

AMERICAN FOUNDRYMEN'S SOCIETY CAST METALS INSTITUTE



CAST METALS TECHNOLOGY SERIES

BASIC PRINCIPLES OF RISERING



**AMERICAN FOUNDRYMEN'S SOCIETY
GOLF & WOLF ROADS, DES PLAINES, IL 60016**

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PREFACE

This programmed learning course is one of a series of courses prepared by the Cast Metals Institute of the American Foundrymen's Society, and is primarily designed to enrich the technical knowledge of a person who is beginning a career in the metalcasting industry. These courses, however, may also be used by more experienced foundrymen to learn scientific principles in specific areas of cast metals technology. They may be used individually or as instructional and testing material to supplement group instruction.

This course is on the basic principles of risering. In it you will study the use of risers and how they can aid the foundryman in producing sound castings when they are properly applied. In too many cases, the application of risers is a "hit-or-miss" proposition. The fundamentals presented in this course are based on research projects conducted by AFS and individual companies. It is hoped and expected that after you have completed this course you will have a better understanding of risers and be able to use them to their fullest capabilities.

The course is divided into four sections. The first section presents a brief and basic study of heat transfer and solidification in the casting process. The second section discusses shrinkage, riser types and locations, and ways of keeping the riser liquid. Section Three deals with the shapes and dimensions of risers and riser necks. Section Four briefly covers the effect of atmospheric pressure and how to help the riser feed the maximum distance, and closes with a review of the text.

Generally speaking, much of the material presented in this programmed course can be applied to the many varieties of alloys and casting shapes poured in the cast metals industry. It is recognized that some of the principles discussed will be more generally applicable to some alloys and casting shapes than others. It must be realized further that the course teaches scientific principles which in some isolated cases may not be practical because of other factors involved. In such cases, sound judgment and experience must be applied. However, the broad background of basic risering principles taught by this course should be beneficial to all foundrymen.

The critical review, comments, and helpful suggestions of Messrs. Jack B. Caine, Donald L. LaVelle, and Ronald W. Ruddle aided in the preparation of this course, and are greatly appreciated.

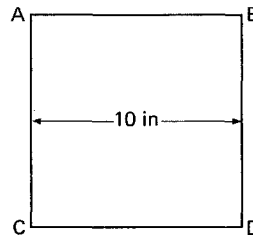
INTRODUCTION

- A. This is a programed text, and you do not study it the same way that you would a regular textbook. To begin, remove the response mask from the rear cover and place it so that it *completely* covers the answer column at the right-hand side of this page.

Each small part of the text (each frame, as they are called) will give you a bit of information and at the same time require that you *supply* a bit of information in a space allowed for it. For example, you are interested in learning about the casting of metals, and the purpose of this course is to teach you something about how metals are _____.

Write the proper word in the blank, then slide your response mask down until it is even with the bottom of this frame, and stop! The correct answer will be shown in the answer column. Do *not* move the mask again until you have read all of the next frame.

- B. Sometimes you may be given a choice of words, as in "This frame is printed in _____ (green/black/red) ink." Did you fill in the answer, as you should? But more often you will be asked to provide one particular _____ for the blank. Now slide your mask down to here.
- C. If you said "answer" for the second part of the frame above, that will do. Most of the time you will provide just the exact word or words, and no others. Sometimes, however, it will be just as correct to use words that mean _____ (the same/a different) thing.
- D. Besides what it said in words, the frame above told you that the number of blanks allowed for one answer _____ (is equal to/does not equal) the number of words in the answer.
- E. Here and there you will find a long blank with a broken line, like this: _____. This means that the answer has *one or more* words; it's up to you to provide it, or them.
- F. Sometimes you may just indicate a part: The top side of this square is indicated by line _____. Or you may work out something: The area of the square is _____.



cast

black
word

the same

is equal to

AB
100 sq. in.

G. A word or two of caution:

(1) If you give a wrong answer, go back and study that frame (and as many others before it as you need to) until you find out what went wrong. It is important that you understand each frame before going on to the next.

(2) Remember, this is a text, not a test. Looking ahead will give you the answers, but it won't teach you how to get them; that comes only from doing the work yourself.

(3) In programmed texts, even if you're studying with a group, the rate of study and how well you learn are both determined by *you*. So you have both the opportunity and the responsibility to study carefully and thoroughly.

I. HEAT TRANSFER AND SOLIDIFICATION

[1]

Before we get into the study of rising, we'll have to briefly discuss several terms that will pop up quite frequently during the course: The first two are *heat* and *temperature*.

[2]

Heat is the energy that makes a material hot, and temperature is the measurement of that energy.

[3]

Remember, heat is _____, and temperature is the _____ of that _____.

energy
measurement
energy

[4]

The degree is the unit of measurement for temperature. We've all heard people say, "What a day! it must be 90 _____ in the shade."

degrees

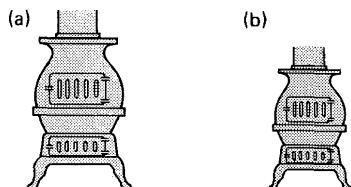
[5]

And we know that when the doctor tells us that we have a fever of 102 degrees, he is talking about our body (heat/temperature) _____.

temperature

[6]

The two old-fashioned stoves shown below are of different sizes, but they both burn with the same efficiency. This means that the metal skin of both stoves will be warmed up to the same _____.



temperature

[7]

Although the skin of both stoves is at the same temperature, stove (a) is bigger and so will produce more _____.

heat

[8]

Keep in mind that _____ is energy, and _____ is the measurement of that energy in degrees.

heat
temperature

[9]

(By the way, although there are several different temperature scales, the only one we will use in this book will be the Fahrenheit scale, the same as that on any thermometers you have around your house.)

[10]

A hot material will transfer its heat to other substances with which it is in contact, but only if they are cooler. Heat, like water, flows "down hill," from a high temperature to a _____ temperature.

lower

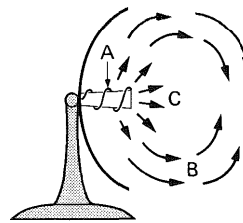
[11]

Heat transfer occurs in three different ways, as shown by this sketch of an electric heater.

A *Conduction* through solids or liquids (in this case the metal coil of the heater) from molecule to molecule.

B *Convection* by currents in gases or liquids.

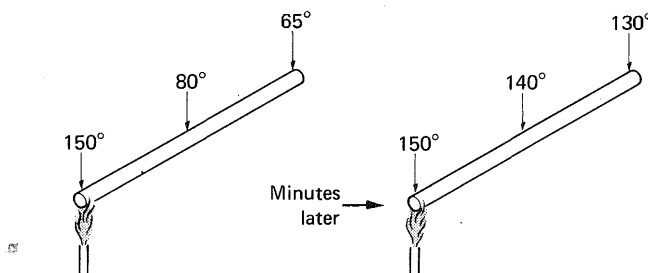
C *Radiation* through space in a straight line.



[12]

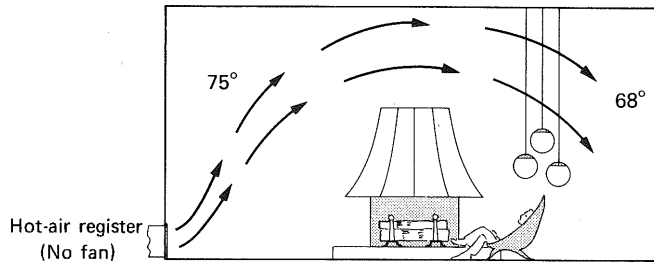
A solid metal rod is heated at one end. After a while, the other end is almost as hot as the end that is heated. Heat transfer has occurred by (conduction/convection/radiation) _____.

conduction



[13]

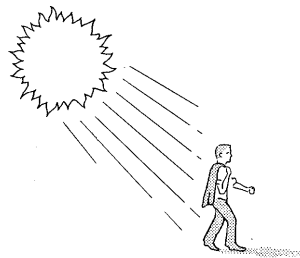
Heat transfer in the room shown here occurs by (conduction/convection/radiation) _____.



convection

[14]

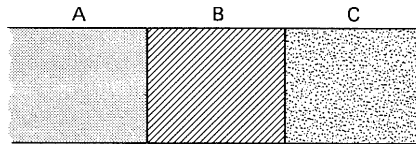
Heat from the sun is being transferred to the man by (conduction/convection/radiation) _____.



radiation

[15]

This figure shows a cross section of a mold and casting after the molten metal has been poured. Part A represents liquid metal; part B represents solid metal (molten metal which has lost enough heat so that it solidifies); and part C represents the sand of the mold.



Note: These materials will be represented this way throughout this book.

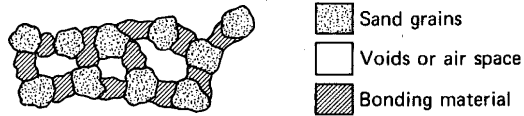
[16]

In the figure in the preceding frame, heat transfer in part A occurs by (conduction/convection/radiation) _____. In part B it occurs by _____.

convection
conduction

[17]

Within the sand mold surrounding the casting, all three methods of heat transfer take place at the same time.



Heat transfer within the sand grains and the bonding material occurs by _____.

Heat is transferred straight across the voids by _____.

Heat absorbed by the mold also is transferred by the movement of gases, that is, by _____.

conduction
radiation
convection

[18]

Awhile ago we said that heat transfer can occur only when there is a temperature difference; that heat will flow only from a material having a (high/low) _____ temperature to a material having a (higher/lower) _____ temperature.

high
lower

[19]

This figure shows a cross-sectional view of molten metal in the mold. The molten metal is shown by A, and B represents the mold. Heat flows in the direction of the (top/bottom) _____ arrow.



top

[20]

In your own words, write down *why* the heat flows in that direction.

Because heat always flows from hot to cold, that is, from a high temperature to a lower temperature. (Any answer that means the same thing is o.k.)

[21]

A temperature difference forms something that is called a *thermal gradient* ("thermal" = heat and "gradient" = grade, or slope). A thermal gradient affects heat the same way a hill affects water; neither heat nor water can flow from a low point on the slope (or gradient) to a high point.

[22]

Now, for our purposes, thermal gradient is determined by how much of a temperature drop there is in a given distance. For example, if we heat one end of a two-foot metal rod at 700° while the other end stays at 100° , the temperature difference between the two ends is _____.

600°

[23]

A difference of 600° in two feet gives us a thermal _____ of 300° per foot.

gradient

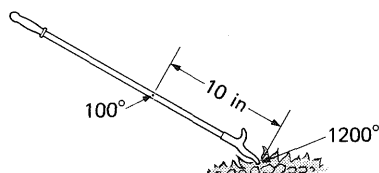
[24]

We would normally write this as $300^{\circ}/\text{ft}$. However, since thermal gradients are usually measured in inches, we divide the 300° by 12, and say that we have a thermal gradient of _____/in.

25°

[25]

Here is a poker with one end in the fire and with a mark on the handle a certain distance from that end. What is the *difference in temperature* between the end in the fire and the mark on the handle? _____
What is the *thermal gradient* between the end in the fire and the mark on the handle? _____.



$$1100^{\circ} \text{ (} 1200^{\circ} - 100^{\circ} \text{)}$$

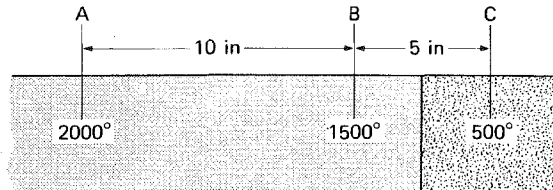
$$110^{\circ}/\text{in. (} \frac{1100^{\circ}}{10''} \text{)}$$

[26]

This figure represents molten metal cooling in the mold. Take your time and look it over carefully.

What is the thermal gradient from:

A to B? _____ B to C? _____ A to C? _____



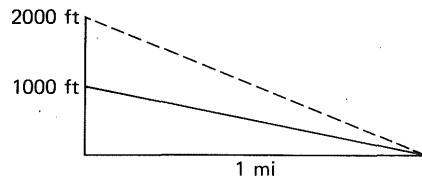
$$50^{\circ}/\text{in.} \quad \frac{500^{\circ}}{10''}$$

$$200^{\circ}/\text{in.} \quad \frac{1000^{\circ}}{5''}$$

$$100^{\circ}/\text{in.} \quad \frac{1500^{\circ}}{15''}$$

[27]

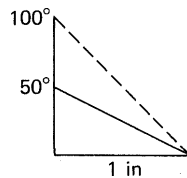
When we speak of thermal gradients in the foundry we usually refer to their steepness. Now, a hill that descends 1000 ft. in one mile is moderately steep, but one that descends 2000 ft. in a mile is, as you can see, much _____.



steeper

[28]

It's the same with a thermal gradient. One that decreases in temperature by $100^{\circ}/\text{in.}$ is _____ than one that decreases by $50^{\circ}/\text{in.}$



steeper

[29]

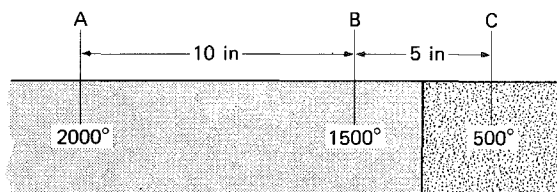
And just as with water flowing down hill, the steeper a thermal gradient, the (faster/slower) _____ heat will flow.

faster

[30]

Here again is that figure on which you found the three thermal gradients. The *slowest* rate of heat transfer will be between what two points?

