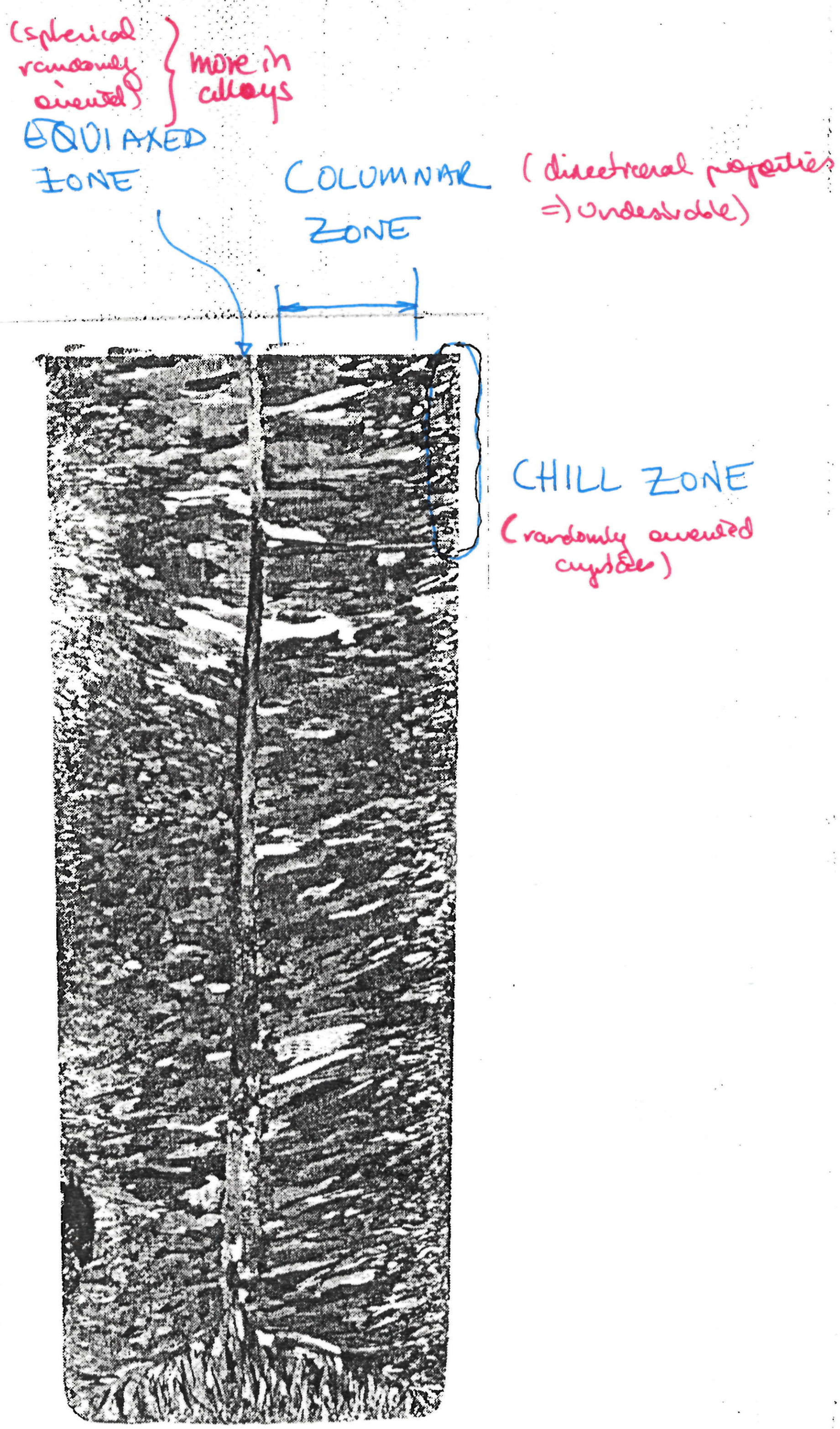
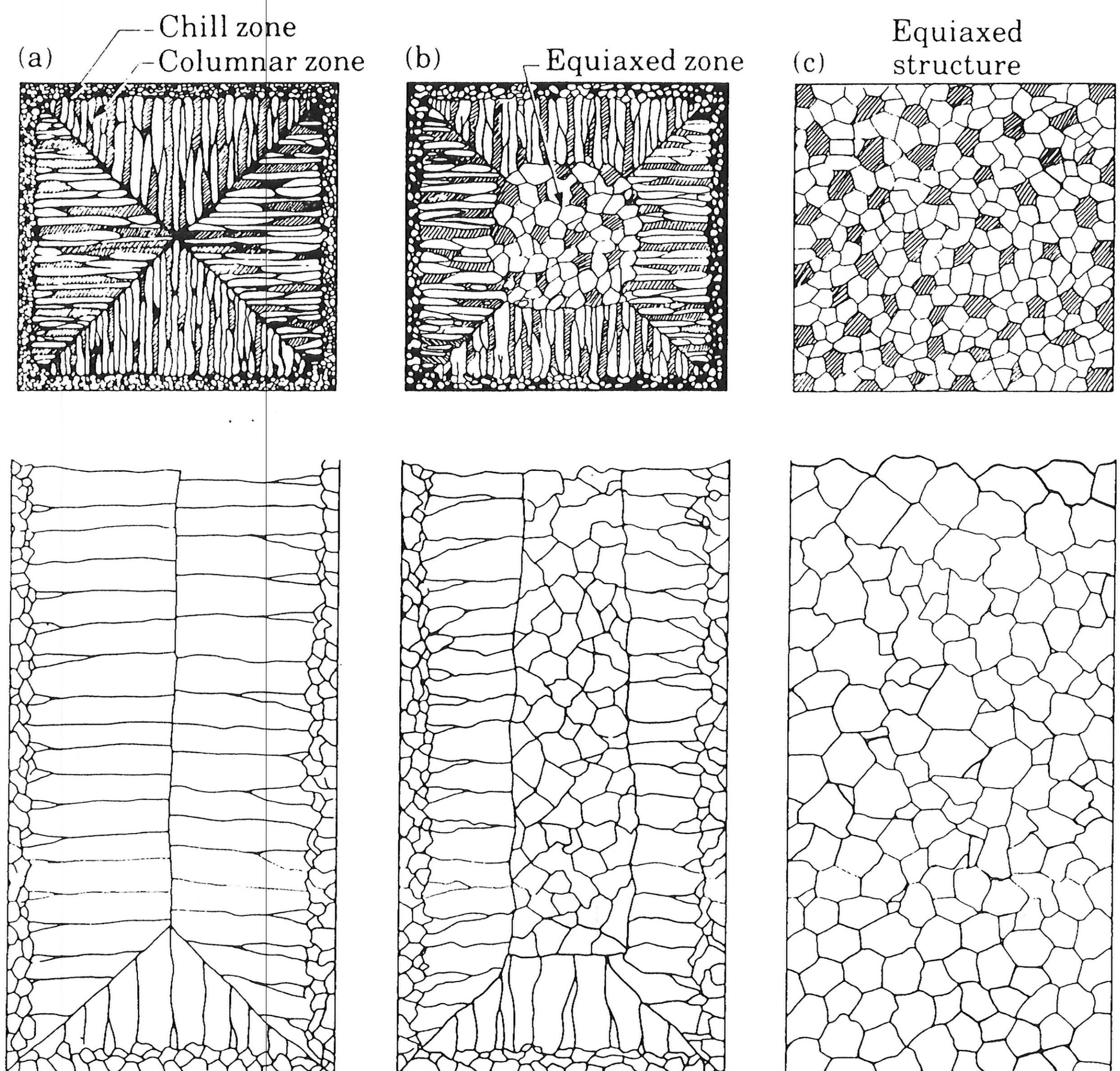

