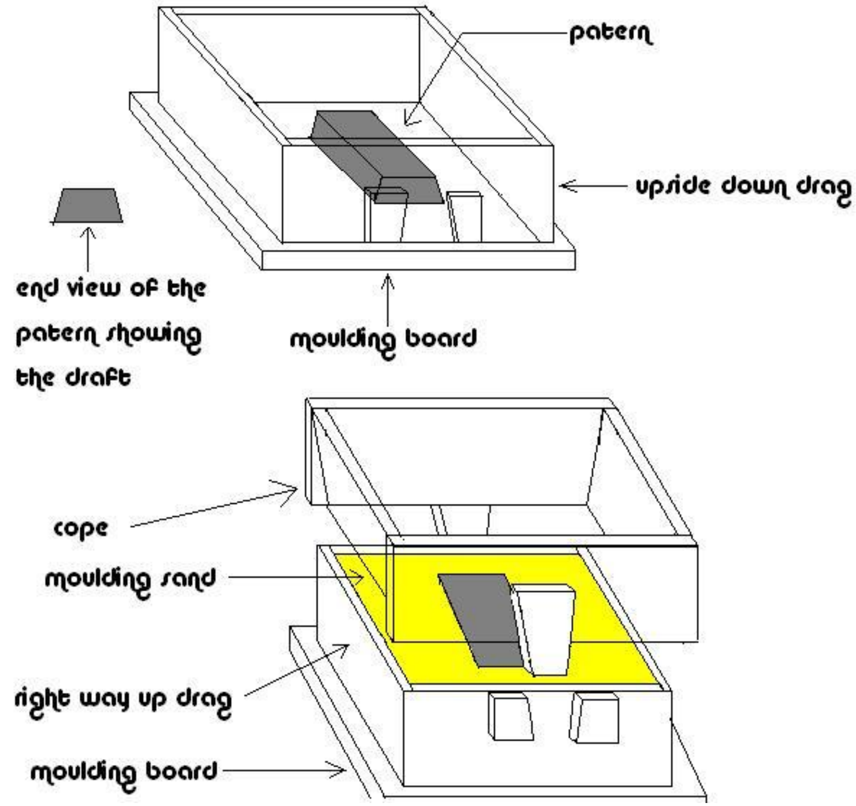
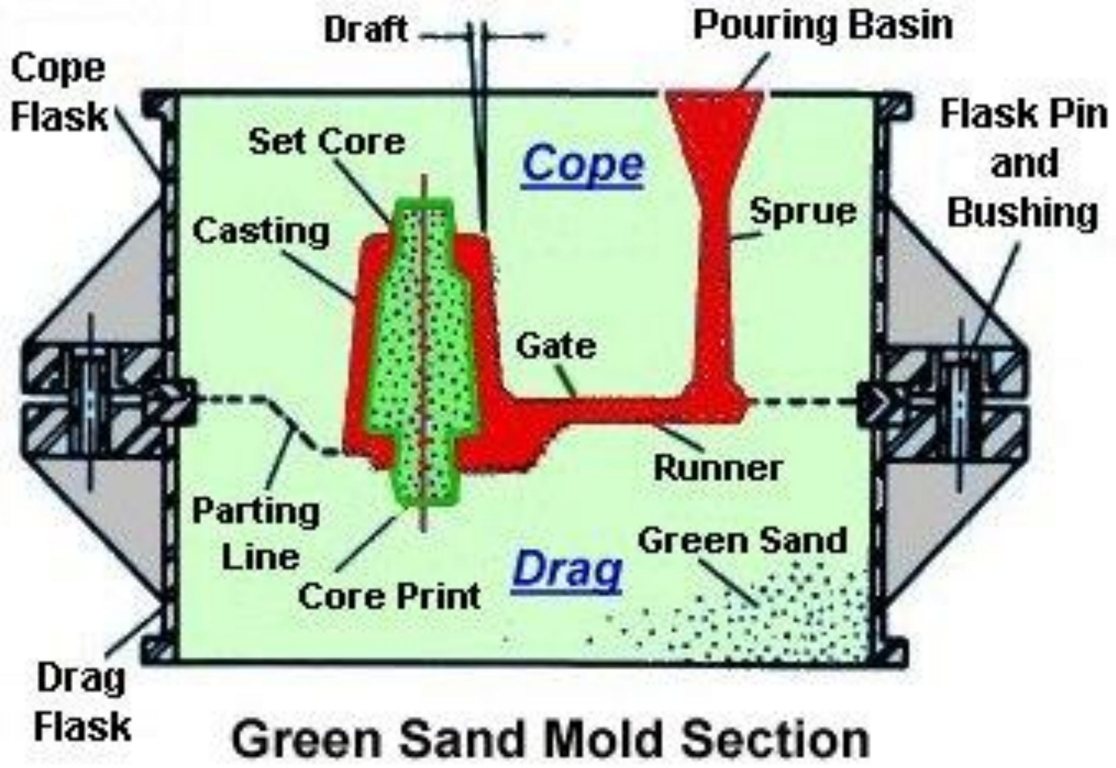
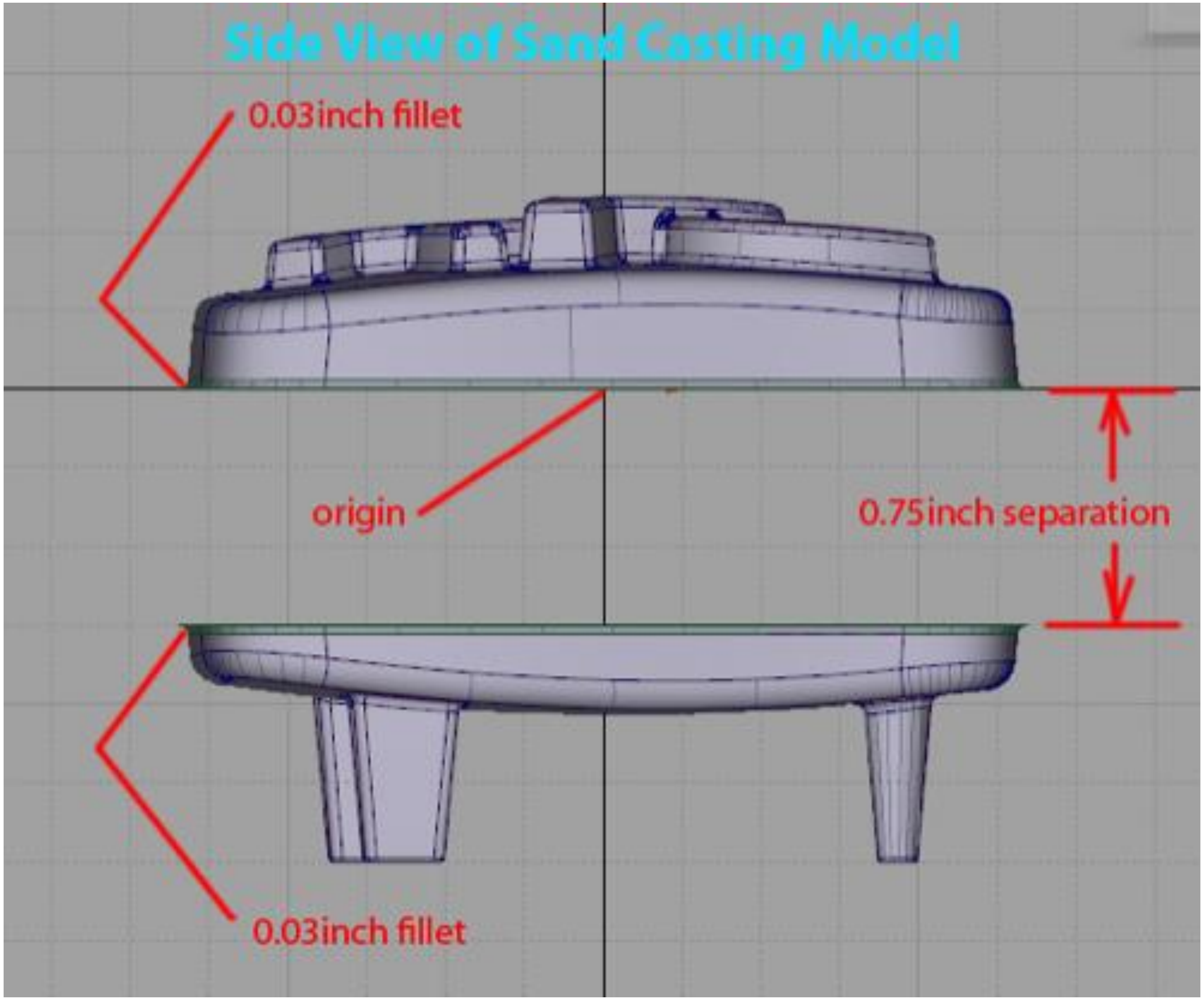
# Sand Casting

# Assignment 2

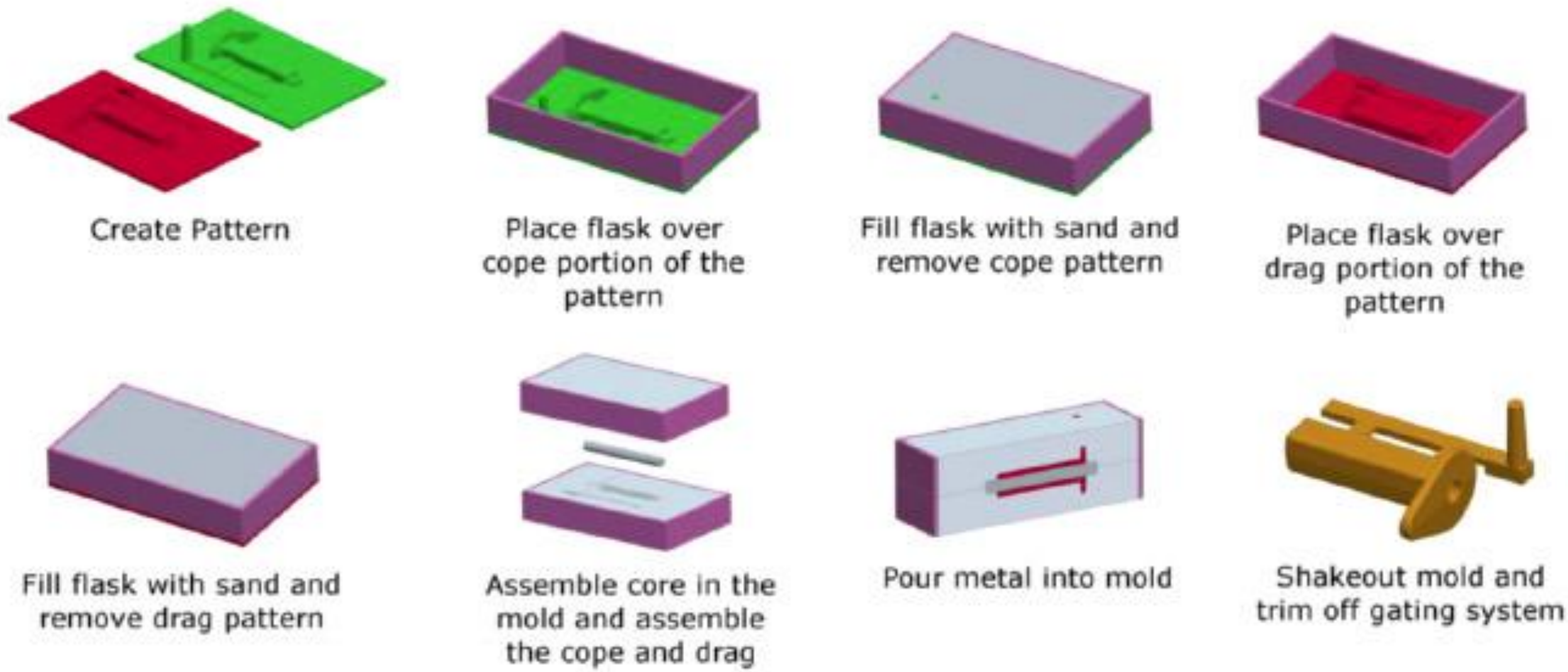
- Create a two patterns that interlock in some way. These will be cast in aluminum using green sand and with the class built crucible furnace.
- Your original patterns need to be made from a relatively hard substance (high density foam, wood or 3D printed pattern are some things I would suggest).
- The patterns can be hand formed, printed or milled.
- They may be two-sided, although they will need to have perfect draft along a straight parting line.
- Each team will need to cast at least two sets of patterns (you only need to make one pair of originals). In the final cast the parts must be interchangeable (some final chasing of the patterns will be allowed – however they should fit without major milling).
- Each pattern should not be larger than x,y,z: 5”x4”x3” and the part line should occur along the xy plane.


patern
upside down drag
end view of the
patern showing
the draft
moulding board
cope
moulding sand
right way up drag
moulding board


Draft
Pouring Basin
Cope
Flask
Flask Pin
and
Bushing
Set Core
Cope
Casting
Sprue
Gate
Runner
Parting
Line
Green Sand
Core Print
Drag
Drag
Flask
Green Sand Mold Section



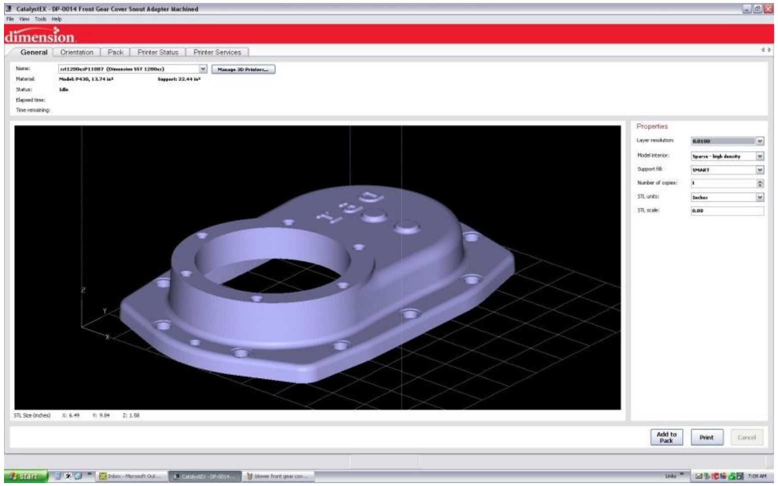
Side View of Sand Casting Model
0.03inch fillet
origin
0.75inch separation
0.03inch fillet


Create Pattern
Place flask over cope portion of the pattern
Fill flask with sand and remove cope pattern
Place flask over drag portion of the pattern
Fill flask with sand and remove drag pattern
Assemble core in the mold and assemble the cope and drag
Pour metal into mold
Shakeout mold and trim off gating system

# Wood Patterns

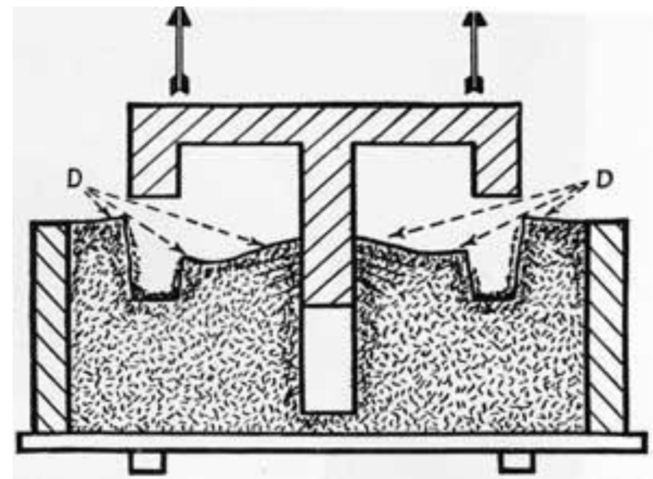
# Foam Patterns

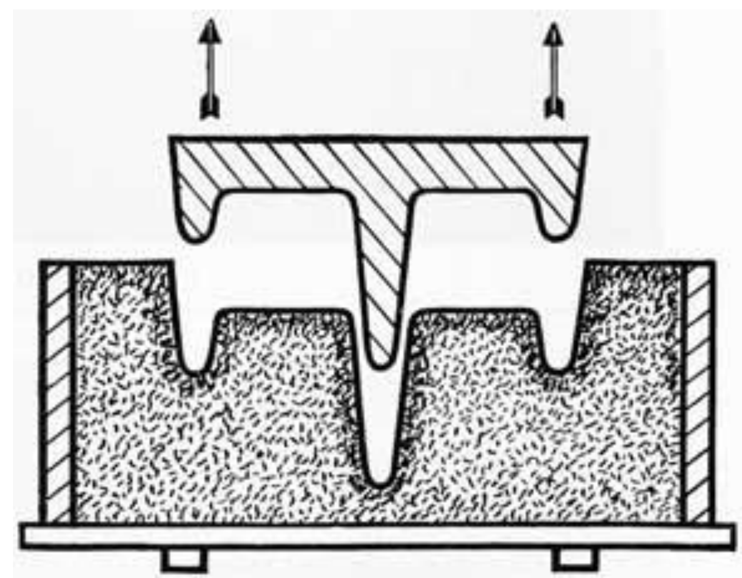
3D printed pattern for sand casting




# Draft

- The biggest thing to keep in mind when designing a pattern for sand is how to get the pattern out of the sand without wrecking the sand.
- If the pattern has 90 degree angles or undercuts the pattern will destroy the mold when you pull it out.
- On the other hand if the pattern has as little as 2% of draft, then you will be able to safely remove it without any damage.




