

FUNDAMENTAL MOLDING SAND TECHNOLOGY



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PREFACE

This programmed learning course, prepared by the Cast Metals Institute, American Foundrymen's Society, is designed to aid those beginning a career in metal casting. The principles are basic and can be used by experienced foundrymen as a refresher or reference. The material can be read by an individual, or used to instruct and test groups of beginners.

This course covers the basic principles governing the ability of molding sands to make acceptable molds and to withstand the thermal effects which occur when compacted sand is in contact with molten metal. The format of the presentation is to study the variables affecting the process of compacting the sand grains to produce a mold. The text is divided into these sections —

Basic Concepts

Compaction, Grain Size, Void Size

Clay Bonded Sands

Supplementary Bonds

Mixing and Mulling of Molding Sands

Reused Sand, New Sand Additions, Reclamation

Bibliography

Appendix A — Ferrous Sand Formulas and Properties

Appendix B — Nonferrous Sands

Appendix C — Illustrations

It is evident that all of the details pertaining to molding sands cannot be discussed in one small volume. Therefore, this discussion concentrates on basic concepts. Those readers interested in further details are referred to the bibliography where several important papers pertaining to each section are listed.

TO GET THE MOST FROM THIS COURSE

Study a relatively small part of it at one time, the amount varying with the individual, but probably not to exceed 50 frames. To be effective, the rate should be comfortable. There is no reward for speed when studying this course but there is a reward for a careful thorough study of the material — understanding the subject.

Write the answer in the spaces provided before looking at the correct answer, otherwise you cheat yourself for you will not understand or remember the material nearly as well as you would otherwise.

The post test (pA-1) is an important part of the learning process. It gives you a chance to see what you have learned. In the formal classroom training situation it allows the instructor to see whether the trainee did his assigned work.

HOW TO USE THIS TEXTBOOK

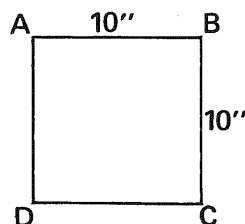
Do not study this as you would a regular textbook. To begin, remove the answer mask from the rear cover (tear along dotted line) and place it to *completely* cover the answer column at the right-hand side of this page. Each small, numbered part (frame) of the text will give you information and at the same time most will require you to supply information in a space allowed. 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 the mask down until it is even with the bottom of this frame and stop. Do not move the mask again until you have read all of the next frame and have answered its questions.

You may be given a choice of words, as in, "This frame is printed in _____ (green/black/red) ink." But more often you will be asked to provide one particular _____ for the blank. Now slide the mask down to here.

If you said answer for the second part of the frame above, that will do. In most cases you will provide 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.

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.

Sometimes you may just indicate a part: The top 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 in.²

A word or two of caution:

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.

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 from doing the work yourself.

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.

Go to it, and good luck!

(1)

The molding sands covered in this Programmed Learning Course are sands containing appreciable amounts of “bond” and water when they are compacted around a pattern to form a mold. The “bond” most widely used is a type of clay bentonite. This clay when mixed with water is sticky and sticks the sand grains together.

The most widely used binder used in molding sands is called _____.

bentonite

(2)

When water is present the sands are called “green sands”, but not because of color. “Green” means undried in the sense that undried wood is called green wood.

The molding sands are always molded (“compacted” — “rammed”) in the “Green” undried state. The molds are filled with metal in either the “green” state or the molds may be dried after compaction and removal of the pattern. The latter practice is known as “dry sand” molding.

Molding sand that is used without drying out the water before metal is poured into the mold is called _____.

green sand

(3)

“Green” molding sand is relatively weak, and has 5 to about 25 pounds per square inch strength in compression. Therefore most molding sands are supported by “flasks” made of wood or metal. Flasks are frames with open tops and bottoms.

The frames used to support and contain the sand are called _____.

flasks

(4)

In order to support the molding sand and also the metal poured into the mold “bottom boards” or “bottom plates” are used. Flasks are used to support and contain the _____ whereas, “_____” or “_____” are used to support the sand and metal poured into the mold.

sand
“bottom boards”
“bottom plates”

(5)

Molds are made in two ways. One involves "tight flasks" that remain around the sand when the molds are poured. All "dry sand" molds are made in "tight flasks", as well as many "green sand" molds. Green sand molds are also made in "pop off", or "snap" flasks that are removed after the mold is made. The sides of these molds are supported during pouring by "jackets" that are in turn removed after the casting has solidified. It is essential when using pop off or snap flasks that these molds be handled on bottom boards.

There are two types of flasks used in the foundry _____ flasks and _____ or _____ flasks.

tight
pop off
snap

(6)

There are four chief methods used to compact molding sand around a pattern in a flask:

- (a) By "squeezing". Literally applying a squeezing force as high as several hundred pounds per square inch (psi) to the sands in the flask.
- (b) By some type of impact. The most widely used method is to lift the flask full of sand several inches and allow it to fall. This is called "jolting".
- (c) "Jolting" followed by squeezing.
- (d) By "slinging", literally throwing the sand mechanically into the flask.