(spherical randomly oriented)
more in alloys
EQUIAXED ZONE
COLUMNAR ZONE
(directional properties => undesirable)
CHILL ZONE
(randomly oriented crystals)

Master 18

Schematic illustration of three cast structures of metals solidified in a square mold

Figure 10.1 (page 267)

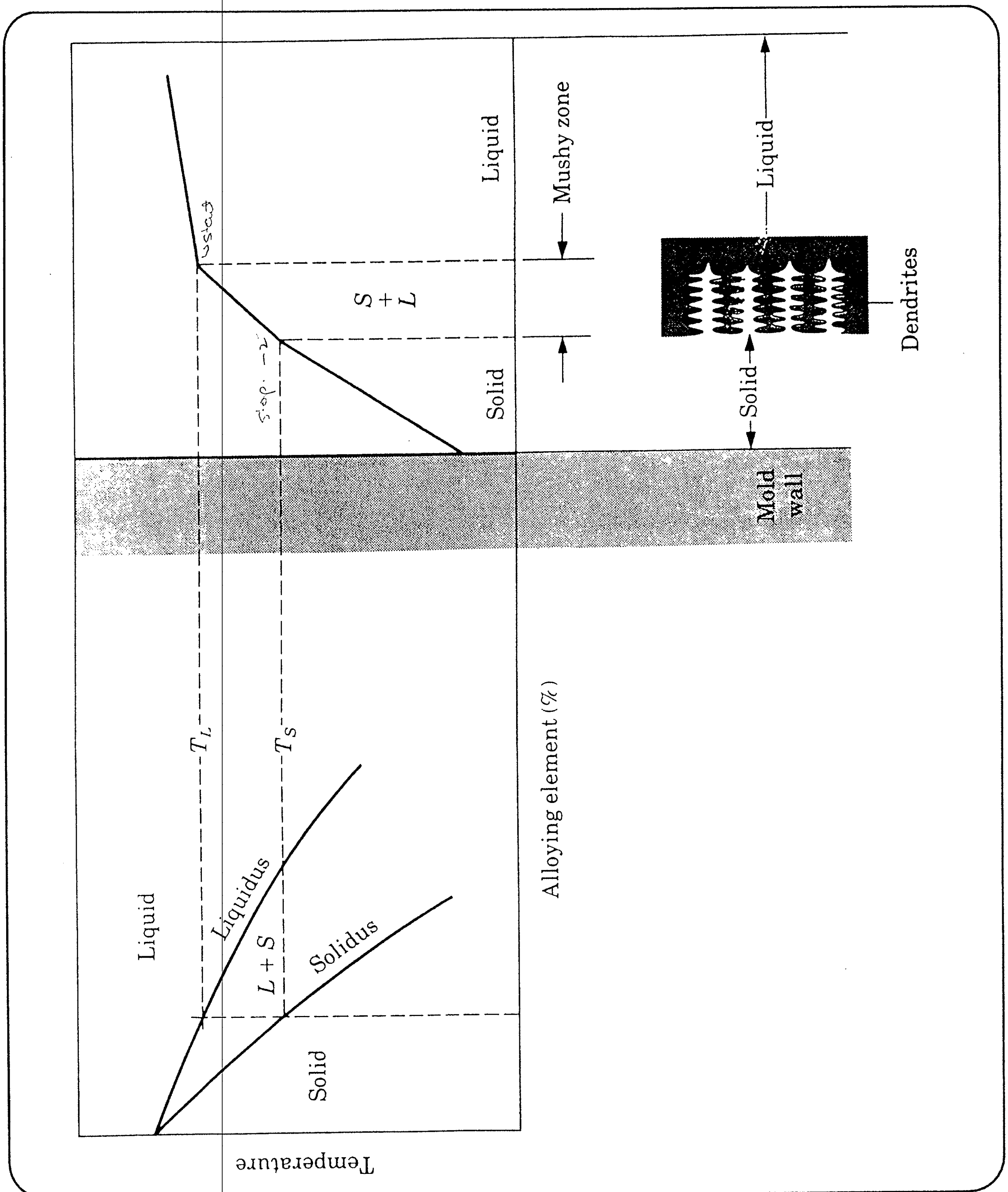


(Pure Metals)

(solid solution) alloy

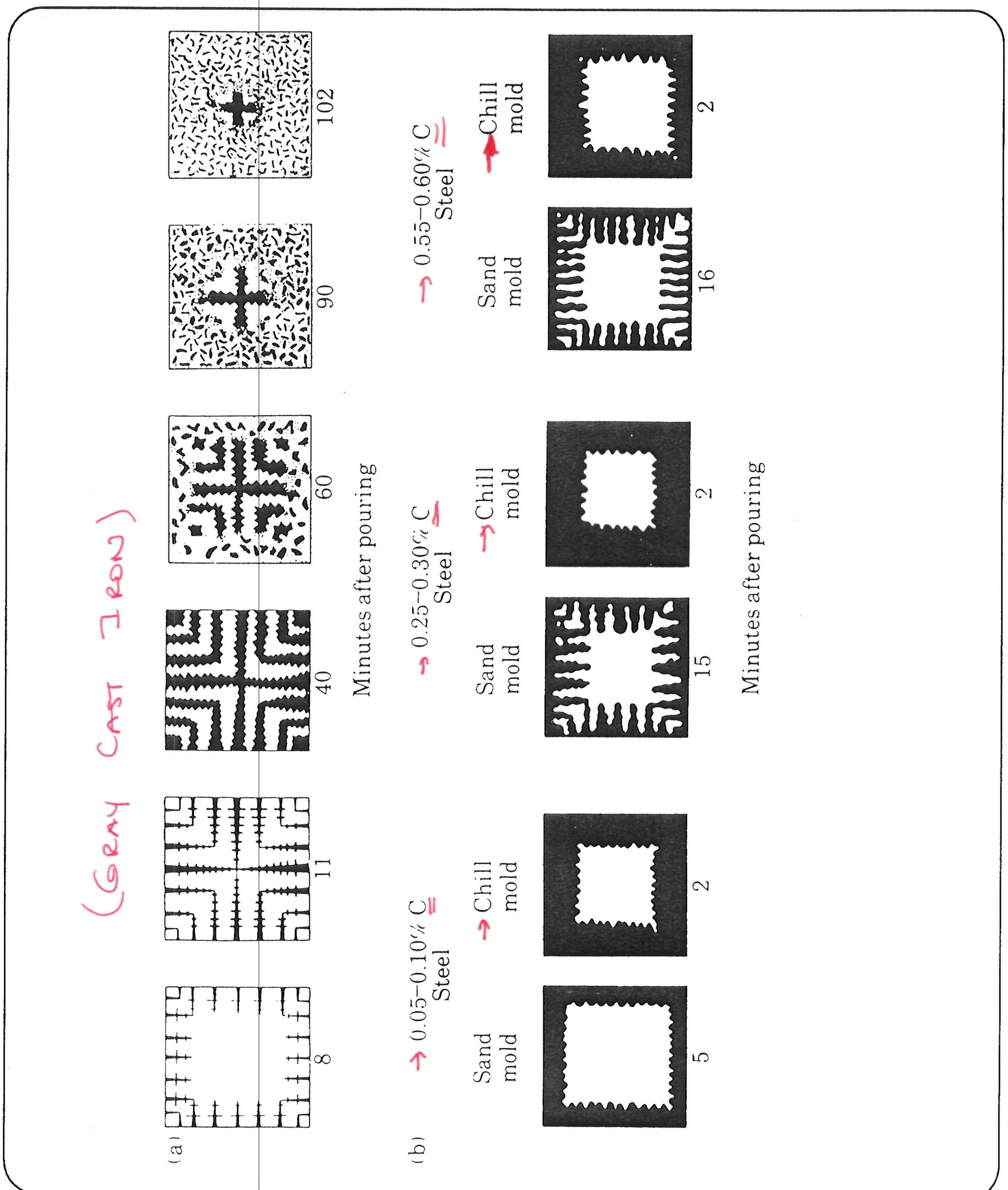
solid solution alloy + inoculants.

