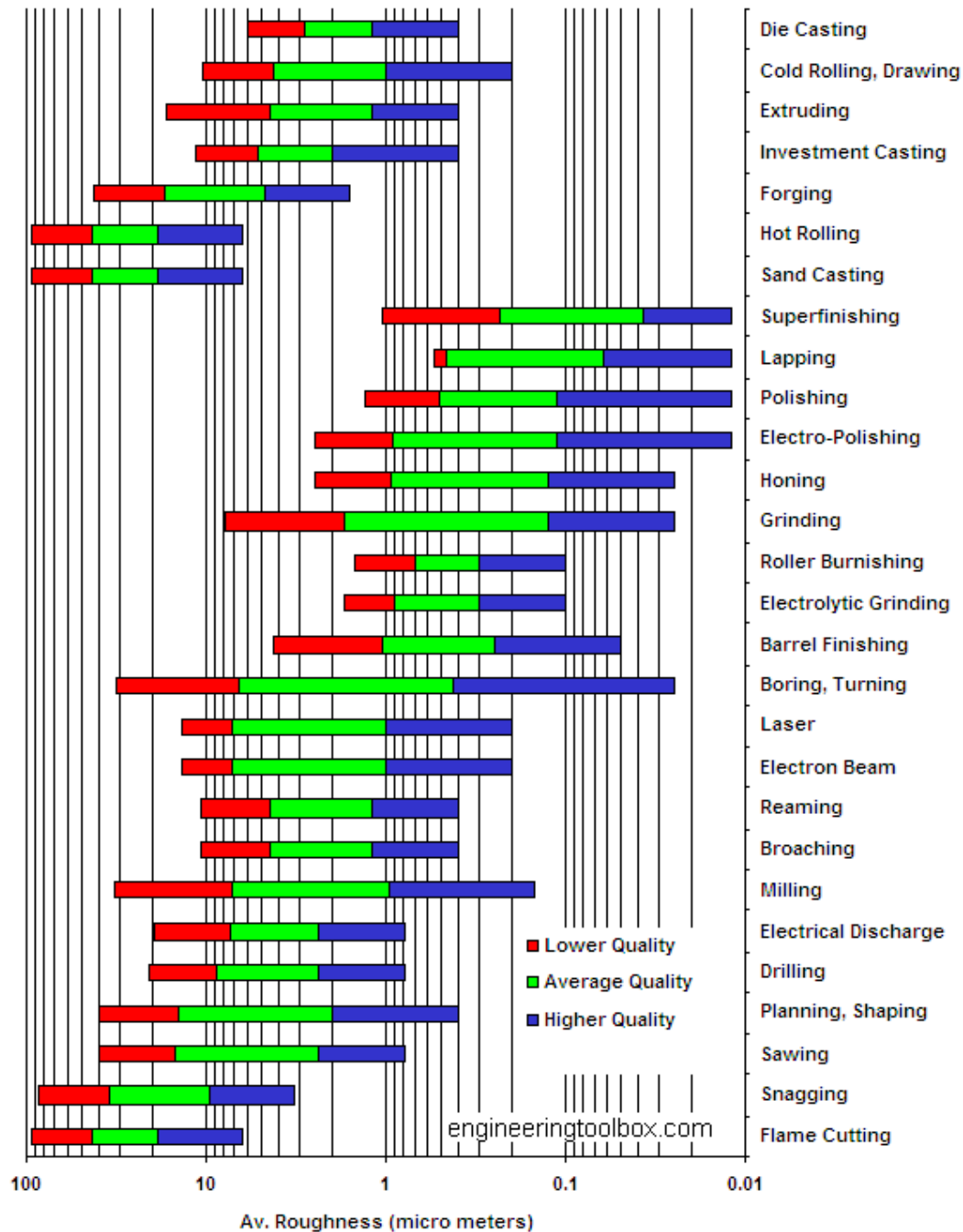


Cast iron Sand Casting

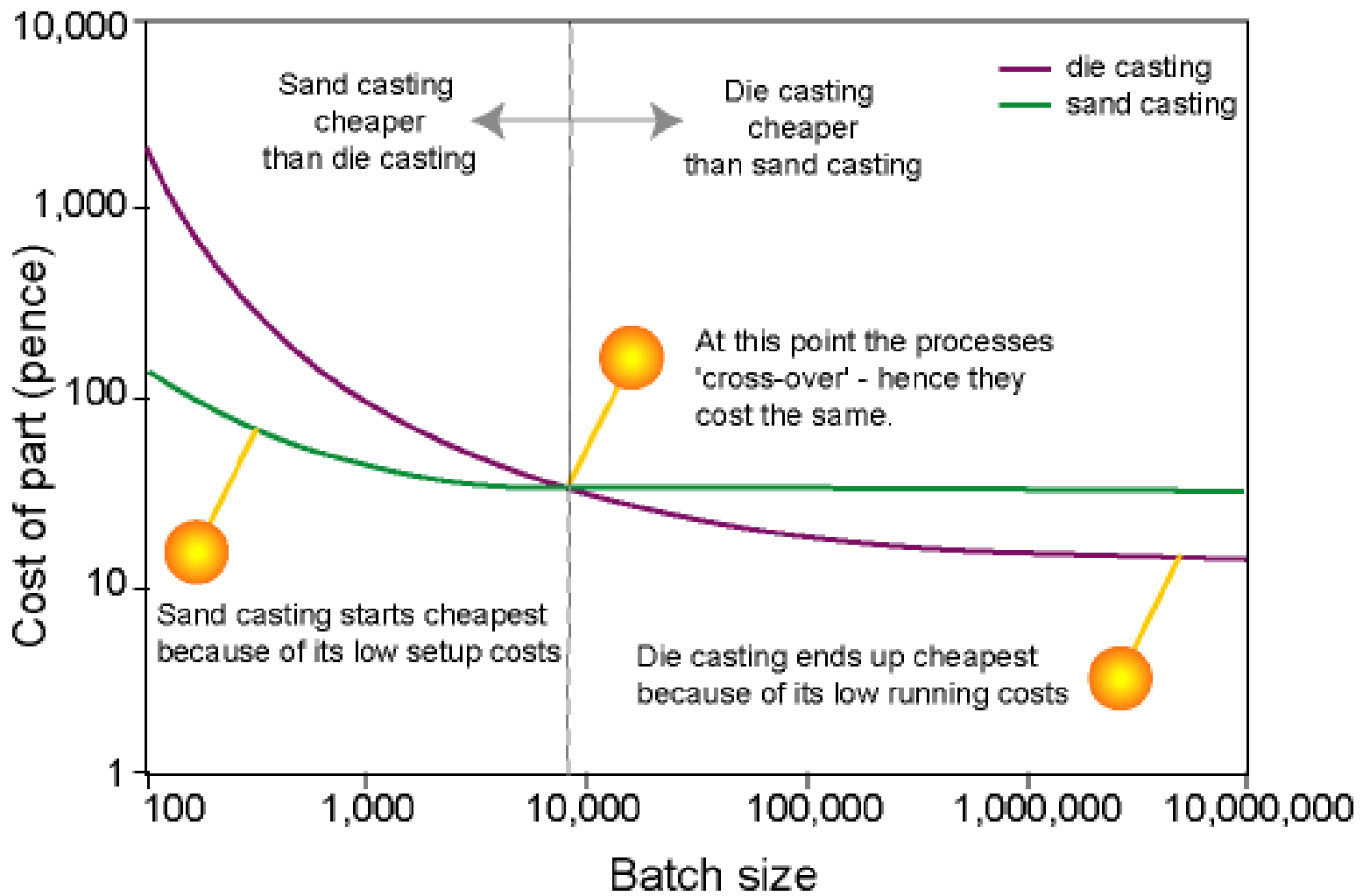


Cast iron Sand Casting

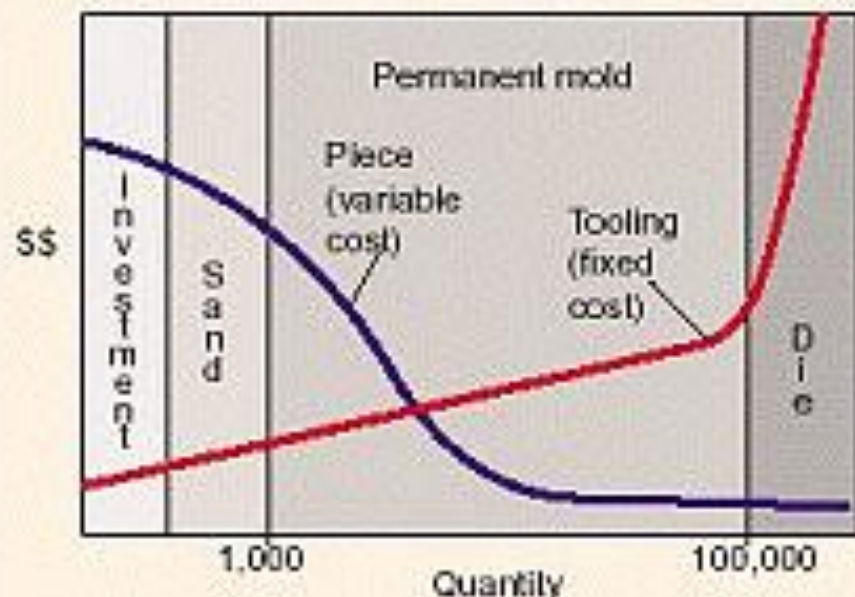




engineeringtoolbox.com

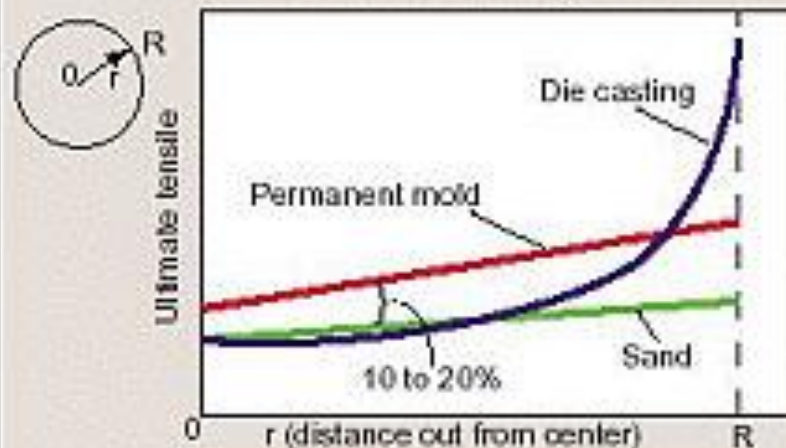


Casting comparison



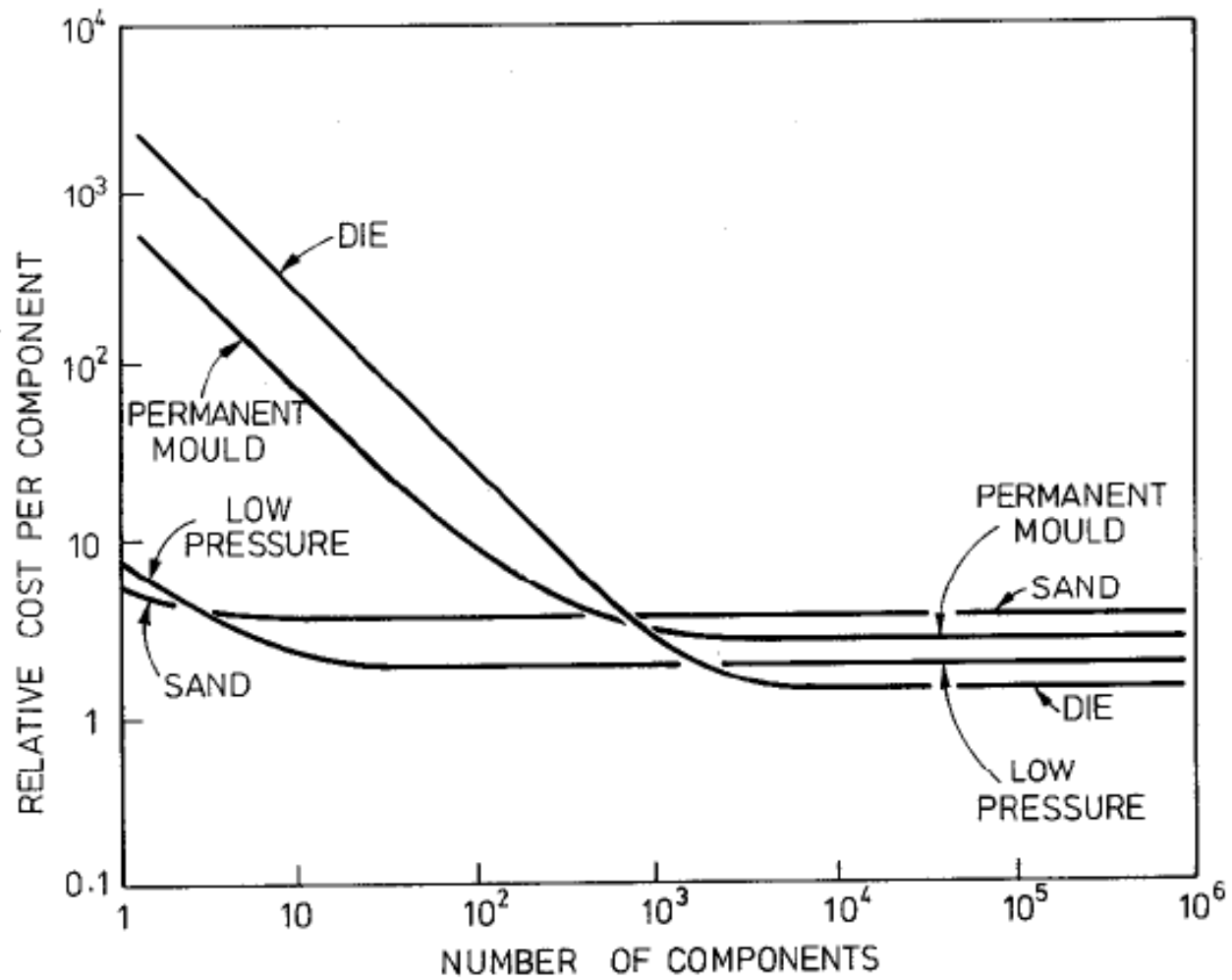
Sand casting involves temporary molds made from metal or wood patterns. Consequently, up-front investment for tooling is low, but per-part prices are usually higher than permanent-mold castings. Conversely, pressure-die casting has shorter cycle times which lower the per-part price, but tooling can cost up to 10 times that of permanent-mold tooling.

