Metals Forming

Metal Casting Processes

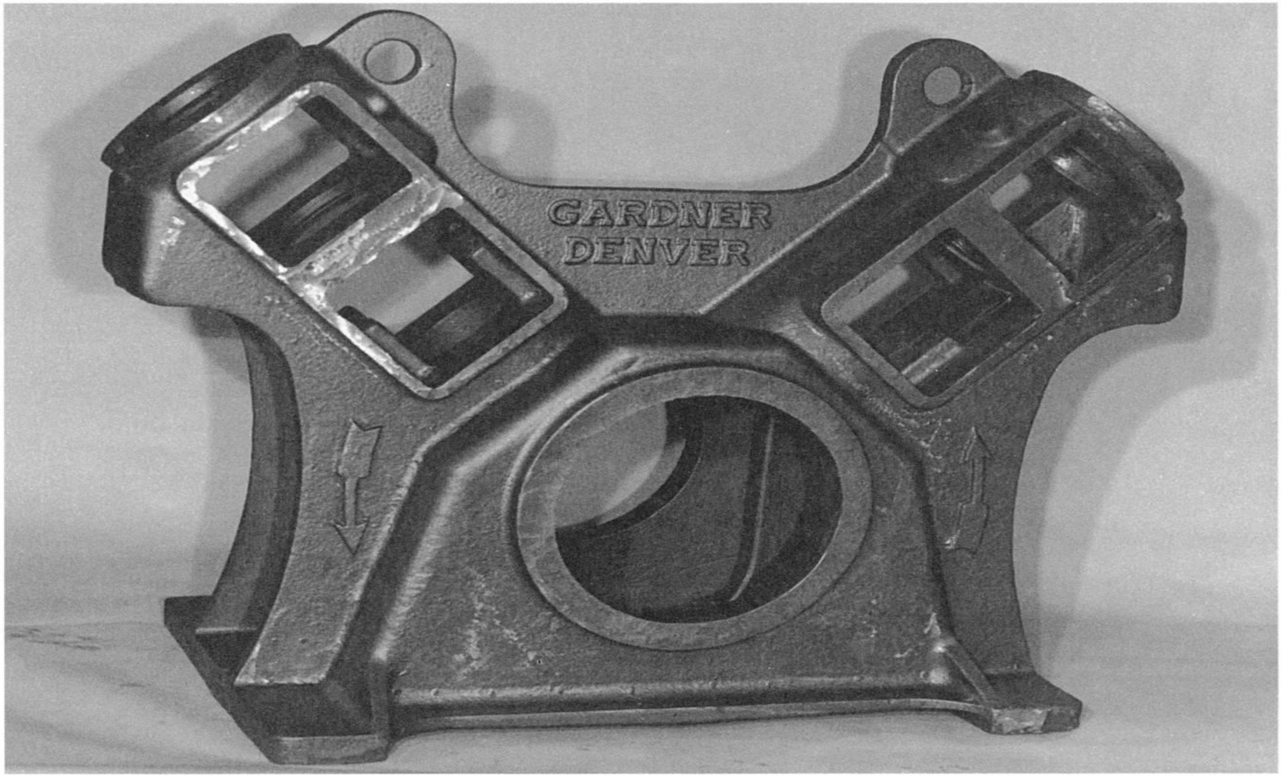
Two Categories of Casting Processes

1. **Expendable mold processes:-** mold is sacrificed to remove part.
   - **Advantage**: more complex shapes possible.
   - **Disadvantage**: production rates often limited by time to make mold rather than casting itself.

2. **Permanent mold processes:-** mold is made of metal and can be used to make many castings.
   - **Advantage**: higher production rates.
   - **Disadvantage**: geometries limited by need to open mold.

Overview of Sand Casting

- **Sand casting** is a cast part produced by forming a mold from a sand mixture and then pouring molten liquid metal into the cavity in the mold. The mold is then cooled until the metal has solidified.
- **Most widely used casting process**, accounting for a significant majority of total tonnage cast.
- **Nearly all alloys can be sand casted**, including metals with high melting temperatures, such as steel, nickel, and titanium.
- **Castings range in size from small to very large**.
- **Production quantities from one to millions**.