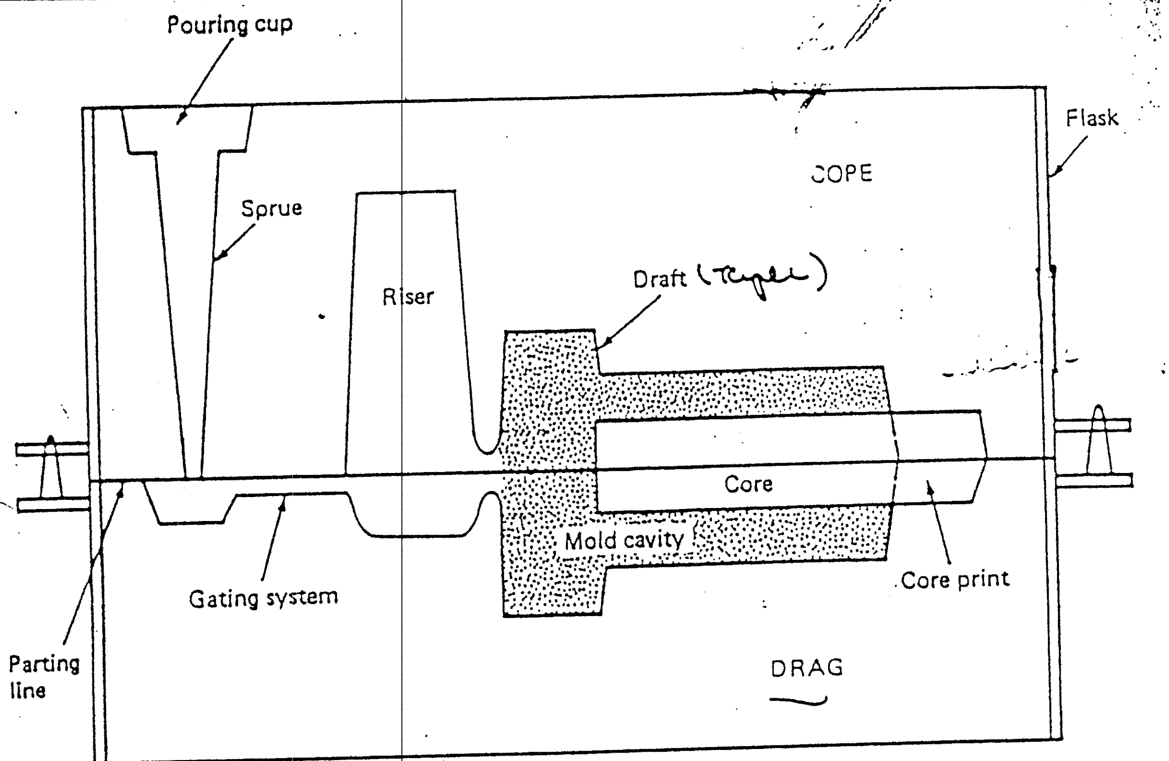
Figure 10.3 (page 268) **Schematic illustration of alloy solidification and temperature distribution in the solidifying metal**

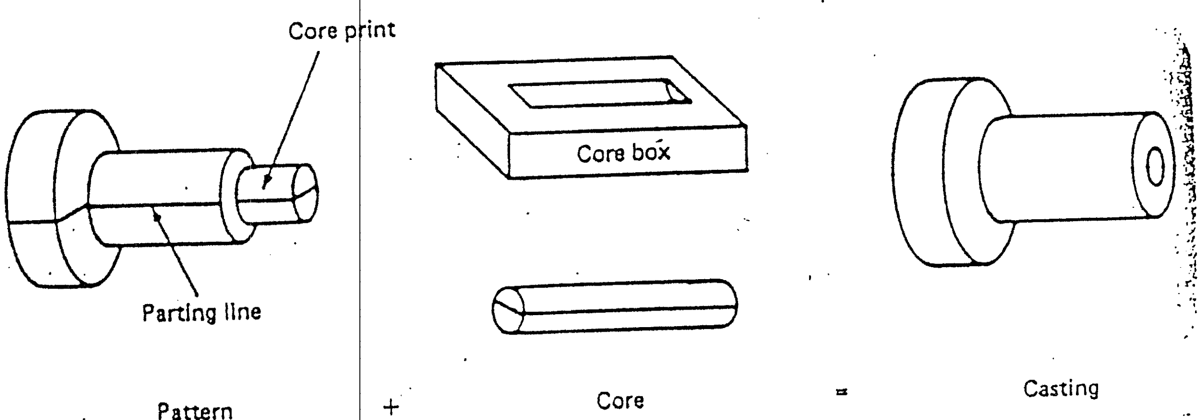


(a) Solidification patterns for gray cast iron in a 180-mm (7-in.) square casting.
(b) Solidification of carbon steels in sand and chill (metal) molds.

Figure 10.4 (page 269)




Pouring cup
Flask
COPE
Sprue
Riser
Draft
Core
Mold cavity
Core print
Gating system
Parting line
DRAG


Core print
Parting line
Core box
Pattern
+
Core
=
Casting

Casting Terminology:

Pattern: An approximate duplicate of the final casting.

Flask: the box containing the aggregate.

If the mold is a two part mold, the **cope** is the top part f the pattern, flask, mold and core.

The bottom part of any of these features is called the **drag.**

Core: a sand shape that is inserted into the mold to produce internal features (holes or passages for water cooling).

Core Print: Region added to the pattern , core or mold to locate and support the core within the mold.

Mold Cavity: mold material + core form the void where the metal is poured.

Riser: Extra void created that will be filled with molten metal, it provides a reserve of molten metal that can flow into the cavity to compensate for any shrinkage during solification. Shrinkage voids should occur here, not in the final casting.

Gating System: A network of channels used to deliver the mtal from outside the mold to the mold cavity.

Pouring Cup: Receives the molten metal from the pouring vessel.