A
B
A - UNSATISFACTORY
B - SATISFACTORY
DRAFT

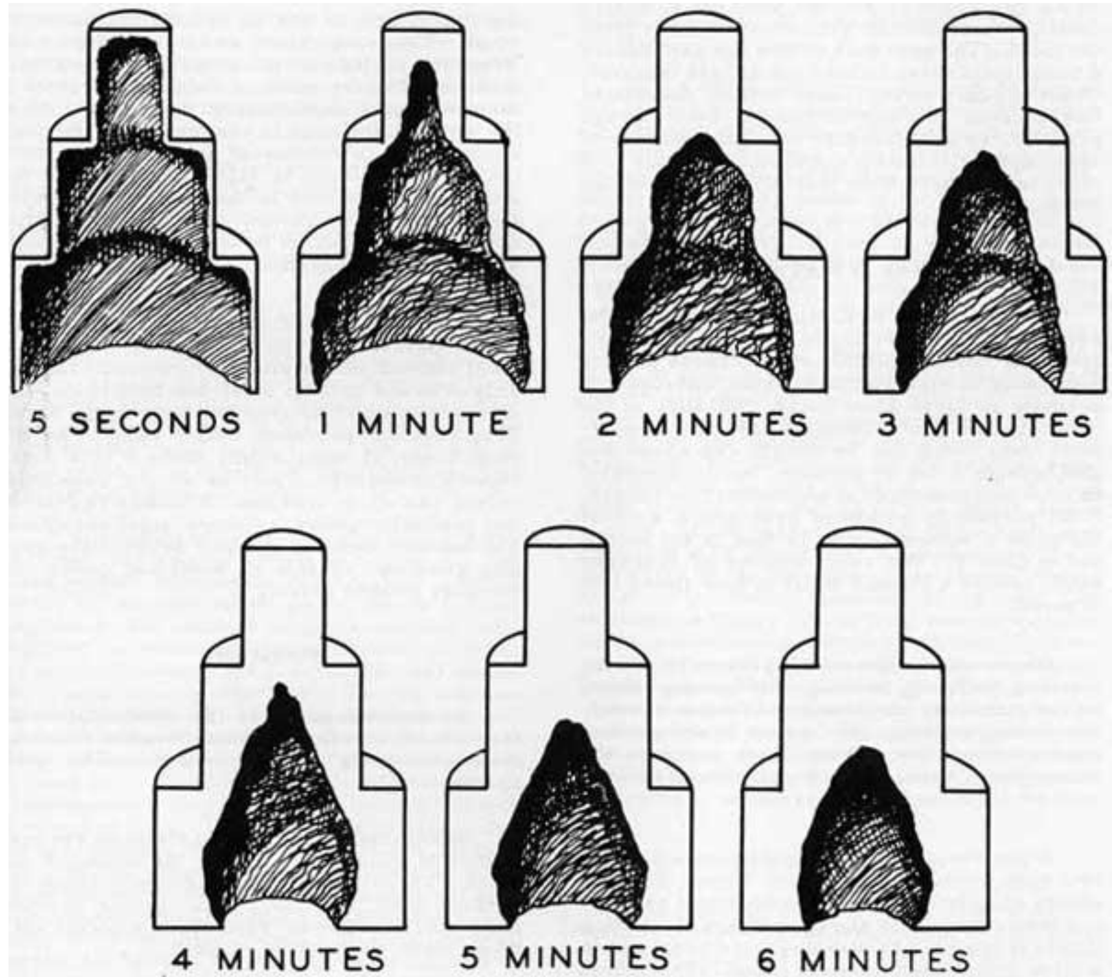
# What is aluminum?

# The nature of metal as it transforms from liquid to solid

- A casting is made up of many closely packed and joined grains or crystals of metal.
- Within any particular crystal, the atoms are arranged in regular orderly layers, like building blocks.
- There is no orderly arrangement of atoms in molten metal.
- Solidification, therefore, is the formation and growth of crystals, layer by layer, from the melt.
- The size of the crystals is controlled by the time required for the metal to solidify and by its cooling rate in the mold.

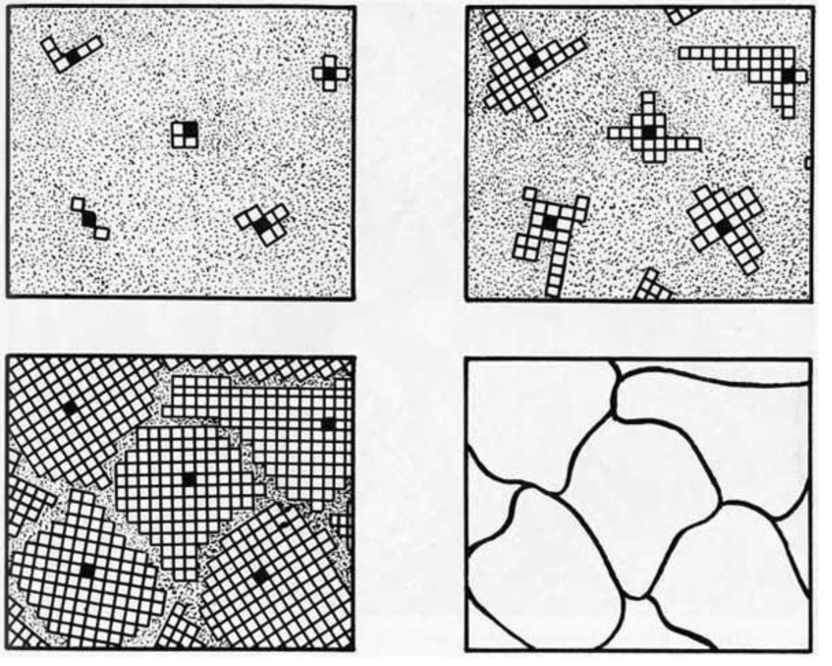
# Cooling pattern of metal.

- Solidification of a casting is brought about by the cooling effect of the mold.
- Within a few seconds after pouring, a thin layer of metal next to the mold wall is cool enough for solidification to begin.
- At this time, a thin skin or shell of solid metal forms. The shell gradually thickens as more and more metal is cooled, until all the metal has solidified.
- Solidification always starts at the surface and finishes in the center of a section. In other words, solidification follows the direction that the metal is cooled.



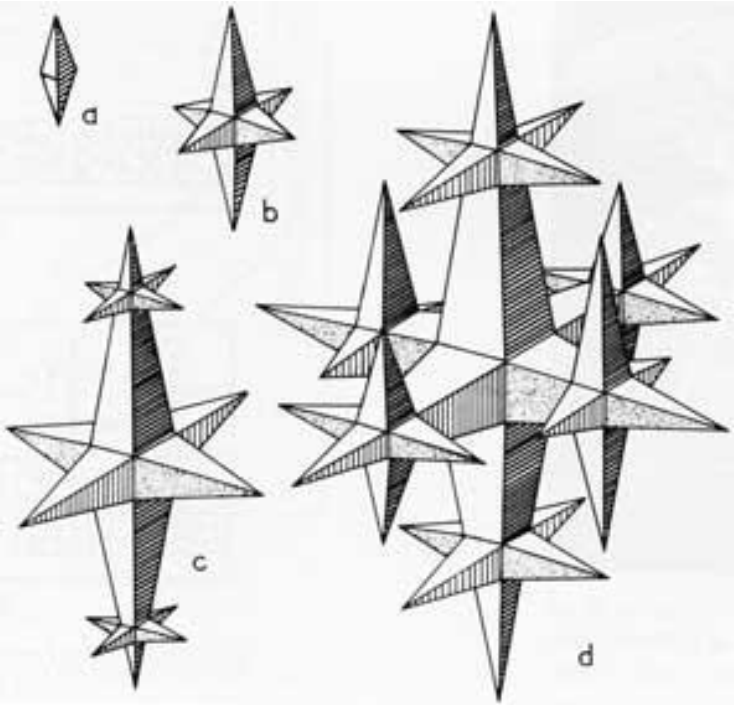
# Solidification

- Crystals start to grow in the metal as it cools.
- They will continue to grow until they run into other crystals.
- This is similar to the frost patterns that grow on glass.

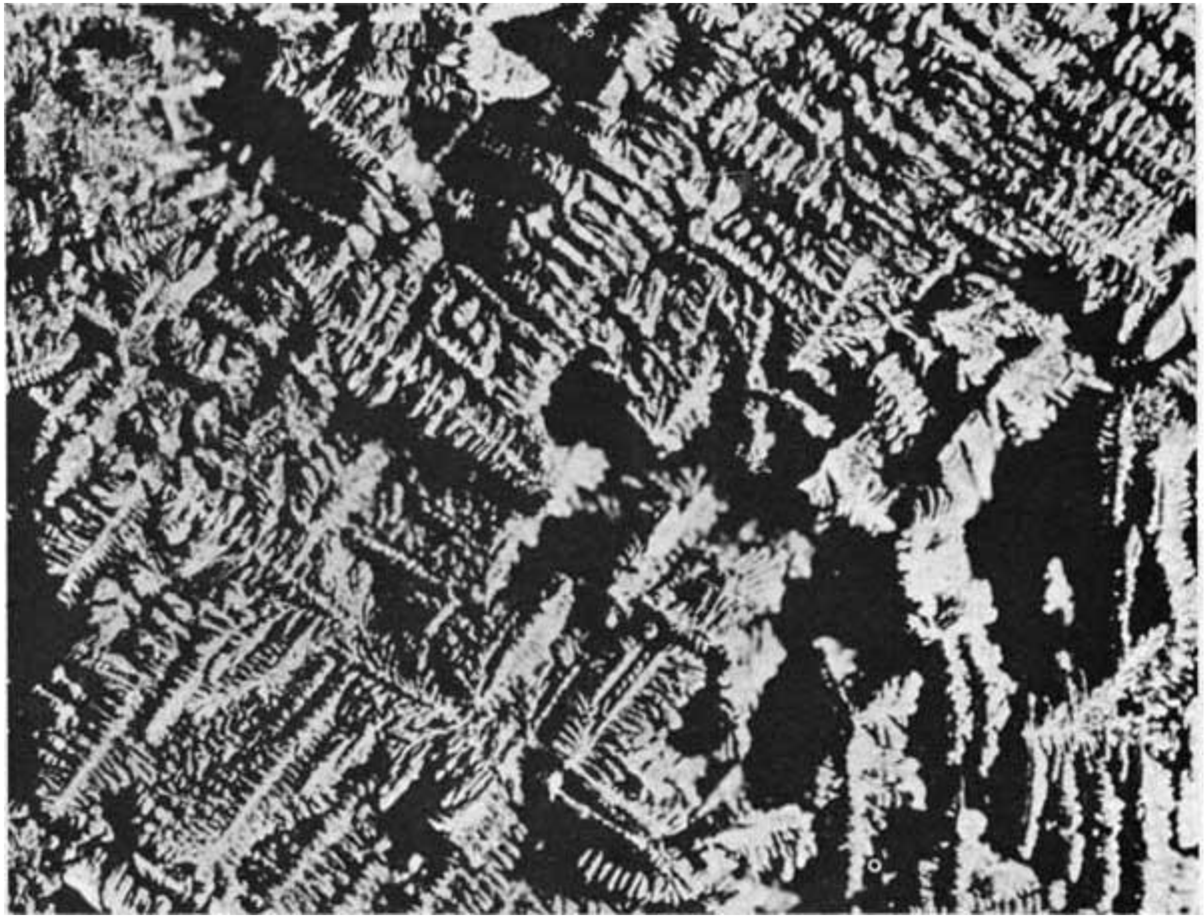


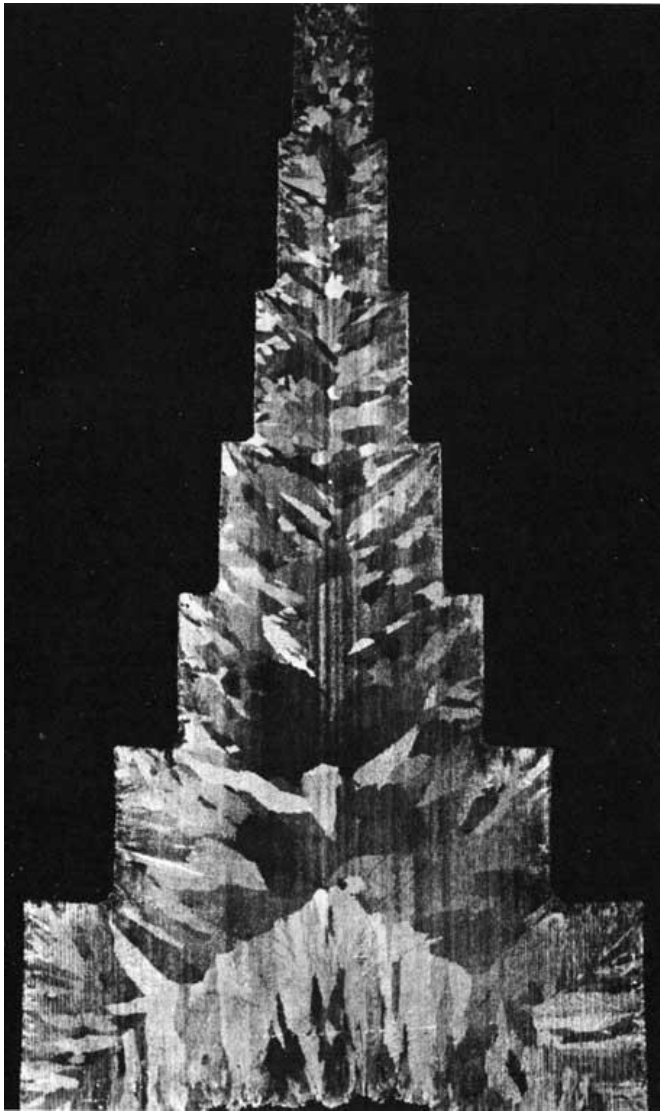
# Dendrites

- Metals crystallize in tree like patterns which are called dendrites.
- (a) shows the crystal shortly after it has formed and has started to grow.
- (b) the crystal has become elongated and growth has started in two other directions.
- (c) still further growth is shown by part The original body of the crystal has grown still longer and has become thicker in cross section. Two other sets of arms have started growing near the ends of the longest arms of the crystal.
- (d) even more progressed stage of growth



# High magnification of an aluminum casting to show dendrite growth





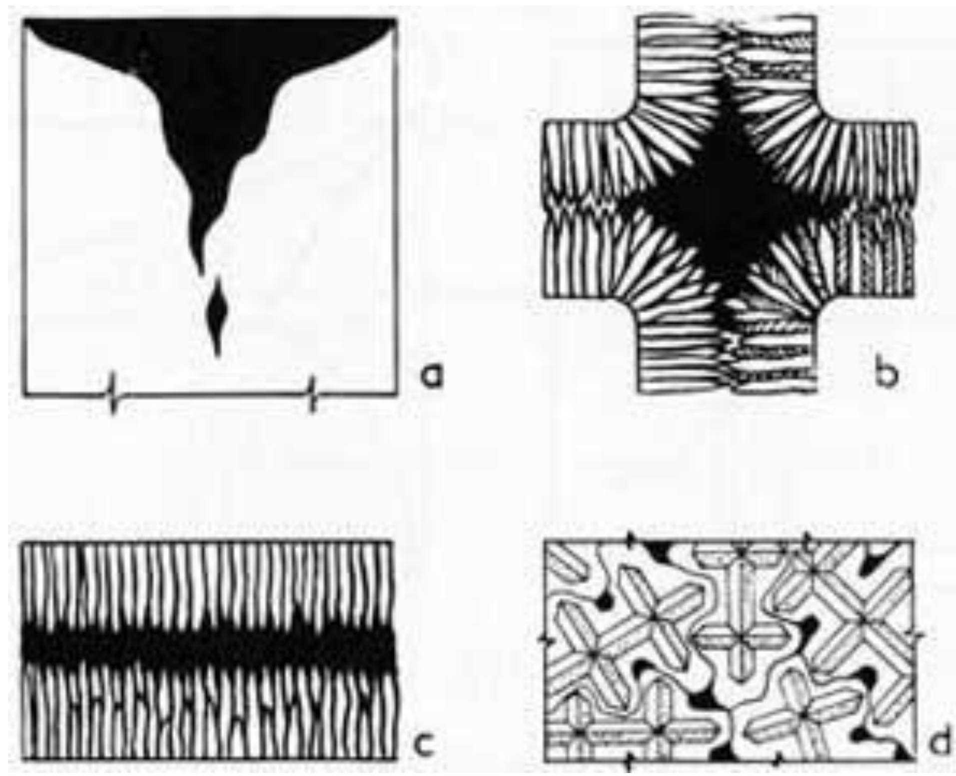
How the thickness of the casting effects crystal size

Crystal growth in gun metal casting dumped before solidification was complete.