Cylinder cross section for aluminum alloy



Permanent-mold castings cool faster than sand castings, giving them a much finer, more uniform microstructure. This boosts mechanical properties by up to 20%. In comparison, pressure-die-cast parts have a much stronger skin, but weaker interior sections.

Process economics



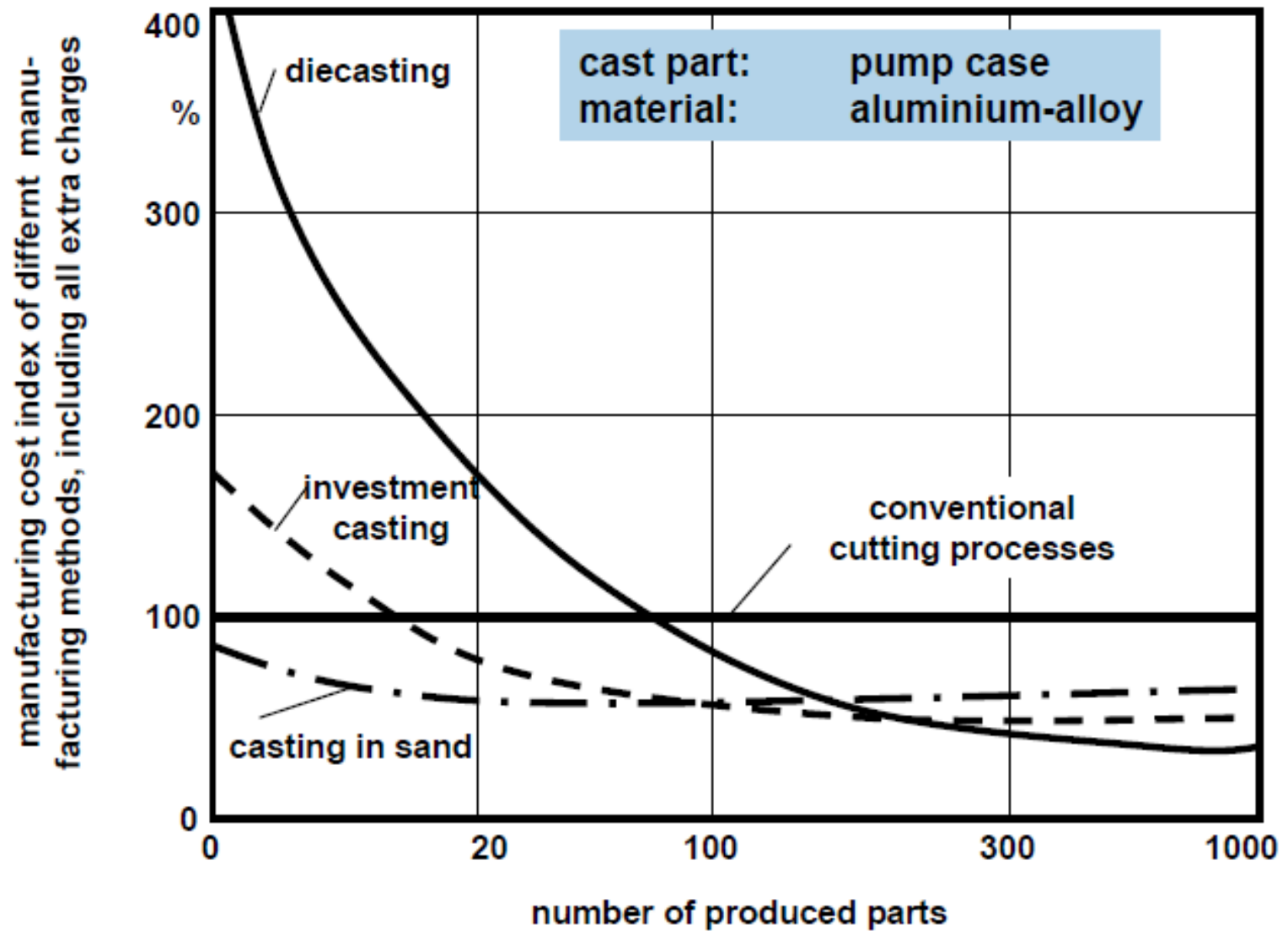
Casting costs

TABLE 5.10

| Process | Cost* | | | Production rate (Pc/hr) |
|----------------|-------|-----------|-------|-------------------------|
| | Die | Equipment | Labor | |
| Sand | L | L | L-M | <20 |
| Shell-mold | 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-M | <200 |
| Centrifugal | M | H | L-M | <50 |