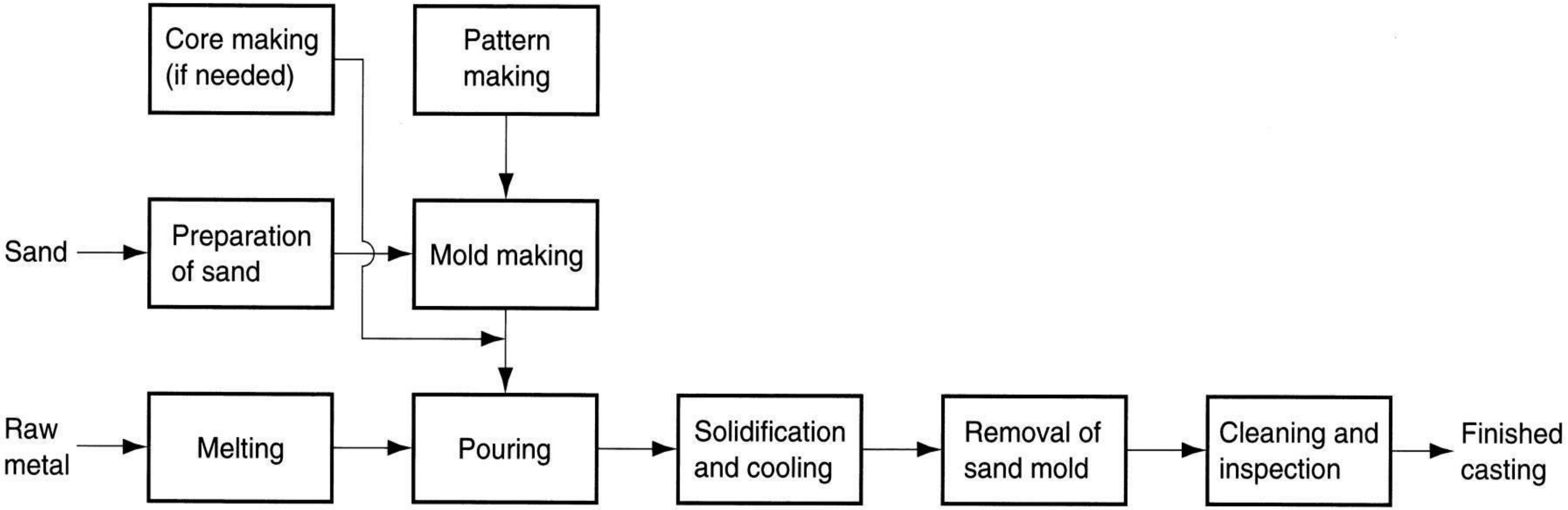


A large sand casting weighing over 680 kg for an air compressor frame

Steps in Sand Casting

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

Sand Casting Production Sequence

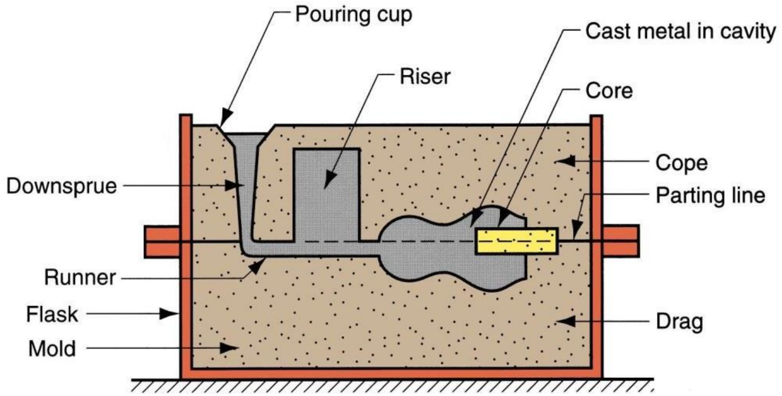


<u>Steps of the production sequence in sand casting</u>

The steps include not only the casting operation but also pattern-making and mold making.

Making the Sand Mold

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



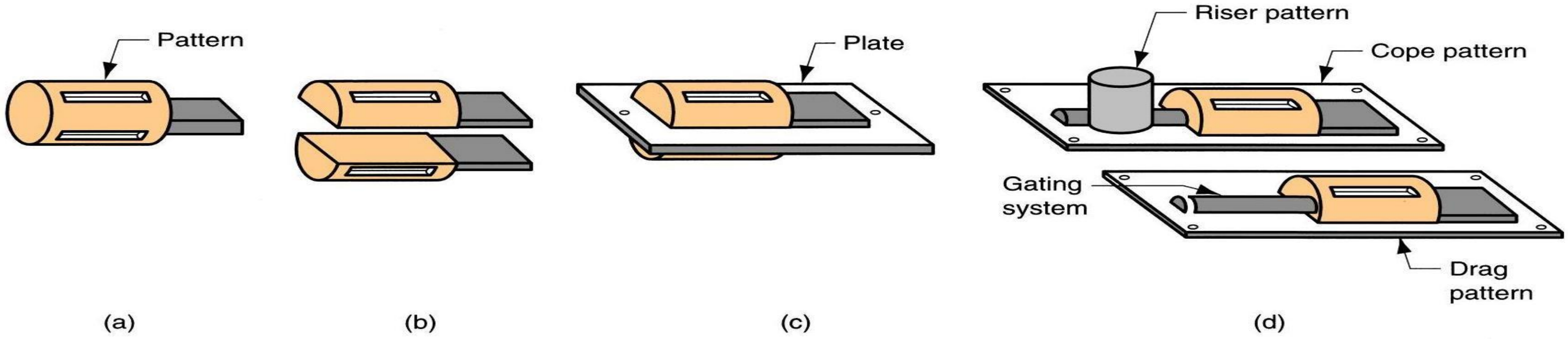
(b)

The Pattern

A full-sized model of the part, slightly enlarged to account for **shrinkage** and **machining allowances** in the casting:-

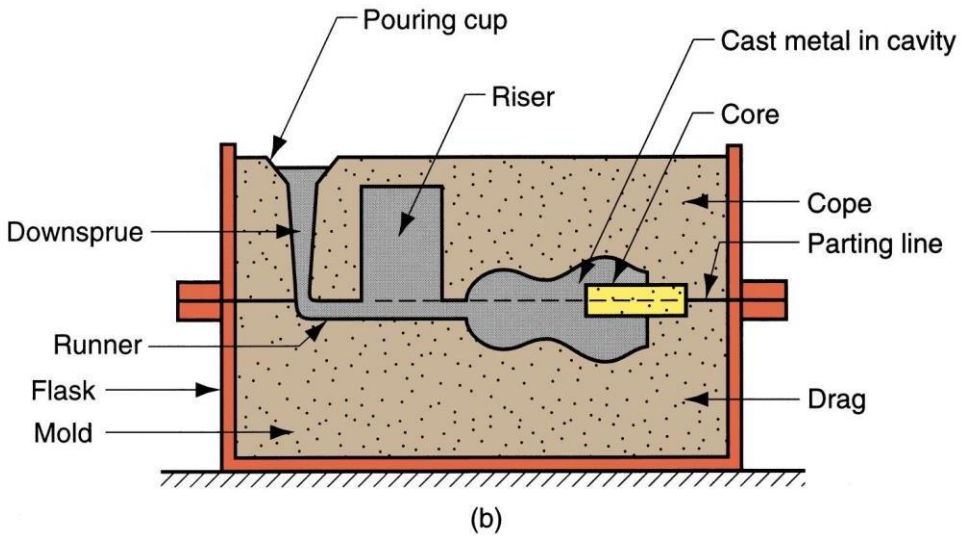
- **Pattern materials:-**
  - **Wood:-** Common material because it is easy to work, but it warps.
  - **Metal:-** More expensive to make but lasts much longer.
  - **Plastic:-** Compromise between wood and metal.