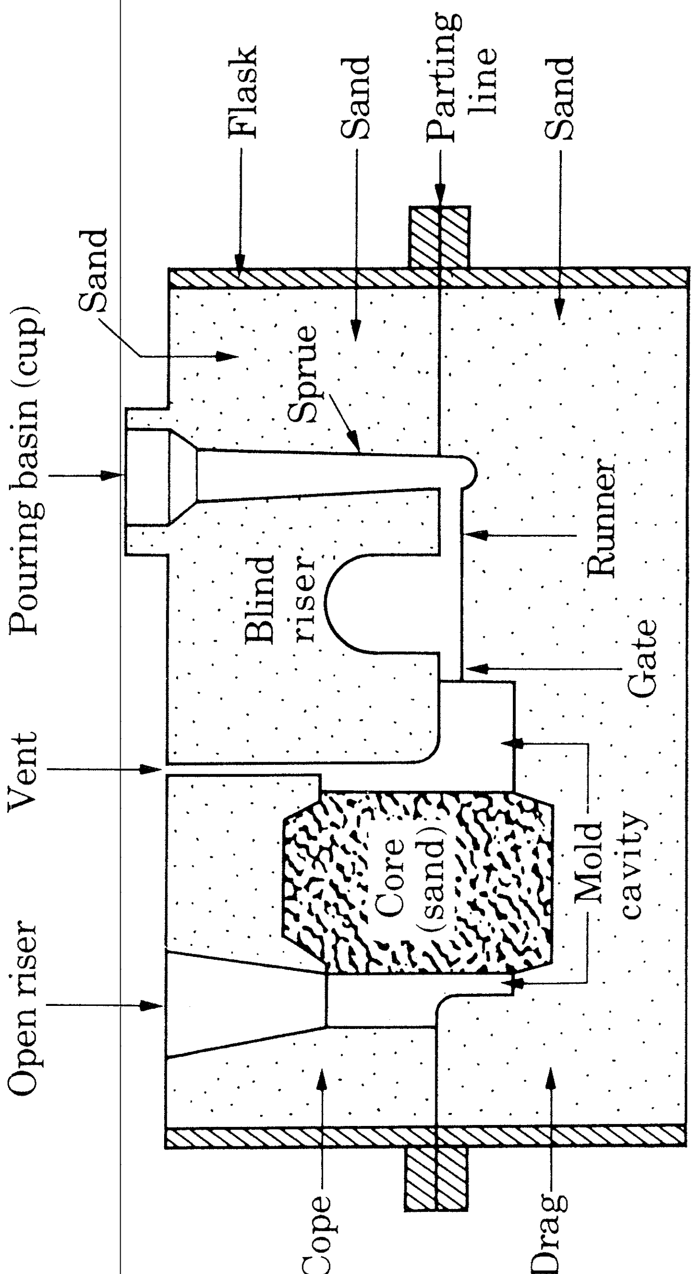
It then flows down the **sprue**, along the horizontal channels **(runners)** and finally through the **gates** into the cavity.

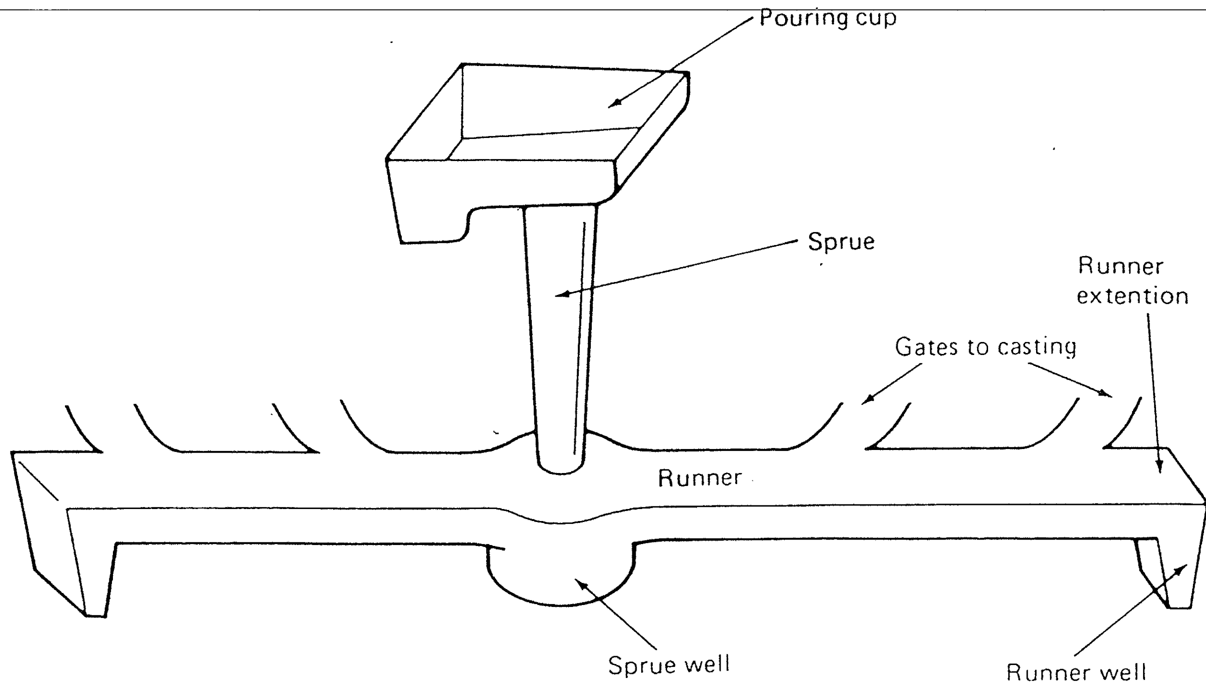
Parting line: the interface that separates the cope and drag halves of the mold, flask, or pattern, and the halves of the core.

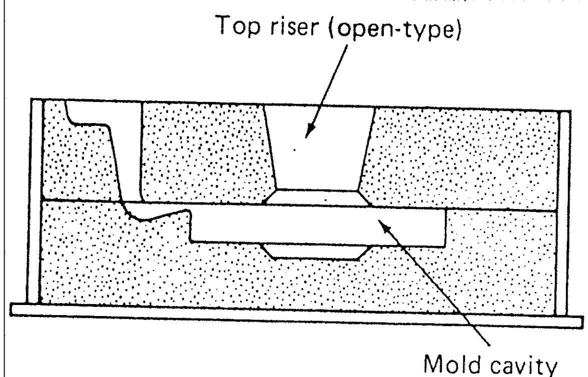
Draft: taper on a pattern that lets it be withdrawn from the mold.

Core box: the mold or die used to make the core.