_____ The *fastest* rate of heat transfer will be between what two points? _____. (These rates are based on thermal gradients only.)



A and B
B and C

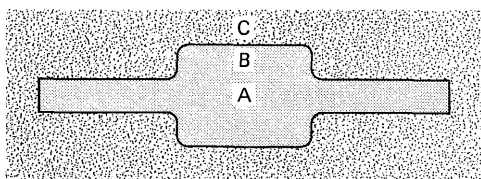
[31]

Note: There are thermal gradients within one type of material. For example; within a single mass of molten metal, the temperature of the part that touches the comparatively cool mold will be much (higher/lower) _____ than that of the molten metal in the center. Of course, immediately after pouring, the mold itself will be much (hotter/colder) _____ than the metal touching it.

lower
colder

[32]

Here is a mold that has just been filled with molten metal. The temperature at A will be (hotter/colder) _____ than that at B. The temperature at B will be (hotter/colder) _____ than that at C. And the rate of heat transfer will be fastest from (A to B/B to C) _____.



hotter
hotter
B to C

[33]

Let's review before continuing. Heat transfer will take place only from a point with a (high/low) _____ temperature to a point with a (higher/lower) _____ temperature, and the difference in temperature *in a given distance* is called the _____.

high
lower
thermal gradient

[34]

The steeper the thermal gradient, the (faster/slower) _____ heat will transfer from a (hot/cold) _____ point to a (hot/cold) _____ point.

faster
hot
cold

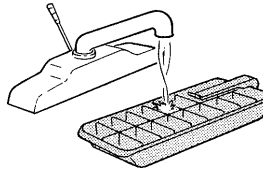
[35]

When molten metal becomes cool enough it goes through the process of solidification. That is, it changes from a liquid to a _____.

solid

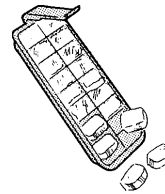
[36]

We see this same process (though not with metal) every day in our own homes. We pour a liquid into a mold, thus:



[37]

And in a little while, what we take out of the mold is no longer liquid, but _____.



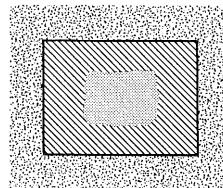
solid (ice, yes, but the point is that it's solid.)

[38]

There are two types of solidification. When solidification begins on the sidewalls of the mold and *progresses* more or less evenly toward the center, we call it *progressive solidification*. When it begins in the sections of the mold furthest from the supply of new molten metal and moves uniformly in the *direction* of that supply, we call it *directional solidification*.

[39]

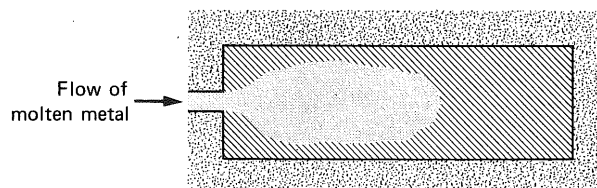
The figure below shows an example of (progressive/directional) _____ solidification, just the same way an ice cube freezes.



progressive

[40]

This figure shows an example of (progressive/directional) _____ solidification.

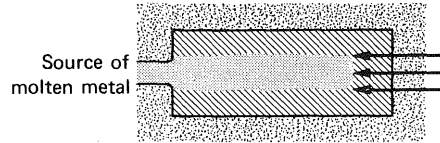


directional

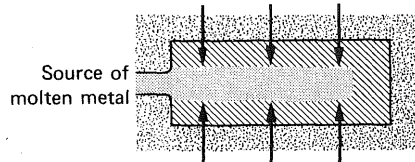
[41]

Both types of solidification occur within a single casting at the same time.

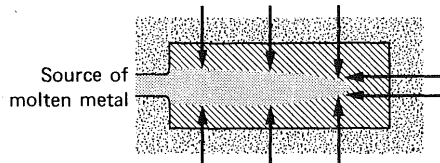
Directional solidification proceeds toward the supply of molten metal.



Progressive solidification proceeds toward the center of the casting.



And together they make a solidification pattern like this.



[42]

Because of shrinkage, which we will soon discuss, we don't want to be left with any isolated areas of molten metal in the casting; we would much prefer to have the metal solidify from the furthest point of the casting toward the supply of molten metal. In other words, we must try to promote _____ solidification and reduce the amount of _____ solidification.

directional
progressive

[43]

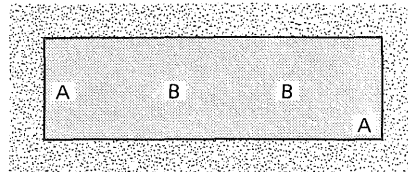
Pure metals and a few alloys solidify over very narrow temperature ranges. Most alloys, however, solidify over wide temperature ranges. Each group has its own distinct solidification characteristics.

[44]

(Alloys, as you probably know, are simply combinations of two or more metals that have been mixed while in the molten state. For example, brass is primarily a mixture of copper and zinc. For your information, a brief list of narrow- and wide-range alloys, by no means complete, is included on the summary card attached to the rear cover of this book.)

[45]

Metals (pure and alloyed) that solidify over narrow temperature ranges have two distinct solidification zones. The first, or *chill zone*, is next to the mold wall, as indicated in the figure by the letter _____.



A

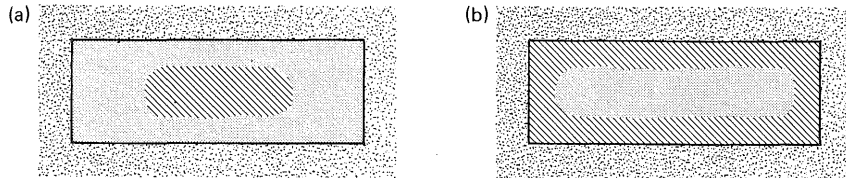
[46]

Heat transfer from the molten metal to the mold walls is very rapid, due to the steep _____ between them.

thermal gradient

[47]

This rapid heat transfer causes the metal at the mold wall to solidify quickly into a fine-grained skin, enclosing the molten metal in the center, as shown in figure _____.



(b)

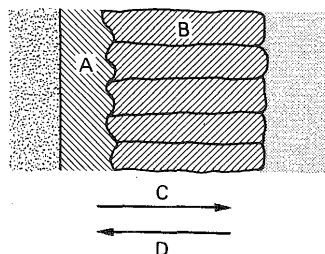
[48]

After the fine-grained skin has formed in the chill zone, the second solidification zone begins to develop. This is the *zone of columnar* (columnar) *growth*, in which those grains that are favorably oriented grow inward from the skin toward the (top/bottom/center) _____ of the casting.

center

[49]

In the figure below, the chill zone is indicated by _____; the zone of columnar growth is indicated by _____, and the direction of columnar growth is indicated by _____.

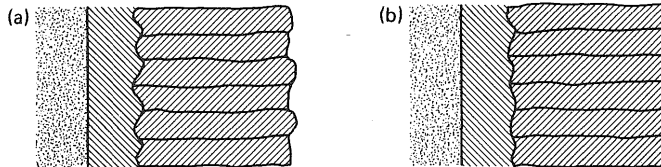
A
B
C

[50]

As the columnar grains grow in pure metal, they link up to form a nearly smooth solidification front. As they grow in an alloy with a narrow solidification range, they form an irregular solidification front.

Columnar growth in a pure metal is shown in _____.

The other figure shows columnar growth in an alloy with a _____ range.



(b)
narrow solidification

[51]

Pure metals and the few alloys with a narrow solidification range go through only *two stages* as they solidify; as they cool they turn directly from liquid to _____.

solid

[52]

Now let's consider the many alloys that have a wide solidification range. When they first enter the mold they behave the same way as pure metals and alloys with a narrow solidification range; that is, they form a skin in the _____ zone.

chill

[53]

Once the skin is formed, those grains that are favorably oriented grow toward the center of the casting in the form of *dendrites*, a treelike pattern of solid metal similar to that shown in figure _____.



(b)

[54]

As the dendrites grow, molten metal is trapped among their branches and remains liquid until it reaches its solidification temperature. In some cases the dendrites may actually be floating in the molten metal. The area in which this mixture of _____ metal and _____ metal occurs is called the *ushy zone*.

liquid
solid (or reverse order)

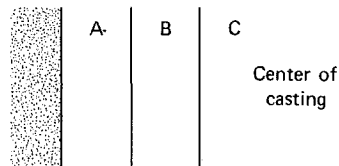
[55]

So, unlike narrow-range alloys, which go directly from a _____ to a _____ when they solidify, the wide-range alloys go through *three* stages. When they are poured, of course, they are _____, then they get _____, and then they become _____.

liquid
solid
liquid
mushy
solid

[56]

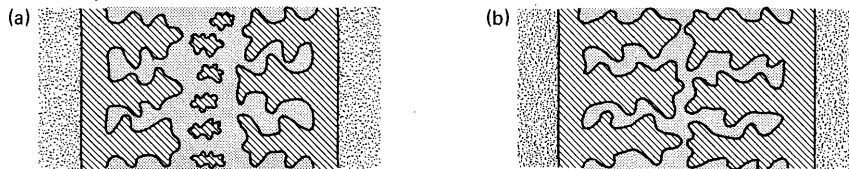
In which area would you expect to find the liquid stage? _____. The mushy stage? _____. The solid stage? _____



C
B
A

[57]

Unless solidification is very fast, the dendrites stop short of the center of the casting, and the process is completed by the random solidification of the dendrites, as shown in figure _____.



(a)

[58]

Now, a narrow-range metal or alloy may be thought of as solidifying at a certain temperature, but a wide-range alloy may be thought of as solidifying at *two* temperatures: the one at which it *begins* to solidify and the one at which solidification is *complete*.

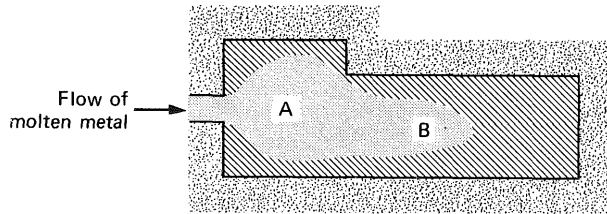
[59]

So when we say that a metal will solidify at 1900° , we are talking about a _____-range metal, and when we say that a metal will solidify at 1900° to 1600° , we are talking about a _____-range alloy.

narrow
wide

[60]

Let's review again. The figure below shows the two types of solidification. The solidification at A is _____, while B is an example of _____ solidification.



progressive
directional

[61]

Metals that solidify over a narrow temperature range have _____ (how many?) solidification zones. The first of these forms next to the mold _____ and is called the _____ zone. The second is called the zone of _____ growth.

two
wall
chill
columnar

[62]

Narrow-range metals have two stages in the mold. They turn right from _____ to _____.

liquid
solid

[63]

Alloys with a wide solidification range go through three stages in the solidification process, from the liquid to the _____ to the _____.

mushy
solid
(and that's enough
review for now)

[64]

No matter whether the solidification pattern is progressive or directional, or whether the metal has a narrow or wide solidification range, the solidification process cannot take place unless there is a transfer of _____ across a _____ gradient, that is, from a high temperature to a _____ temperature.

heat
thermal
lower (or low)

[65]

Now, the quicker the molten metal loses its heat, the (faster/slower) _____ the solidification process.

faster

[66]

So the steeper the thermal gradient, the (faster/slower) _____ the metal will solidify.

faster

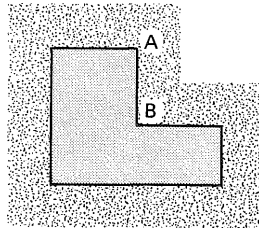
[67]

There are several factors that affect the solidification process, and one of the most important is the shape of the casting.

[68]

The corners of a casting (when there are any) always point either toward some internal part of the casting or some external part of it, and so we refer to them as internal or external corners.

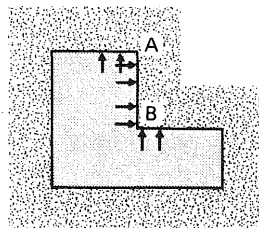
In this figure, A indicates an _____ corner, and B indicates an _____ corner.



external
internal

[69]

As you can see, the molten metal at A, the external corner, can transfer its heat to the cooler mold in two directions. However, at B, the internal corner, the mold receives heat from two sides. At which point, A or B, will the *mold* be hotter? _____



B

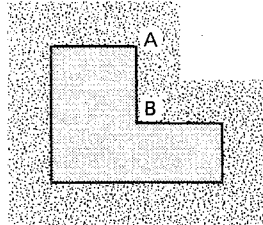
[70]

The molten metal at points A and B is the same temperature, but the mold is cooler at A than at B. Therefore the thermal gradient is steeper at _____.

A

[71]

This being the case, the metal will solidify faster at point _____.



A

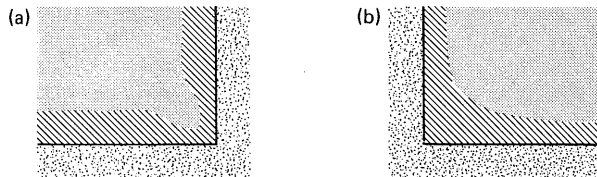
[72]

Therefore we can say that molten metal will solidify faster at an _____ corner than it will at an _____ corner.

external
internal

[73]

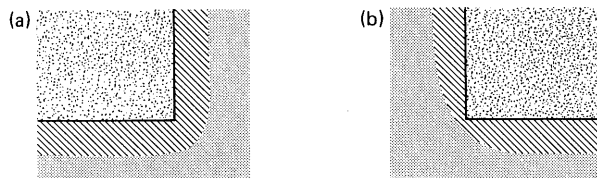
The solidification pattern at an external corner is best shown in figure _____.