# Types of shrinkage

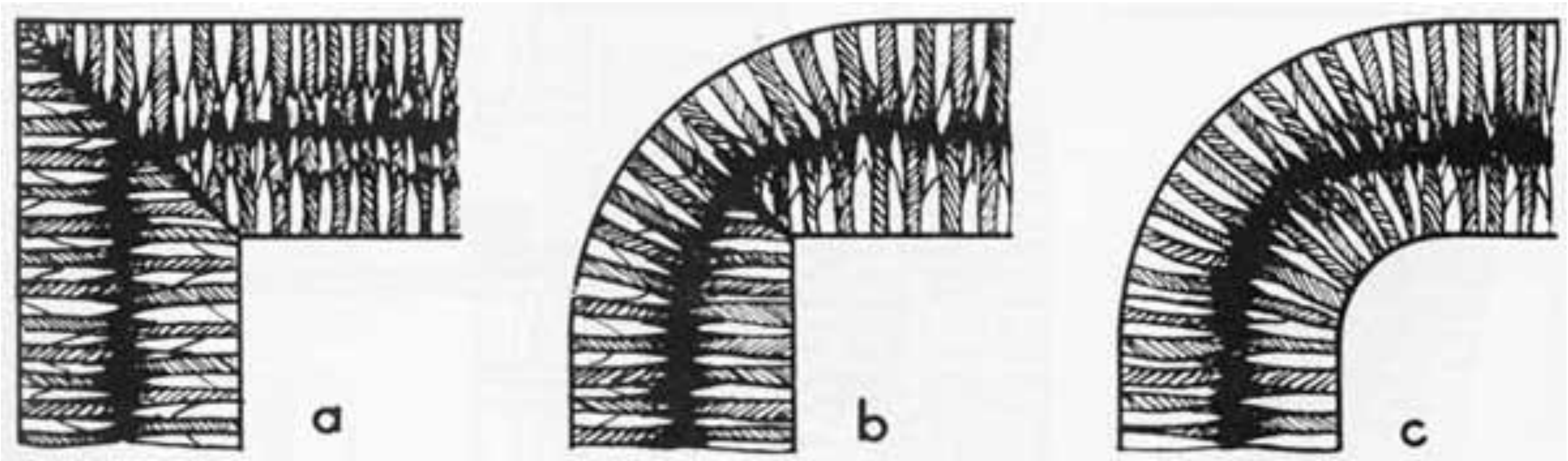
Casting defects which can occur if the freezing characteristics of metals are not taken into account are as follows:

(1) microshrinkage,
(2) centerline shrinkage,
(3) shrink holes,
(4) certain types of gas holes, (5) piping, and
(6) hot tears.

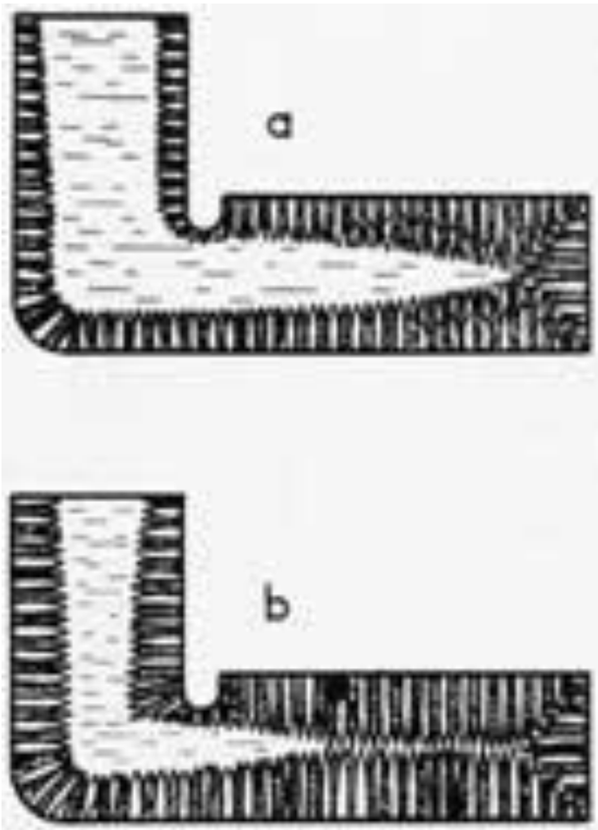


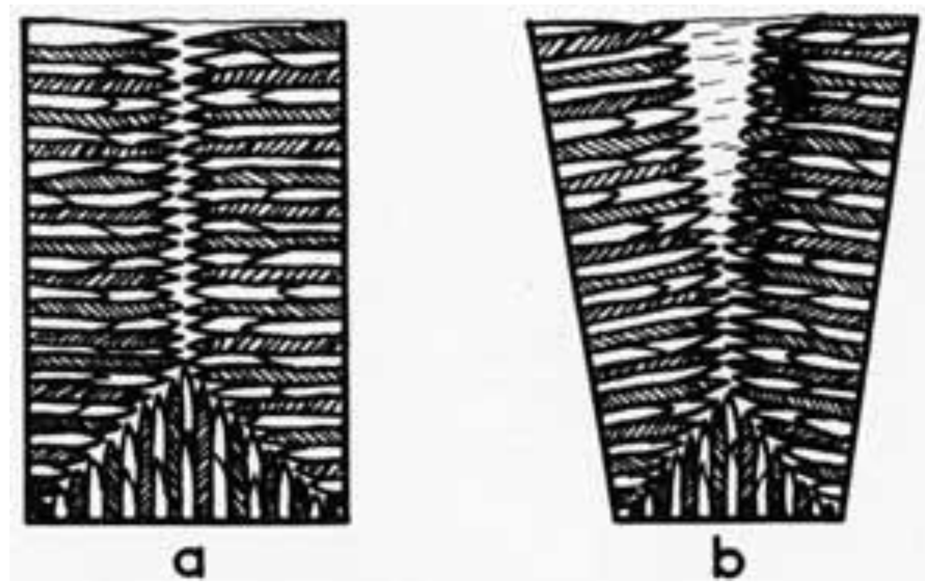

(a) piping
(b) gross shrinkage
(c) centerline
(d) microshrinkage

# Effect of fillets on shrink and crystal growth



# Directional Solidification



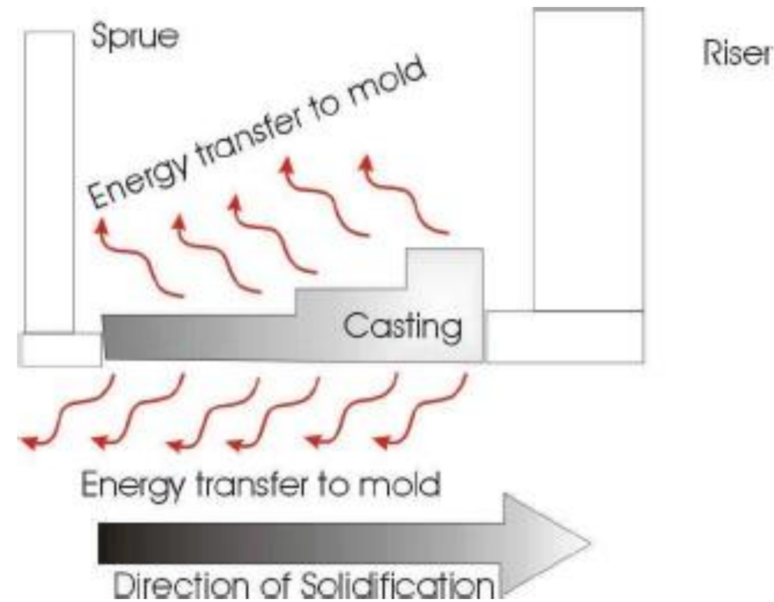




Design your casting for strength – this includes thoughts about directional solidification, what is the pathway that the material solidifies

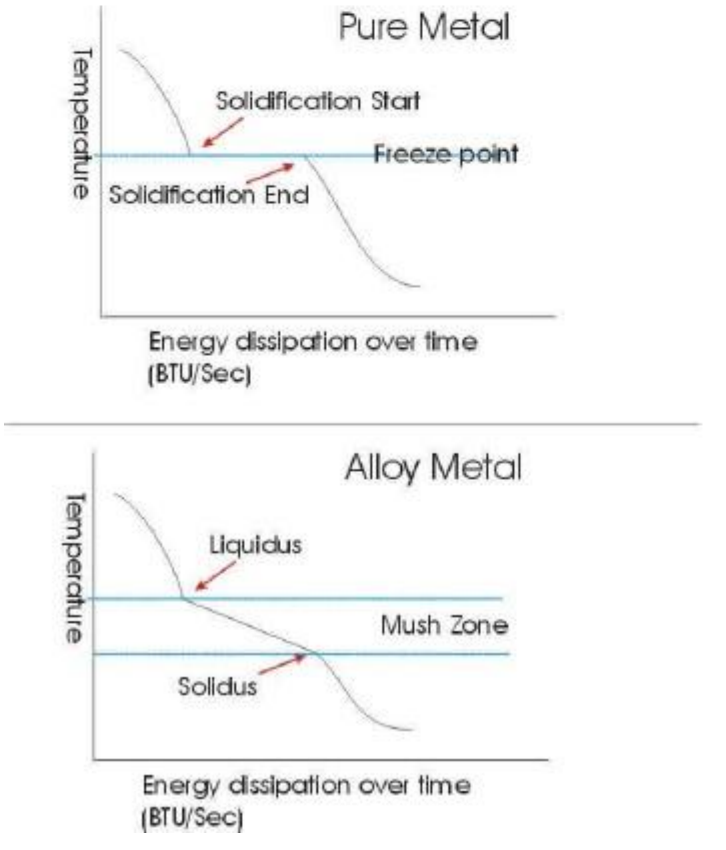
# Directional solidification

- Directional solidification means that solidification will start in one part of the mold and gradually move in a desired direction; it means that solidification will **not** start in some area where molten metal is needed to feed the casting.
- An effort is always made by the metal caster to get solidification to progress toward the riser from the point furthermost from the riser.
- Casting design is a determining factor in the control of the direction of solidification, and every effort should be made to apply the principles of good design to reach this objective.
- All sections should be tapered so that they are thickest near the risers.
- Heavy sections should not be located so that feeding must take place through thin sections.

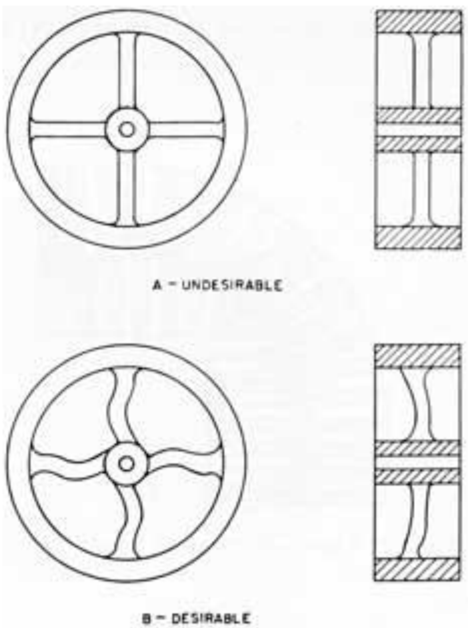
- Thinner sections are going to cool first
- Thicker sections will pull from thinner ones so placement of risers that allow the casting to pull from is important.

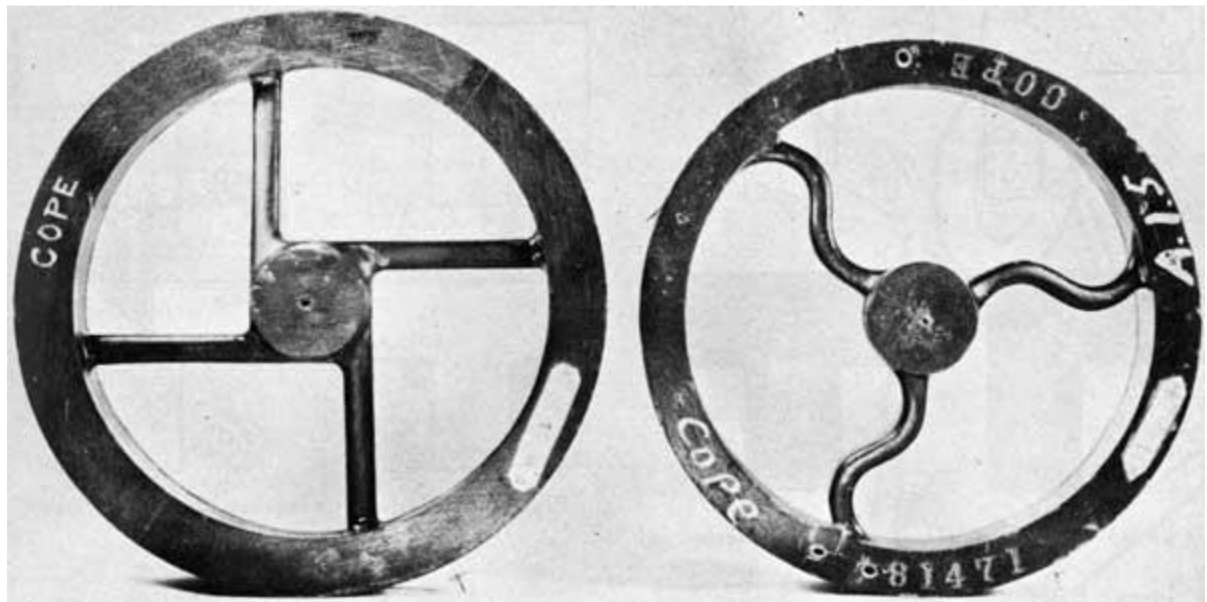


- Knowing how long the metal take to go from solidus to to liquidus is important.
- Pure metals have a very small mush zone, and this is one of the major reasons for the use of alloys.