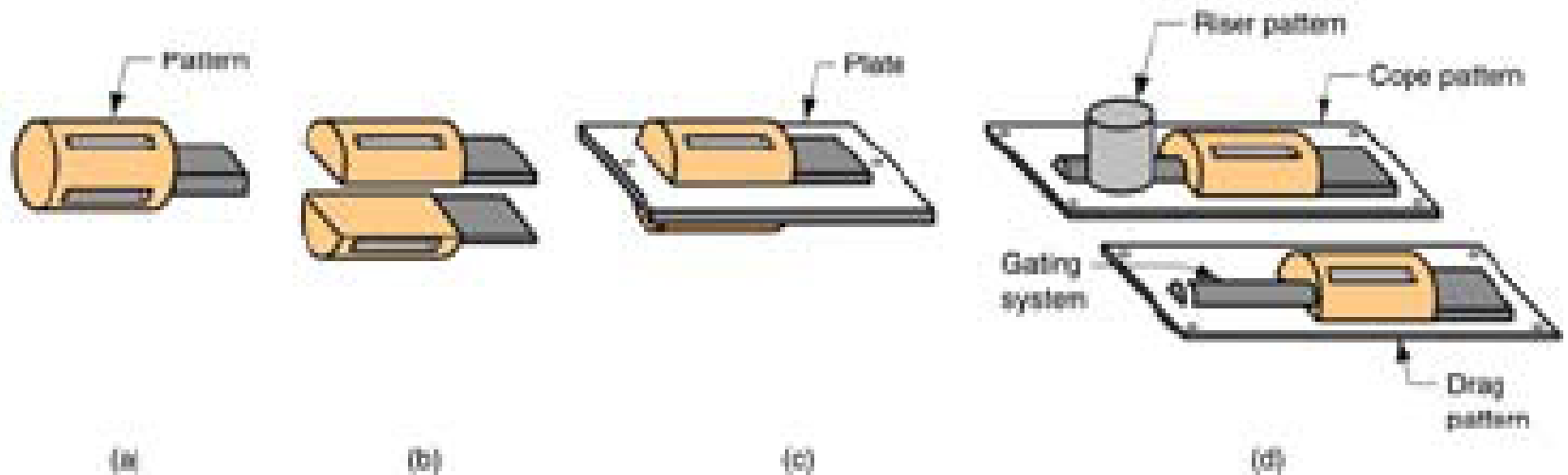
* L, low; M, medium; H, high.

Comparison of manufacturing costs for a gear case



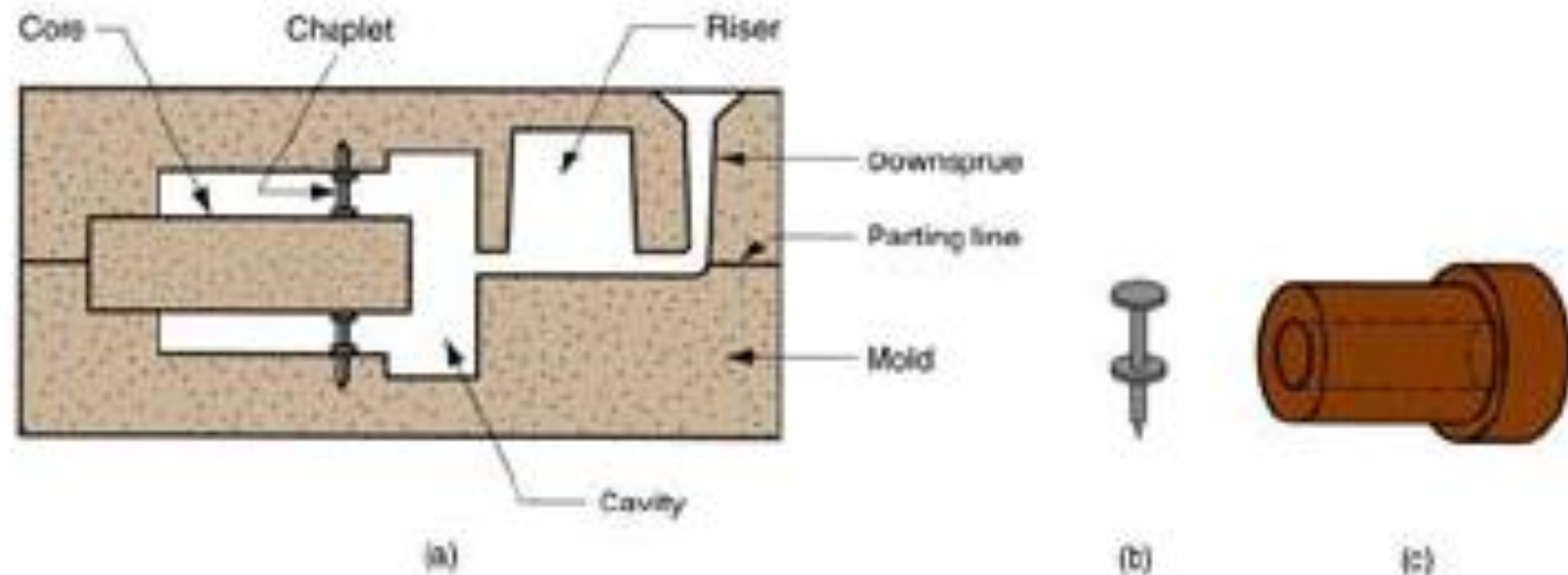
- Casting (process) – melt the metal, pour into a mold by gravity or other force and solidify.
- Casting (Part)
- Advantages
 - Complex geometries – external and internal
 - Can be net-shaped or near net-shaped
 - Can produce very large parts
 - Any metals
 - Can be mass-produced
 - Size variety – big and small
- Disadvantages
 - Limitation in mechanical properties, porosity,
 - Dimensional accuracy, surface finish
 - Safety Hazard
 - Environmental problems

Types of patterns used in sand casting:



- (a) solid pattern
- (b) split pattern
- (c) match-plate pattern
- (d) cope and drag pattern