Types of Patterns



Types of patterns used in sand casting

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



Buoyancy Force during Pouring

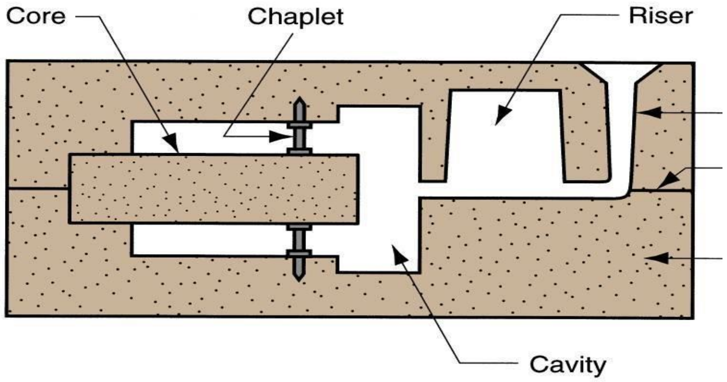
- One of the hazards during pouring is that buoyancy of molten will displace the core with the force:

$F_b = W_m - W_c$ (Archimedes principle).

[W_m] Weight of molten metal displaced.

[W_c] Weight of core.

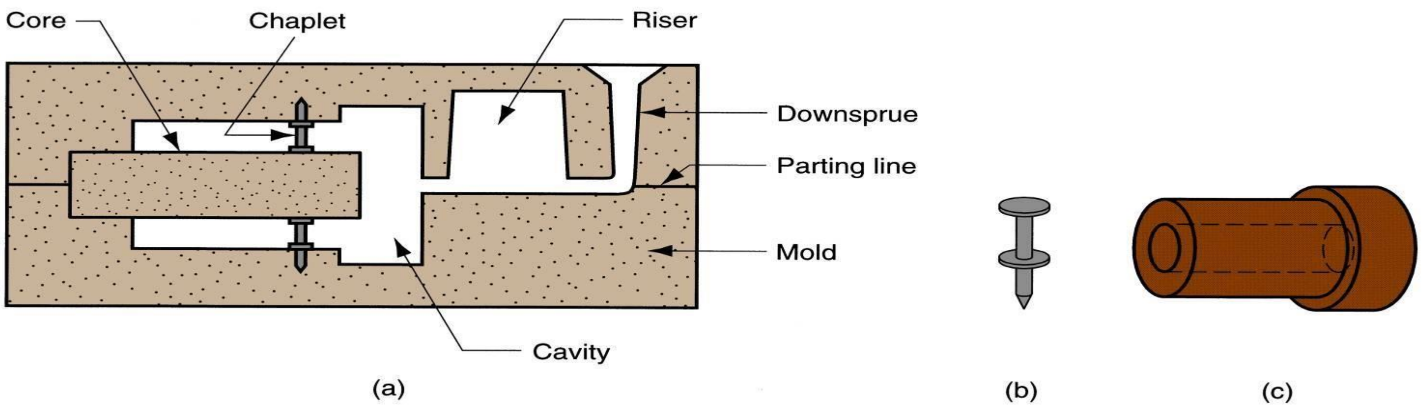
**** In order to avoid the effect of Fb, chaplets are used to hold the core in cavity of mold.**



Core in Mold

A core is a full-scale model of interior surfaces of the part.

1. Like pattern, shrinkage allowances are also provided in core. (-ve or +)?
2. It is usually made of compacted sand or metal.



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

Desirable Mold Properties

- **Strength**:- Ability of mold to maintain shape and resist erosion caused by the flow of molten metal. Depends on grain shape, adhesive quality of binders.
- **Permeability**:- Ability to allow hot air and gases to pass through voids in sand.
- **Thermal stability:-** Ability of sand at the mold surface cavity to resist cracking and buckling on contact with molten metal.
- **Collapsibility**:- Ability to give way and allow casting to shrink without cracking the casting.
- **Reusability**:- Ability of sand from broken mold be reused to make other molds.

Foundry Sands

Silica (SiO_2) or silica mixed with other minerals.

Advantages:-

- Good refractory properties - capacity to endure high temperatures.
- **Small grain size** yields **better surface finish** on the cast part.
- **Large grain size** is **more permeable**, allowing gases to escape during pouring.
- **Irregular grain shapes** strengthen molds due to **interlocking**, compared to round grains.

Disadvantages:-

  - interlocking tends to reduce permeability.

Binders Used with Foundry Sands

- Sand is held together by a mixture of water and bonding clay.
  - **Typical mix**:- **90% sand, 7% clay and 3% water.**

- **Other bonding agents also used in sand molds:-**
  - Organic resins (e.g , **phenolic resins**).
  - Inorganic binders (e.g , **sodium silicate and phosphate**).

- Additives are sometimes combined with the mixture to increase strength and/or permeability.

Types of Sand Mold

- **Green-sand molds:-** Mixture of sand, clay, and water;
  - “Green" means mold contains moisture at time of pouring.

- **Dry-sand mold:-** **Organic binders** rather than clay
  - And mold is baked to improve strength.

- **Skin-dried mold:-** Drying mold cavity surface of a green-sand mold to a depth of **10 to 25 mm**, using torches or heating lamps.