(7)

There are a few exceptions to the preceding statements.

Some molds are made and poured without flasks. The sands used are bonded with special binders that promote much higher strengths than can be obtained with clays. There are also new molding machines that do not use flasks.

(8)

There are at least six basic properties of a molding sand which must be controlled to produce satisfactory castings. They are:

Grain size
Flowability (compactibility)
Strength - Brittleness
Thermal stability
Collapsibility
Ease of shakeout.

The significance of these properties are discussed in detail in the frames to follow.

(9)

In addition to these molding sand properties, “non-sand” factors are also important. Some are:

- Size and shape of castings
- Type of metal
- Molding method
- Pouring and gating.

The influence of these non-sand factors will be discussed later.

(10)

In order to produce satisfactory castings, the metal caster must control both the m_____s_____ properties and “non-sand” properties.

molding
sand

(11)

At times special properties in addition to the six basic ones listed in frame 8 may become important to compensate for special “non-sand” conditions.

For example, should some drastic changes be made in pouring practice, it may be necessary to provide the m_____s_____ with special properties to produce satisfactory castings.

molding
sand

(12)

Let's now consider the six properties of a molding sand.

The first two properties, grain size and flowability go hand in hand. The majority of castings produced today are formed in sand molds. The sand grains are mixed with a bonding material which makes them stick together after being compacted, forming a _____ into which molten metal can be poured.

mold

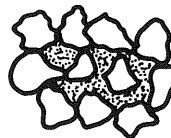
(13)

This mixture of sand grains and a binding material is placed in a container (flask) and compacted, or rammed. Even when the sand grains are fully compacted there will be voids (holes) between the many sand grains.

A rammed (compacted) sand mold is not solid, but has many small v_____ in it.

voids

shaded area represents voids



(14)

The size of these voids is important for several reasons. One is if the voids are too large, molten metal will enter them. Rough casting surfaces will result. Under certain conditions molten metal will penetrate the voids to appreciable depths. The metal will lock the sand to the casting surface. This is called metal penetration.

On the other hand the voids must be large enough to allow the heated air and the gases generated by the heated organic binders and water to escape through the sand.

Metal can penetrate into _____ voids easier than into _____ voids.

large
small



(15)

The size of the voids in the mold is important to prevent rough casting _____ and allow _____ and _____ to escape from the mold.

surfaces
air
gas

(16)

Too large voids in the compacted sand can cause the sand grains to be locked to the casting. This is called metal _____.

penetration

(17)

The size of the voids is determined by three main factors:

1. The grain size of the sand
2. How the grains fit together, called grain distribution
3. The ease with which the molding sand can be rammed, called flowability, or better still, compactibility.

Three factors that determine the size of the voids in the sand mold are: g _____ s _____, d _____ and f _____

grain size
distribution
flowability

(18)

As you can tell from these last few frames molding sands are a compromise. First of all we need voids in the sand to allow _____ and _____ to escape. On the other hand these voids cannot be too large because then we get rough casting _____.

air
gas
surfaces

(19)

The best void size for a given foundry is determined by the “non-sand” factors of frame 9. Sometimes different sands are need in the same foundry. In general, the smaller the castings and the lower the pouring temperature of the metal the smaller can be the void size, thus, smaller void size means smaller grain size.

As aluminum is poured at a lower temperature than most other metals, a small aluminum casting should be poured into a _____ grain size sand than a large steel casting which is poured at higher temperature.

smaller

(20)

In general, sand grain size and void size should be as large as possible to allow the best opportunity for gas to escape through the sand. The limit is unacceptable casting roughness, or metal penetration into the sand.

Too large grain size may cause _____ casting surfaces.

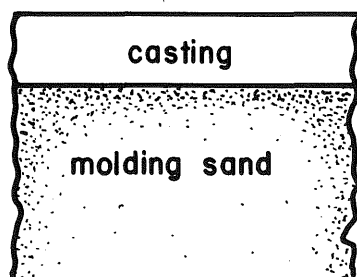
rough

(21)

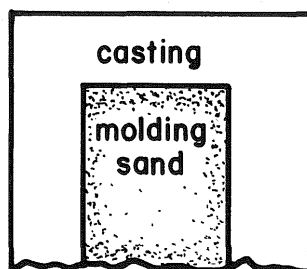
Casting shape is important. Gas pressure can be much higher when the casting shape causes areas of sand to be in contact with metal on more than one surface. Whereas, gas pressure is lower when the sand is contacted on only one surface.