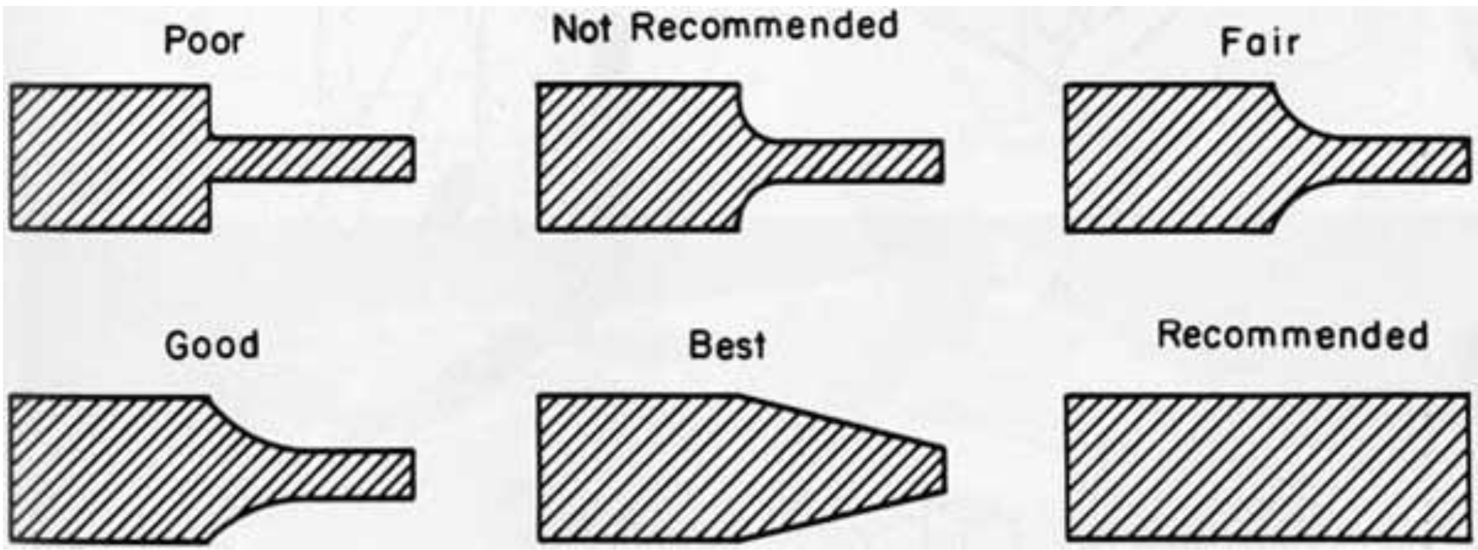


# Wheel designs – taking in account solidification patterns

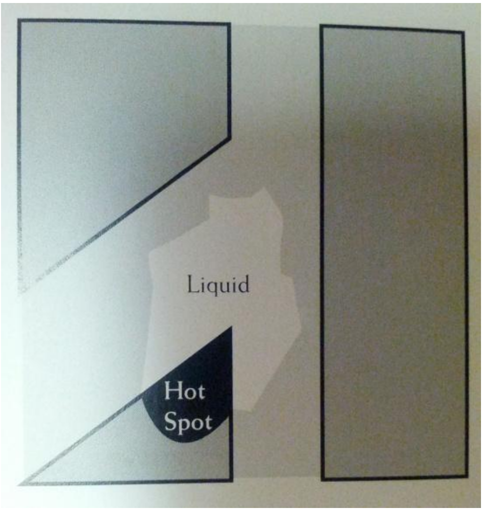


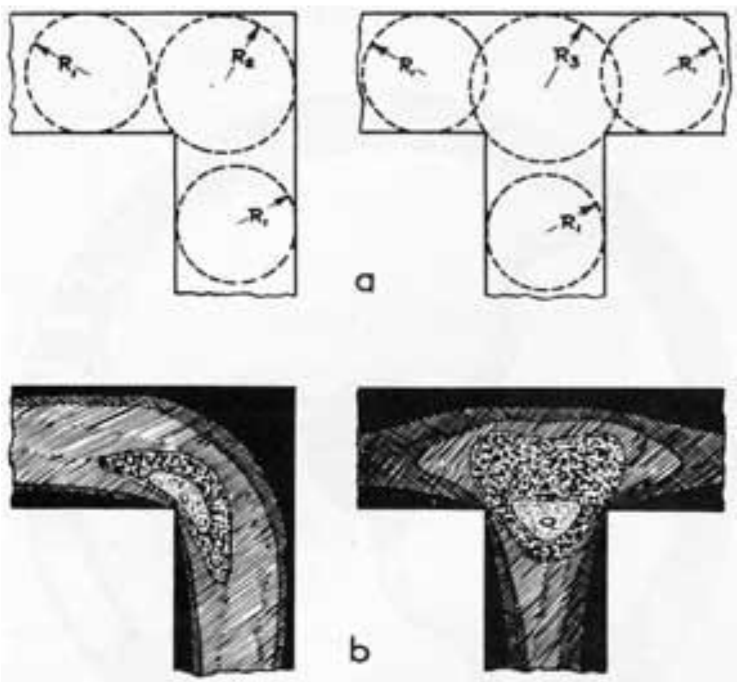
# Cross sections that consider strength and solidification

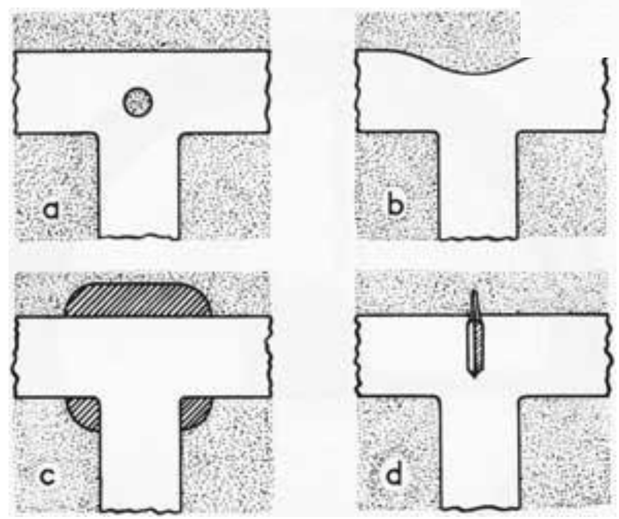


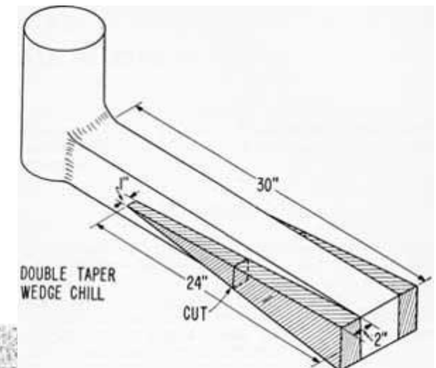
# Hot spots



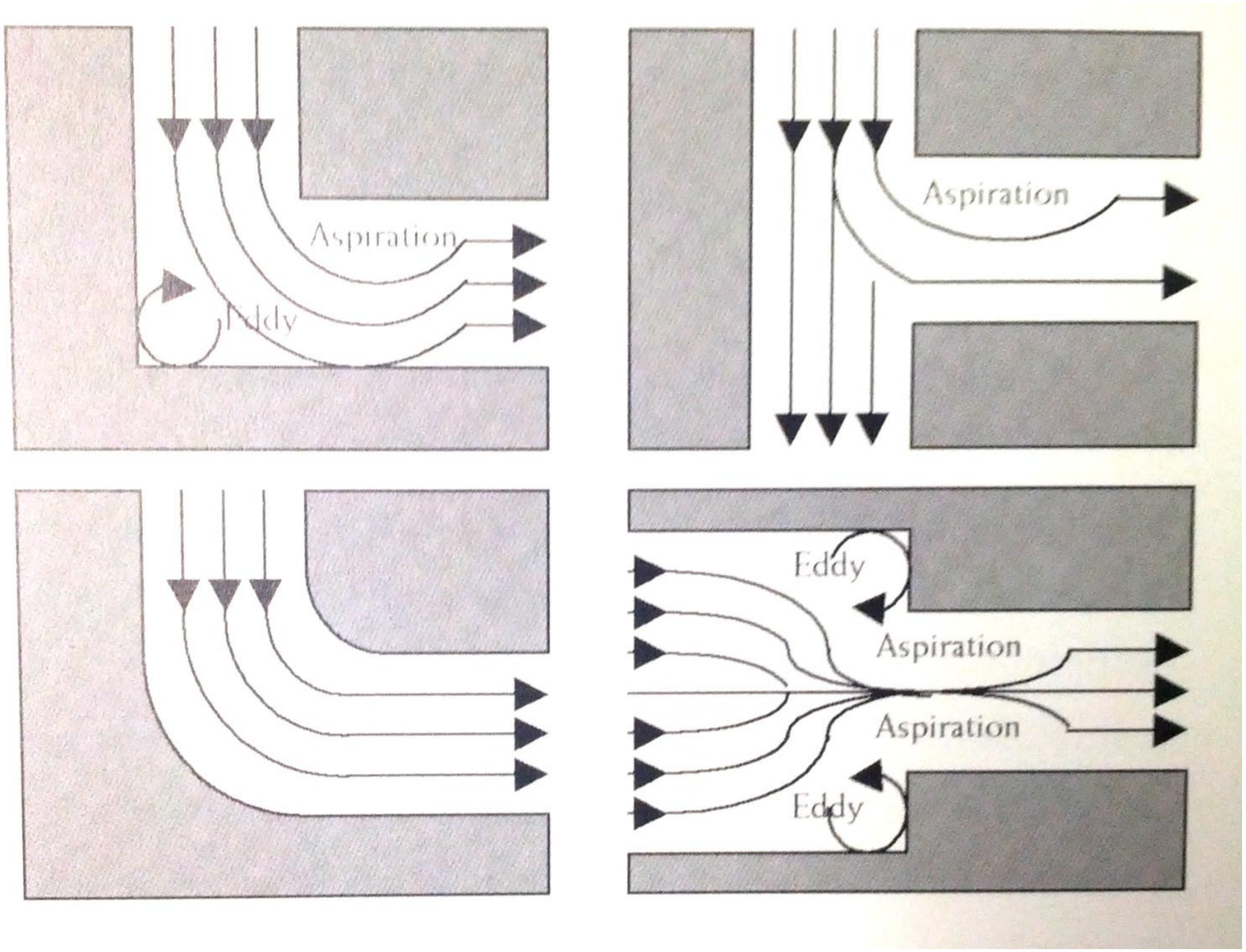

Part of this is considering where hot spots are going to remain and what techniques you are going to use to combat them. Aluminum is one of the hardest metals to deal with in this factor because its liquidus to solidus time is very long.

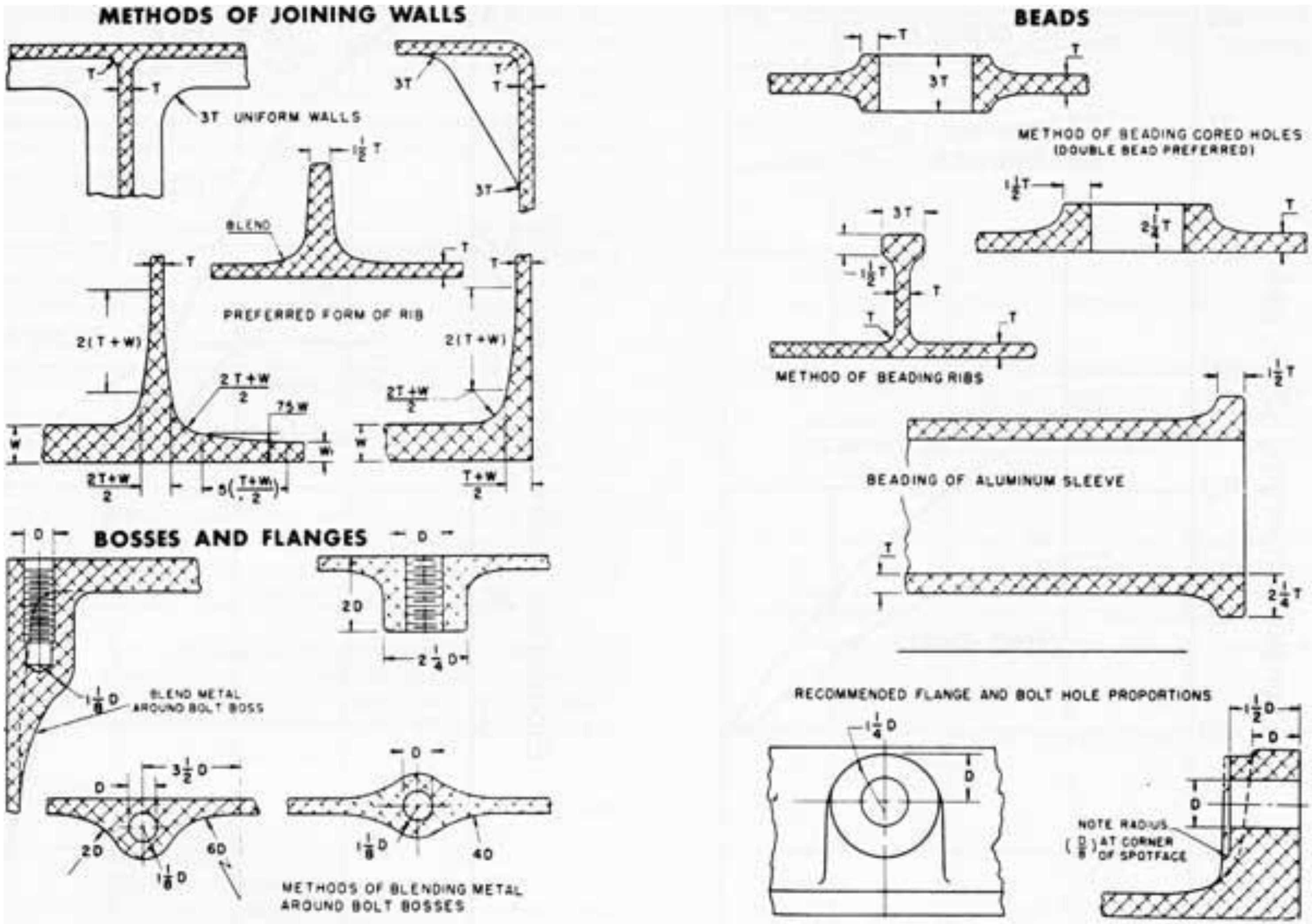


# How does the shape of the pattern effect the flow of the metal?



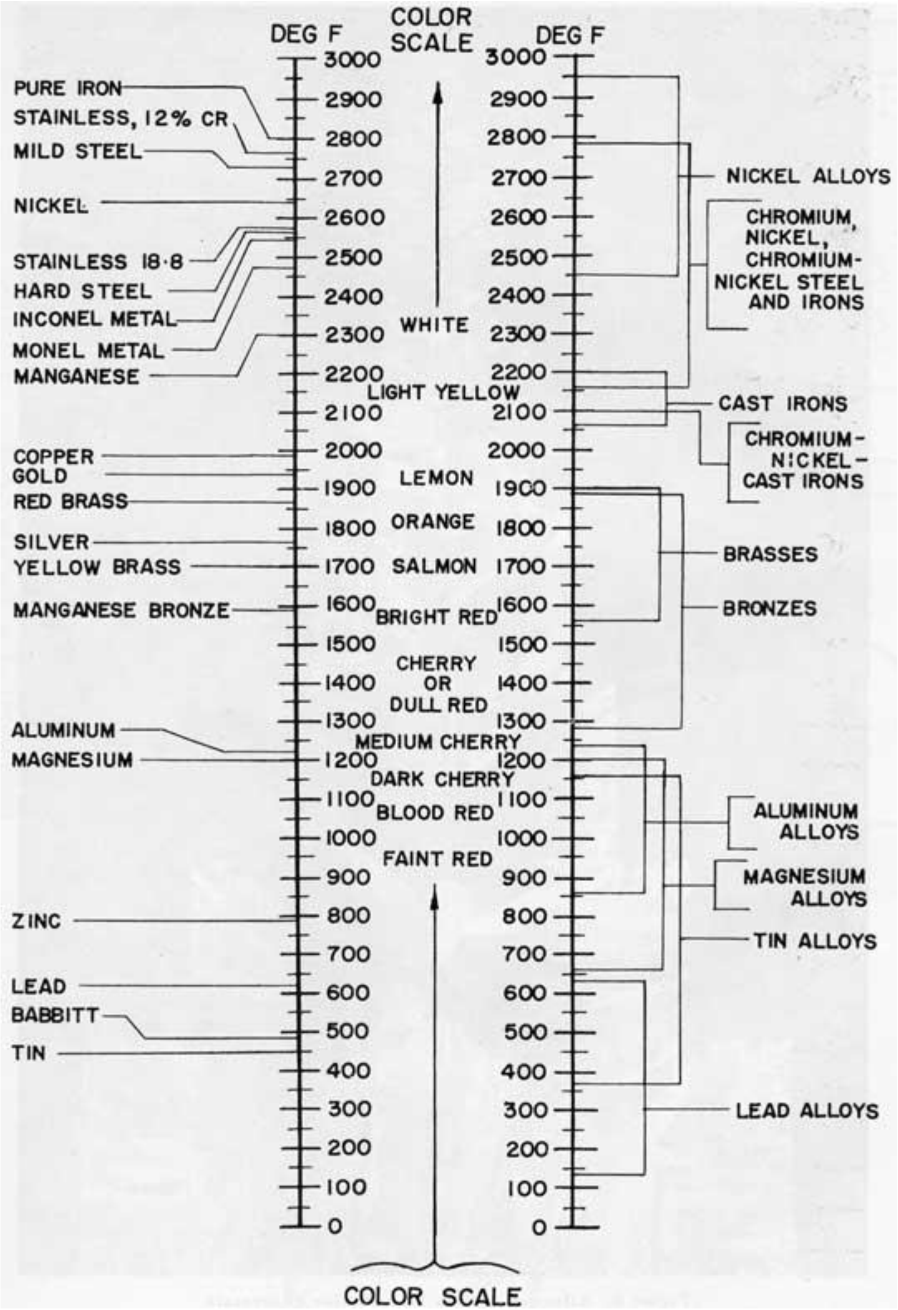



*Suggested design details for aluminum alloy castings.*

# Pouring temperature

- The pouring temperature and method of pouring determine whether a properly melted heat and a properly made mold will produce a good casting. Aluminum and its alloys should be poured at as low a temperature as possible without causing misruns. For any given alloy, the pouring temperature will determine whether a casting will have a fine grain structure and good properties or a coarse grain structure and lower properties. A high pouring temperature will tend to give a large grain size, and a low pouring temperature will tend to give a small grain size. The pouring temperature will vary between 1,240°F. and 1,400°F., depending on the alloy and section size of the casting. If a casting poured at 1,400° F., misruns, the gating should be revised to allow faster pouring.
- Because aluminum absorbs gases easily, pouring should be done with the lip of the ladle as close as possible to the sprue of the mold. The stream of molten metal should be kept as large as possible (as large a stream as the sprue will handle). A thin stream or trickle of molten metal from a ladle that is held high above the mold will cause a gas pickup and unnecessary agitation of the metal.