Other Expendable Mold Processes

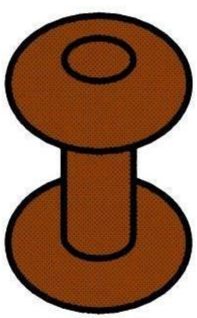
- Shell Molding
- Vacuum Molding
- Expanded Polystyrene Process
- Investment Casting
- Plaster Mold and Ceramic Mold Casting

Shell Molding

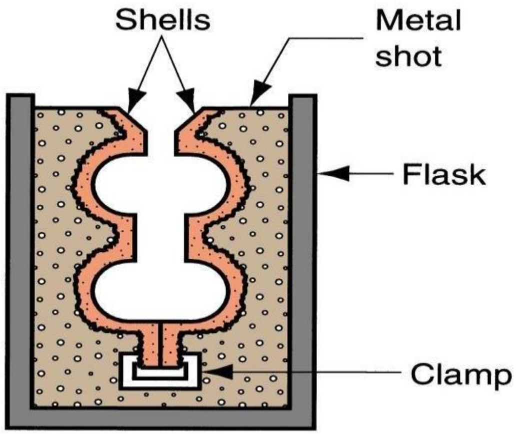
Casting process in which the **cavity** (& gating system) is a **thin shell of sand held together by thermosetting resin binder**

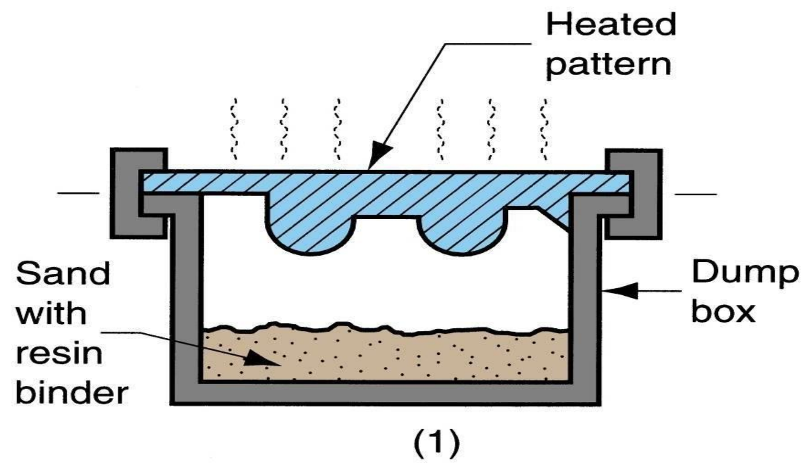
Steps in shell molding:-

(1) a match plate or cope and drag metal pattern is heated and placed over a box containing sand mixed with thermosetting resin.



part

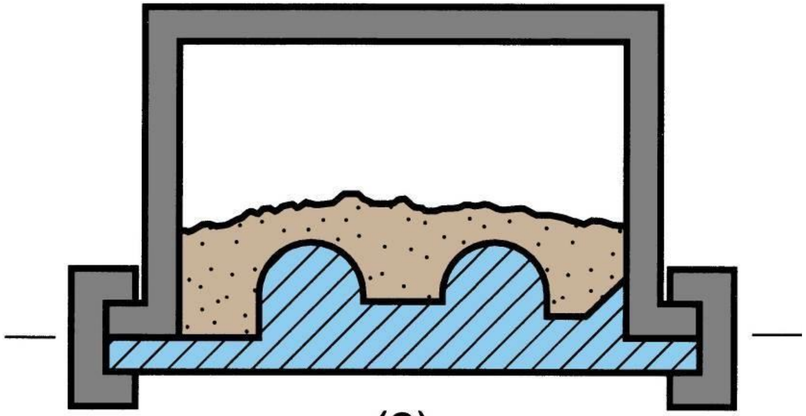




Shell Molding

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

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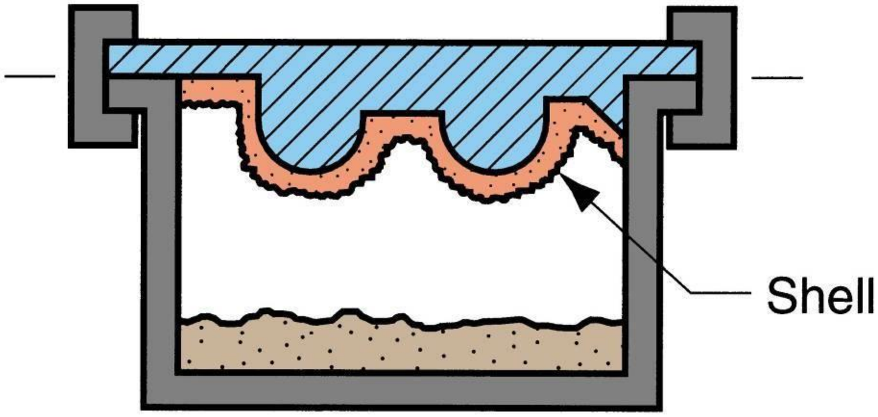
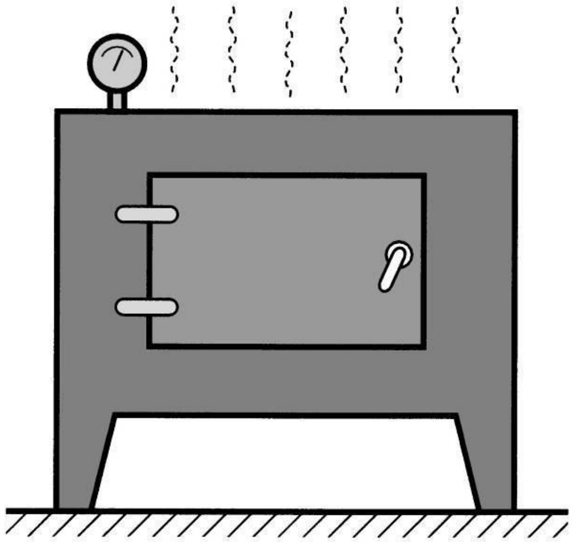


(3)

Shell Molding

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

(5) Shell mold is stripped from the pattern.