A major factor other than grain size and void size affecting gas pressure and its escape through the sand, or metal is the _____ of the casting.

shape



(low gas pressure)



(high gas pressure)

(22)

Based on the information given in frames 20 and 21:

Which condition causes the greatest gas pressure? _____

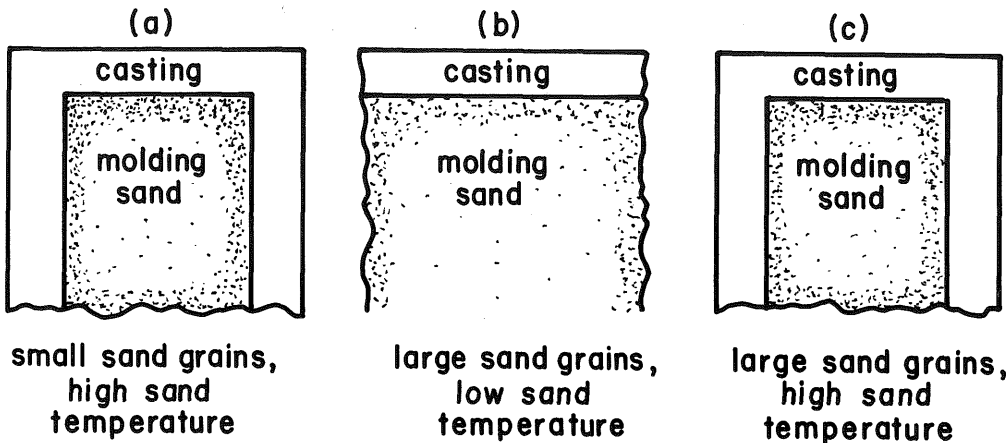
Which condition causes the least gas pressure? _____

Which condition causes the greatest danger of penetration?

(a)

(b)

(c)



(23)

A dry twig will crack when bent slightly and is said to be brittle. A green twig will bend or deform a given amount without breaking. The ability to deform slightly is an important property of compacted molding sand. "Brittle" sands cause molds to crack when the pattern is "drawn" (removed) from the mold and when the molds are handled.

A sand that causes cracked molds is said to be _____

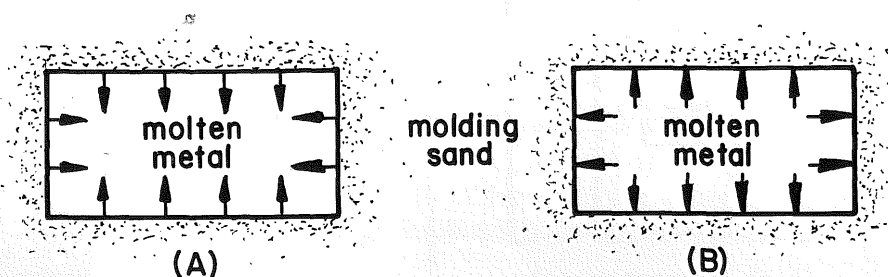
brittle

(24)

Strength is the ability of the sand to withstand the pressure imposed on it by the liquid metal. All liquids exert an outward pressure in all directions. Weight (gravity) is one factor affecting force.

If the arrows indicate the direction of pressure, which illustration is correctly drawn? _____

(B)



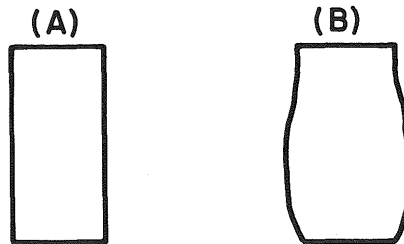
(25)

If the sand is not strong enough either as molded, or when heated, to withstand the pressure, the molten metal pressure will change the surface contours of the mold causing the casting to "strain" or "swell", that is, make the casting larger than it should be.

Which of the following casting has strained? _____

(B)

(casting should be rectangular)

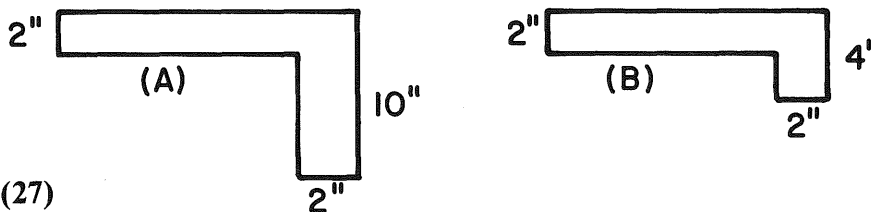


(26)

Pressure against the mold surface increases with casting height.

Which of the following castings would require a stronger molding sand? _____

(A)



(27)

Thus, in order to produce accurate castings from accurate patterns the molding sand has to have s_____ to withstand the p_____ exerted on it.

strength
pressure

(28)

You will have noticed several times that we have used the term molten metal. This leads us into our next basic property, thermal stability. Thermal means heat and stability means unchangeable. Thus, a molding sand must have resistance to drastic changes in temperature.