Internal Cavity with Core

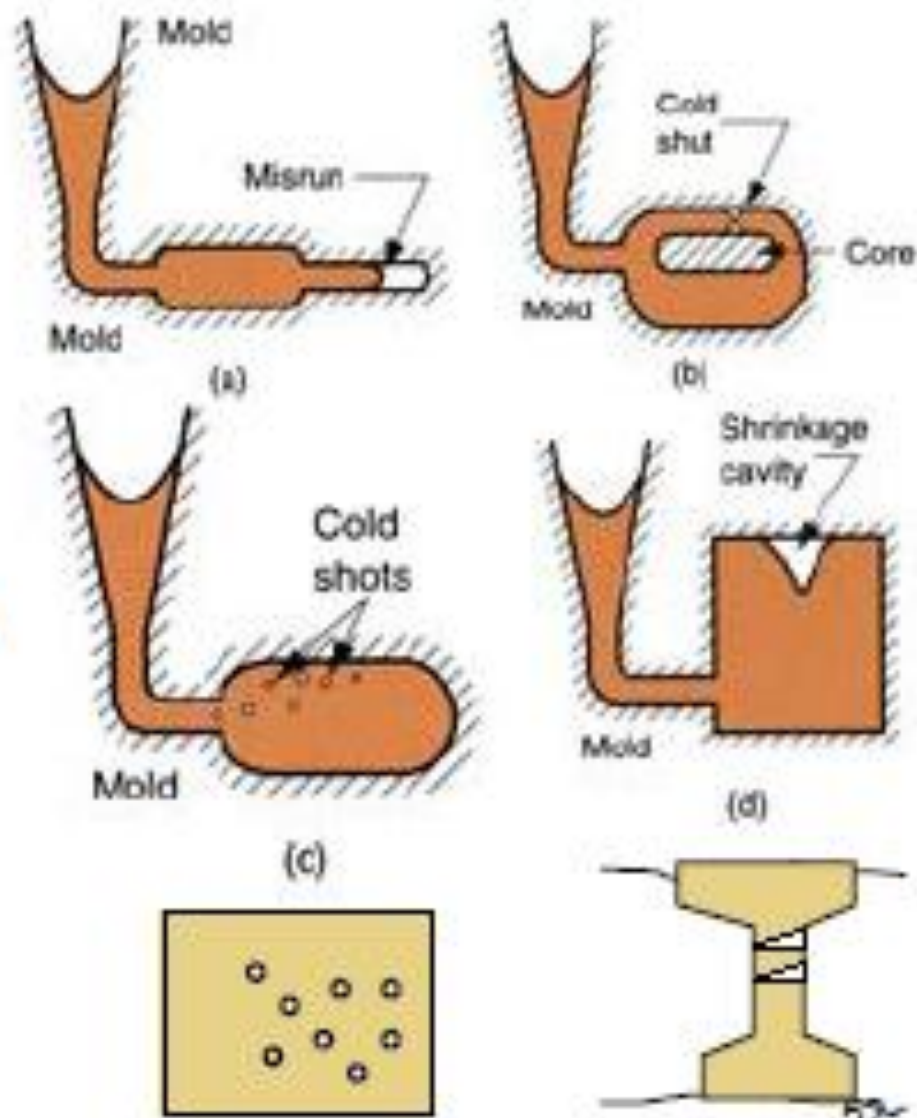


- (a) Core held in place in the mold cavity by chaplets
- (b) possible chaplet design
- (c) casting with internal cavity

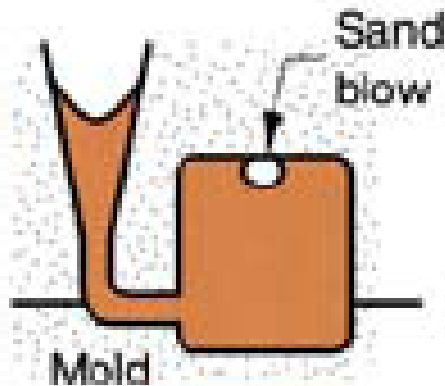
5. Casting Quality

- Casting defects

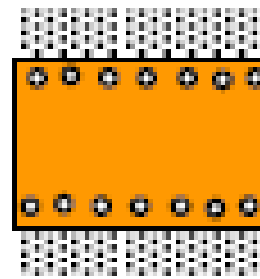
- a) Misruns
- b) Cold shut
- c) Cold shots
- d) Shrinkage cavity
- e) Microporosity
- f) Hot Tearing



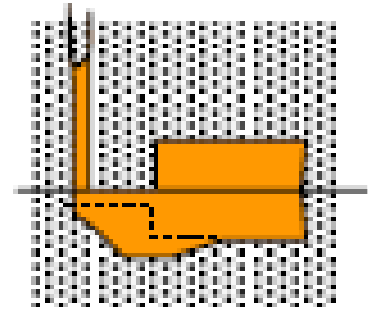
Sand Mold defects



(a)



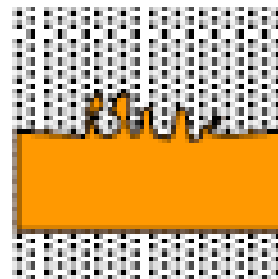
(b) Pin hole



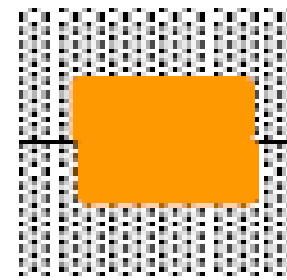
(c) Sand wash



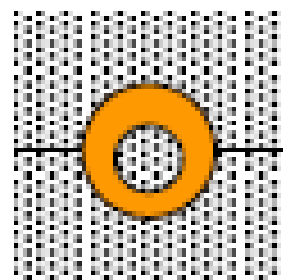
(d) Scabs



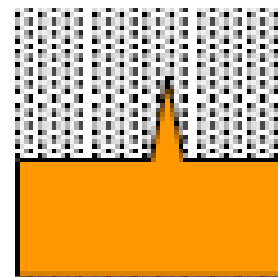
(e) Penetration



(f) Mold shift



(g) Core shift



(h) Mold crack

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:
 - Defects common to all casting processes
 - Defects related to sand casting process