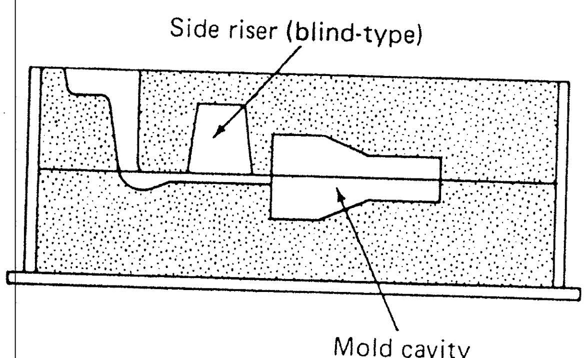
Schematic illustration of a sand mold showing various features




Pouring cup
Sprue
Runner
extention
Gates to casting
Runner
Sprue well
Runner well


Top riser (open-type)
Mold cavity

(a)


Side riser (blind-type)
Mold cavity

(b)

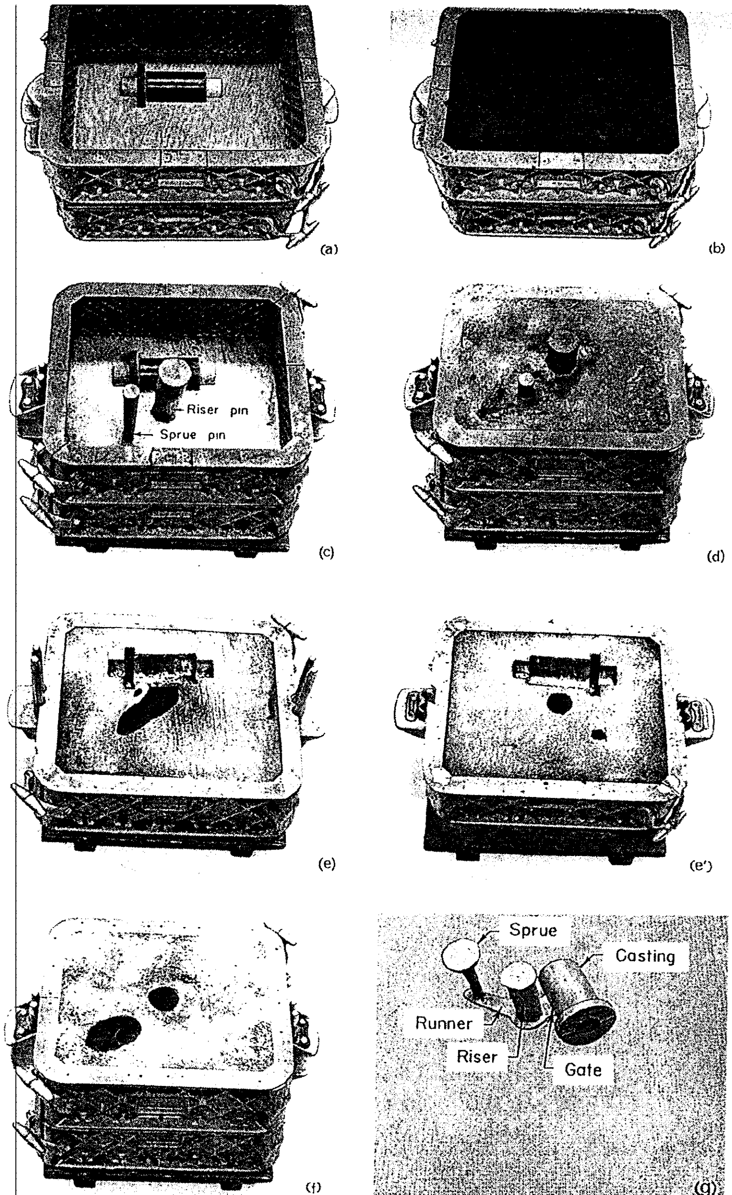
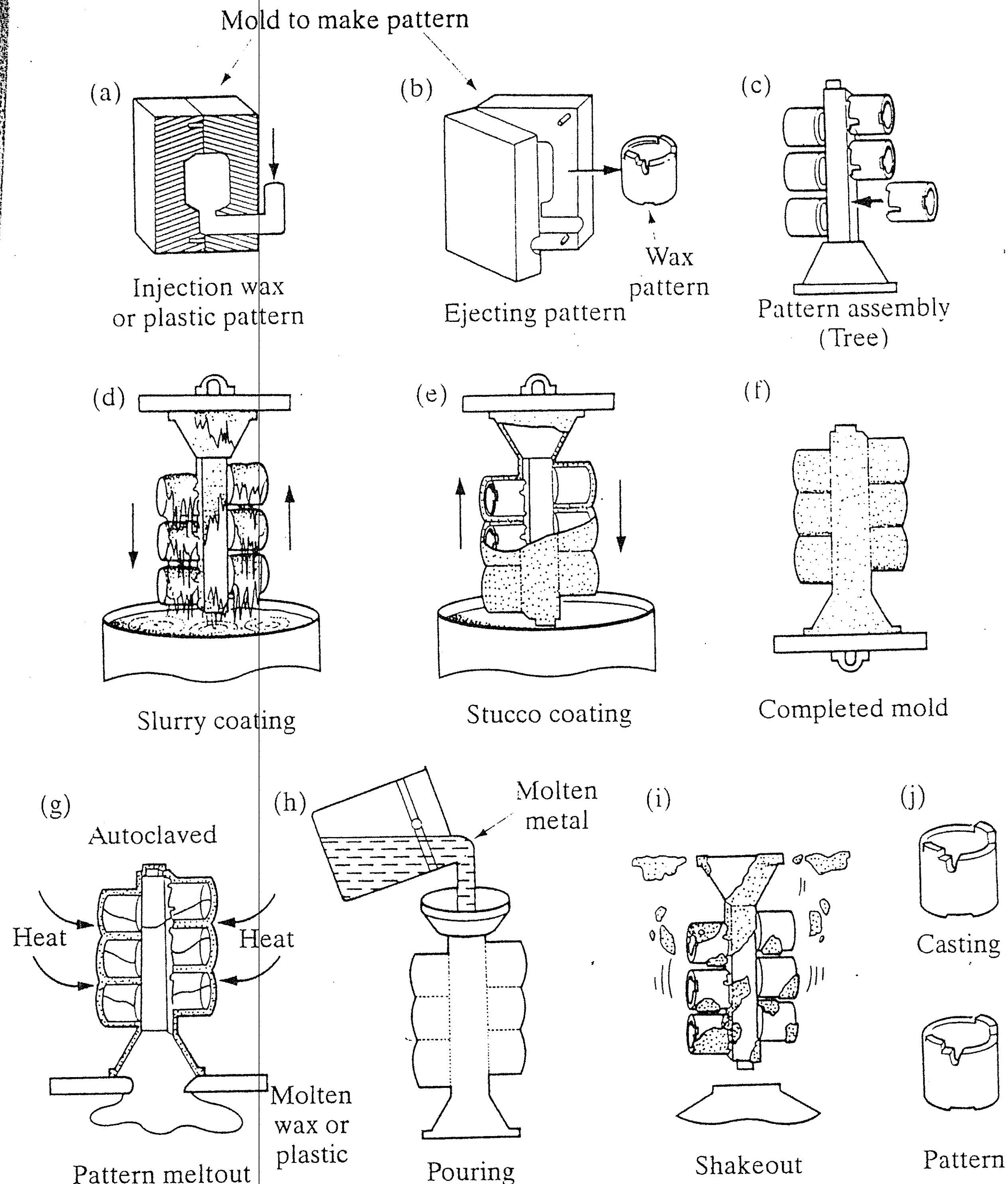
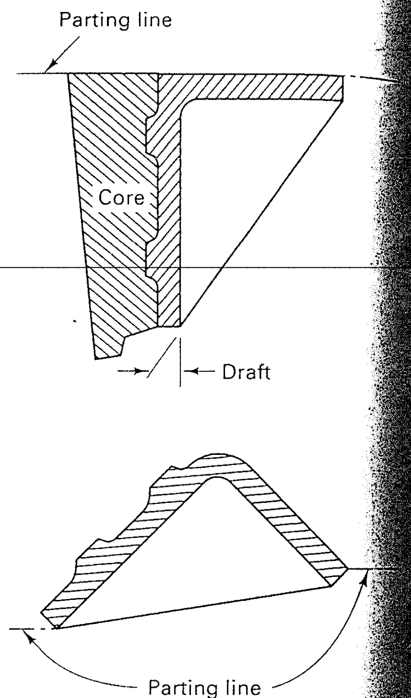


FIGURE 14-1 Sequential steps in making a sand casting. (a) A pattern board is placed between the bottom (drag) and top (cope) halves of a flask, with the bottom side up. (b) Sand is then packed into the drag half of the mold. (c) A bottom board is positioned on top of the packed sand, and the mold is turned over, showing the top (cope) half of pattern with sprue and riser pins in place. (d) The cope half of the mold is then packed with sand. (e) The mold is opened, the pattern board is drawn (removed), and the runner and gate are cut into the surface of the sand. (e') The parting surface of the cope half of the mold is shown with the pattern and pins removed. (f) The mold is reassembled with the pattern board removed, and molten metal is poured through the sprue. (g) The contents are shaken from the flask and the metal segment is separated from the sand, ready for further processing.