(b)

[74]

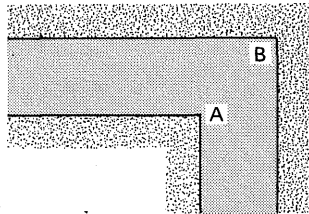
The solidification pattern at an internal corner is best shown in figure _____.



(b)

[75]

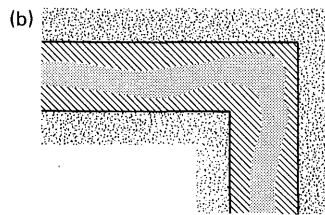
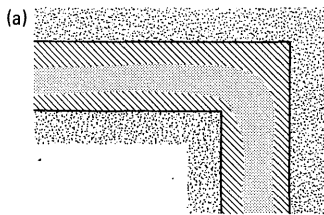
Of course, an L-shaped section has both an internal corner and an external corner. In this figure, the internal corner is at _____ and the external at _____.



A
B

[76]

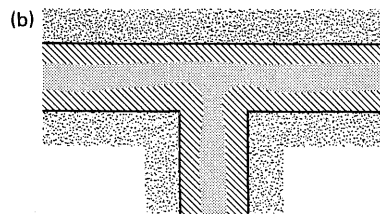
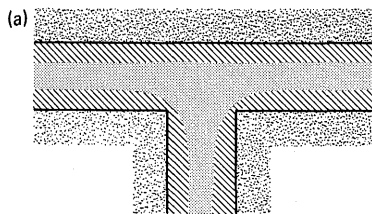
Which figure best represents the solidification pattern in an L-shaped section? _____



(a)

[77]

A T-shaped casting, which has two _____ corners, also has a distinctive solidification pattern, and this is shown in figure _____.



internal
(a)

[78]

To summarize: The mold at an external corner is (hotter/cooler) _____ than the mold at an internal corner. This means that the thermal gradient is steepest at an _____ corner, and also that that is where the solidification process is (fastest/slowest) _____.

cooler
external
fastest

II. SHRINKAGE; RISER TYPES AND LOCATIONS

[79]

We have seen how solidification takes place, and it would be fine if that were all there was to it. Unfortunately, however, when most metals and alloys go through the solidification process, they shrink. That is, their volume (increases/decreases) _____.

decreases

[80]

(The word "contraction" is often used to mean the same thing, but throughout this book we will call it shrinkage.)

[81]

There are three types of shrinkage: liquid, solidification, and solid, and unless allowances are made for them, any one can cause a casting to be scrapped.

[82]

Liquid shrinkage, of course, occurs while the metal is still a liquid. That is, it occurs between the temperature at which the metal is _____ into the mold and the temperature at which it starts to _____.

poured
solidify

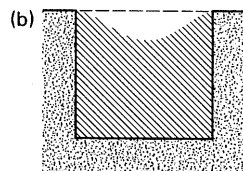
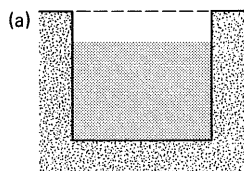
[83]

The second type takes place while the metal is solidifying, and is called _____ shrinkage. It usually causes an indentation to form on the surface of the metal.

solidification

[84]

Both molds shown here were filled with molten metal. Figure (a) is an example of _____ shrinkage, and figure (b) is an example of _____ shrinkage.



liquid
solidification

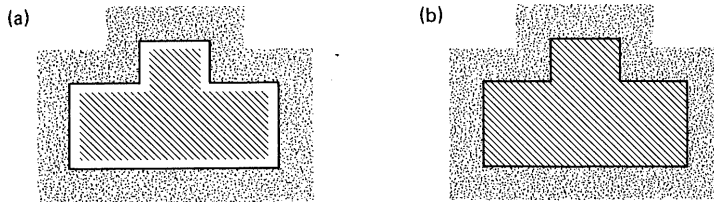
[85]

The third type of shrinkage occurs as the *solid* metal of the casting cools to room temperature, and is called _____ shrinkage.

solid

[86]

Both castings are at room temperature. Which one shows the effects of solid shrinkage? _____



(a)

[87]

Actually, solid shrinkage is more the patternmaker's problem than it is ours, and he uses a shrinkage rule to help him allow for it when he makes the pattern.

[88]

Since we are going to use risers to make sure that the mold is full of molten metal before it solidifies and during solidification, we are mainly interested in what two kinds of shrinkage? _____

Liquid and solidification

[89]

Now list the three types of shrinkage in the order in which they occur after the molten metal has been poured into the mold. _____

Liquid, solidification, solid

[90]

Before we start talking about how to feed shrinkage, we should mention the special case of cast iron. Cast iron is an alloy with a wide solidification range. Like the others, it forms a skin in the _____ zone at the wall of the mold.

chill

[91]

Cast iron also goes through the usual three stages of solidification: _____, _____, and _____.

liquid
mushy
solid

[92]

But instead of shrinking during the solidification process, some cast irons do just the opposite; they _____.

expand (or word meaning the same)

[93]

This expansion occurs because some of the carbon (which is one of the alloying elements) comes out of the cast iron as graphite. And because carbon takes up more volume in the graphitic form, this puts an extra pressure on the walls of the _____.

mold

[94]

This precipitation of graphite, as it's called, can actually put enough pressure on the walls of the mold to make them move outward, leaving us with a mold that is (smaller than/the same size as/larger than) _____ it was when we poured the cast iron into it.

larger than

[95]

So when using some cast irons we make allowances for the extra _____ on the mold walls resulting from the precipitation of _____.

pressure
graphite

[96]

We also have to make the riser larger than we would for other metals, because the expansion of the cast iron can (increase/decrease) _____ the size of the mold cavity.

increase

[97]

So far as cast iron is concerned, it is advisable that each foundry determine experimentally the amount of casting expansion and mold-wall movement and then figure their riser sizes from the data gathered.

[98]

Now, about feeding shrinkage in a mold. Once the pouring operation is completed, the original supply of molten metal is removed. Therefore, some source of molten metal must be provided to feed the _____ that occurs as the metal cools in the mold.

shrinkage

[99]

In some instances, especially with small castings, the gates and sometimes even the runners will be able to _____ the shrinkage.

feed

[100]

Gates also are used to scatter shrinkage, distributing it so that the shrinkage at any one point is slight and the soundness of the casting is not appreciably affected.

[101]

In most cases, however, we must use reservoirs called *risers* to supply _____ to the casting after the pouring operation has been completed.

liquid (or molten)
metal

[102]

The main requirement of a riser is that it stay liquid longer than the section of casting it is to feed. (We customarily speak of the riser or the casting staying liquid even though we are really speaking of the metal in them.)

[103]

Don't look back. Now, in your own words, what is the main requirement of a riser? _____

That it stay liquid
longer than the section
of casting it is to feed
(or words to that
effect).

[104]

Properly used, the riser will feed shrinkage even while solidification is going on. In other words, it will feed both _____ shrinkage and _____ shrinkage.

liquid
solidification
(or the other way
around).

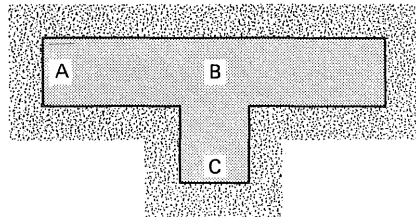
[105]

While it is difficult to make any firm rules for riser placement, it is safe to assume that every *hot spot* should be risered. Hot spots are those sections of a casting that stay hot the longest, or, to say it more accurately, the sections that solidify (first/last) _____.

last

[106]

In most cases you can determine the areas in which a hot spot will exist by studying the casting design and applying the information you gained earlier in this course on heat transfer and solidification. For example, where would the hot spot be in this figure? _____



B

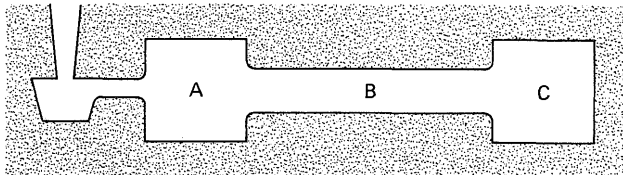
[107]

The hot spot will occur at that point for two reasons: First, there is a (large/small) _____ amount of molten metal in that area. Second, the corners nearest that point are (internal/external) _____ corners, and so will (help/restrict) _____ the flow of heat away from the area.

large
internal
restrict

[108]

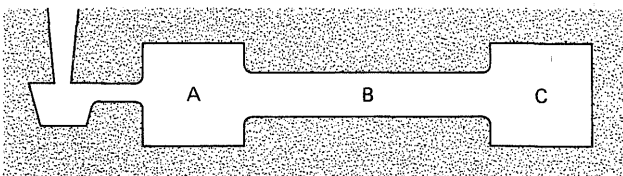
Look at another casting. By the same reasoning, in what two areas would hot spots be most likely to occur? _____



A and C

[109]

Under normal conditions, section _____, which contains the smallest mass of metal, would solidify (first/last) _____. Section _____, which is nearest the source of molten metal, would solidify (first/last) _____.



B
first
A
last

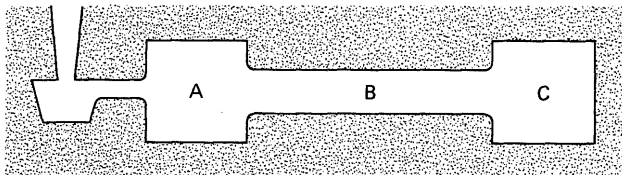
[110]

In the previous figure, sections A and C could actually serve as *risers*, since they would feed _____ as it occurred in section B.

feed shrinkage

[111]

As was mentioned earlier in this course, we should try to get (directional/progressive) _____ solidification wherever possible. In this figure, that would mean that solidification should start in section _____ and move toward section _____.

directional
C
A

[112]

As you can see, the molten metal enters the mold in section A. There is a very good chance that, after pouring has been completed, solidification in section B will work from the walls of the mold inward. In other words, we will probably have _____ in section B.

progressive solidifica-
tion

[113]

That sort of solidification will probably shut off the supply of molten metal to section _____. This means that as that section solidified there would probably be a great deal of _____.

C
shrinkage

[114]

You probably have already noticed that the gate leading into section A could also solidify before that section does, which would, of course, cause _____ in section _____.

shrinkage
A

[115]

The simplest way to combat shrinkage in sections A and C would be to attach reservoirs of molten metal, or _____, to them.

risers

[116]

Note: There are other methods and materials that will help produce proper solidification, and these will be discussed later in the course.

[117]

So far we have mentioned only rather simple castings. On more complex castings it is often a good idea to treat the casting as if it were divided into a number of separate risering systems. Of course, this means that the separate systems would have to be fed by separate

risers

[118]

In some castings, heavy sections feed light, or "thin," sections, and the heavy sections are themselves fed by _____. This gives us the (directional/progressive) _____ solidification we most want.

risers
directional

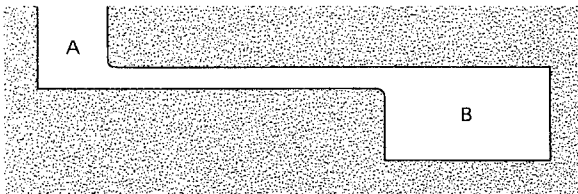
[119]

An important point to remember is that, under normal conditions, a thin section will solidify (before/after) _____ a heavy section. Therefore any risers that are used should be attached to the (thin/heavy) _____ sections.

before
heavy

[120]

Under normal conditions, would riser A feed section B? _____



Note: Risers shown in this book are for illustrative purposes only. They should *not* be taken as the correct size for any particular casting or casting section.

No

[121]

In some cases, the shape of the casting may make it impossible to place a riser where it might be needed. Then the foundryman must decide, on the basis of his own experience, how the risers should be attached to the casting to feed _____.

shrinkage

[122]

The use of risers on a hit-or-miss basis can result in waste, spoilage, and unnecessary expense. Answer the following questions for every job and you will find risering to be both practical and economical.

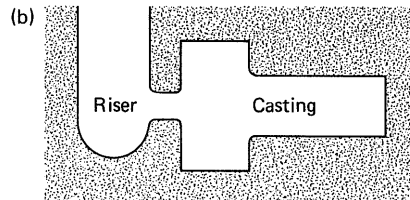
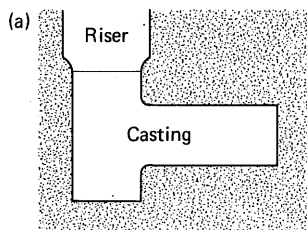
1. Do we need risers? Many castings, having the right metal composition (nonshrinking) and being made in rigid molds, do not require molds.
2. Where should the risers be located so that they may meet their requirements and still be removed as economically as possible?
3. What size and shape should they be?
4. How can they be kept liquid as long as possible?

[123]

Although there are several shapes and sizes of risers, there are normally only two types. These types are named according to their position on the casting.