Misrun

A casting that has solidified before completely filling mold cavity

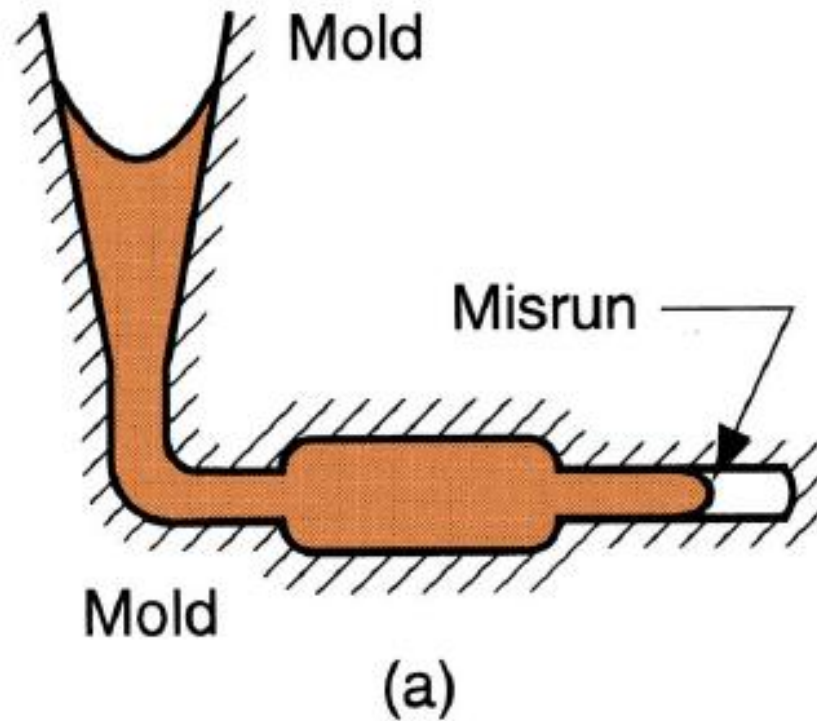


Figure 11.22 - Some common defects in castings: (a) misrun

Cold Shut

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

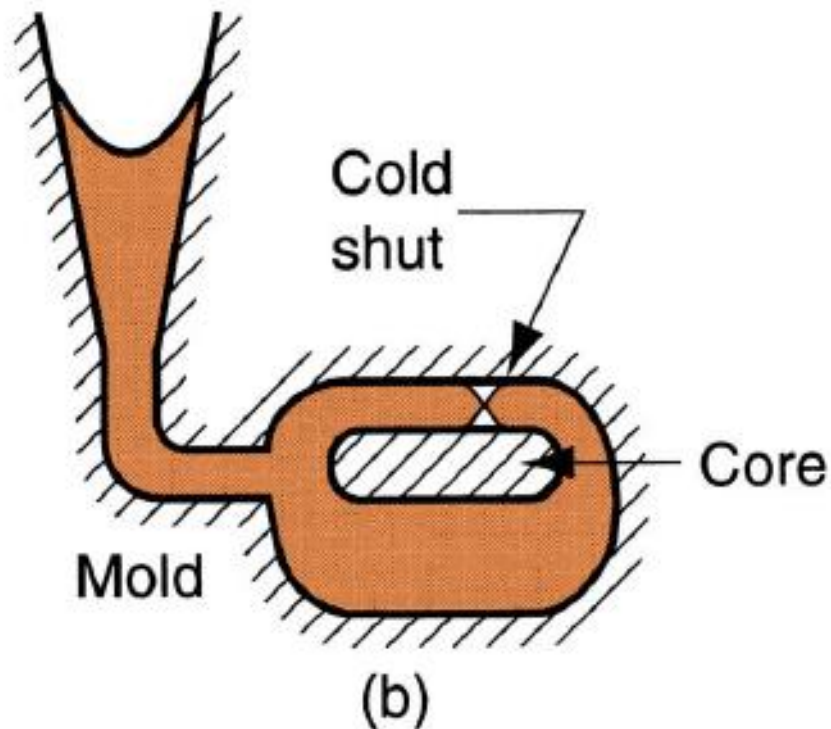


Figure 11.22 - Some common defects in castings: (b) cold shut

Shrinkage Cavity

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

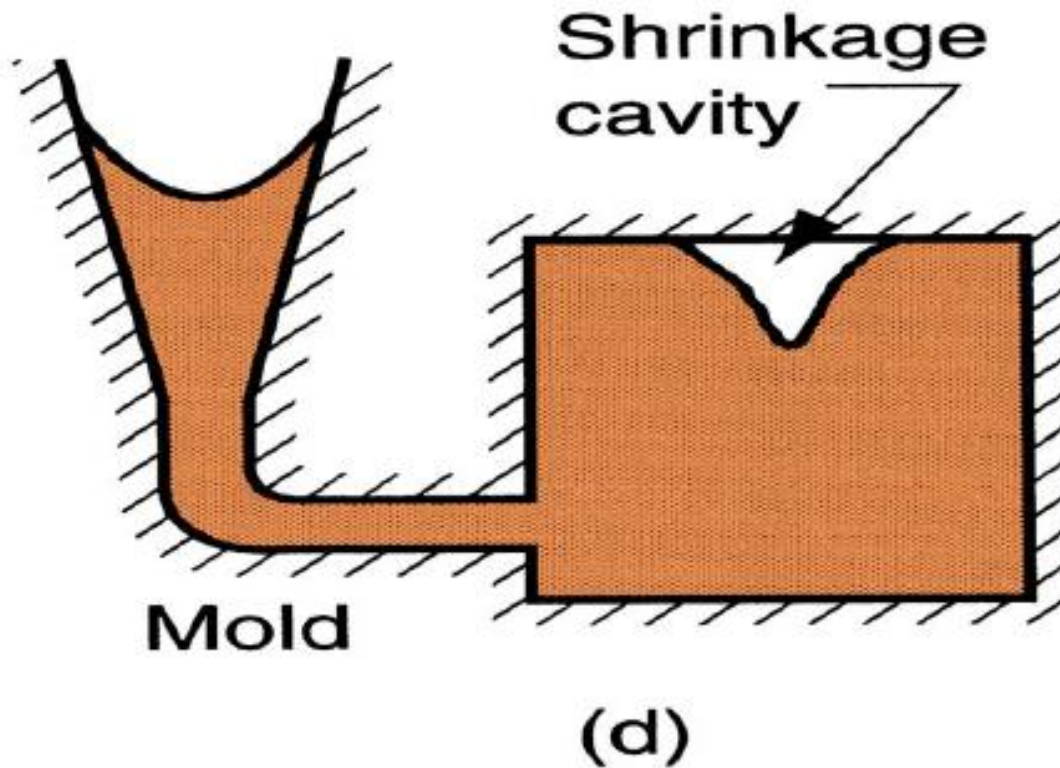
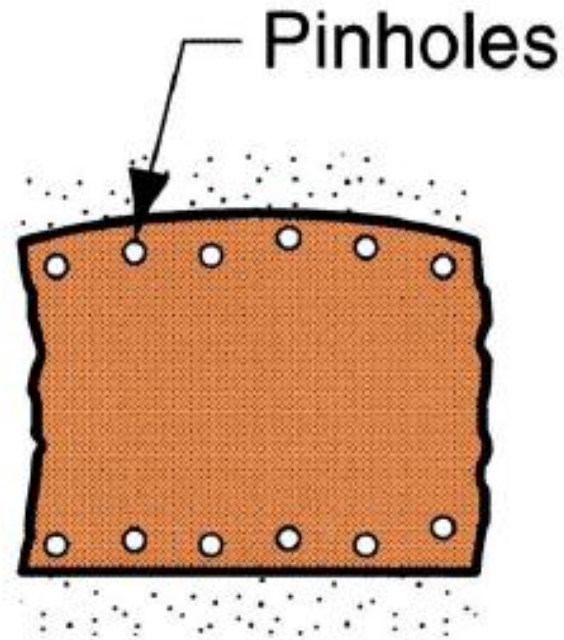