Mold to make pattern
(a)
Injection wax or plastic pattern
(b)
Wax pattern
Ejecting pattern
(c)
Pattern assembly (Tree)
(d)
Slurry coating
(e)
Stucco coating
(f)
Completed mold
(g)
Autoclaved
Heat
Heat
Molten wax or plastic
Pattern meltout
(h)
Molten metal
Pouring
(i)
Shakeout
(j)
Casting
Pattern



e by changing

STINGS

at the lowest possible cost, it is important that the de-
ntion to several process requirements and, if possible,
undry. It is not uncommon for minor and readily per-
facilitate and simplify the casting of a component and
of defects.
must be considered by a designer is the *location of the*
all processes that use segmented or separable molds
can affect each of the following: (1) the number of
economical gating, (3) the weight of the final casting,
cores, (5) the final dimensional accuracy, and (6) the

inimize the use of cores. Often, a change in the loca-
ne can assist in this objective, as illustrated in Figure
duces the weight of the casting by eliminating the need
er example of how a simple design change can elimi-

ne can also be dictated by certain design features. Fig-
on of round edges can restrict the location of the part-

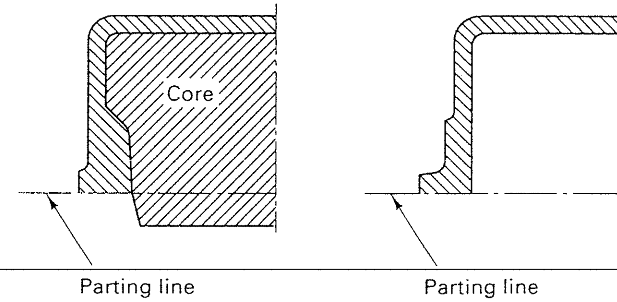


FIGURE 13-14 Elimination of a dry-sand core by change in part design.

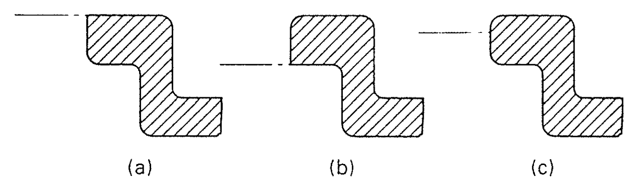


FIGURE 13-15 Parting planes should not intersect rounded edges. Three alternative designs are presented.

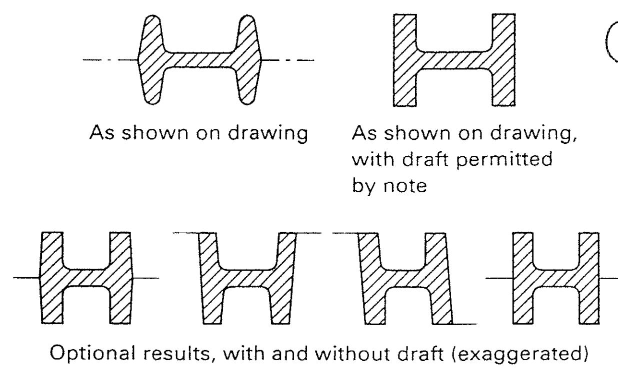
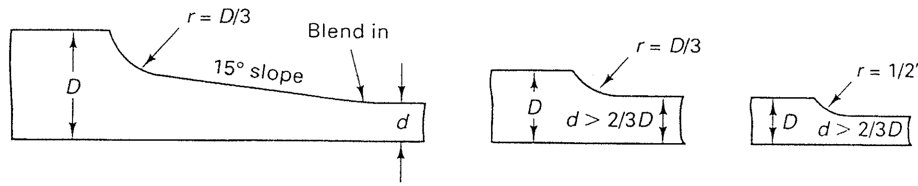


FIGURE 13-16 (*Top left*) Design where the location of the parting plane is specified by the draft. (*Top right*) Part with draft unspecified. (*Bottom*) Various options in producing that part, including a no-draft design.

Controlling the solidification process is of prime importance in obtaining quality castings, and this control is also related to design. Those portions of a casting that have a high ratio of surface area to volume will experience more rapid cooling and will be stronger and harder than the other regions. Heavier sections will cool more slowly and, unless special precautions are observed, may contain shrinkage cavities and porosity or have large grain-size structures. Ideally, a casting should have uniform thickness in all directions. In most cases, however, this is not possible. When the section thickness must change, it is best if these changes be gradual, as indicated in the recommendations of Figure 13-17.

When sections of castings intersect, two problems can arise. The first of these is stress concentration. This problem can be minimized by providing generous fillets (inside radii) at all interior corners. Excessive fillets, however, can augment the second problem, known as *hot spots*. Figure 13-18 shows that localized thick sections tend to exist where



If $D > 1.5"$ and $d < 2D/3$ then $r = D/3$ with a 15° slope between the two parts

If $D > 1.5"$ and $d > 2/3\ D$ then $r = D/3$

If $D < 1.5"$ and $d > 2/3\ D$ then $r = 1/2"$

FIGURE 13-17 Guidelines for section changes in castings.

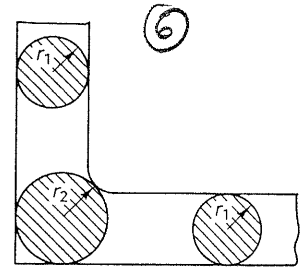


FIGURE 13-18 "Hot spot" at section r_2 caused by intersecting sections.

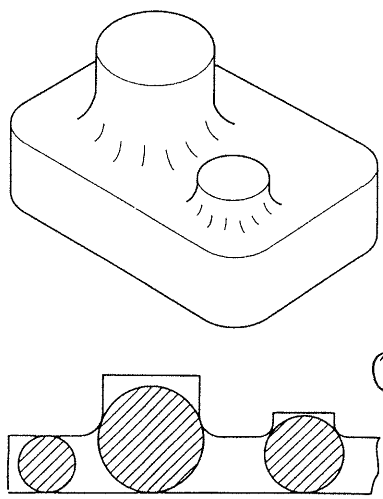


FIGURE 13-19 Hot spots resulting from intersecting sections of various thickness.

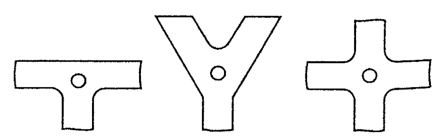


FIGURE 13-20 Method of eliminating unsound metal at the center of heavy sections in castings by using cored holes.