[124]

In figure (a), the riser is attached to the (top/side) _____ of the casting and is called a _____ riser. In figure (b), the riser is attached to the (top/side) _____ of the casting and is called a _____ riser.



side
side
top
top

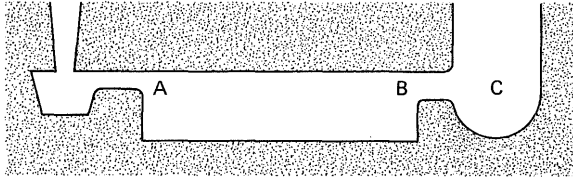
[125]

As far as location is concerned, we can set a riser upstream from the casting, so that the metal must flow through the riser to get to the casting, or we can put it downstream, so that the metal must flow through the _____ to get to the _____.

casting
riser

[126]

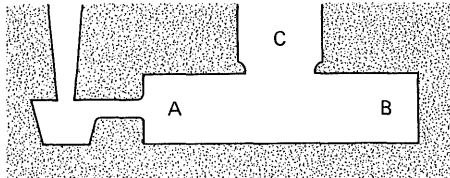
This riser is set downstream from the casting, and is called a *cold* or *dead* riser. As the metal flows through the mold cavity, it gives up some of its _____ to the walls of the mold. Thus, when pouring is completed, you will find the hottest metal at point _____ and the coolest metal at point _____.



heat
A
C

[127]

We can have a cold or _____ top riser, too. Where would the coldest metal in this system be right after pouring? _____



dead
C

[128]

Since a cold or dead riser contains the coolest metal in the system, the riser could very well solidify (before/after) _____ the casting does.

before

[129]

And if it solidifies before the casting does, the riser will not be able to feed the _____ that occurs in the casting as it cools.

shrinkage

[130]

In fact, things might happen just the opposite of the way they are supposed to. That is, the casting might even feed the shrinkage in the _____.

riser

[131]

So, ideally, the riser should be located upstream from the casting. This way the metal will have to flow through the _____ to get to the _____.

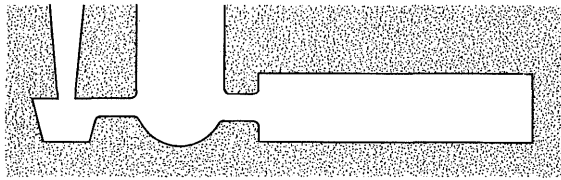
riser
casting

[132]

A riser located upstream from the casting should still be as close to the casting as possible, so the best place for it is right in the gating system itself.

[133]

A riser located in the gating system is called a *hot* or *live* riser. In this case, which is shown below, the metal in the casting will be (hotter/cooler) _____ than the metal in the riser.



cooler

[134]

Also in this case, the _____ will normally remain liquid longer than the _____, which is what it's supposed to do.

riser
casting

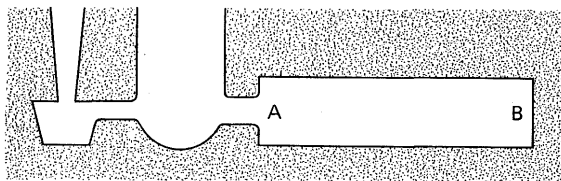
[135]

Setting the riser in the *gating* system will help us get the type of solidification we most want, that is, (directional/progressive) _____ solidification.

directional

[136]

In the system shown here, solidification would start at point _____ and end at point _____, because the metal at the point where solidification starts will be the (hottest/coolest) _____ in the system.

B
A
coolest

[137]

Note: While we have used side risers in our examples, all that has been said applies to top risers as well. However, it is difficult and in most cases not a good idea to gate through a top riser. In such cases we have to use some other means to help keep the riser liquid, and we will study some of these means later in the course.

[138]

To summarize, a hot or live riser (one located in the _____ system) will normally solidify (before/after) _____ the casting, thus helping us to get _____ solidification.

gating
after
directional

[139]

You won't always be able to use a hot riser; sometimes the conditions will require a cold riser. Also, there will be times when even a hot riser won't stay liquid as long as it should. When these problems come up, they are often handled by the use of insulating and/or exothermic materials.

[140]

We use insulating materials in our homes to help keep them warm in the winter and cool in the summer. The principal feature of insulating materials is that they (slow down/speed up) _____ heat transfer.

slow down

[141]

In other words, a good insulating material is a (good/poor) _____ conductor of heat.

poor

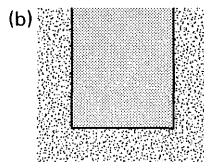
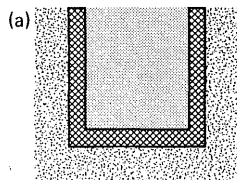
[142]

So the metal in a riser which has been surrounded by an insulating material will (stay hot longer/cool off faster) _____ than it would otherwise do.

stay hot longer

[143]

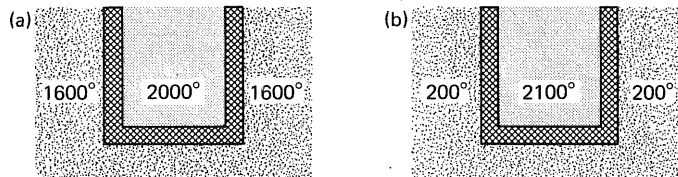
Riser (a) is insulated; riser (b) is not. They are the same size and they have both just been filled with molten metal at 2000°. Which one will stay liquid longer? _____



(a)

[144]

Both risers are insulated, and they were filled two minutes ago with molten metal at 2100° . Which riser has the better insulation? _____



(b)

[145]

An insulating material slows down the transfer of heat, but *exothermic* materials actually produce heat.

[146]

When the molten metal comes in contact with an exothermic material there is a chemical reaction which causes the exothermic material to (absorb/generate) _____ heat.

generate

[147]

There have been instances in which an exothermic material has actually raised the temperature of the metal in a riser. However, the main reason we use an exothermic material is to (slow down/speed up) _____ heat transfer from the riser.

slow down

[148]

It should be noted that an exothermic material will produce _____ only for a short time after the metal has been poured. After that time it serves as an insulator, (reducing/increasing) _____ the rate of _____.

heat
reducing
heat transfer

[149]

Note: An exothermic reaction is a chemical reaction. Before you use any exothermic material, you should make certain that it will not have any undesirable effect on the metal with which it will come in contact.

[150]

One more thing. There are size limitations on exothermics; you should not expect satisfactory results from _____ materials in risers that are 20 in. or more in diameter.

exothermic

[151]

From the economic standpoint it is interesting to note that when insulation and/or exothermic materials are used, the riser need not be as large as it would otherwise have to be.

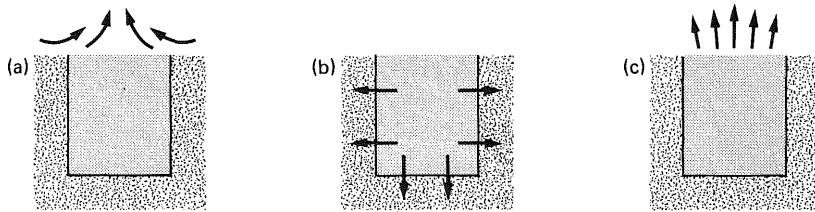
[152]

We have been talking about *open* risers, those with their tops open to the air. But we have not mentioned the loss of _____ from those top surfaces.

heat

[153]

You remember that some time ago we talked about the three methods of heat transfer: conduction, shown in figure _____; convection, shown in figure _____; and radiation, shown in figure _____.



(b)
(a)
(c)

[154]

Heat loss from a riser by conduction has already been discussed, and we have seen how it can be reduced by the use of _____ and _____ materials.

insulation
exothermic

[155]

But we can see that an open riser permits the two other types of heat loss, by _____ and _____, from its top surface.

convection
radiation
(or reverse order)

[156]

Well, the answer to that problem is pretty obvious; we use some insulation or some exothermic material to _____ the top of the riser.

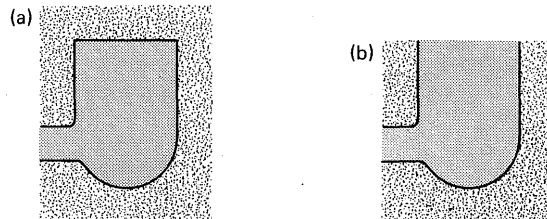
cover

[157]

In your foundry you may have seen someone throw dry sand on the top surface of an open riser to serve as an insulator. To some extent this will reduce heat loss. But we can go a step further and improve on this practice.

[158]

To cut heat transfer from a riser we can design it so that it is not exposed to the air at all. This type is called a *blind riser*, and it is shown in figure _____.



(a)

[159]

The sand covering the top of a blind riser is not an exothermic material, of course, and since it allows some heat to escape from the riser to the air, it is not a perfect _____, either, but it definitely does help keep the riser _____ for an extended period of time.

insulator
liquid

[160]

So far we have discussed riser location and ways of helping the riser retain its heat. We have also talked about metals that solidify over _____ temperature ranges and those that solidify over _____ temperature ranges. But no matter how those conditions may change, our problem is still to help the riser stay _____ for a (longer/shorter) _____ time than the casting it feeds.

narrow
wide (or reverse order)
liquid
longer

III. RISER SHAPES, DIMENSIONS, AND NECKS

[161]

One thing that can complicate our job somewhat is the necessity of sometimes using a core in a casting.

[162]

Suppose we heat an empty oven to, say, 1800° and then turn it off. *In a certain amount of time* it will cool down to its original temperature, right?

[163]

Now we put a chunk of metal into the oven and heat the oven up to 1800° and hold this temperature for a sufficient time. If we test the metal we will find that it, too, registers _____ (how hot?).

1800°

[164]

Now we turn off the oven and let it *and* the metal cool off together. Compared to the empty oven, the oven and the metal together will take (less/more/the same) _____ time to cool down to the original temperature.

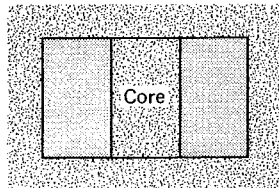
more

[165]

Right; they'd take longer. And that is because the chunk of metal would act as a heat source; as the oven cooled, so would the metal – by radiating its heat to the oven.

[166]

It's the same with a casting, as we can show by means of this bushing. As you can see, the core is inside the casting, and it will heat up and cool off with the casting.



[167]

Now, let's say that the volume of the casting alone is 4 cu in. and the volume of the core is 2 cu in. Since the core is going to be just about as hot as the metal in the mold, the total volume of material (core and casting together) that will have to cool down to solidifying temperature comes to _____ (how much?).

6 cu in.

[168]

So in planning our riser for this casting, we should proceed *almost* as though the capacity of the mold was _____ cu in.

6

[169]

Of course the core is not molten metal, and we can not go ahead exactly as though we had a 6 cu in. mold. The point is that the core must be taken into consideration for proper risering. Foundry technical literature will provide more detailed information on the effect of cores.

[170]

We said before that the basic requirement of a riser is to stay liquid until after the section it feeds has become solid. The size, shape, and location of the riser all have an effect on how the riser meets this requirement as well as on the quality and cost of the casting itself.

[171]

The shape of the riser plays an important part in keeping the metal it contains in liquid form. Therefore, the riser should be shaped so that it promotes a (fast/slow) _____ cooling rate.

slow

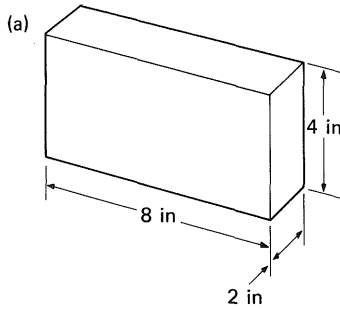
[172]

You recall that we found that the flow of heat is down the thermal gradient, that is, from a high temperature to a lower one. And, of course, the greater the area of contact between the liquid metal and the cooler mold, the (more/less) _____ heat can be transferred in a given time.

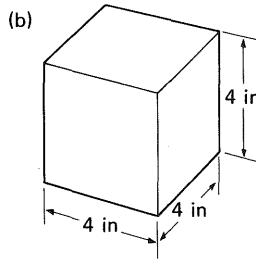
more

[173]

Each of the risers shown here contains 64 cu in. of molten metal. However, riser (a) has a greater surface area than riser (b). The riser that will cool faster, then, will be riser _____.



Surface Area = 112 sq in
Volume = 64 cu in



Surface Area = 96 sq in
Volume = 64 cu in

(a)

[174]

So, when we have two risers with the same volume, the one with the larger surface area will cool (faster/slower) _____ than the other.

faster

[175]

In other words, the greater surface area a riser has *in relation to its volume*, the (faster/slower) _____ it will solidify.

faster

[176]

This relationship is what we call the ratio of surface area to volume, or the *sa/v ratio*, and to keep a riser liquid *as long as possible*, we should have as (large/small) _____ an area as we can get for that particular volume.

small

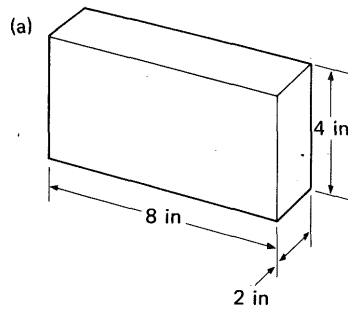
[177]

We can think of the sa/v ratio as just a fraction, $\frac{\text{surface area}}{\text{volume}}$, and remember that the smaller the fraction, the longer the metal in the riser will stay _____.