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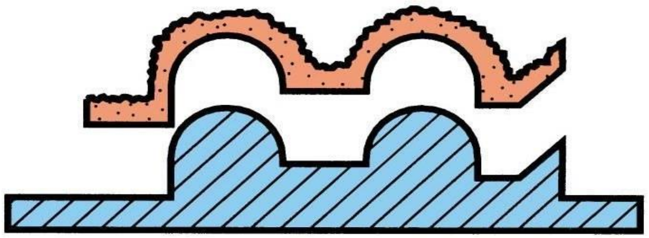
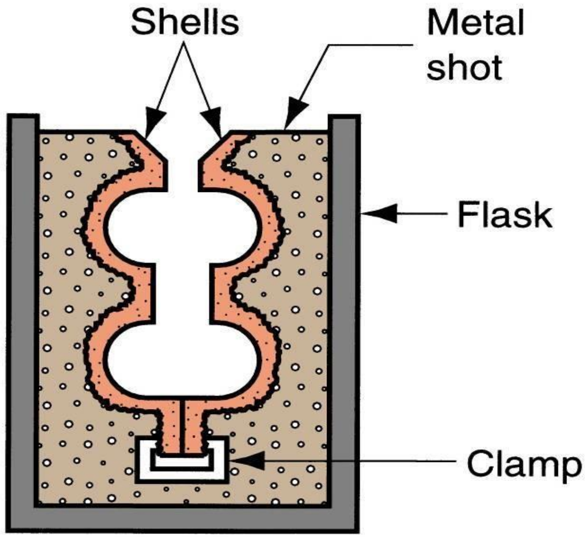


(5)

Shell Molding

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

(7) The finished casting with sprue removed.



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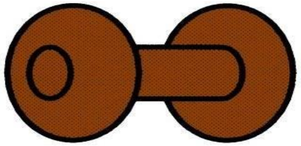
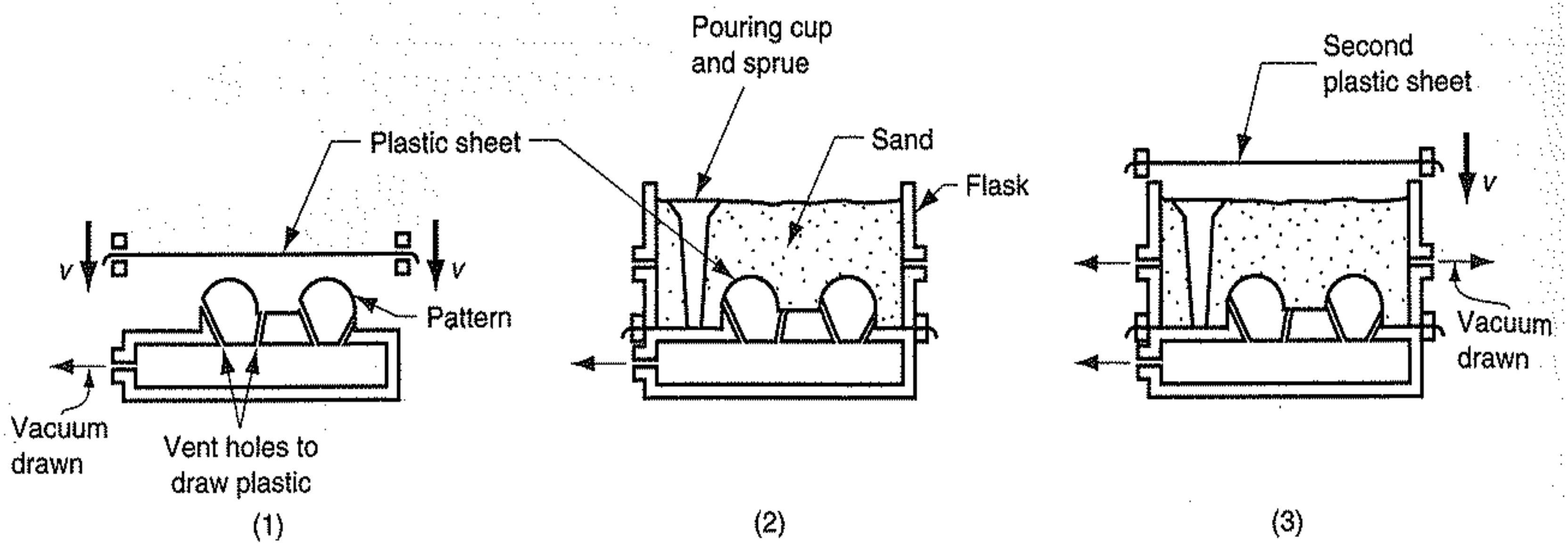


(7)

Advantages and Disadvantages

- Advantages of shell molding:-
  - Smoother cavity surface permits easier flow of molten metal and better surface finish.
  - Good dimensional accuracy - machining often not required.
  - Mold collapsibility minimizes cracks in casting.
  - Can be mechanized for mass production.
- Disadvantages:-
  - More expensive metal pattern.
  - Difficult to justify for small quantities.