# Color and melting points of a wide variety of metals

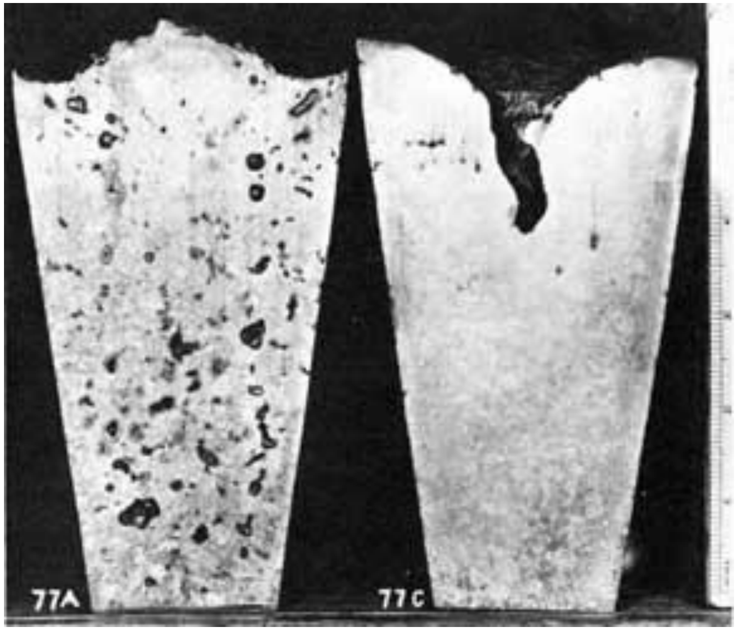


# Gas

- Many defects in castings are caused by gases which dissolve in the metal and then are given off during solidification. These defects may range in size and form from microscopic porosity to large blow holes. Because of the large volume that a small weight of gas occupies, very little gas by weight can cause the foundryman a lot of trouble.
- As an example, at room temperature and atmospheric pressure, 0.001 percent by weight of hydrogen in a metal occupies a volume equal to that of the metal, and at 2,000°F., the same amount of hydrogen would occupy a volume equal to four times that of metal.

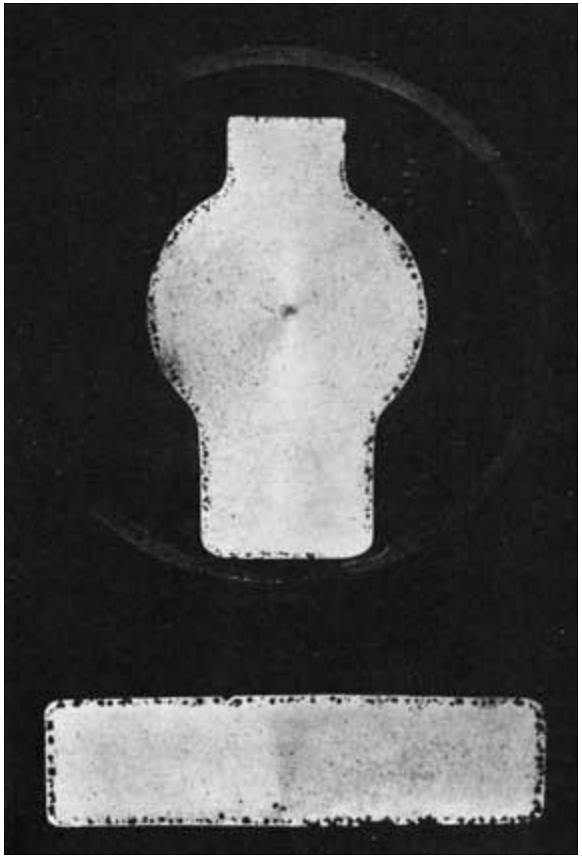
# Porosity

- Pinhole porosity in aluminum castings is caused by poor melting practice. This type of defect is common and shows up as very small gas holes that are scattered through the casting. They may or may not show up on the casting surface.
- Porosity of this nature can be cured only by correct melting practice.
- Melting tools must be clean and dry to prevent any pickup of moisture by the melt.
- **Degassing procedures must be used to remove any gases** which are dissolved in the melt.

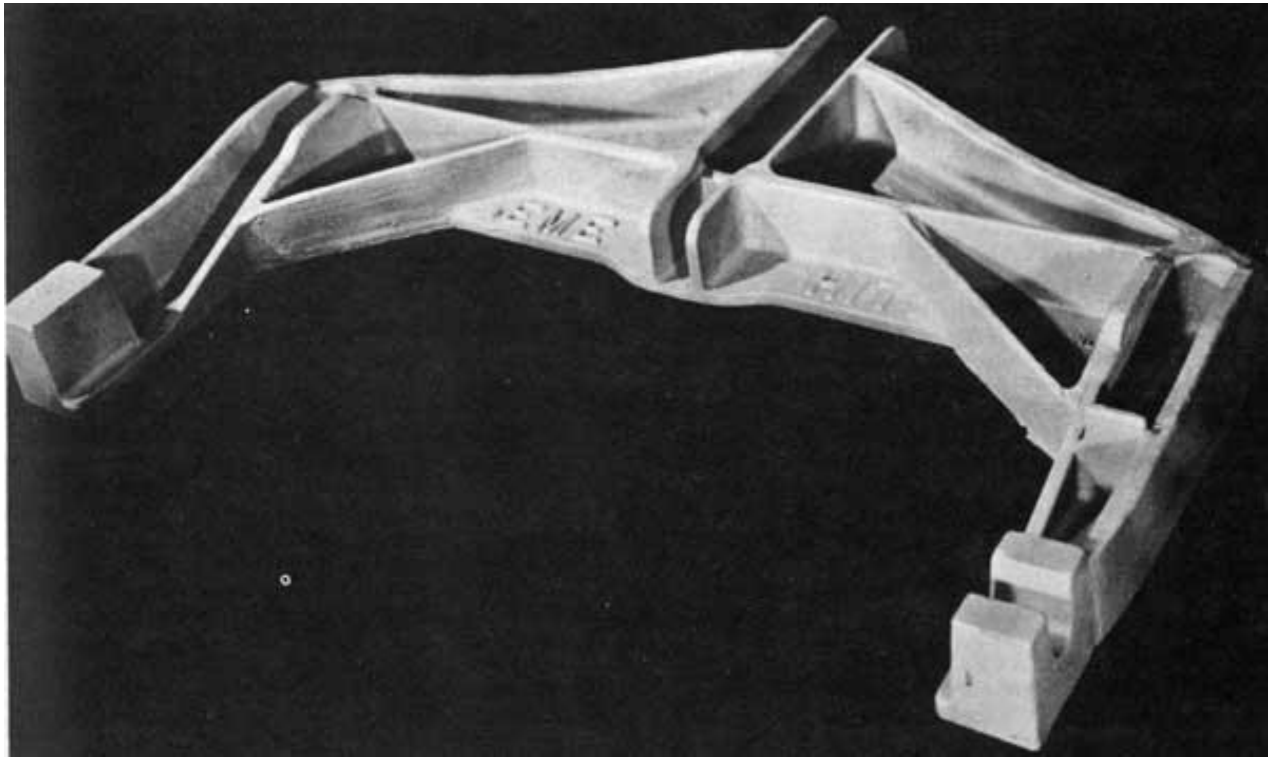


# Porosity at surface of metal

- Excessive moisture in the molding sand will cause porosity in aluminum castings.
- This defect can be easily identified because it occurs just below the surface of the casting and on all surfaces.
- The cure for this defect is to use the correct moisture content in the molding sand. This can be done only through proper testing procedures.



With aluminum casting, the goal is generally to make the part both light and strong.  This is one of the reasons the process of designing an aluminum part can be so very complicated.



Use ribs to avoid warpage or to add stiffness. Ribbed construction can often be used to replace a heavier section.

In spite of all of these factors, you should try to keep your pattern as simple as possible.  If it is not possible to create a simple casting, you may want to consider breaking your design into smaller parts.

# Green Sand

- Green sand is not green in color, it is green because only water and clay holds it together as a binder.
- It is the oldest of the sand molding processes.
- The molds are usally two part and built into a flask.

# Chosing Sands

- All the following recipe guidelines are based on weight not volume.

- Start with sand, "foundry sand" in particular works nicely because of the structure of the grains. This is usually a silica sand.
- Olivine sand is also frequently used. It is more expensive, but does not have the silicosis hazards of silica
- Selection of grain size is also very important. Generally most foundry sand ranges from 80-200 mesh. Finer sand yields a finer casting but have the potential to trap gas. Coarser sands result in the reverse.
- In resin bonded sand molds, it is not uncommon to use two meshes of sand – fine sand close to the pattern and coarse sand in the exterior.
- It is also important to note that the American Foundry Society (AFS) has there own grain classification that is based on average grain size as opposed to smallest grain size. If the casting is very important, you may want to use AFS graded sands.

# Silica Sand

- Silica sand is the most common type of sand. Generally most types of silica sand contain 98% silica
- It is the least expensive and the most commonly used sand
- There is danger in breathing silica particles – use a respirator!
- The purest type of silica sand in North America is found in Illinois and Missisouri, but can be found on any river bank or beach and is usually white or brown in color.
- High thermal Expansion 0.018"/inch, Melting point 3110F/1710C, a varied shape and acidic pH

# Olivine

- Olivine Sand is an ortho-silicate of Magnesium (Mg) and Iron (Fe) and is found in it's natural state within Forsterite.
- It usually is composed of less than 50% Magneium, just over 40% silica and just over 7% iron (remaining trace elements).
- It is slightly greenish in color.
- It is more expensive than silica, but also with reduced inhalation danger.
- It is commonly used in non-ferrous foundries and is significantly more expensive than silica, but produces finer results.
- Low thermal Expansion 0.0083"/inch, Melting point 3400F/1875C, an angular shape and basic pH

# Chromite

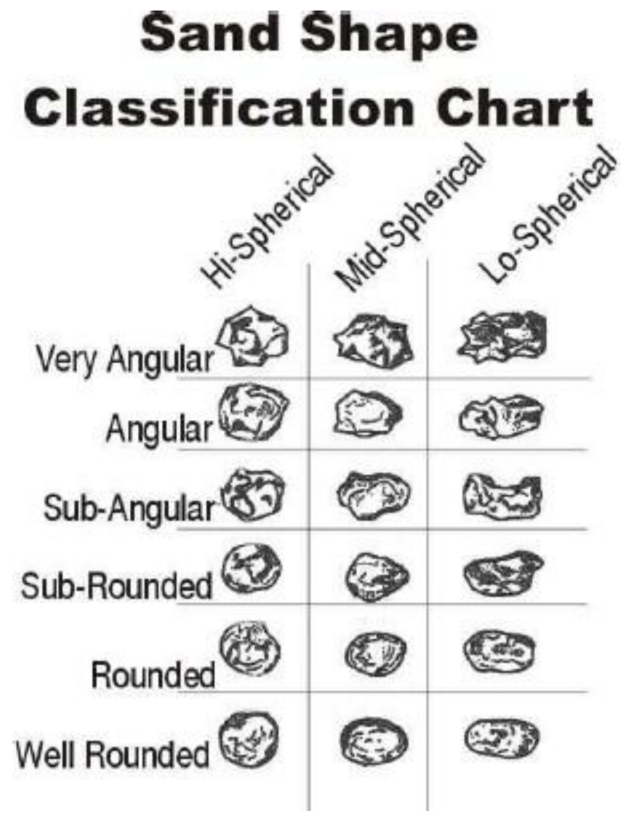
- This sand consist of 45% chromium, approximately 20% each of iron and aluminum
- This is a very expensive sand that is found only in Africa
- It is used primarily in steel foundries and mostly in facecoats where its superior thermal properties are necessary
- It is black in color and very dense
- Low thermal Expansion 0.004"/inch, Melting point 3800F/2093C, an angular shape and basic/neutral pH

# Zircon

- 33% silicon, 65% zirconim and traces of uranium and thorium (although most packaging does not mention it).
- Is the densest/heaviest of all foundry sands
- Very expensive, but usually worth the cost in its thermal expansion and insulation properties.
- Because of its stable thermal properties, it is used as a mold or mold facing material where very high temperatures are encountered and refractoriness becomes a consideration.
- Found in California, Florida and Austraila and is white or brownish in color
- Lowest thermal Expansion 0.003"/inch, Melting point 4600F/2538C, an elliptical or rounded shapeand slightly acidic pH, an AFS gfn of 65 to 140 with 100 as the most common.

# Classification and Size

- It is important to know the shape of the sand grains you are using .
- It is also important to know the size of the grains of sand you are using.
- The AFS (American Foundry Society) classifies sand on the average particle size verses the largest size.  AFS graded sands can be worth the extra money for consistent molds over the long run.
- Remember a good green sand can last for years.



# Clay added to recipie

- Clay is added to the sand to act as a binding agent. You need to have enough clay in the mix to make a strong bond, but not so much clay that air is trapped in the mold
- Any fire clay will work (the Red Art clay we are using for the first molds is a fire clay). Fire clay is any clay that can withstand over 2765 degrees F and have fusion points over 2900 degrees F. If using most standard fire clays you will need to add 25-35% by weight.
- Bentonite clay is superior to standard fire clay and you only need 5-10% by weight. Its colloidal properties and grain size make it easier for the material to coat the grains of sand.
- Mix ingredients dry.