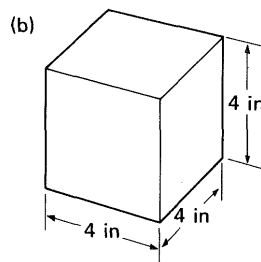
liquid
(or molten)

[178]

Let's take for an example the two riser shapes we saw a moment ago. Each has a volume of 64 cu in. Riser (a) has a surface area of 112 sq in., so we can write our fraction this way: $\frac{\text{surface area}}{\text{volume}} = \frac{112 \text{ sq in.}}{64 \text{ cu in.}}$. Dividing through by 64 we get $\frac{1.75 \text{ sq in.}}{1 \text{ cu in.}}$, or 1.75/1. So riser (a) has an sa/v ratio of 1.75 square inches of area to every cubic inch of volume.



Surface Area = 112 sq in
Volume = 64 cu in



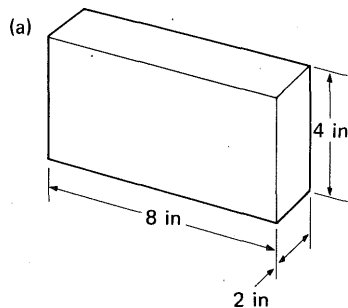
Surface Area = 96 sq in
Volume = 64 cu in

[179]

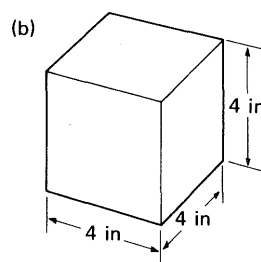
Note: Throughout this book, when we compare two or more risers or castings with one another, we assume that the metal in each of them was the same temperature when poured.

[180]

Riser (b) has an area of 96 sq in., so our fraction looks like this: $\frac{96 \text{ sq in.}}{64 \text{ cu in.}}$. Dividing through by 64 we get $\frac{1.5 \text{ sq in.}}{1 \text{ cu in.}}$, or 1.5/1. So riser (b) has an sa/v ratio of 1.5 square inches of area to every cubic inch of volume.



Surface Area = 112 sq in
Volume = 64 cu in



Surface Area = 96 sq in
Volume = 64 cu in

[181]

Just a couple of frames ago we said that the smaller our fraction (that is, the smaller the sa/v ratio), the longer the riser will stay liquid.

Riser (a) has an sa/v ratio of _____.

Riser (b) has an sa/v ratio of _____.

Metal will stay molten longer in riser _____.

1.75/1

1.5/1

(b)

[182]

The same principle holds true for risers of all sizes and shapes: The riser with the _____ sa/v ratio will stay liquid the longest.

smallest

[183]

What we've just said about risers goes for castings, too. The casting that will stay liquid longest is the casting with the (highest/lowest) _____ sa/v ratio.

lowest

[184]

But we *don't want* the casting to stay liquid a long time; we want it to solidify fairly quickly, and always (before/after) _____ the riser does.

before

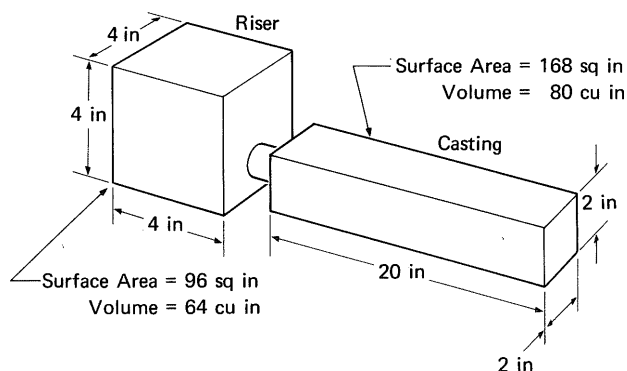
[185]

So that we will get the results we want, which should have the lower sa/v ratio, the casting or the riser? _____

riser

[186]

In the figure shown here, what is the sa/v ratio of the riser? _____
What is the sa/v ratio of the casting? _____ Which will stay liquid longer? _____



$$1.5/1 \left(\frac{96}{64} = 1.5 \right)$$

$$2.1/1 \left(\frac{168}{80} = 2.1 \right)$$

riser

[187]

Of course, you might think that if we make the riser bigger than the casting, we wouldn't have to think about sa/v ratios. After all, it seems reasonable that the more molten metal there is, the (more/less) _____ time it will take to cool.

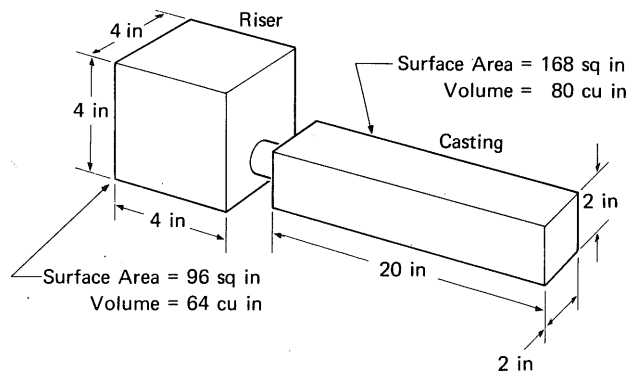
more

[188]

But except for very rare cases, economic and physical limitations would not allow us to make risers with more volume than the casting sections they feed.

[189]

Besides, look at that figure again. The _____ has the larger volume, yet it solidifies first. Why? Because the riser has the smaller _____.



casting
sa/v ratio

[190]

Now then, the shape with the smallest possible ratio of area to volume is the sphere, or ball. The ball-shaped riser is being used more often now than ever before, but production molding considerations still restrict its use in many instances.

[191]

The next best shape for a riser is the cylinder, because, except for the sphere, the cylinder has the (largest/smallest) _____ sa/v ratio of any shape. So from here on we will consider that all risers are shaped as _____.

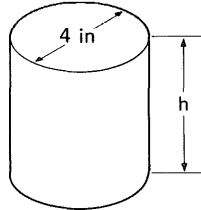
smallest
cylinders

[192]

We're not going to talk about what diameter our cylindrical riser should have because that depends on too many factors. But we can determine how high it should be.

[193]

Most authorities and researchers in risering agree that the minimum height of a riser should be *no less than one-half* its diameter and the maximum height should be *no more than one and a half times its diameter*. Fill in the minimum and maximum heights of the riser shown here.



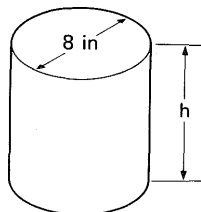
[194]

This is because of the sa/v ratio. Dimensions outside those limits would make the sa/v ratio (higher/lower) _____ than it is within them.

higher

[195]

Try another. What are the maximum and minimum heights of this riser?



12 in.
4 in.

[196]

These limitations apply to both top and side risers. The height of a riser should be not less than _____ its diameter and not more than _____ times its diameter.

one-half
one and a half

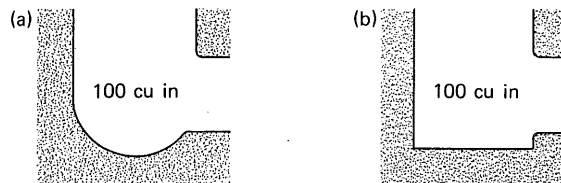
[197]

Now we have a cylindrical riser of the proper dimensions. Let's see if there is anything we can do to help keep it liquid aside from using i _____ or e _____ m _____.

insulation
exothermic materials

[198]

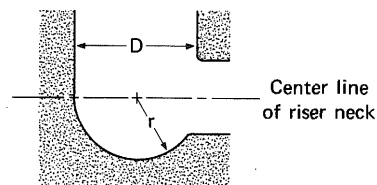
Well, we know that a rounded shape has a (higher/lower) _____ sa/v ratio than a flat-sided shape, so which riser shown here would you expect to stay liquid longer? _____.



lower
(a)

[199]

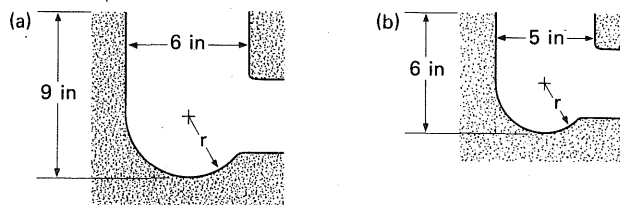
That *bulb*, as it's called, on the bottom of the riser will help keep the riser liquid. Of course, it has the same diameter as the riser, so the radius will be (the same as/one-half/twice) _____ the diameter.



one-half

[200]

What is the radius of the bulb on riser (a)? _____ On riser (b)? _____



3 in
2.5 in

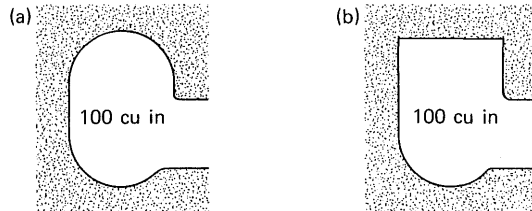
[201]

That's right, the height has absolutely nothing to do with the dimensions of the bulb. The bulb radius is always _____ of the riser.

one-half the
diameter

[202]

When we have a blind riser we can use this same technique on the top of it — and for the same purpose. Which of these two risers should stay liquid longer? _____.



(a)

[203]

The *dome*, as we call it, of a blind riser has the same dimensions as the bulb. That is, the radius of the dome is one-half the _____ of the _____.

diameter
riser

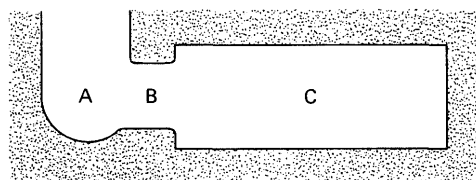
[204]

It's not enough to make a riser the right size, or to put a bulb on the bottom of it, or to put a dome on the top of a blind riser. It does no good if the metal can't get from the riser to the _____.

casting

[205]

To get from the riser to the casting, the metal must go through the neck, indicated here by _____.



B

[206]

If we make the neck too big, we may run into problems when we try to remove the riser from the casting. If we make the neck too small — or too long — it may solidify too soon and shut off the flow of metal from the _____.

riser

[207]

Like the riser, the neck should stay liquid as long as possible. That means that we want the (highest/lowest) _____ sa/v ratio we can get. And that means that the cross-sectional shape of the neck should be (square/circular/rectangular) _____.

lowest
circular

[208]

Note: With thin plate castings a round neck may be impossible, but that's a special case, and we'll get to it in a little while.

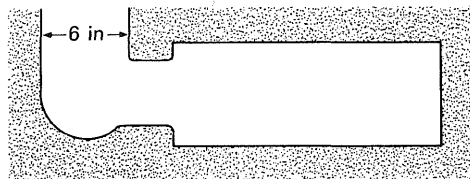
[209]

Even though the neck has a circular cross section, the longer it is for a given diameter, the more area it will have and the more (rapidly/slowly) _____ it will solidify.

rapidly

[210]

While some people have reported success with riser necks no longer than an inch, the length is usually determined by the size of the riser, thus: *The length of the riser neck should never exceed one-half the diameter of the riser.* In the case shown here, the neck should be no more than _____ long.



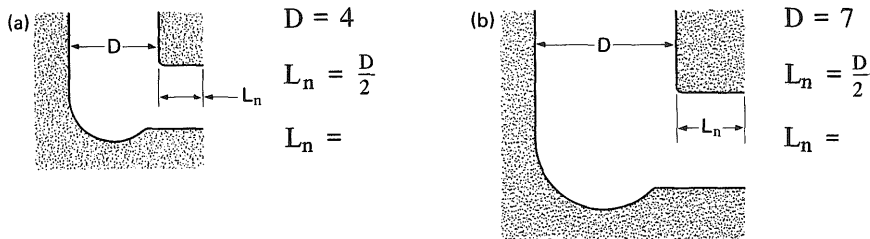
3 in.

[211]

Note: The calculations given here are for use with the most common types of iron castings, on which some experimental work has already been done. The same data may also be applicable to nonferrous metals. Steel, however, is not covered in this course, since the casting of steel requires its own special methods and formulas. Selected neck dimensions for steel castings are given in the summary card attached to the rear cover of this book.

[212]

Now let's figure the dimensions of some riser necks. Lengths first.
 D = diameter of the riser and L_n = length of the neck.



2 in.
 3.5 in.

[213]

Figuring the diameter is a little more complicated, but not much. The diameter of the neck, D_n , is equal to 1.2 times the length, L_n , plus 0.1 times the diameter of the riser, D . Of course we can put in a simpler form:
 $D_n = (1.2 \times L_n) + (0.1 \times D)$

[214]

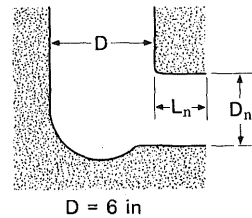
Now we just plug in our figures and perform the operations. All we need to start with is D , and to remember that, at maximum, L_n equals one-half of D . Fill in the spaces as you go along.

$$D_n = (1.2 \times L_n) + (0.1 \times D)$$

$$D_n = (1.2 \times \quad) + (0.1 \times \quad)$$

$$D_n =$$

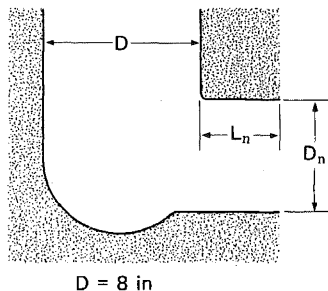
$$D_n =$$



3 in 6 in
 3.6 in + 0.6 in
 4.2 in

[215]

Same problem with different dimensions. Remember that the formula is $D_n = (1.2 \times L_n) + (0.1 \times D)$ and take it from there.