Figure 13-20, can be used to avoid hot spots. Where heavy sections must exist, an adjacent riser is often used to feed the section during solidification and shrinkage. If the riser

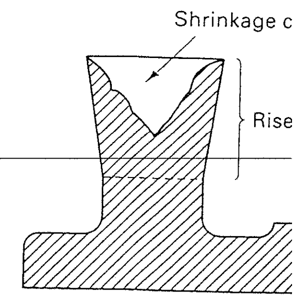


FIGURE 13-21 Use of a rise
shrinkage cavity out of a cas

occurs at the intersections.
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would otherwise induce crac

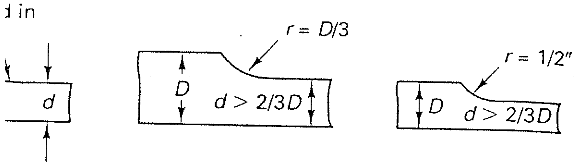
Large unsupported are
tend to warp during cooling.
ance that is so often desired.
ing line. Some small amou
flash is removed, or if it is
imperfection will be present.
ible. However, if the parting
go largely unnoticed.

When designing castir
Specific values are rarely giv
of the casting, the type of m
foundry. Table 13-2 present
nesses for some common fou

TABLE 13-2. Recommen for Various Engineering M

Material	mm
Steel	4.76
Gray iron	3.18
Malleable iron	3.18

d in

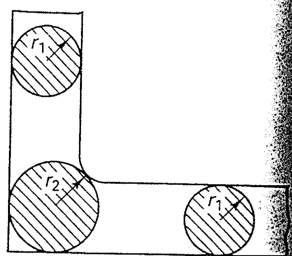


veen

If $D > 1.5''$ and $d > 2/3\,D$ then $r = D/3$

If $D < 1.5''$ and $d > 2/3\,D$ then $r = 1/2''$

ction changes in castings.



n r_2 caused by

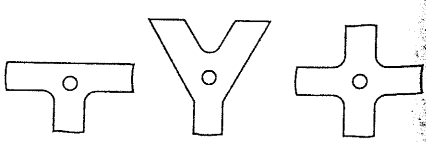


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FIGURE 13-20 Method of eliminating unsound metal at the center of heavy sections in castings by using cored holes.

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ction during solidification and shrinkage. If the rise

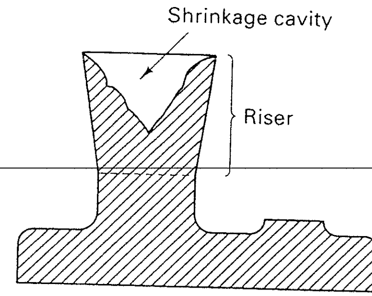


FIGURE 13-21 Use of a riser to keep the shrinkage cavity out of a casting.

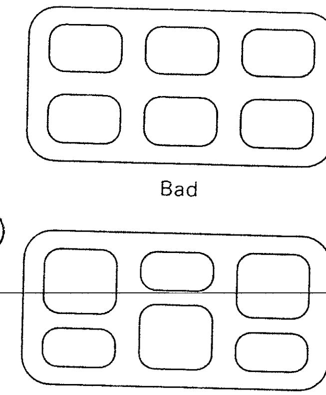


FIGURE 13-22 Method of using staggered ribs to prevent cracking during cooling.

occurs at the intersections. By staggering the ribs, as shown in Figure 13-22, there is opportunity for distortion to occur, providing relaxation to the high residual stresses that would otherwise induce cracking.

Large unsupported areas should be avoided in all types of casting, since these regions tend to warp during cooling. The warpage then disrupts the good, smooth surface appearance that is so often desired. Another appearance consideration is the location of the parting line. Some small amount of fin, or flash, is often present at this location. When the flash is removed, or if it is considered small enough to leave in place, a region of surface imperfection will be present. If this is in the middle of a flat surface, it will be clearly visible. However, if the parting line is placed to coincide with a corner, the "defect" line will go largely unnoticed.

When designing castings, minimum section thickness should also be considered. Specific values are rarely given, however, because they tend to vary with the shape and size of the casting, the type of metal, the method of casting, and the practice of the individual foundry. Table 13-2 presents average values of the minimum and desirable section thicknesses for some common foundry materials and compatible casting processes.

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

Material	Minimum		Desirable		Casting Process
	mm	in.	mm	in.	
Steel	4.76	$\frac{3}{16}$	6.35	$\frac{1}{4}$	Sand
Gray iron	3.18	$\frac{1}{8}$	4.76	$\frac{3}{16}$	Sand
Malleable iron	3.18	$\frac{1}{8}$	4.76	[illegible]	Sand

Most metals and alloys shrink when they solidify. Therefore, all members of the parts should be designed to increase in dimension progressively to one or more suitable locations where feeder heads can be placed to offset liquid shrinkage. All of the rules set forth here have been proven in practice.

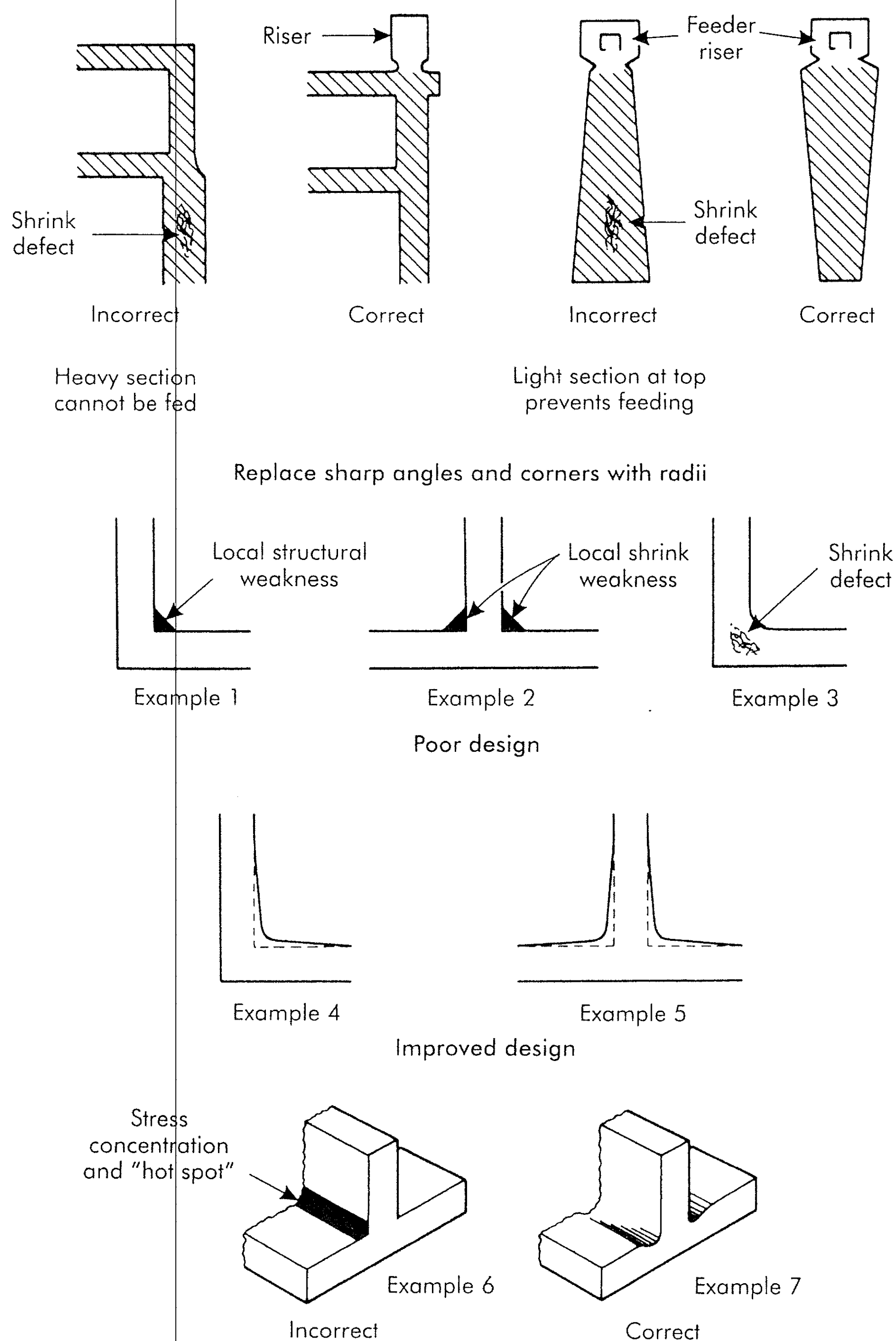
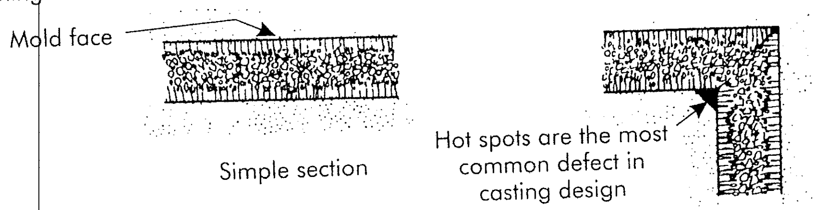