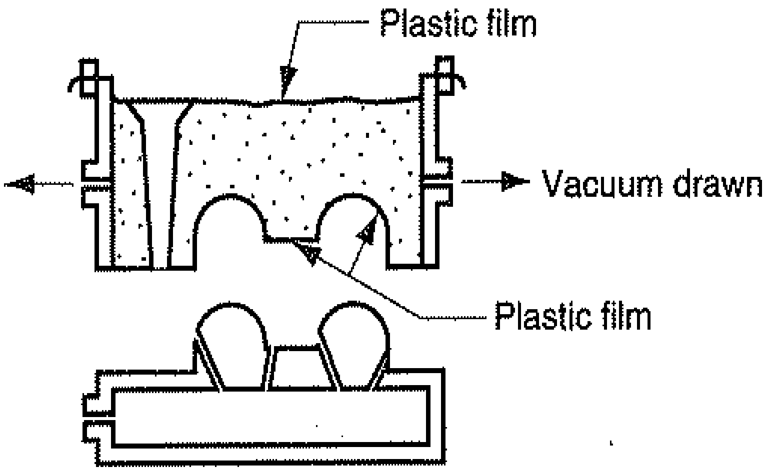
Vacuum Molding

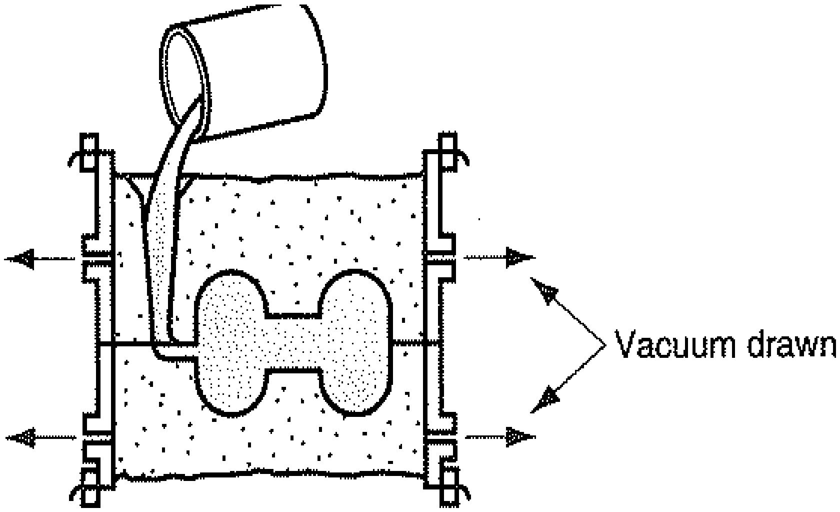


Steps in vacuum molding:- (1) A thin sheet of preheated plastic is drawn over a mach plate or cope and drag pattern by vacuum

FIGURE 11.6 Steps in vacuum molding: (1) a thin sheet of preheated plastic is drawn over a match-plate or cope-and-drag pattern by vacuum—the pattern has small vent holes to facilitate vacuum forming; (2) a specially designed flask is placed over the pattern plate and filled with sand, and a sprue and pouring cup are formed in the sand; (3) another thin plastic sheet is placed over the flask, and a vacuum is drawn that causes the sand grains to be held together, forming a rigid mold; (4) the vacuum on the mold pattern is released to

Vacuum Molding





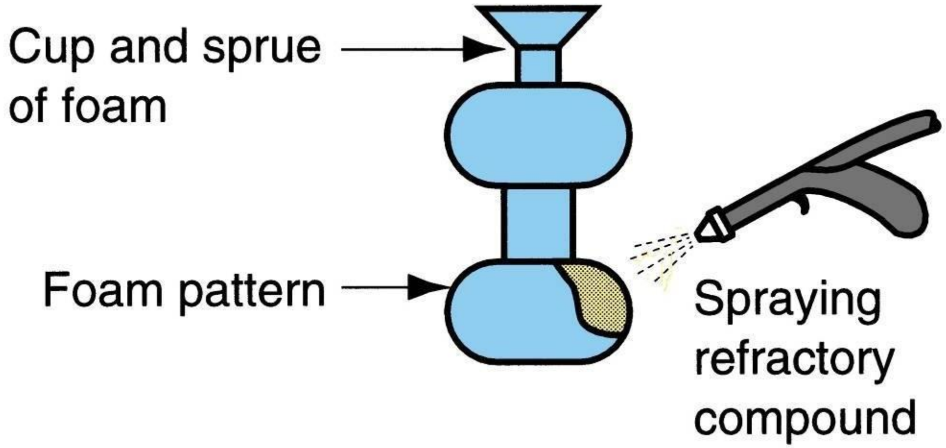
vacuum is drawn that causes the sand grains to be held together, forming a rigid mold; (4) the vacuum on the mold pattern is released to permit the pattern to be stripped from the mold; (5) this mold is assembled with its matching half to form the cope and drag, and with vacuum maintained on both halves, pouring is accomplished. The plastic sheet quickly burns away on contacting the molten metal. After solidification, nearly all of the sand can be recovered for reuse.

Expanded Polystyrene Process or lost-foam process

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

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

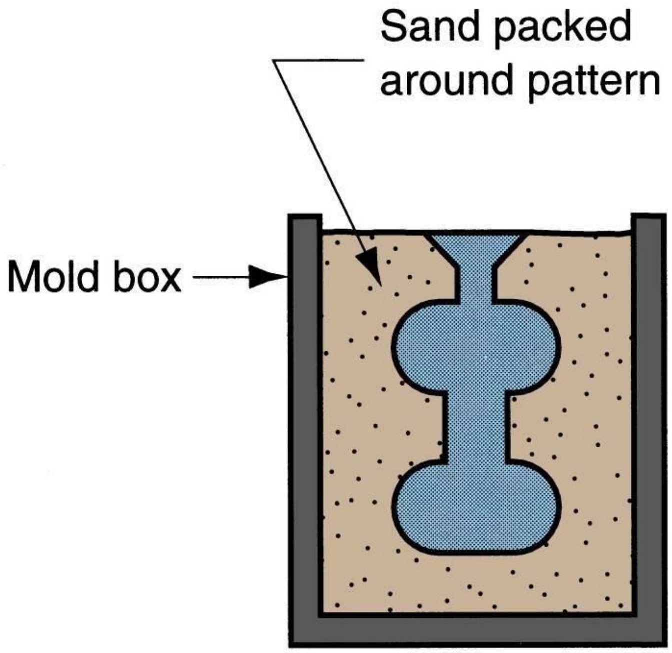
Expanded Polystyrene Process



(1)

(1) pattern of polystyrene is coated with refractory compound;