5.6 in.
 $[(1.2 \times 4) + (0.1 \times 8)]$

[216]

Of course, L_n doesn't *have* to be one-half of D . That's the maximum allowed, but it could be less. If that were so, you'd have to have two dimensions available before you could start, D and L_n . Let's say that D is 7 in. Now, L_n could be as much as 3.5 in., but we'll say it's only 2 in. Then: $D_n = (1.2 \times 2) + (0.1 \times 7)$

$$D_n =$$

3.1 in.

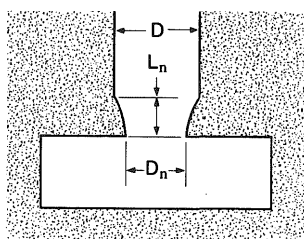
[217]

The neck dimensions for top risers are even simpler to figure. In the first place, the *length* of the neck, L_n , is figured the same way for a top riser as for a side riser. That is, it can be as much as _____ of the riser.

one-half the diameter

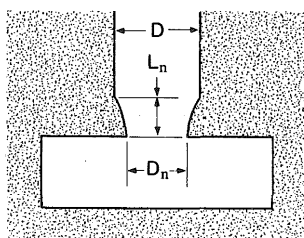
[218]

For a top riser the *diameter* of the neck is simply the length of the neck plus 0.2 times the riser diameter. In other words, $D_n = L_n + (0.2 \times D)$. What is D_n in the case shown here?

 $D = 8$ in5.6 in.
(4 + 1.6)

[219]

Try one more. $D_n = L_n + (0.2 \times D)$

 $D = 5$ in3.5 in.
(2.5 + 1)

[220]

You remember that we said just a little while ago that a round neck is often impossible with a thin plate casting. This means that we will have to use a neck with a square, or perhaps rectangular, cross section.

[221]

With a round riser neck we had to find the length and diameter. With a square or rectangular neck we will have to find the length, width, and thickness.

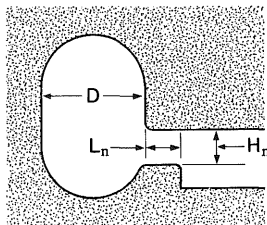
[222]

That makes three formulas we have to use, but they are all very simple. What we need to know first is the thickness of the plate and, of course, the _____ of the riser.

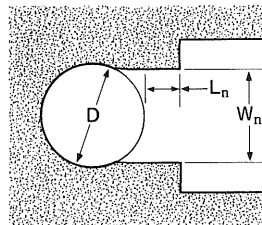
diameter

[223]

For a round neck, the maximum length is one-half the diameter of the riser, or $\frac{D}{2}$. For a square or rectangular neck the maximum length is *one-third* the diameter of the riser, or $\frac{D}{3}$. So for the neck shown here, $L_n = \underline{\hspace{2cm}}$.



$D = 6 \text{ in}$



2 in.

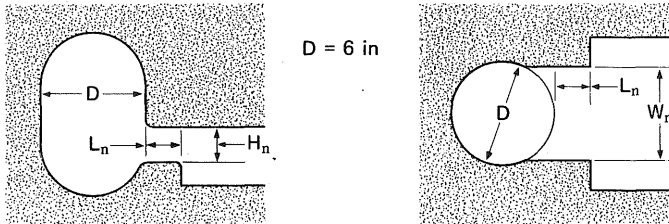
[224]

Suppose the diameter of the riser was 7.5 in. What would be the length of the neck? _____

2.5 in.

[225]

To get the width of a square or rectangular neck, W_n , we use the same type of formula as we did for the round neck. The only difference is in the numbers we plug into it: $W_n = (2.5 \times L_n) + (0.18 \times D)$. Since you have already worked this type of formula, go ahead and find the width of the neck shown here. _____



$$\begin{aligned}
 W_n &= 6 \text{ in.} \\
 [(2.5 \times 2) + (0.18 \times 6)] \\
 5 &+ 1.08 \\
 6.08 \\
 \text{Drop the .08}
 \end{aligned}$$

[226]

Suppose that the diameter of the riser is 4 in. Find W_n . _____

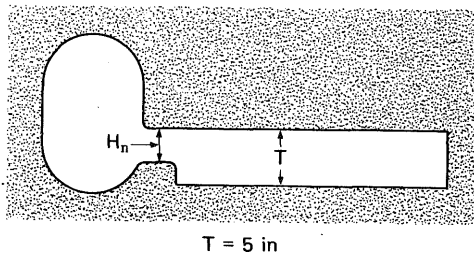
$$\begin{aligned}
 W_n &= 3.9 \text{ in.} \\
 [(2.5 \times 1.3) + (0.18 \times 4)] \\
 3.25 &+ 0.72 \\
 3.97 \\
 \text{Drop the 0.07}
 \end{aligned}$$

[227]

All the dimensions we've figured so far in this book have been based on the diameter of the riser. But when we're after the thickness (or height) of a square or rectangular neck, we couldn't care less about the riser.

[228]

You see, H_n , the thickness or height of the neck, is simply from 0.6 to 0.8 of the thickness, T , of the plate itself. In other words, $H_n = 0.6$ to $0.8 T$. In the case shown here, H_n would be not less than _____ and not more than _____.



3 in.
4 in.

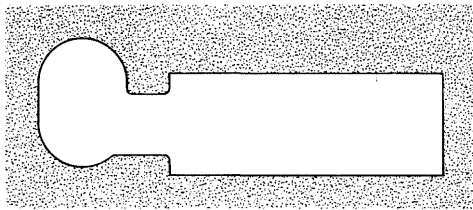
[229]

It's easier, and o.k. for our purposes, to use the average of these two limits, and say that $H_n = 0.7 T$. So if the plate were 4 in. thick, H_n would be _____ . And if $T = 3$ in., $H_n =$ _____ .

2.8 in.
2.1 in.

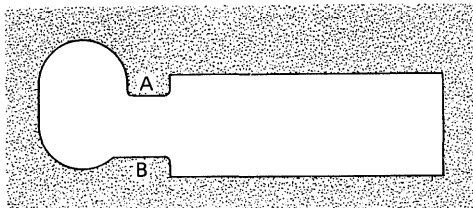
[230]

You may find in some cases that the neck dimensions calculated by these formulas may be reduced *without* causing the neck to solidify before the casting. Look at the location of the neck, and its relationship to the molten metal in and around it. Notice anything special about it?



[231]

It's the corners. All the corners of the neck are internal corners. This means that the sides of the neck, indicated by A and B, are partly surrounded by molten metal. And this means that the mold at points A and B will be (hotter/cooler/the same temperature as) _____ the other parts of the mold.



hotter

[232]

This being true, the thermal gradient at those points will be (steeper/flatter) _____ than at other points.

flatter

[233]

And the flatter the thermal gradient, the (faster/slower) _____ the rate of heat transfer.

slower

[234]

The slower the rate of heat transfer, the (faster/slower) _____ the rate of solidification.

slower

[235]

Therefore the very location of the neck, which causes it to have only internal corners, helps make it possible for the neck to solidify (faster/more slowly) _____ than the casting.

more slowly

[236]

As we have already said, the formulas given here are for the most common types of iron castings. Foundry technical literature contains many others for use with various alloys.

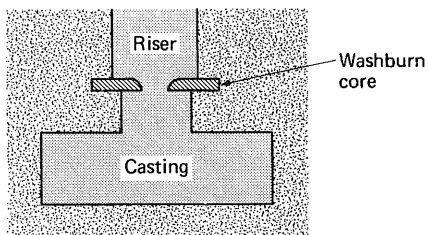
IV. ATMOSPHERIC PRESSURE, FEEDING DISTANCE, AND REVIEW

[237]

When the casting has cooled to well below the solidification temperature, the riser necks are broken or cut and the risers are removed.

[238]

Sometimes *Washburn*, or “knock-off,” cores are used with ferrous alloys to make the removal of risers more economical. As you can see below, the Washburn core is set into the mold between the _____ and the _____.



riser
casting (or
reverse order)

[239]

The Washburn core is relatively thin, and very little heat is conducted through it to the mold. Thus it helps keep the neck liquid longer, which allows us to make the neck (smaller/larger) _____ than we otherwise could.

smaller

[240]

The thinner the neck, the less metal we have to break to remove the riser. This is more economical than a thick neck would be and also makes the removal (easier/harder) _____.

easier

[241]

Note: The neck of a riser used with nonferrous metals and alloys has to have a larger cross-sectional area than the neck of a riser used with ferrous alloys.

[242]

We've discussed at length how to make the riser stay liquid longer than the casting, but we have not yet said much about the riser's other basic requirement: how to feed the _____ that occurs in the casting.

shrinkage

[243]

What causes a riser to feed shrinkage? Well, to put it as simply as possible: *Atmospheric pressure*, aided by the weight of the molten metal in the riser, pushes the metal into the casting.

[244]

At sea level, the atmosphere (air) about us exerts a constant pressure of 14.7 pounds per sq in. (14.7 psi) on everything—our bodies, the chair you're sitting in, and castings and risers.

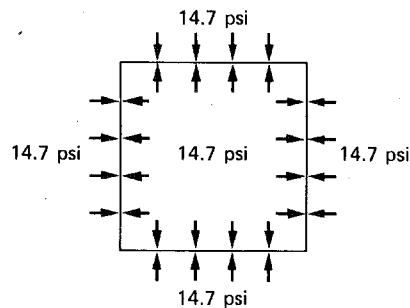
[245]

The only reason that a hollow container doesn't collapse under this pressure is that the *atmospheric pressure* on the inside of the container is (about the same as/greatly different from) _____ that on the outside.

about the same as

[246]

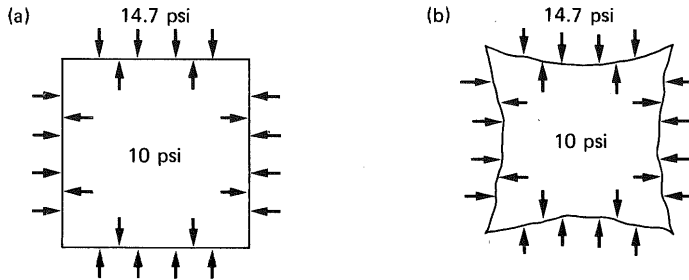
But what happens when we reduce the pressure inside the container? Let's see. Here is a sealed tin container which is 12 in. on a side and which is filled with air at _____ pressure.



atmospheric

[247]

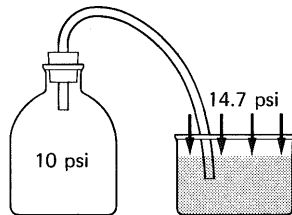
Now we hook up the sealed container to a vacuum pump and reduce its internal pressure to 10 psi. A little arithmetic will show that the pressure on the whole outside of the container is now almost 4061 pounds greater than that on the inside. So the sealed tin container will most likely look like the one in figure _____.



(b)

[248]

Of course; the sealed container would collapse. But here's another case: The container is open and is partly filled with liquid. It is also connected by a tube to a jug in which the pressure is only 10 psi. The atmosphere is exerting on the liquid a force of 14.7 psi. Will the liquid flow up the tube and into the jug? _____



Yes

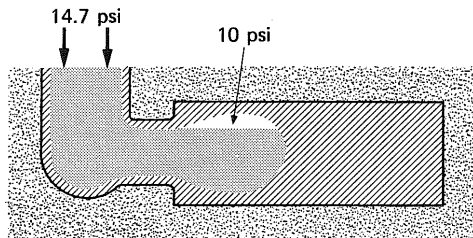
[249]

Right. The liquid is actually pushed up the tube by the force of the _____ on the liquid's surface.

atmospheric pressure

[250]

Will the riser feed the shrinkage cavity in the casting shown here? _____



Yes

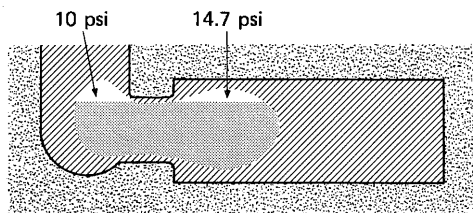
[251]

You remember that the riser is going to solidify the same as the casting, only a little slower. So what will happen if the skin on top of the riser gets too thick to let the air through it? The pressure on the molten metal in the riser will become (greater/less) _____ than normal.

less

[252]

In fact, if air happens to get into the casting and not into the riser, we could have real difficulty. In the case shown here, you would even expect that the _____ would feed the _____.



casting
riser

[253]

So we have got to see to it that the top surface of the riser is exposed to normal _____ pressure until the casting has solidified.

atmospheric

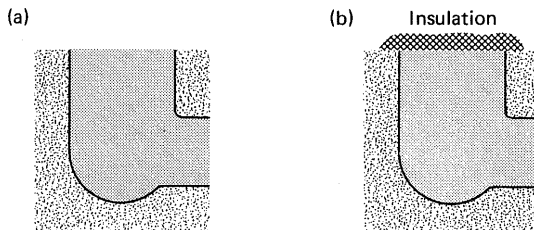
[254]

You remember that one way to help do this is to cover the top surface of the riser with i _____ or with e _____ m _____.

insulation
exothermic materials

[255]

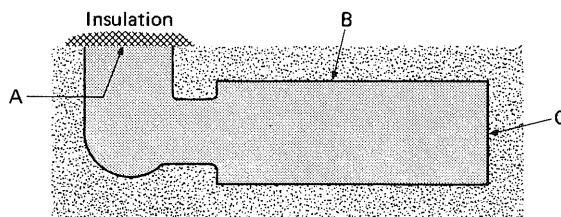
The riser most likely to keep its top surface liquid longest is the one in figure _____.