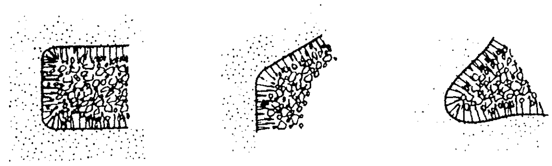
Figure 8-35. Rules for the design of castings.

A cooling surface should always be presented. Sharp angles and corners should be avoided.



Simple section

Conjoining sections

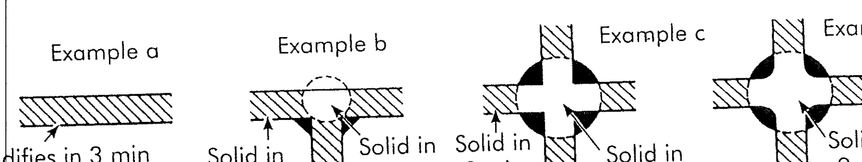


Rounding corners avoids local structural weakness

Metal structure is affected by shape of casting section

Solidification of molten metal always proceeds from the mold face, forming unbalanced crystal grains that penetrate into the mass at right angles to the plane of the cooling surface. A simple section presents uniform cooling and greatest freedom from mechanical weakness. When two or more sections conjoin, mechanical weakness is induced at the junction and free cooling is interrupted, creating a "hot spot."

The minimum number of sections should be brought together



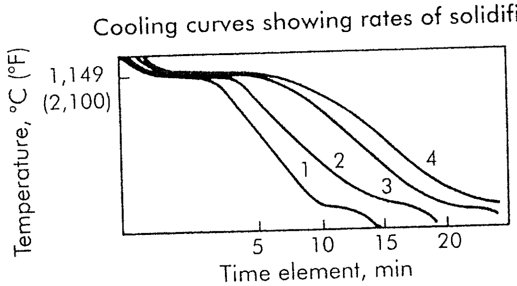
A simple section that cools freely from all surfaces.

In Example b, adding a second section creates "hot spots." The area inside circle cools at the rate of a section 50% larger.

When two sections cross, as in Example c, only material outside the circle represents true properties. Area inside the circle solidifies at the rate of a bar twice its cross-sectional area.

Adding fillets that are too large aggravates defect.

Cooling curves showing rates of solidification



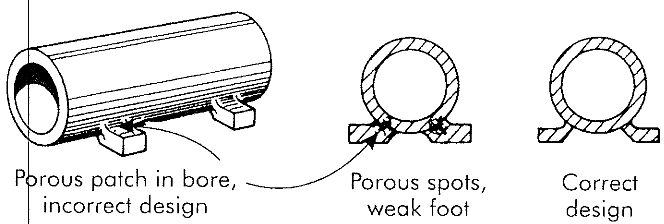
Cooling curves at center of:
1. Bar number 1
2. Single right-angle section
3. Double right-angle section
4. Fillets too large

To portray the serious casting problems involved in the joining of an excessive number of members, cooling curves are made by inserting thermocouples at the adjoining sections. The results of these measurements are plotted as shown in the graph above. A well-designed casting brings the minimum number of sections together and avoids acute angles.

Figure 8-35. (cont.)

All sections should be designed as nearly uniform in thickness as possible

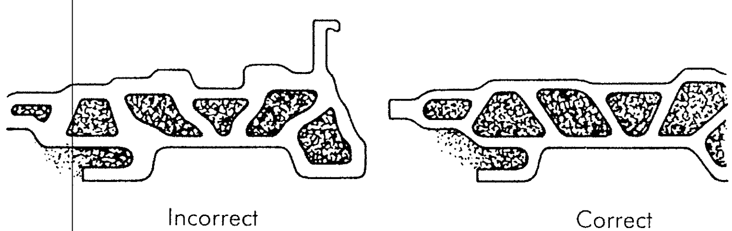
Cylinder with lugs



Design on left caused defects shown. Correct design shown on right. All sections should be designed as uniform in thickness as possible. Failing this, all heavy sections should be accessible for feeding.

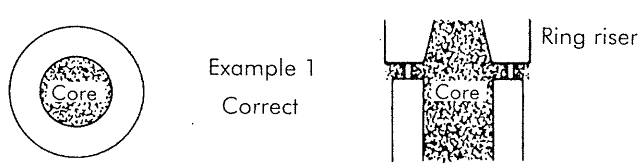
Dimensions of inner wall should be correctly proportioned

Inner sections of castings, resulting from complex cores, cool much slower than outer sections and cause variations in strength properties. A good rule is to reduce inner sections to 9/10ths of the thickness of the outer wall. Rapid section changes and sharp angles should be avoided. Wherever complex cores must be used, the design for the section should be uniform to avoid locally heavy masses of metal.



Cylinders and bushings

The inside diameter of cylinders should exceed the wall thickness of the casting.



When the inside diameter of the cylinder is less than the wall thickness of the casting, as shown in Example 2, it is better to cast solid. Holes can be produced by cheaper and safer methods than by coring.

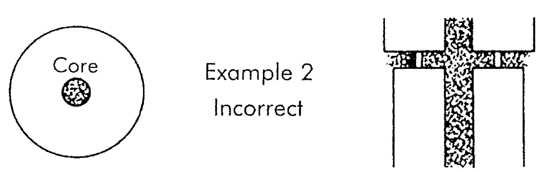


Figure 8-35. (cont.)