# Other additives

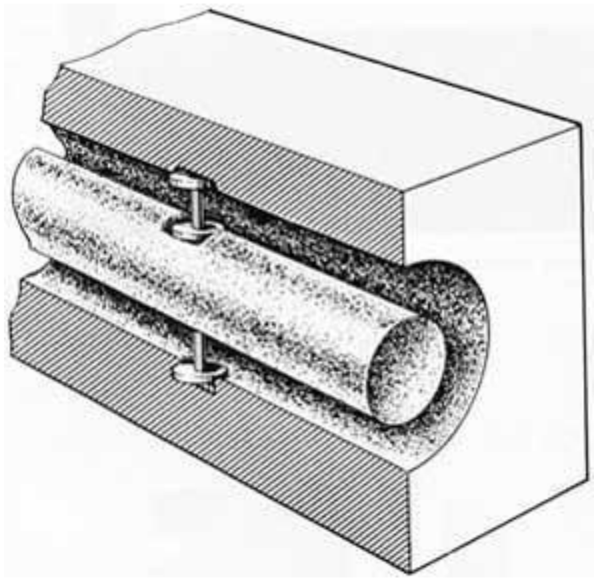
- You also should add 1-2% of some sort of burnable “flour.”
- This adds to the water absorbing properties as well as having a material to burn and which in turn creates a gas shield between the metal and the sand.
- The best is coal dust, wood flour or graphite, but wheat or corn flour will actually work.  Powdered wall paper paste is also particularly good.

# Mixing and tempering

- All the ingredients are mixed dry.  You should wear a dust mask – especially if you are using silica flour!
- When they are very thoroughly mixed 5% water by weight is added.  If the sand is “new” then let it rest for a day before testing.
- Properly mixed sand will feel moist but not wet.  It will hold the impressions of your fingers clearly when squeezed.  It will break in half cleanly with out crumbling and will hold together when bounced in the hand.
- It will also still remain porous.  Take a handful and close your fist around it, then wipe off the thumb side of your hand and blow through the clay.  If air does not pass through your hand, then you have too much water.
- When the sand is mixed properly it is said to be tempered.

# Core Sands

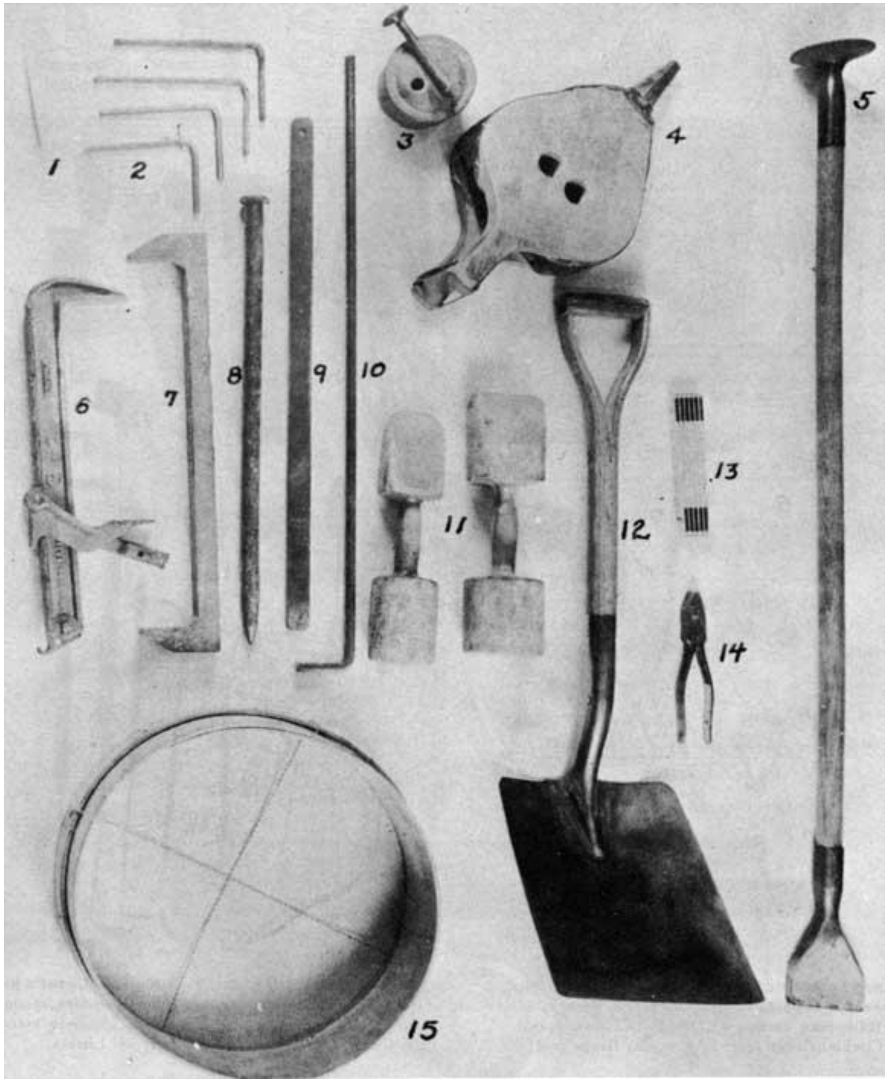
- Core sands will have additional binders that give them extra strength
- The materials used for binders are primarily corn flour, dextrine, raw linseed oil, and commercial core oils. Corn flour and dextrine are cereal binders.
- Molasses and pitch are two materials which can be obtained easily for use as core materials. Molasses should be mixed with water to form a thin solution known as "molasses water." In this condition, it is added to the core mix as part of the temper water during the mulling operation. Pitch is seldom used alone. Used with dextrine, it imparts good strength to a core mix. Sea coal in small amounts is used with pitch to prevent the pitch from rehardening after it has cooled from the high temperatures caused by the molten metal.
- Oils such as linseed oil is also frequently used.



Core with chaplet to hold it in place.

# Tools for sand molding

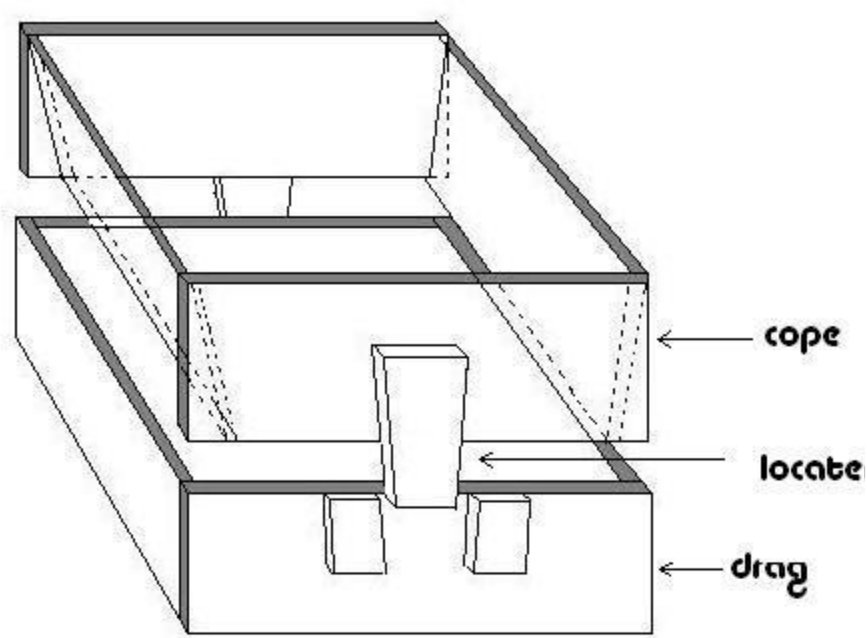
Molder's hand tools.
1. Wedge
2. Gaggers
3. Blow can
4. Bellows
5. Floor rammer
6. Adjustable clamp
7. Clamp
8. Rapping iron
9. Strike
10. Rammer
11. Bench rammers
12. Molder's shovel
13. Six-foot rule
14. Cutting pliers
15. Riddle.

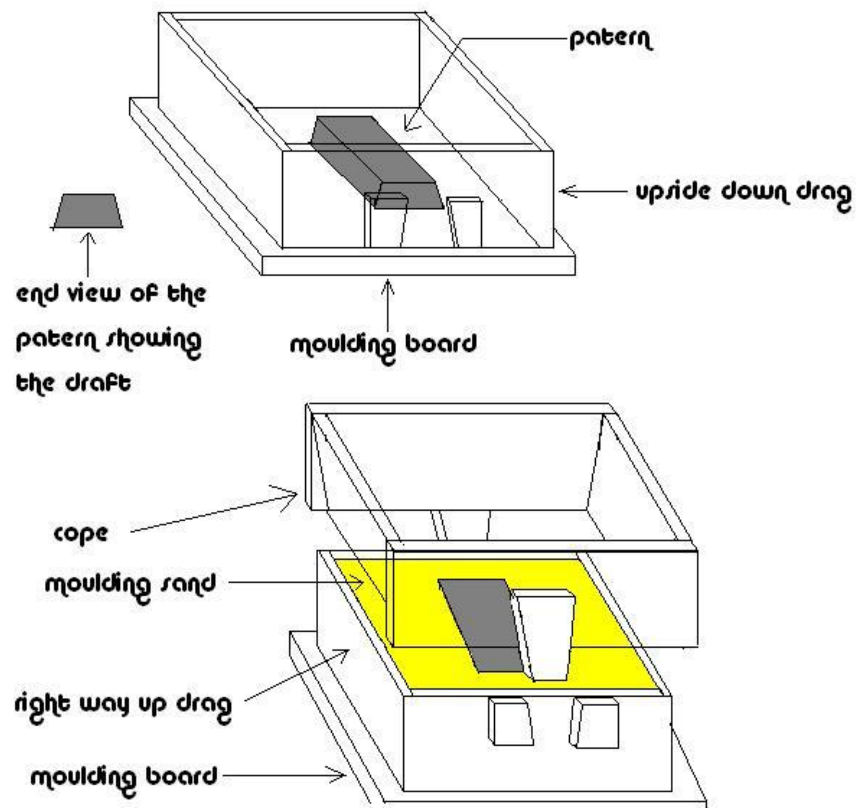


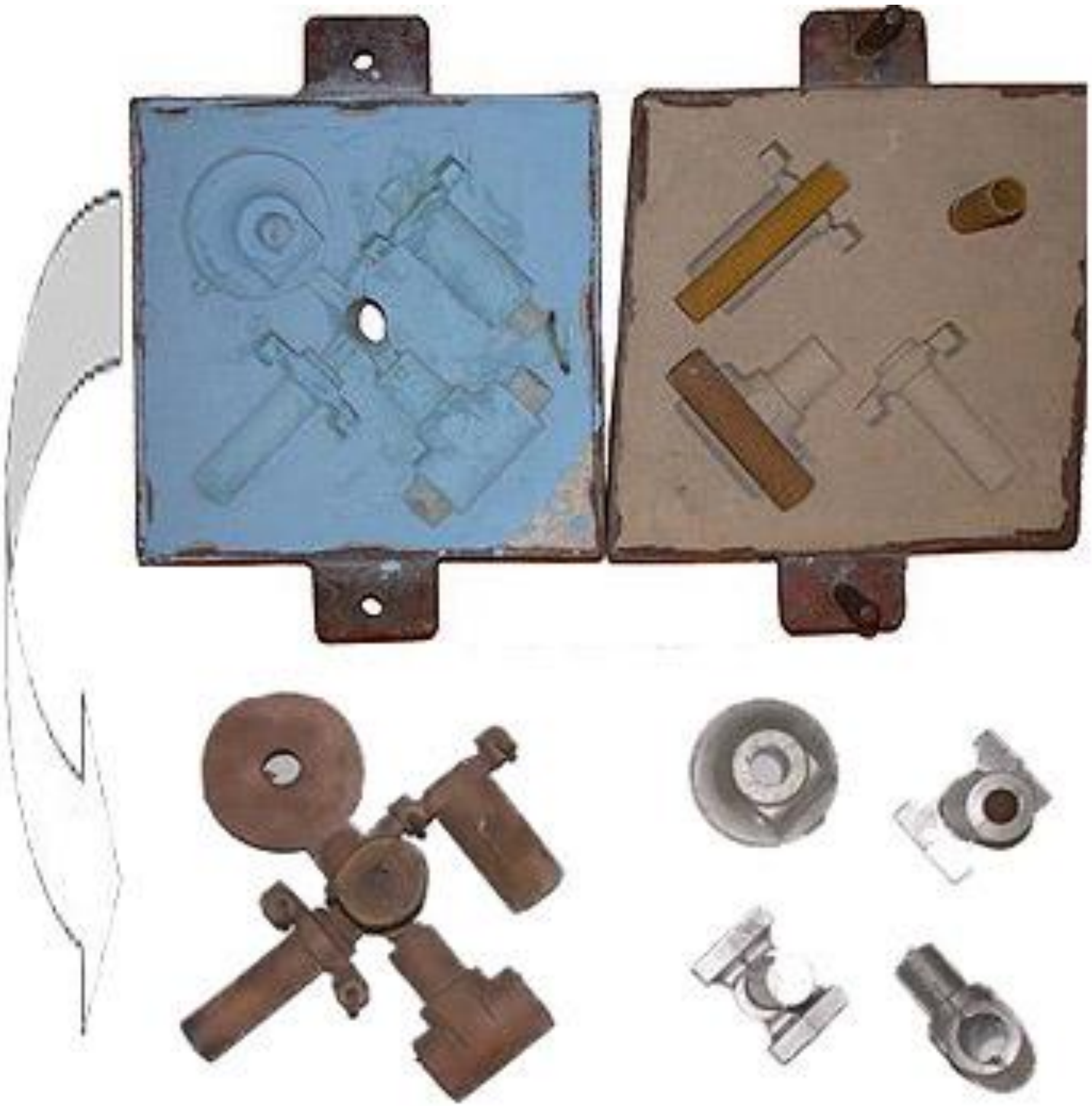
# Additional hand tools

1. Gate stick; 2. Brush; 3. Bosh or swab; 4. Level; 5. Trowels; 6. Camel's hair brushes; 7. Rapping or clamping bar; 8. Wrench; 9. Rawhide mallet; 10. Vent wire; 11. Slickers, double-enders, spoons; 12. Half-round corner; 13. Dogs; 14. Draw spike; 15. Draw screw; 16. Calipers; 17. Flash light; 18. Gate cutter; 19. Circular flange tool; 20. Circular flange tool; 21. Bench lifter (bent); 22. Hub tool; 23. Lifter; 24. Lifters.

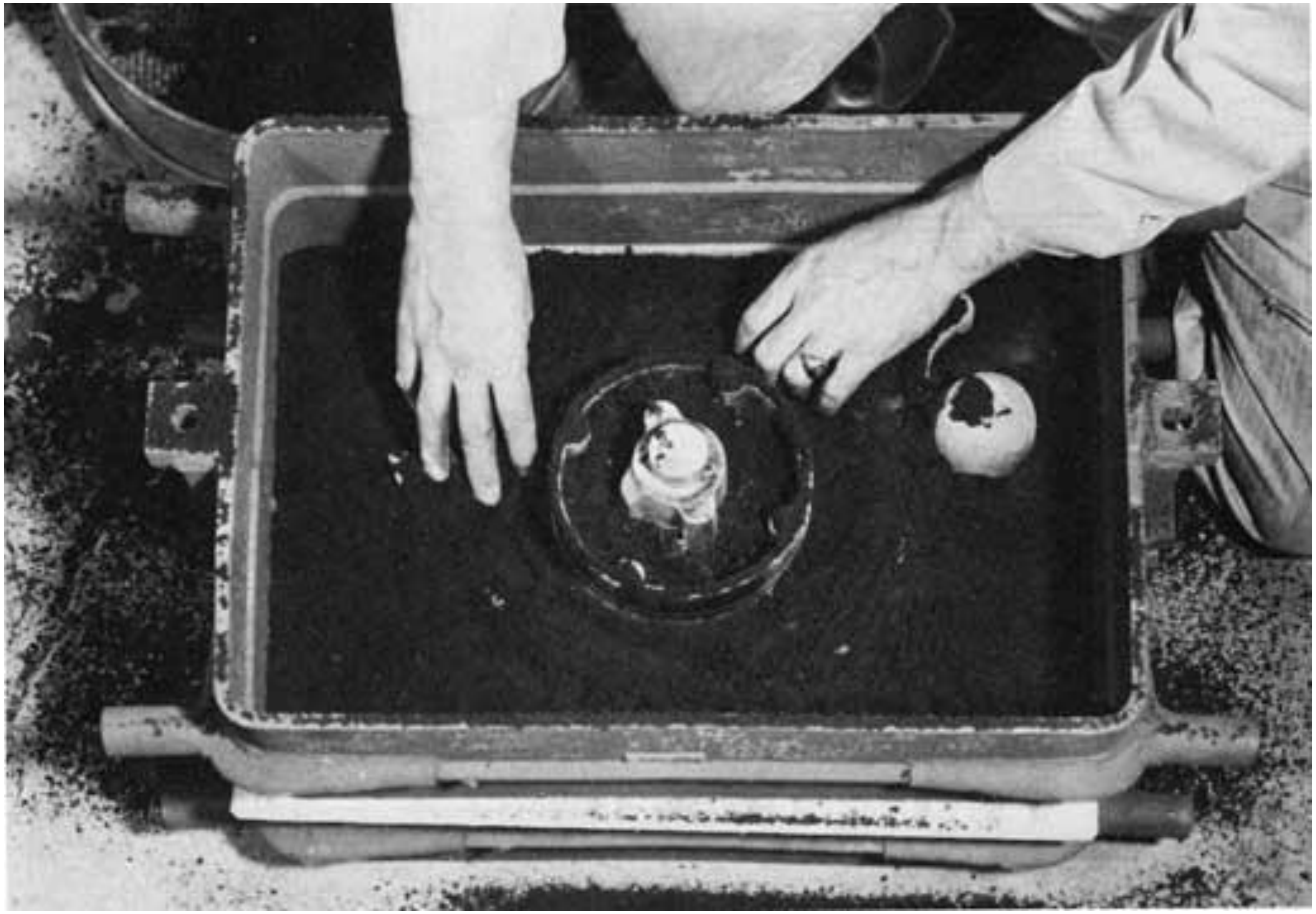
# Mold Flask


cope
locate
drag


patern
upside down drag
end view of the patern showing the draft
moulding board
cope
moulding sand
right way up drag
moulding board