(b)

[256]

And even if a skin should form on all metal surfaces in the figure shown here, the skin will be thinnest (and atmospheric pressure will be most likely to break through it) at point _____.



A

[257]

And this means that atmospheric pressure could indeed push molten metal from the riser into the casting; is that correct? _____

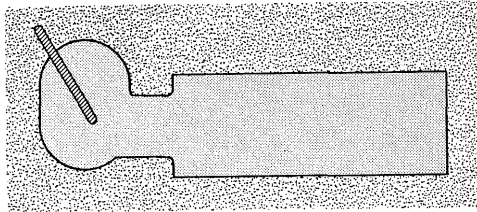
Yes

[258]

Even with a blind riser, air will filter in through the sand of the mold. But we want air to filter into the riser faster than it does to the casting. This is made possible by means of an *atmospheric pressure core*, sometimes called a *pencil core*.

[259]

The pencil, or _____ core, is made of dry sand and is positioned so that it extends from a point out in the mold sand well inward to the heart of the riser, as shown here.



Note: This type of core is not commonly used in nonferrous foundries.

atmospheric pressure

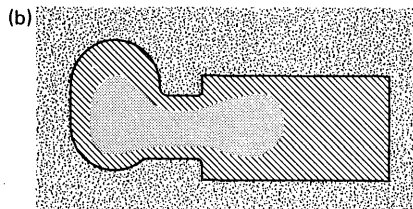
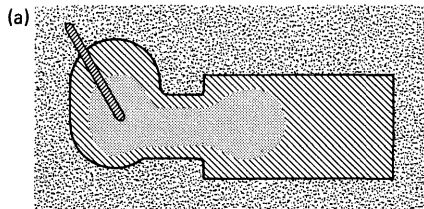
[260]

When the skin forms in the chill zone on the walls of the riser it seals the molten metal off from the outside air. But air can still get into the riser through the _____.

pencil core
(or atmospheric
pressure core)

[261]

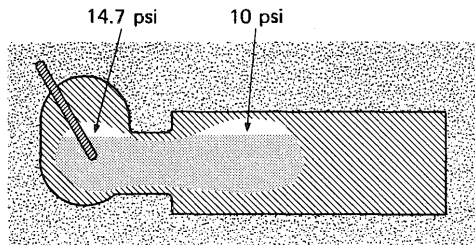
Which riser would most likely be able to feed the shrinkage in the casting?



(a)

[262]

You remember that a while ago we used the example of an open container filled with liquid, connected by a tube to a sealed jug which contained only air at a lower-than-normal psi. Now here we have a casting with a shrinkage cavity which is located higher than the liquid metal in the riser. The question is; Will the riser feed the shrinkage in the casting? _____



Yes

[263]

In your own words, why will the riser feed the shrinkage in the casting?

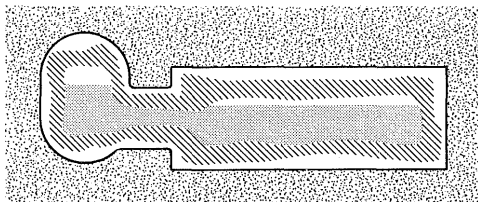
Because atmospheric pressure, filtering through the pencil core, will push the molten metal into the casting (or words to that effect).

[264]

Before we leave this subject we must mention that some nonferrous castings do not readily form a strong skin around the walls of the riser and the casting.

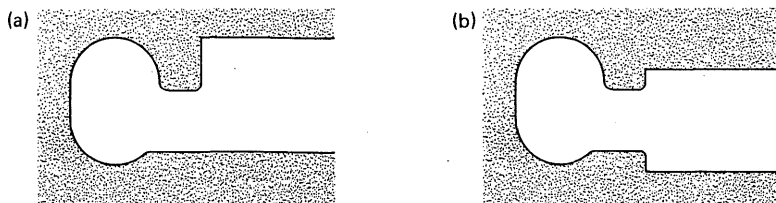
[265]

In such instances, when a partial vacuum forms inside, it is possible for the whole casting and riser to be collapsed by the atmospheric pressure filtering through the sand of the mold.



[266]

A very good way to help avoid this is to position the riser so the top of it is higher than the highest part of the casting, as shown in figure _____.



[267]

In this way, the sheer weight of the molten metal helps it to flow down and feed the _____ in the casting.

(b)

shrinkage

[268]

Let's review for a moment. The force that gets the molten metal into the shrinkage cavities in the casting is partly the _____ of the metal but more importantly, _____.

weight
atmospheric pressure

[269]

Atmospheric pressure will even cause the molten metal to flow upward, feeding shrinkage at a point (higher/lower) _____ than the metal supply.

higher

[270]

A blind riser can be helped to operate properly by means of an _____ core, or *pencil core*.

atmospheric pressure

[271]

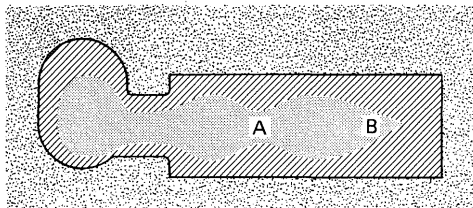
Well, we've got risers of the right size and shape located in the right places; they're staying liquid the right length of time and feeding shrinkage in the right way. The next question is: How *far* can a riser feed; that is, how far into the casting can the riser feed shrinkage?

[272]

(Under ideal conditions, certain gray irons have a feeding distance which, for all practical purposes, is almost unlimited. These are such special cases, though, that we won't deal with them here. As far as we are concerned, most risers are definitely limited in their feeding distance.)

[273]

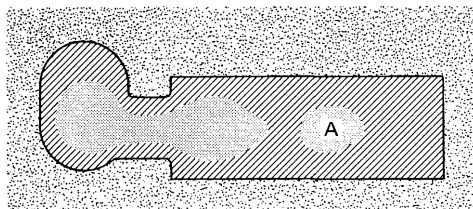
As we learned earlier in the course, there are two types of solidification: progressive, as shown at _____, and directional, as shown at _____.



A
B

[274]

In this case, the feed passage has been sealed off by _____ solidification before _____ solidification could reach the area near the riser. Can the riser now feed the shrinkage at A? _____



progressive
directional
No

[275]

Shrinkage which occurs *at* or *near* the riser can be fed by increasing the size of the riser and keeping it open to _____ pressure.

atmospheric

[276]

Shrinkage occurring some distance from the riser can usually be fed by placing another riser at the point of shrinkage. However, this may not be economical or, due to the shape of the casting, even possible.

[277]

Another way to prevent shrinkage at a distance from the riser is to increase the thermal gradient at the point where the shrinkage would occur.

To review briefly, a thermal gradient is the difference in _____ between two points a given distance apart.

temperature

[278]

And the steeper the thermal gradient, the (faster/slower) _____ the rate of solidification.

faster

[279]

Since we want the quickest solidification at the point furthest from the riser, the thermal gradient at that point should be (increased/decreased) _____.

increased

[280]

We already know that we can keep the metal in the riser hot by gating directly into it and by using _____ and _____ materials.

insulation
exothermic

[281]

What we want to know now is how to promote rapid cooling at the point (nearest to/furthest from) _____ the riser.

furthest from

[282]

We can speed up the rate of solidification by means of what are called chills and/or padding. Let's take up chills first.

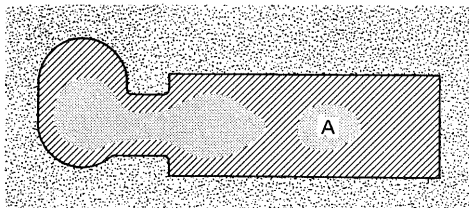
[283]

A *chill* is a piece of material that is used as a wall of the mold at the point where we want solidification to start soonest and progress fastest. Therefore, a chill must be a (good/poor) _____ conductor of heat.

good

[284]

Here's a figure you saw a little earlier. It shows what is actually a solidification race; the _____ solidification from the walls inward has beaten the _____ solidification to the riser.

progressive
directional

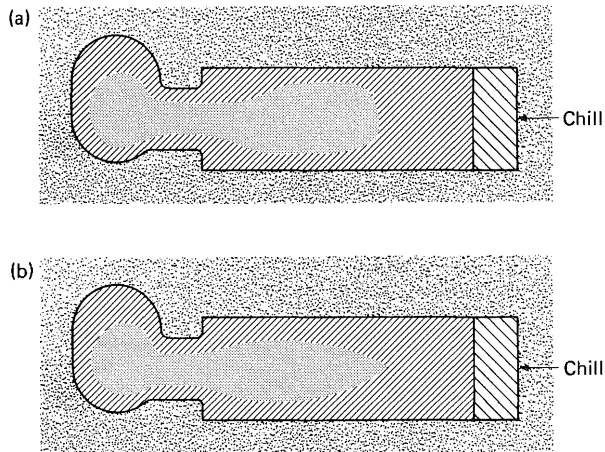
[285]

So we are going to speed up directional solidification by putting a _____ at the far end of the mold.

chill

[286]

The chill will give us a solidification pattern like that shown in figure _____.



(b)

[287]

Note: This use of a chill works very well with nonferrous alloys, which are good heat conductors. However, *this particular use* of a chill does not work well with iron and steel.

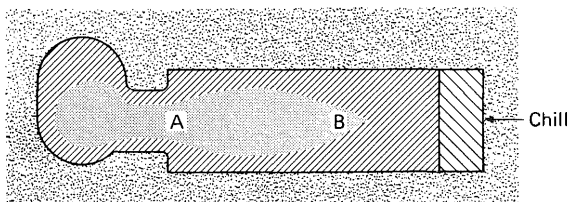
[288]

By using the chill we have (increased/decreased) _____ the rate at which _____ solidification can occur.

increased
directional

[289]

So shrinkage at point _____ will occur while the feeding channel at point _____ is still open.

B
A

[290]

Thus the feeding channel does not close off and leave an unfed shrinkage area in the casting.

[291]

Since this is so, the use of a chill has actually (increased/decreased/not changed) _____ the feeding distance of the riser.

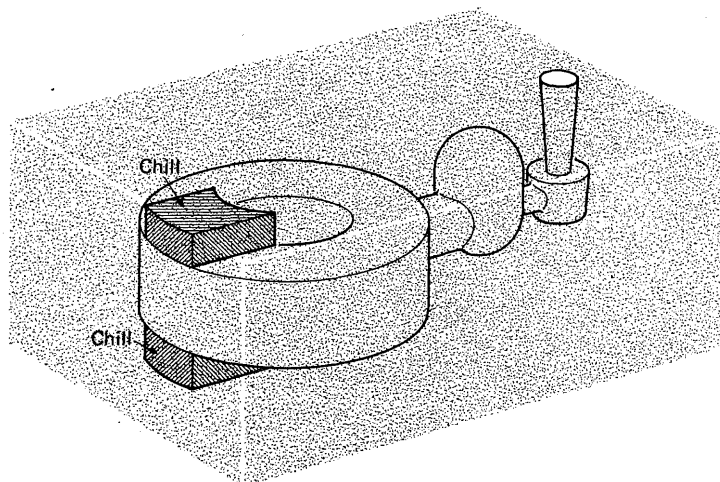
increased

[292]

The use of chills is not limited to the ends of castings; they are also effective (with both ferrous and nonferrous castings) when placed between risers to increase their feeding distance or when placed where shrinkage might occur.

[293]

A properly placed chill can also act as an "end" in a circular casting, helping to promote solidification at the point furthest from the _____.



riser

[294]

Chills can be made of various substances, including metals and certain molding materials. Care must be taken to see that a metal chill does not fuse or stick to the casting. Care must also be taken not to over-chill, since this is sometimes harmful.

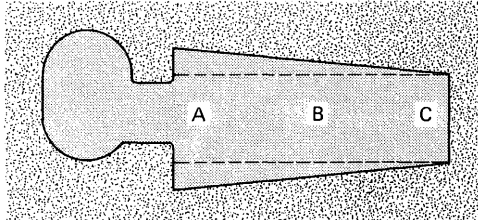
[295]

Now let's discuss *padding*. Padding is extra liquid metal which is added to the casting to increase _____ gradients.

thermal

[296]

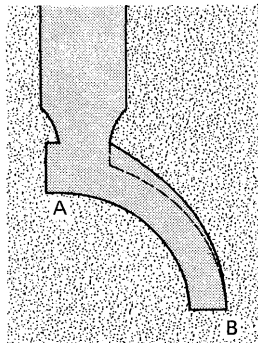
The padding in this casting is in the two wedge-shaped sections set off by dashed lines. The part of the casting that contains the least metal, and which will therefore solidify (first/last) _____, is indicated by _____.



first
C

[297]

Padding can be used on curved surfaces as well as flat. In this figure, solidification will be completed first at point _____ and will work toward point _____.



B
A

[298]

Since padding is intended to increase thermal gradients, and thus speed the solidification process, the bulk of it should be as (close to/far from) _____ the riser as possible.

close to

[299]

There are both economic and production limitations on the use of padding, and you should consult your foundry technical literature before using it.

One of the most obvious questions that must be answered is: Can the padding stay on the casting or will it have to be machined off?

[300]

That about covers all that was intended for this course, but before you go on to the post test, it might be well to have a review of what you've learned.

[301]

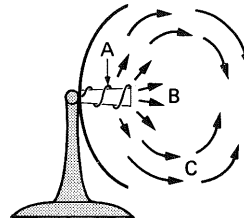
You remember that _____ is the energy that makes a material hot, and _____ is the measurement of that energy.

heat
temperature

[302]

Heat transfer takes place in three different ways, all of which are illustrated in this figure. Write each type beside the proper letter.