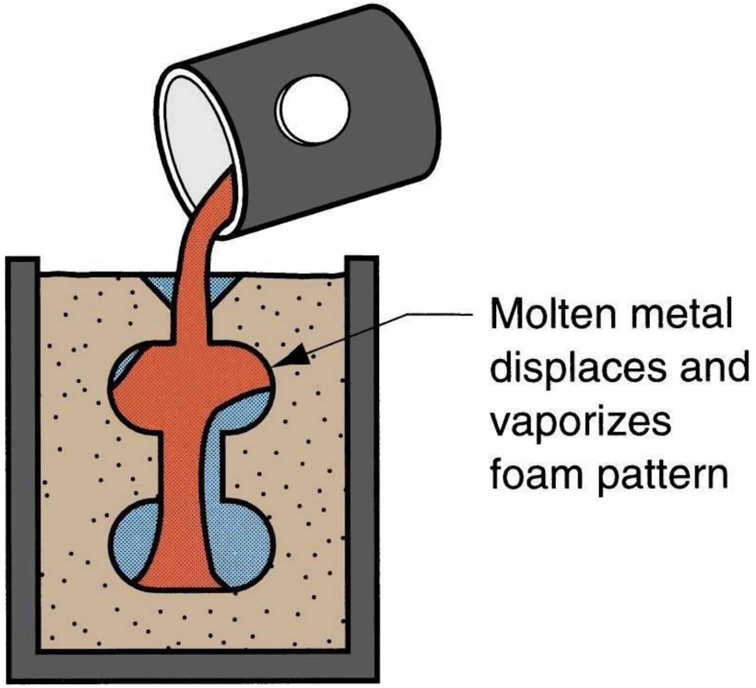
Expanded Polystyrene Process



(2)

(2) foam pattern is placed in mold box, and sand is compacted around the pattern;

Expanded Polystyrene Process



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

Advantages and Disadvantages

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

Expanded Polystyrene Process

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

Investment Casting (Lost Wax Process)

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

- "Investment" comes from a less familiar definition of "**invest**" - "to cover completely," which refers to coating of refractory material around wax pattern.

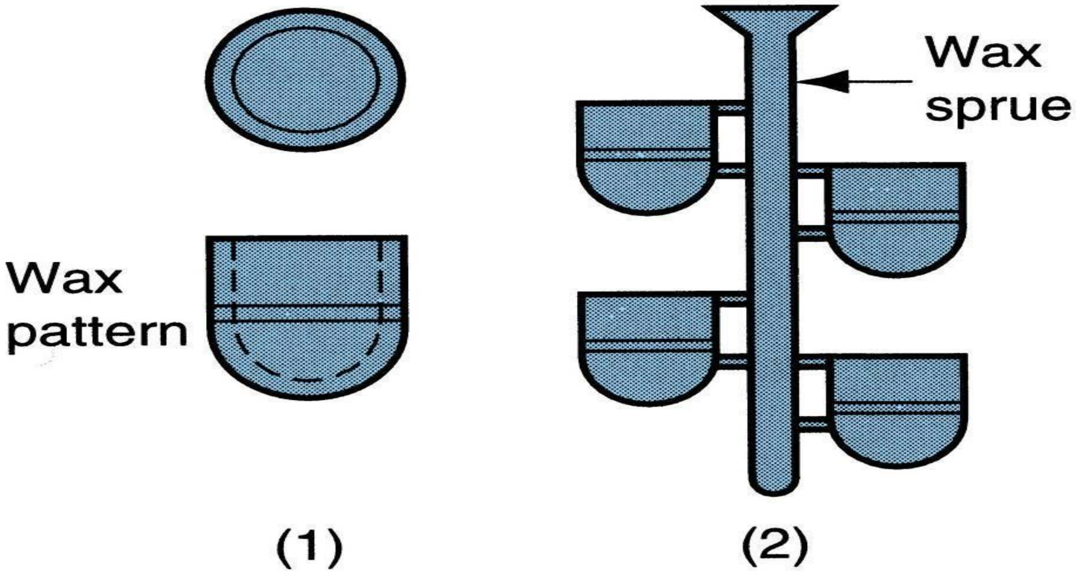
- *It is a precision casting process* - capable of producing castings of high accuracy and intricate detail

Investment Casting

Steps in investment casting:-

(1) Wax patterns are produced.

(2) several patterns are attached to a sprue to form a pattern tree

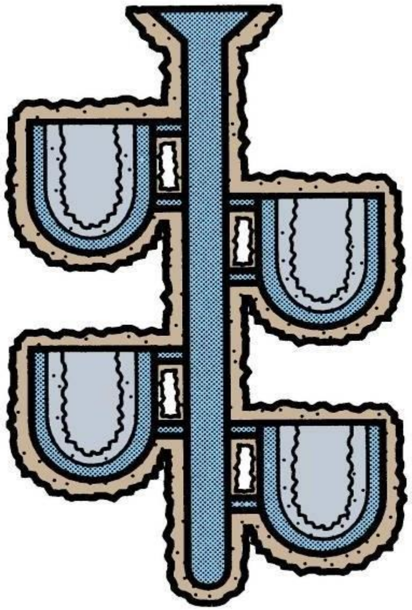


Investment Casting

(3) The pattern tree is coated with a thin layer of refractory material.

(4) The full mold is formed by covering the coated tree with sufficient refractory material to make it rigid.

(3)

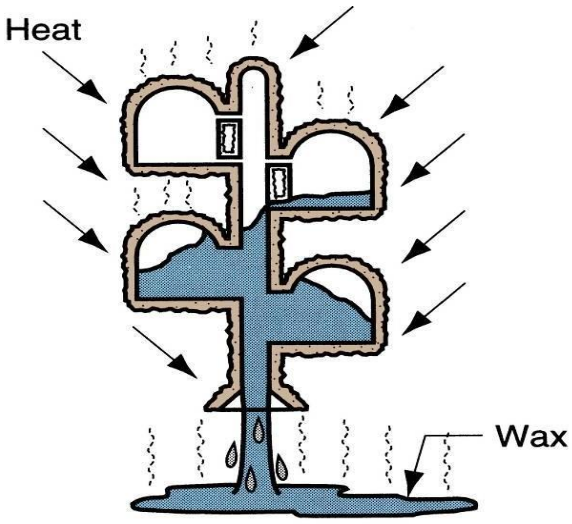


(4)

Investment Casting

(5) The mold is held in an inverted position and heated to melt the wax and permit it to drip out of the cavity.