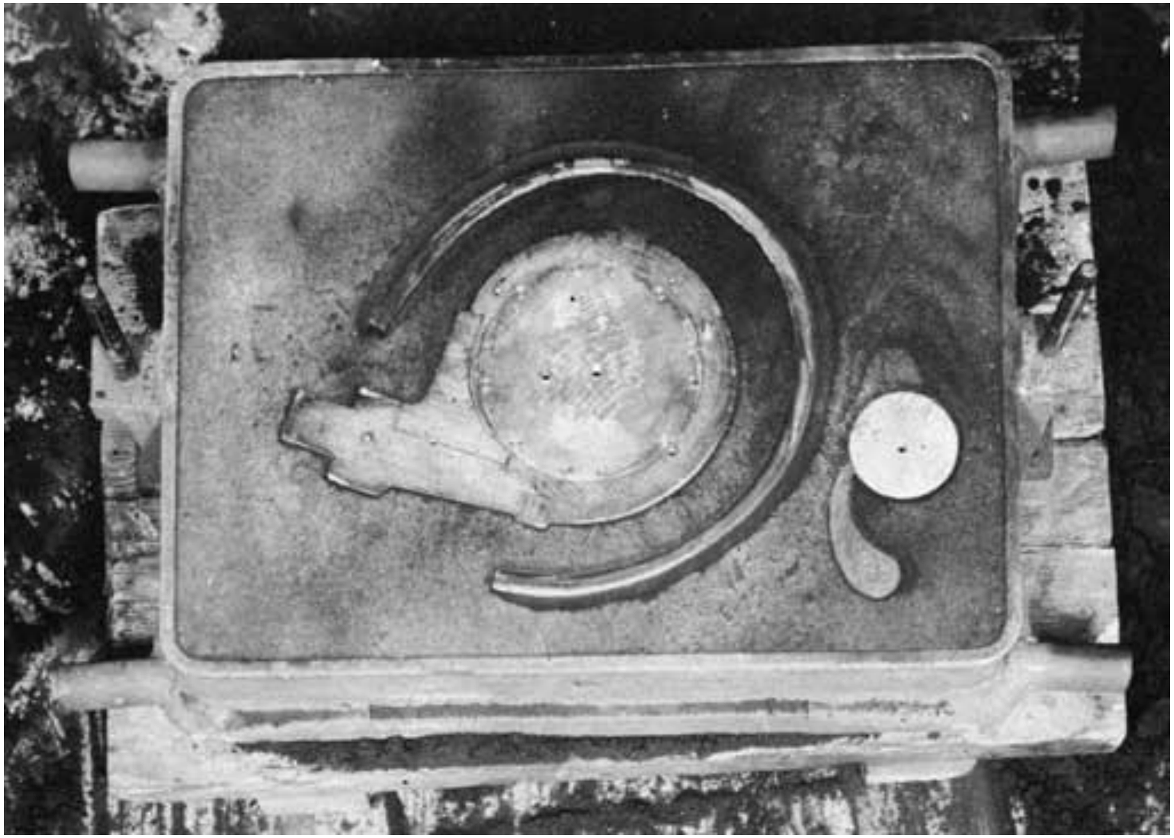
Pattern set in drag with gating system parts



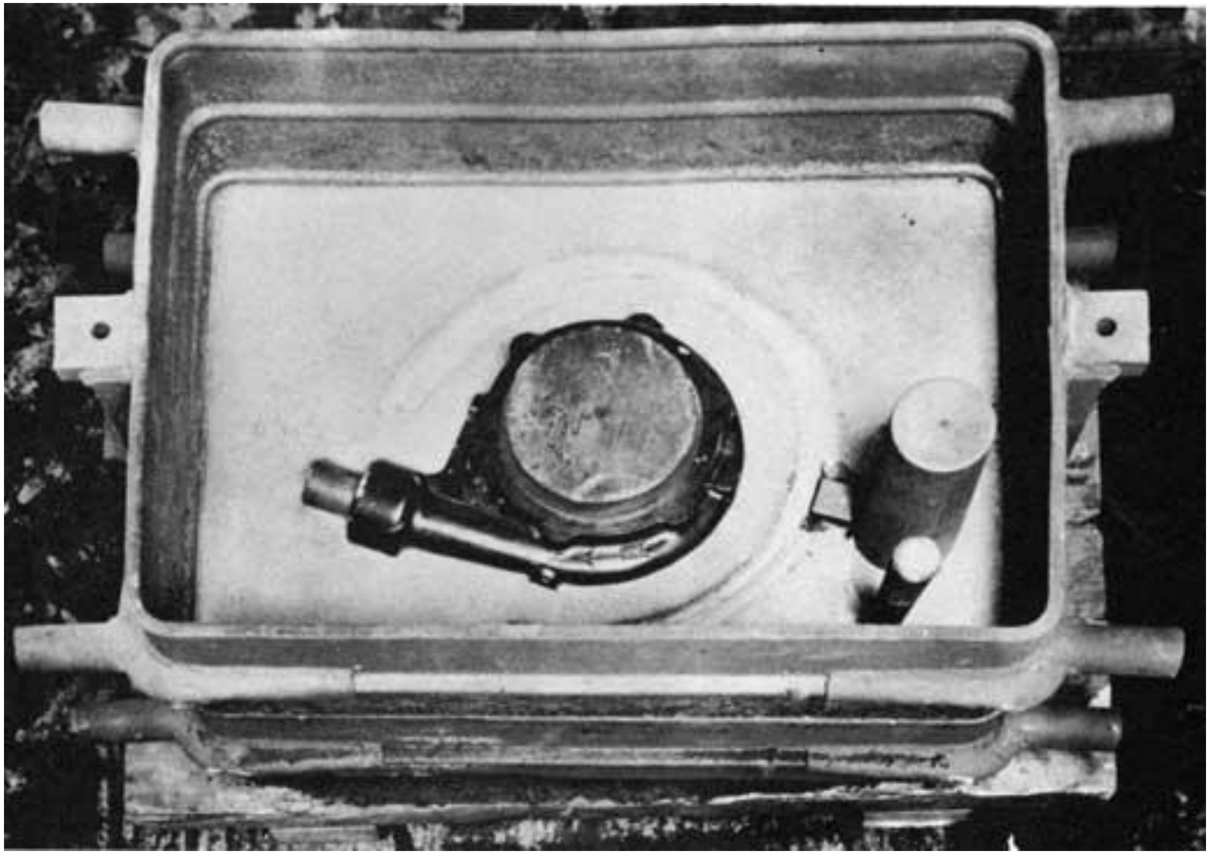
Hand packing riddled sand around the pattern.

Ramming a deep pocket.

Striking off the drag

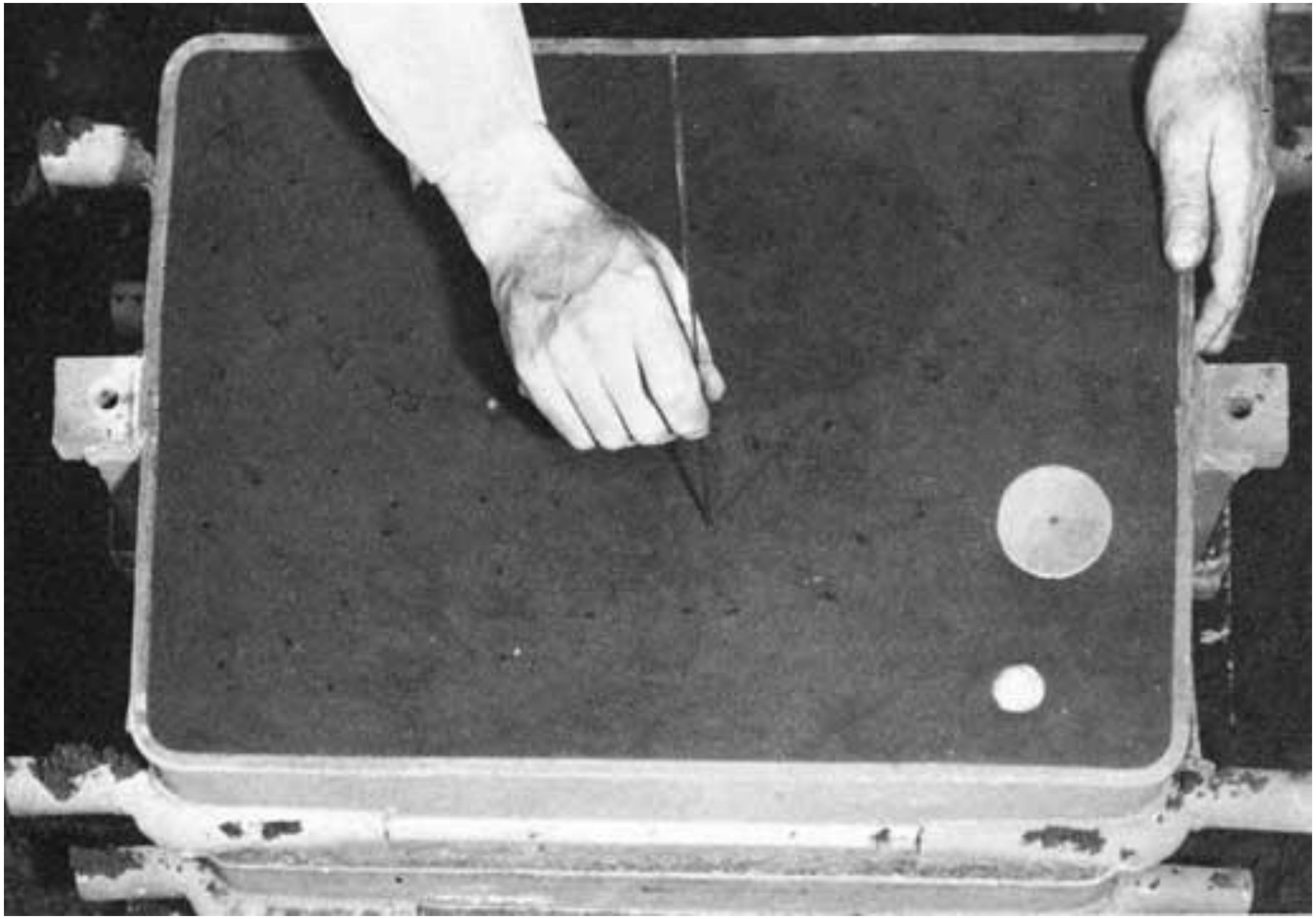


Drag ready for the cope.



Cope with pattern and gating pieces set.

Ramming the partially filled cope.

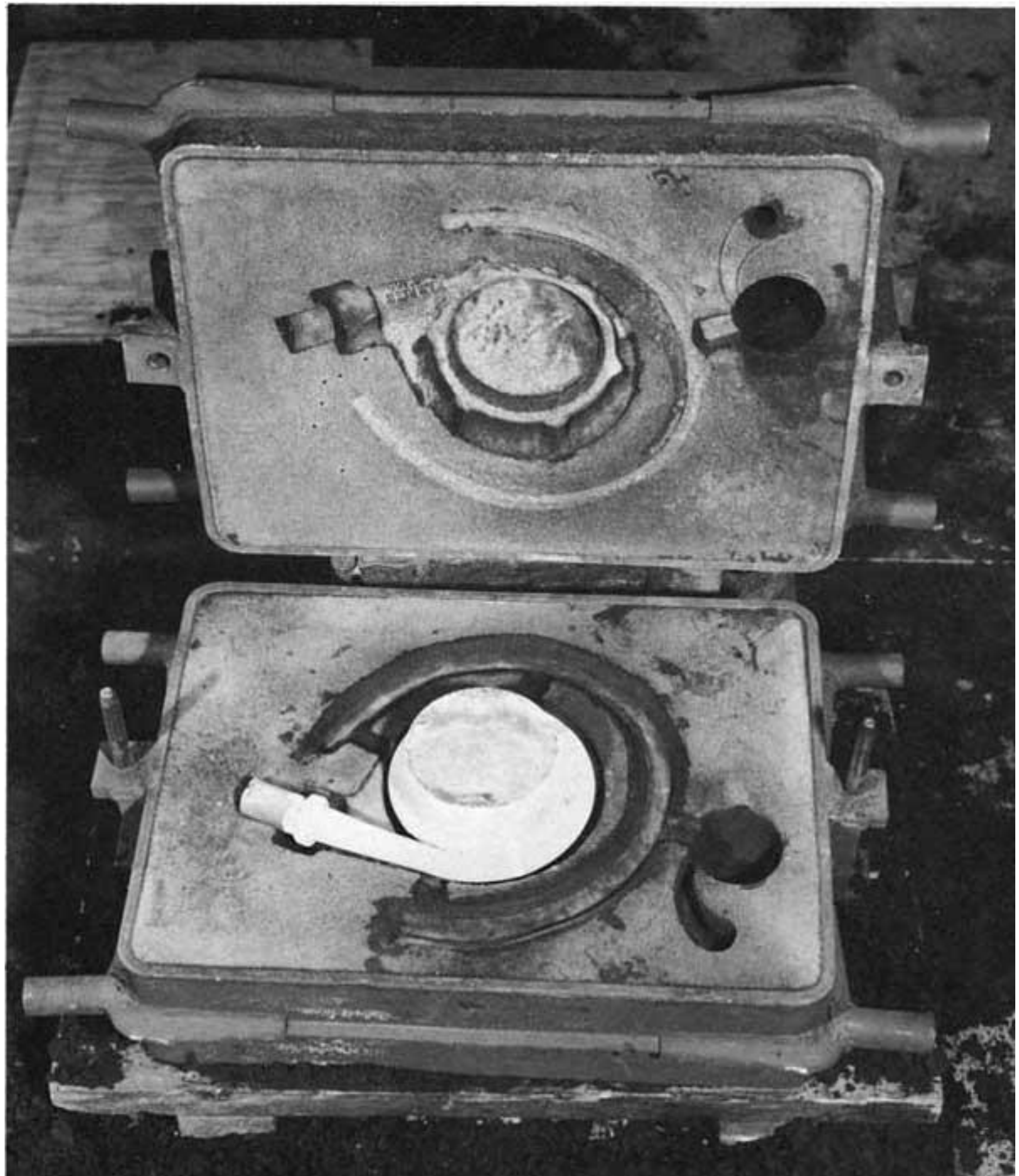


Venting the cope.