Figure 11.22 - Some common defects in castings: (d) shrinkage cavity

Pin Holes

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



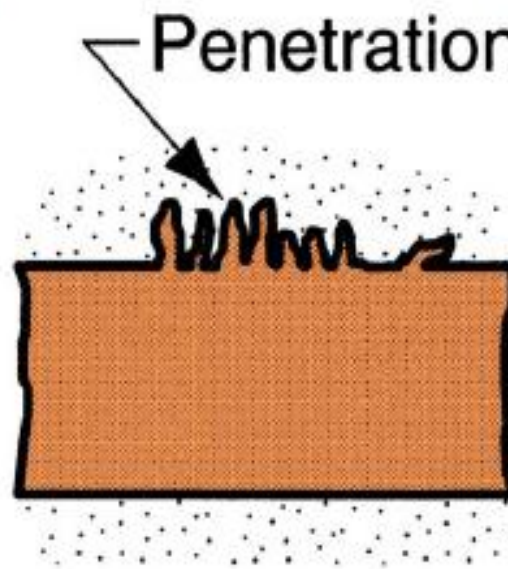
Mold

(b)

Figure 11.23 - Common defects in sand castings: (b) pin holes

Penetration

When fluidity of liquid metal is high, it may penetrate into sand mold or sand core, causing casting defects. Penetration defects consist of a mixture of sand and metal.



(e)

Figure 11.23 - Common defects in sand castings: (e) penetration

Mold Shift

A step in cast product at parting line caused by sideways relative displacement

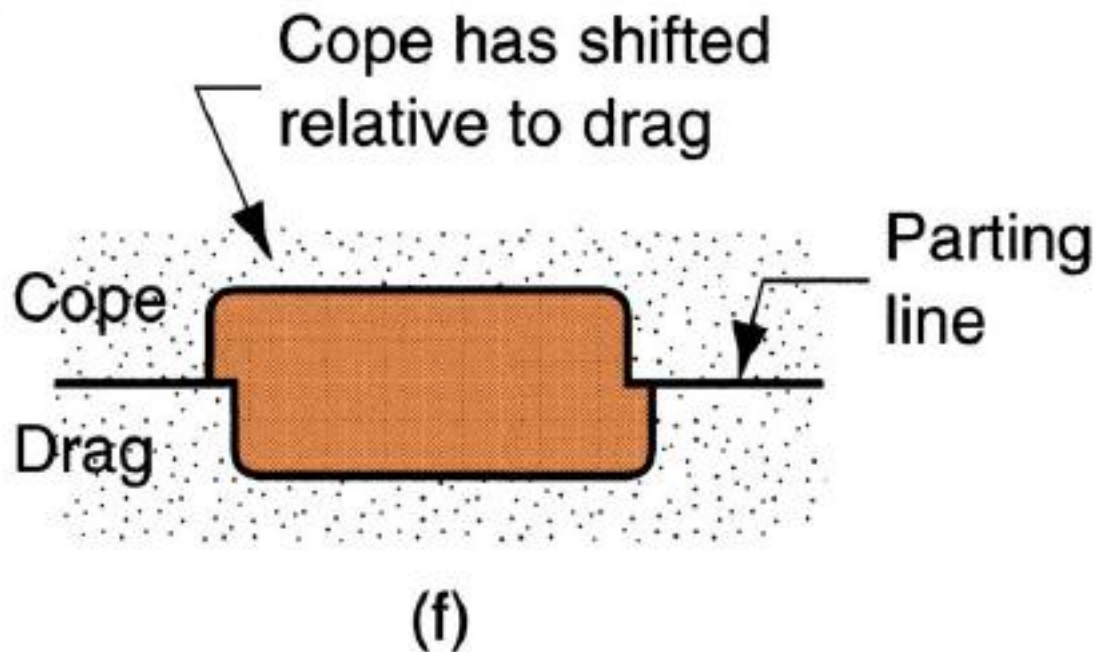


Figure 11.23 - Common defects in sand castings: (f) mold shift

Product Design Considerations: Draft Guidelines

- In expendable mold casting, purpose of draft is to facilitate removal of pattern from mold (1° for sand casting)
- In permanent mold casting, purpose is to aid in removal of the part from the mold (2° to 3° for permanent mold processes)
- Similar tapers should be allowed if solid cores are used