(6) The mold is preheated to a high temperature, the molten metal is poured, and it solidifies.



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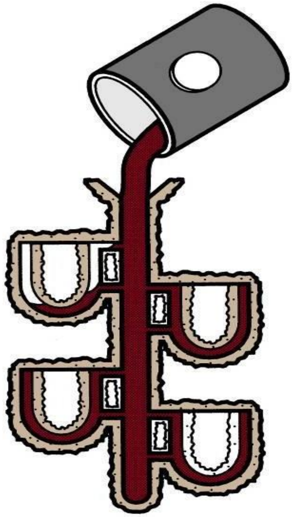
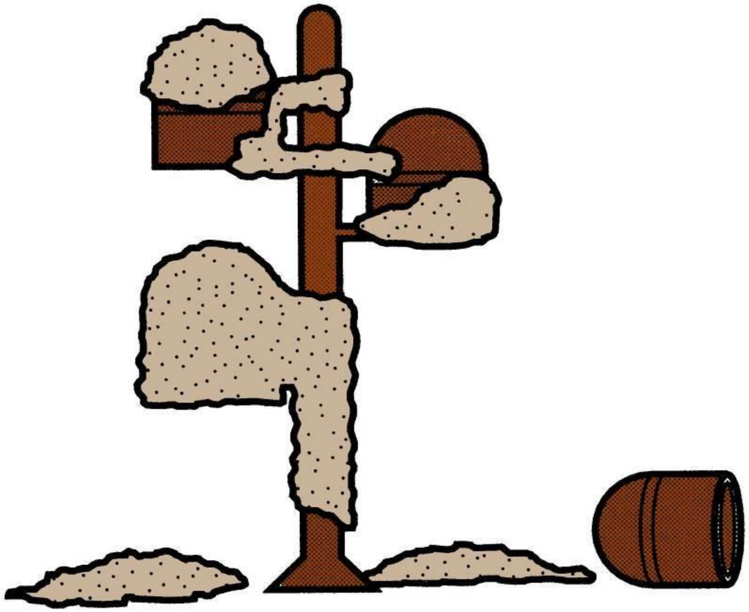


(6)

Investment Casting

(7) The mold is broken away from the finished casting and the parts are separated from the sprue.



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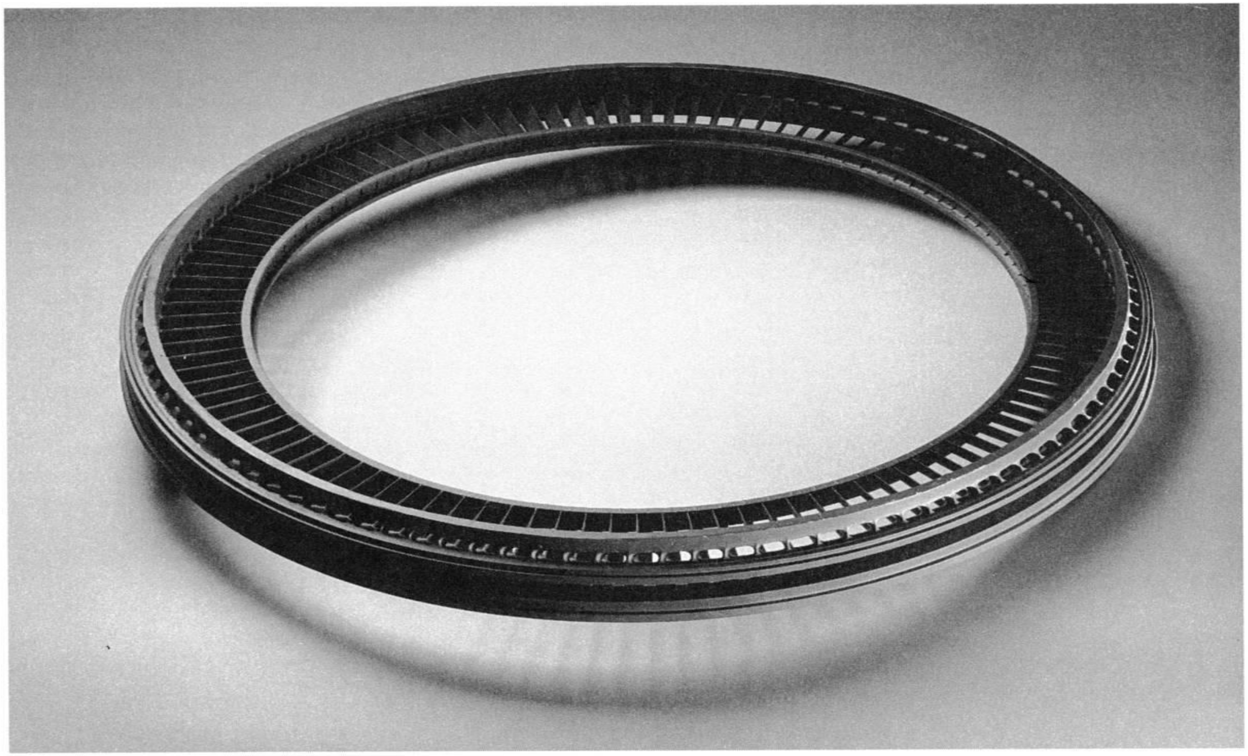
Investment Casting



A one piece compressor stator with 108 separate airfoils made by investment casting

Advantages and Disadvantages

- Advantages of investment casting:-
  - Parts of great complexity and intricacy can be cast.
  - Close dimensional control and good surface finish.
  - Wax can usually be recovered for reuse.
  - Additional machining is not normally required (this is a net shape process).

- Disadvantages:-
  - Many processing steps are required.
  - Relatively expensive process.