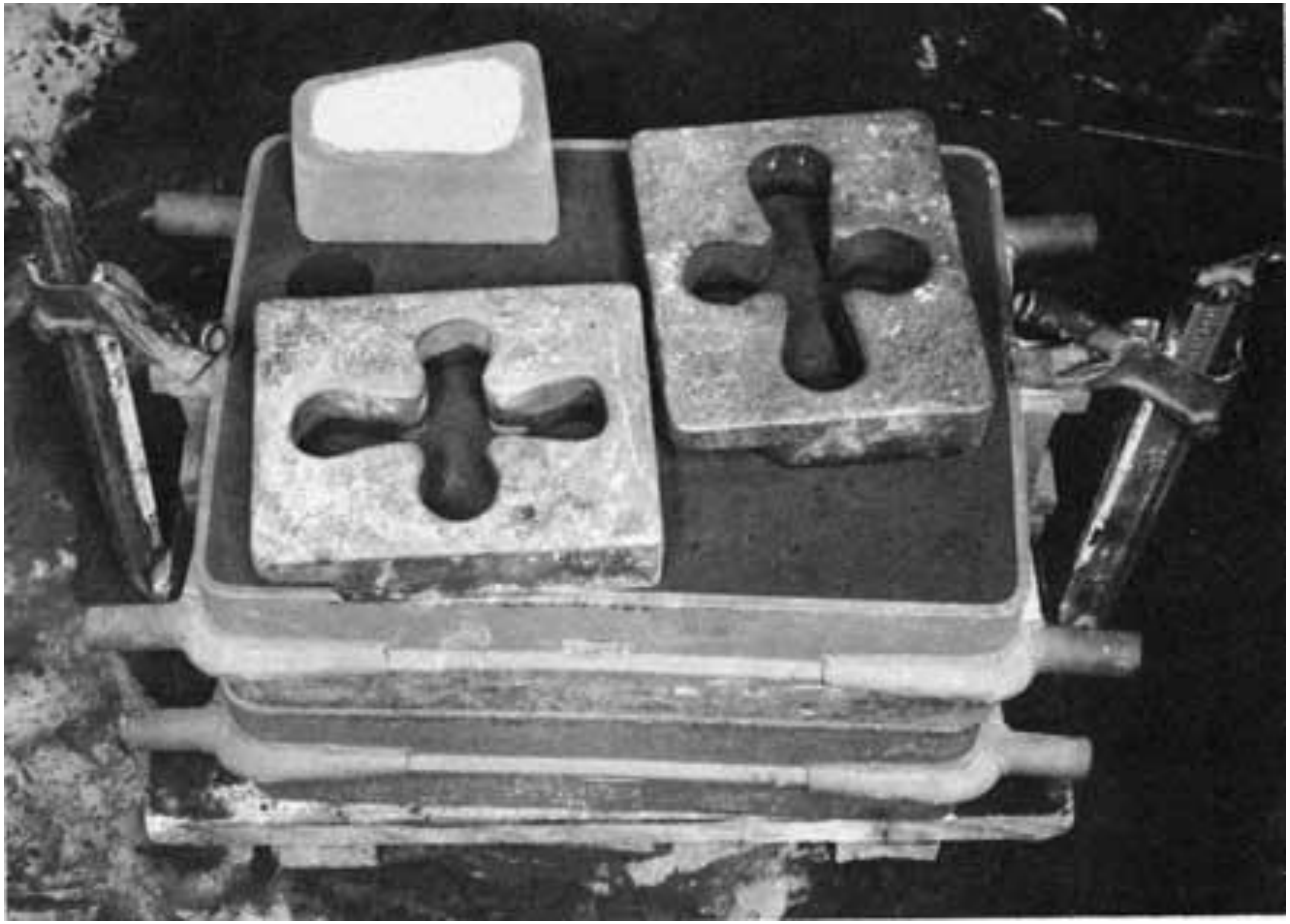
Start of the pattern draw.


Pattern completely drawn.

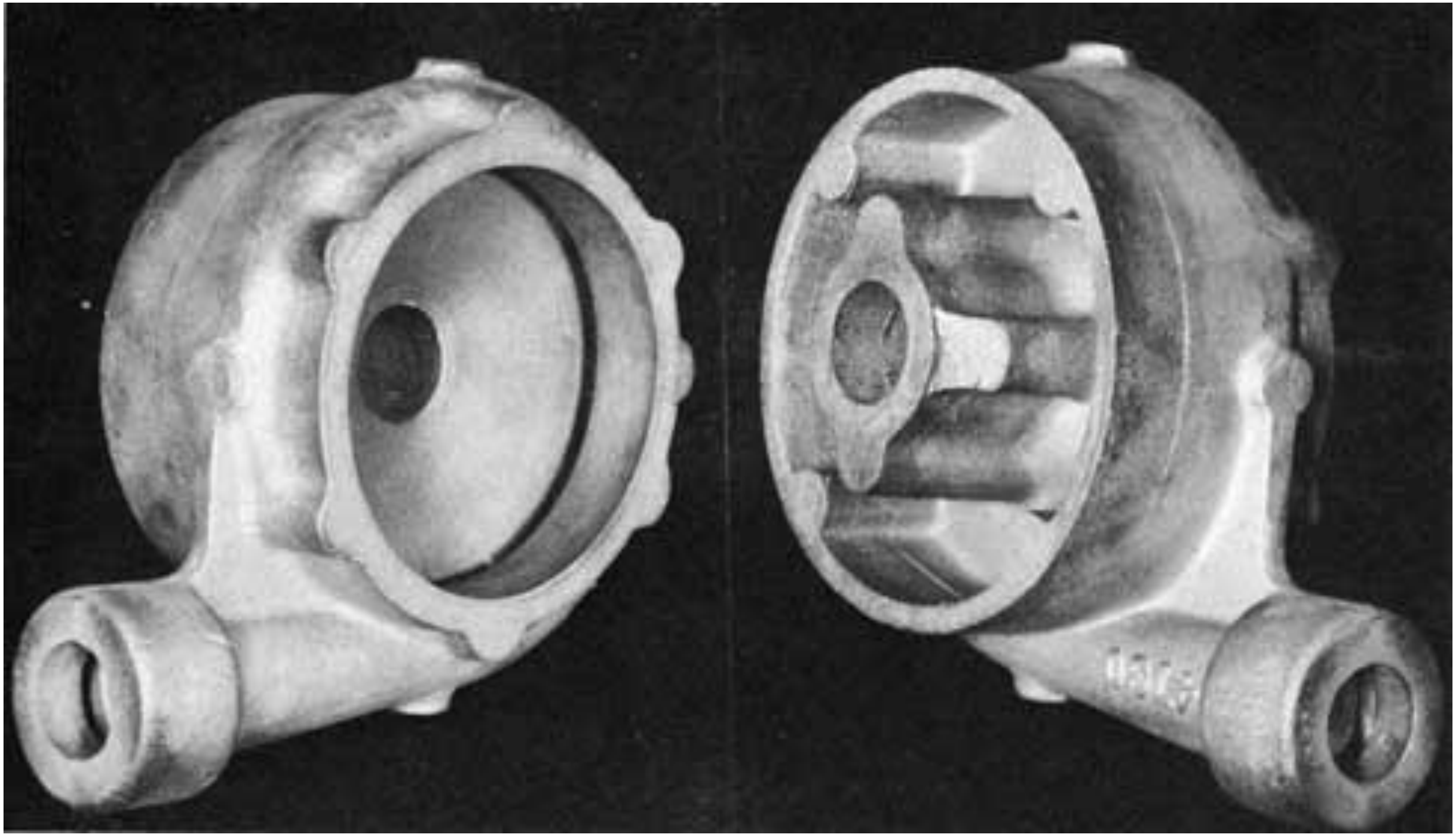
Setting the core.



Cope and drag ready for closing

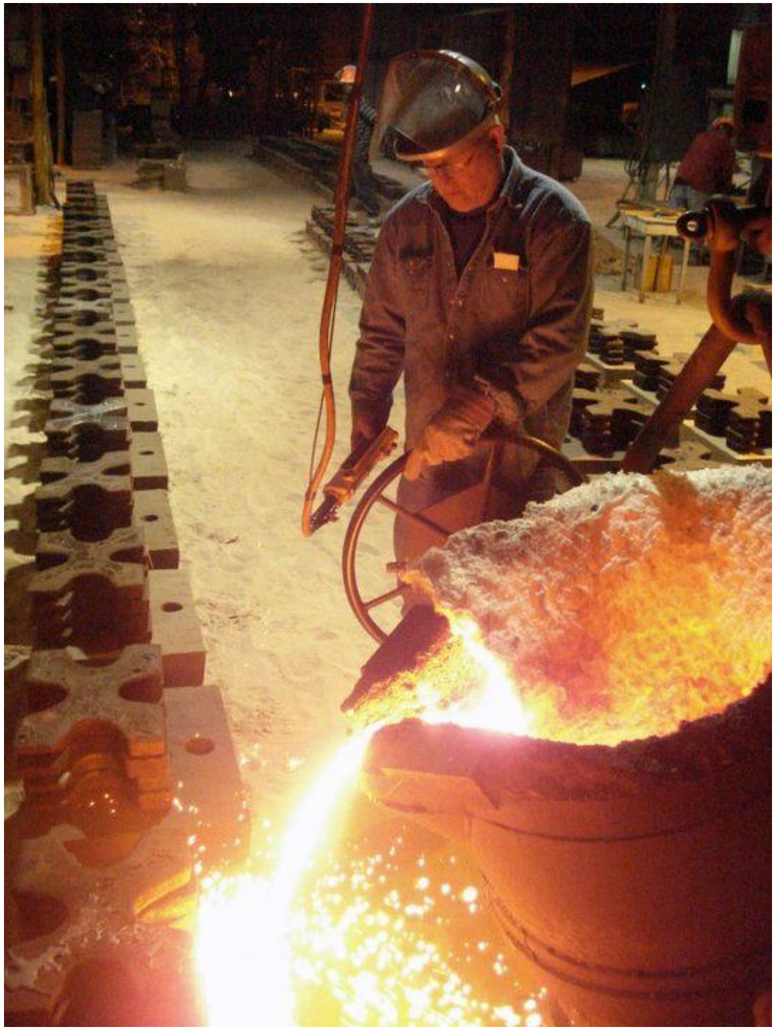


Clamped mold with weights and pouring basin



Finished pump housing casting.

# Keene Foundry in Houston, Texas

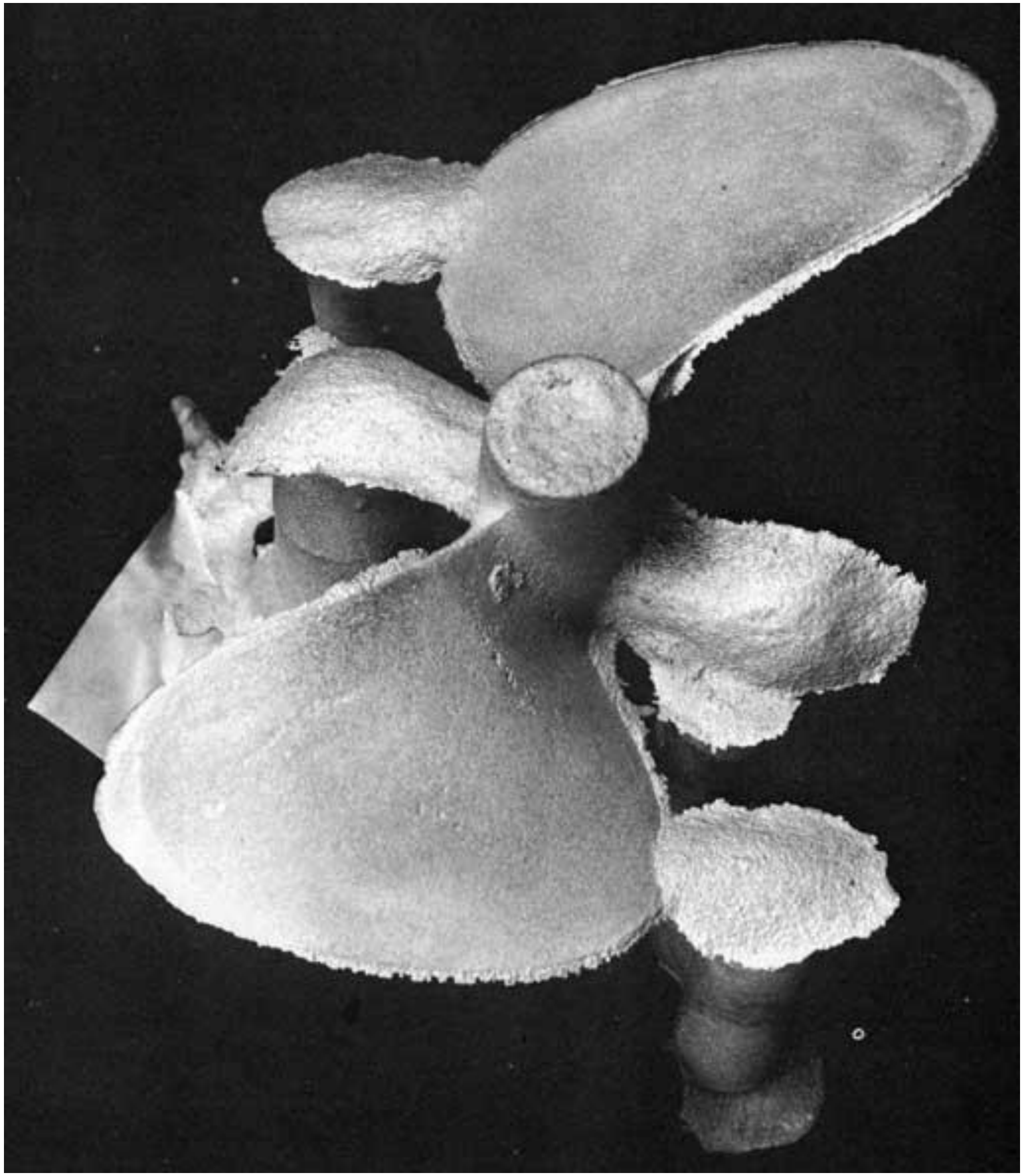


Propeller set in the drag.

Propeller in the drag with parting line cut.

Drawn cope

Mold ready for closing



As-cast propeller.

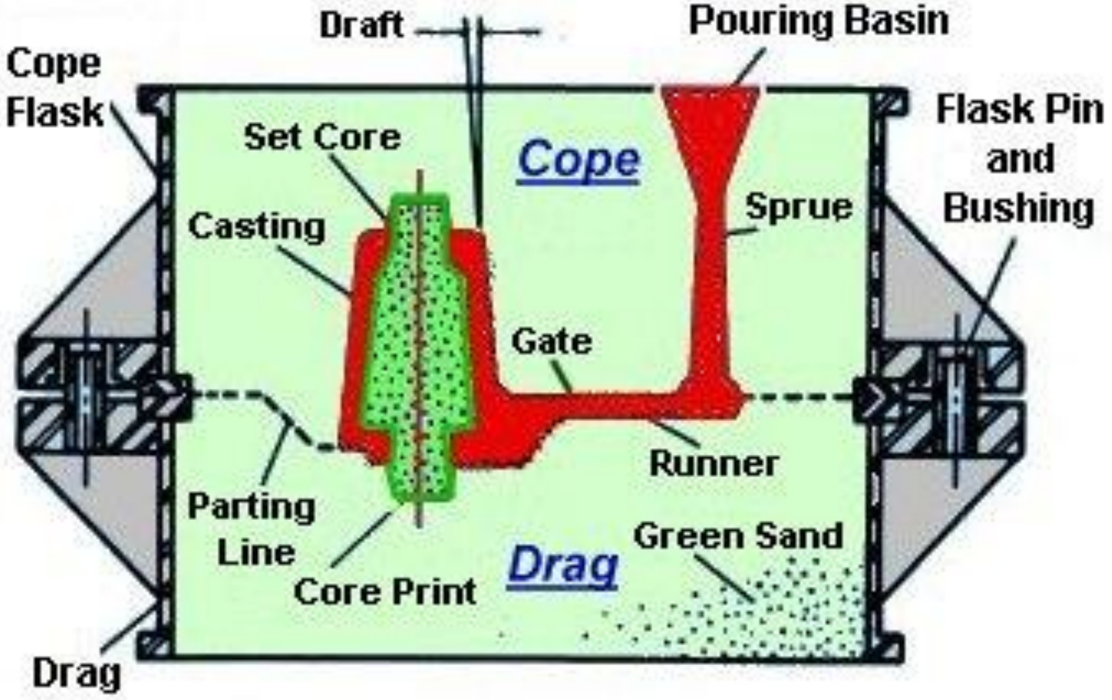






Early experienced vs.
more experience patterns
and gating systems

# Gating your mold



Green Sand Mold Section