- Minor changes in part design can reduce need for coring

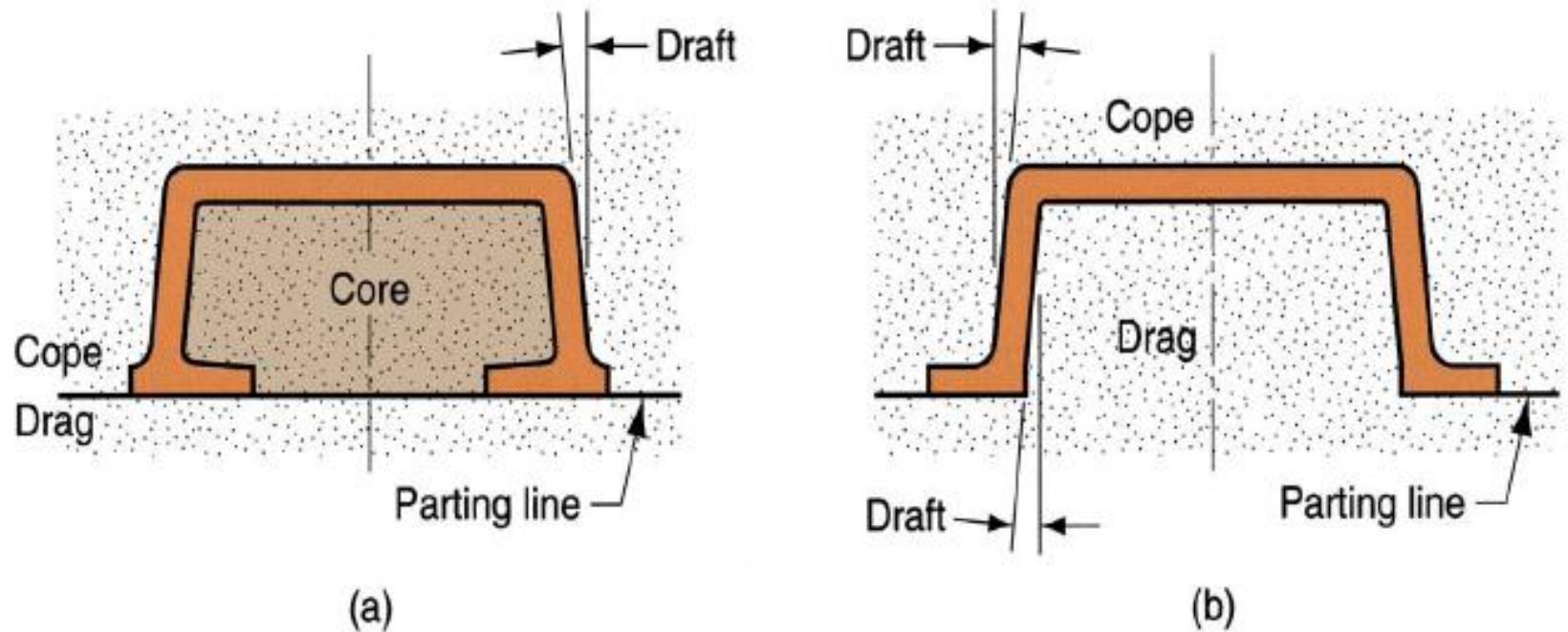


Figure 11.25 – Design change to eliminate the need for using a core:
(a) original design, and (b) redesign

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 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

- 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, whereas 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

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

Product Design Considerations: Geometric Simplicity

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

Product Design Considerations: Corners

- 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: Dimensional Tolerances and Surface Finish

Significant differences in dimensional accuracies and finishes can be achieved in castings, 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*, must be 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)

Pattern Design Considerations (DFM)

- Shrinkage allowance
- Machining allowance
- Distortion allowance
- Parting line
- Draft angle

Typical Shrinkage Allowance

| Metal or alloy | Shrinkage allowances mm / m |
|-------------------------------------|--------------------------------|
| Aluminum alloy | 13 |
| Aluminum bronze | 21 |
| Yellow brass (thick sections) | 13 |
| Yellow brass (thin sections) | 13 |
| Gray cast iron (a) | 8 - 13 |
| White cast iron | 21 |
| Tin bronze | 16 |
| Gun metal | 11 - 16 |
| Lead | 26 |
| Magnesium | 21 |
| Magnesium alloys (25%) | 16 |
| Manganese bronze | 21 |
| Copper-nickel | 21 |
| Nickel | 21 |
| Phosphor bronze | 11 - 16 |
| Carbon steel | 16 - 21 |
| Chromium steel | 21 |
| Manganese steel | 26 |
| Tin | 21 |
| Zinc | 26 |

Typical Pattern Machining Allowance

| Pattern size, mm | Allowances, mm | | |
|------------------------------|----------------|---------|-----------|
| | Bore | Surface | Cope side |
| For cast irons | | | |
| Up to 152..... | 3.2 | 2.4 | 4.8 |
| 152 - 305..... | 3.2 | 3.2 | 6.4 |
| 305 - 510..... | 4.8 | 4.0 | 6.4 |
| 510 - 915..... | 6.4 | 4.8 | 6.4 |
| 915 - 1524..... | 7.9 | 4.8 | 7.9 |
| For cast steels | | | |
| Up to 152..... | 3.2 | 3.2 | 6.4 |
| 152 - 305..... | 6.4 | 4.8 | 6.4 |
| 305 - 510..... | 6.4 | 6.4 | 7.9 |
| 510 - 915..... | 7.1 | 6.4 | 9.6 |
| 915 - 1524..... | 7.9 | 6.4 | 12.7 |
| For nonferrous alloys | | | |
| Up to 76..... | 1.6 | 1.6 | 1.6 |
| 76 - 152..... | 2.4 | 1.6 | 2.4 |
| 152 - 305..... | 2.4 | 1.6 | 3.2 |
| 305 - 510..... | 3.2 | 2.4 | 3.2 |
| 510 - 915..... | 3.2 | 3.2 | 4.0 |
| 915 - 1524..... | 4.0 | 3.2 | 4.8 |

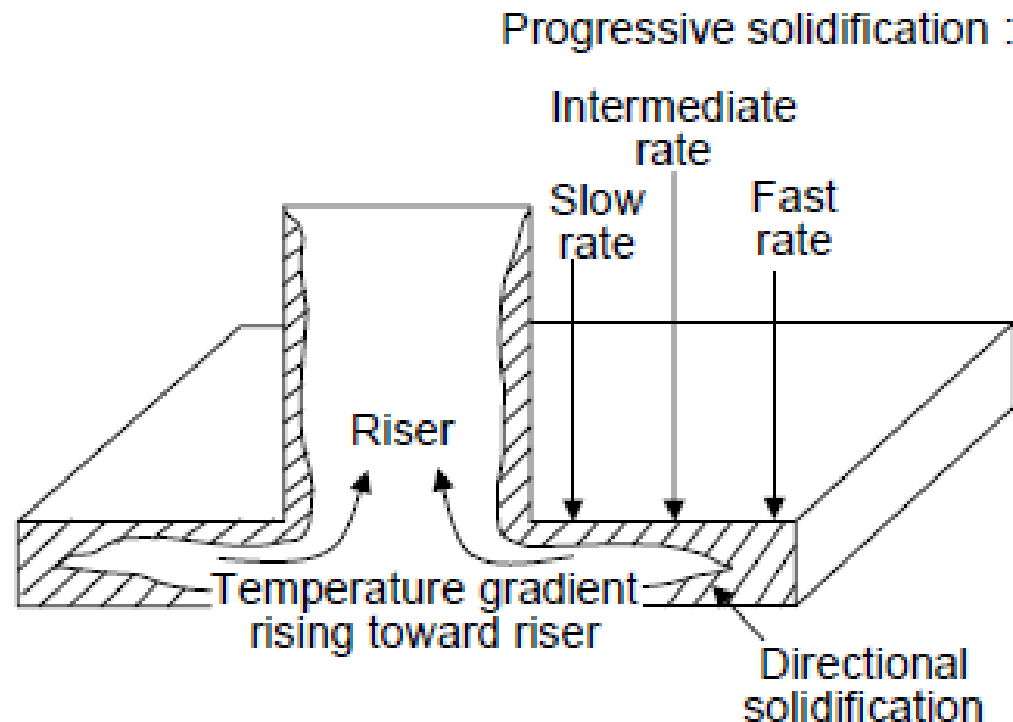
Gating System: Sprue, Runner, and Gate

- Rapid mold filling
- Minimizing turbulence
- Avoiding erosion
- Removing inclusions
- Controlled flow and thermal conditions
- Minimizing scrap and secondary operations

Riser: Location and Size

- Casting shrinkage
- Directional solidification
- Scrap and secondary operation

Progressive Solidification in Riser



Draft in Pattern