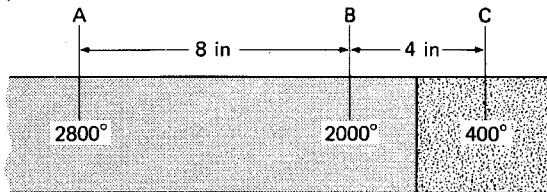
A _____
B _____
C _____



Conduction
Radiation
Convection

[303]

Thermal gradient, for our purposes, is measured in degrees per in. What is the thermal gradient from: A to B? _____ B to C? _____ A to C? _____



100°/in.
400°/in.
200°/in.

[304]

The steeper the thermal gradient, the (faster/slower) _____ the rate of heat transfer. In the preceding figure the fastest transfer of heat will occur between what two points? _____

faster
B and C

[305]

Pure metals and a few alloys solidify over (wide/narrow) _____ temperature ranges, while most alloys solidify over (wide/narrow) _____ temperature ranges.

narrow
wide

[306]

Pure metals and the alloys with narrow solidification ranges go through only two stages as they solidify; as they cool they turn directly from _____ to _____.

liquid
solid

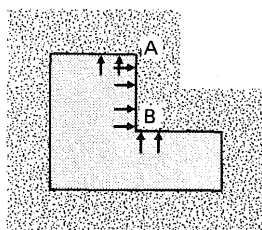
[307]

Wide-range alloys go through three stages as they solidify; first they are _____, then they turn _____; and at last they are _____.

liquid
mushy
solid

[308]

Point A indicates an external corner, while point B indicates an internal corner. At which corner will the metal solidify quickest? _____



A

[309]

The three types of shrinkage, in the order in which they occur, are 1 _____, s _____, and s _____.

liquid
solidification
solid

[310]

Cast iron expands and precipitates graphite, which puts extra _____ on the mold walls and can (increase/decrease) _____ the size of the mold cavity.

pressure
increase

[311]

Hot spots in a casting solidify (before/after) _____ the rest of the casting does. If possible, we should locate a _____ at each hot spot.

after
riser

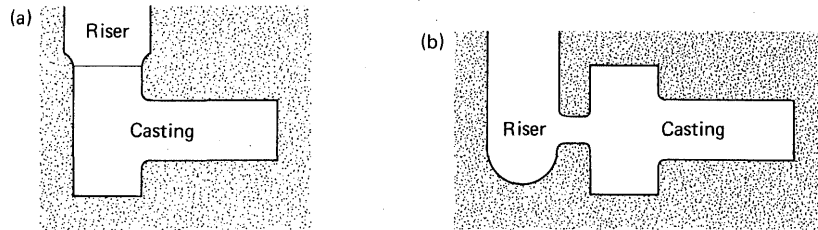
[312]

When a casting is a complex one, it is a good idea to treat each part as though it were a separate system, and supply it with its own _____.

riser

[313]

What type of riser is shown in (a)? _____ In (b)? _____



top
side

[314]

A riser located in the gating system is called a hot or _____ riser, and will normally solidify (before/after) _____ the casting.

live
after

[315]

A good insulating material is a (good/poor) _____ conductor of heat, and so a riser surrounded by insulating material will (stay hot longer/cool off faster) _____ than it would otherwise do.

poor
stay hot longer

[316]

When they come in contact with molten metals, exothermic materials (absorb/generate) _____ heat.

generate

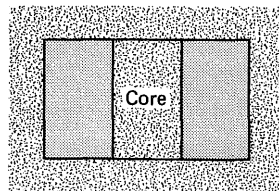
[317]

A riser which is completely enclosed within the mold, so that the top is not exposed to the air, is called a _____.

blind riser

[318]

A core in a casting, like that shown here, acts as a source of heat, and so (speeds up/slows down) _____ the cooling process.



slows down

[319]

The ratio of surface area to volume is what we call the _____ ratio, and to keep a riser liquid as long as possible, we should have as (large/small) _____ a surface area as we can get for the volume.

sa/v
small

[320]

The sa/v ratio is a fraction, $\frac{\text{surface area}}{\text{volume}}$, and the (larger/smaller) _____ the fraction, the longer the riser will stay liquid.

smaller

[321]

The sphere has the smallest sa/v ratio of any shape, but for various economic and production reasons it is not widely used for risers. So most risers are in the shape of a (cube/cylinder/rectangle) _____.

cylinder

[322]

Formulas for figuring the dimensions of risers and riser necks will not be reviewed here. They are given on the summary card attached to the rear cover of this book. Tear off the card and keep it with you for a handy reference.

[323]

The way the riser neck is located means that it has only internal corners, and that means that the neck will solidify (faster/more slowly) _____ than the casting.

more slowly

[324]

Washburn cores, used to help make removal of the riser easier and more economical, are set into the mold between the _____ and the _____.

riser
casting
(or reverse order)

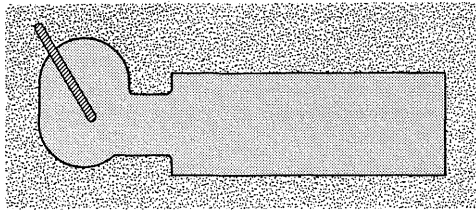
[325]

A riser can feed shrinkage in a casting at a point higher than the riser itself, because of the force that is pushing down on the surface of the molten metal in the riser. And that is the force of a _____
p_____.

atmospheric pressure

[326]

The pencil core shown here is designed to let _____
into a blind riser.



atmospheric pressure

[327]

Since a chill is used to promote solidification, it must be a (good/poor)
_____ conductor of heat.

good

[328]

Padding is extra liquid metal added to the casting to (increase/decrease)
_____ thermal gradients, and so the greatest part of it should be as
(close to/far from) _____ the riser as possible.

increase
close to

POST TEST

POST TEST

Note: Remove the Post Test and its answer sheet from the book. Leave the answers in the book and do not look at them until you have completed the test. Read each statement carefully and then answer by placing an X in the appropriate place on the answer sheet.

TRUE-FALSE

Examples:

Chicago is a city.

The sum of $2 + 2$ is 5.

Answer Sheet

T	F
X	
	X

1. When a substance has changed from a liquid to a solid, we say that it has solidified.
2. Heat is the measure or the degree of hotness.
3. A hot substance always gives up its heat to a colder substance.
4. The movement of heat from a hot substance to a cold substance is called heat transfer.
5. Heat transfer can take place in any of four ways.
6. The transfer of heat through a solid material is called conduction.
7. In order for heat transfer to take place, there must be a difference in temperature.
8. Shrinkage is normally caused by the lack of feed metal.
9. A chill is a reservoir of molten metal which can be used to feed shrinkage.
10. A material that slows down the flow of heat is called an insulator.
11. Shrinkage which occurs in a casting some distance from the riser can be eliminated by increasing the size of the riser.
12. Atmospheric pressure does not play an important part in helping the riser feed shrinkage.
13. The size of the riser is the only factor which will determine if the riser will meet its requirements.
14. There are three types of shrinkage that take place during the casting process.
15. We would rather have directional solidification than progressive solidification.

16. The primary use of a chill is to increase the thermal gradients within the casting.
17. The preferred practice is to gate through the riser into the casting.
18. Heat transfer has to take place in order for a casting to solidify.
19. The smaller the surface contact between the casting and molding material, the more rapid will be the rate of heat transfer.
20. A blind riser will normally solidify faster than an open riser.
21. An exothermic material will produce heat when it comes in contact with molten metal.
22. The surface area to volume ratio (the sa/v ratio) of the riser should be less than the casting or casting section it is to feed.
23. Solidification in a casting normally begins at points farthest away from the point at which molten metal enters the mold cavity.
24. Like pure metals, most alloys will normally solidify at a given, single temperature.
25. The riser should complete solidification after the casting or casting section it is to feed.
26. Risers should always be attached to thin sections of a casting so that they can feed shrinkage in the heavier sections.
27. In order to increase the feeding distance of risers, the thermal gradients in the casting should be increased.
28. The size and shape of the riser neck does not affect the feeding ability of a riser.
29. The use of insulating and/or exothermic materials will help keep a riser liquid over a longer period of time.
30. The shape and the sa/v ratio of a riser have very little to do with how fast it will solidify.

MULTIPLE CHOICE

The following statements are not complete. Place an X in the space on the answer sheet which best completes the statement or answers the question:

Examples:

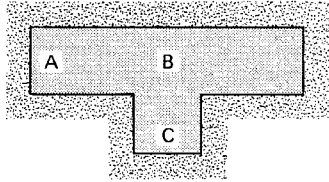
The sum of $2 + 2$ is

- A. 3 C. 6
B. 4 D. 8

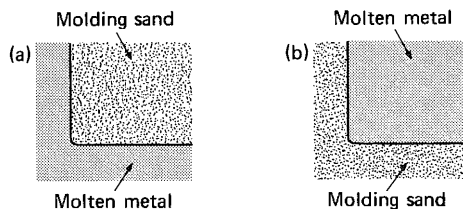
Answer Sheet

A	B	C	D
☐	☒	☐	☐

31. Which of the following shapes is best for a riser?
 A. Square C. Cylindrical (Cylinder)
 B. Rectangular D. Triangular
32. Where in the following casting will a "hot spot" normally be found?

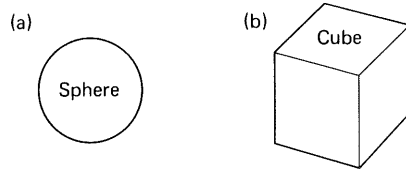


33. A riser located in the gating system is called a _____ riser.
 A. Hot C. Dead
 B. Cold D. System
34. The transfer of heat through space in a straight line, as by the sun's rays, for example, is called _____.
 A. Conduction C. Directional
 B. Radiation D. Convection
35. A "hot spot" is normally the _____ part of a casting to complete solidification.
 A. First C. Smallest
 B. Last D. Top
36. Solidification which begins at the sidewalls of the mold and moves in toward the center of the casting is called _____ solidification.
 A. Directional C. Progressive
 B. Differential D. Conventional
37. Which of the following corners will take longer to solidify?



38. In order to have thermal gradients, there must be a difference in _____.
 A. Materials C. Metals
 B. Temperature D. None of these

39. Which of the following shapes has the smallest sa/v ratio (surface area to volume ratio)?



40. Which of the following will normally solidify over a temperature range rather than at a certain temperature?
- A. Copper C. Tin
B. Zinc D. Cast iron
41. If a riser is to meet its requirements, its sa/v ratio must be _____ than that of the casting or casting section it is to feed.
- A. Less C. Equal
B. Greater D. None of these
42. Heat is transferred through a solid material by means of _____.
- A. Radiation C. Conduction
B. Convection D. Penetration
43. As the mold surfaces get hot, their ability to extract heat from the casting becomes _____.
- A. Greater C. Better
B. Less D. None of these
44. A riser whose top surface is not exposed to the air is called a _____ riser.
- A. Hidden C. Top
B. Blind D. Covered
45. Solidification which begins in areas farthest from the source of molten metal and works back toward it is called _____ solidification.
- A. Progressive C. Longitudinal
B. Aggressive D. Directional
46. There are _____ types of shrinkage.
- A. 2 C. 3
B. 4 D. 5
47. The feeding distance of a riser can be increased by using _____.
- A. Chills C. Squares
B. Cubes D. None of these
48. The following are the sa/v ratios of several risers. Which one will normally remain liquid longest _____.
- A. 1 to 1 C. 1 to 2
B. 2 to 1 D. 3 to 1

49. One thing that is very important in helping a riser meet its requirements is _____.

- A. Inert pressure C. Vacuum pressure
B. Atmospheric pressure D. None of these

50. Which of the following correctly lists the sequence in which shrinkage takes place immediately after pouring has been completed?

- | A. | B. | C. |
|-------------------|-------------------|-------------------|
| 1. Liquid | 1. Solidification | 1. Liquid |
| 2. Solid | 2. Liquid | 2. Solidification |
| 3. Solidification | 3. Solid | 3. Solid |

ANSWER SHEET FOR POST TEST

True or False

	T	F		T	F
1.			16.		
2.			17.		
3.			18.		
4.			19.		
5.			20.		
6.			21.		
7.			22.		
8.			23.		
9.			24.		
10.			25.		
11.			26.		
12.			27.		
13.			28.		
14.			29.		
15.			30.		

Multiple Choice

	A	B	C	D
31.				
32.				
33.				
34.				
35.				
36.				
37.				
38.				
39.				
40.				
41.				
42.				
43.				
44.				
45.				
46.				
47.				
48.				
49.				
50.				

ANSWERS TO POST TEST

- | | | |
|-------|-------|-------|
| 1. T | 18. T | 35. B |
| 2. F | 19. F | 36. C |
| 3. T | 20. F | 37. A |
| 4. T | 21. T | 38. B |
| 5. F | 22. T | 39. A |
| 6. T | 23. T | 40. D |
| 7. T | 24. F | 41. A |
| 8. T | 25. T | 42. C |
| 9. F | 26. F | 43. B |
| 10. T | 27. T | 44. B |
| 11. F | 28. F | 45. D |
| 12. F | 29. T | 46. C |
| 13. F | 30. F | 47. A |
| 14. T | 31. C | 48. C |
| 15. T | 32. B | 49. B |
| 16. T | 33. A | 50. C |
| 17. T | 34. B | |