(29)

What type of temperature changes are we talking about? They can start from room temperature, 50-100° F and reach from 1500 to 3000° F. Let's say we have a molding sand at 100° F and pour molten metal into the mold that is at a temperature of 2900° F. This represents a temperature change of _____ F at the sand surface in contact with the molten metal.

2800° F

(30)

We know that materials expand, or get larger when heated. The same holds true for the sand grains in the mold surface when these surfaces come in contact with molten metal.

If we were to heat a grain of sand we would find that it gets _____ as it is heated.

larger

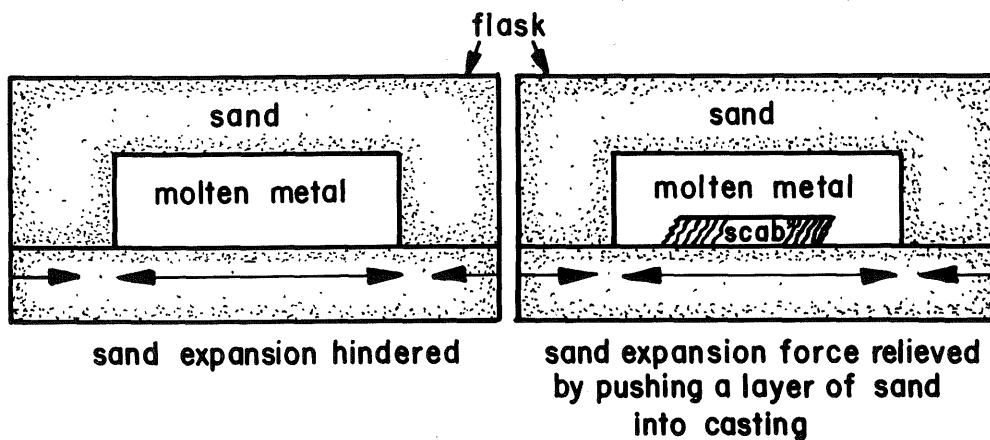
(31)

It is therefore logical to expect those sand grains in contact with and close to the molten metal to get _____ as they are heated by the molten metal.

larger

(32)

The mold surfaces must be able to withstand the extreme heat shock when contacted by molten metal. The sudden increase in temperature of the sand grains causes very rapid expansion of the mold surfaces. Unless this expansion can be compensated in some way, a defect called "expansion scabbing" occurs as illustrated.

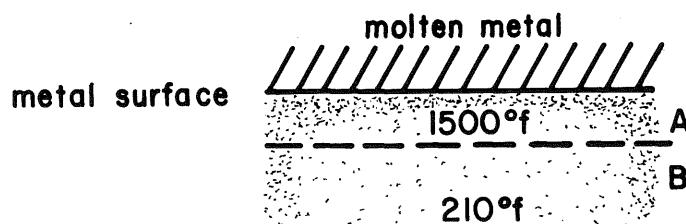


(33)

Another variable is the strength of the sand immediately in back of the heated surface. A weak area of sand called the "wet layer" forms in green sand molds a short distance in back of the heated mold surface.

Where in the following illustration would you expect to find the "wet layer"? _____

B



(34)

Expansion scabbing has many names: "rat tailing", "spalling", "cope spalling" are just a few. All are due to unrelieved expansion forces. One method of decreasing the forces that cause this defect is to "soft ram", or to compact the sand grains so they do not touch one another. This will compensate for the expansion of the sand grains.

cont'd

Here we again run into a compromise. If we "soft ram" a mold we can have a weak mold with large voids causing which of the following to occur? _____ and _____

- A. *Strains*
- B. *Rough casting surfaces*
- C. *Spalling*
- D. *Penetration*

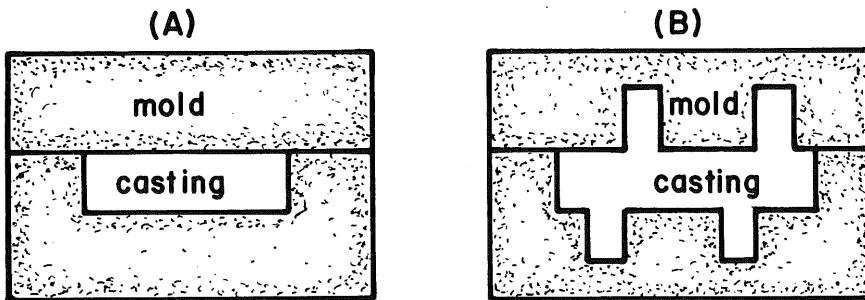
A
B
D

(35)

An important non-sand factor affecting expansion scabbing is the size and shape of castings. Large, continuous flat area are most prone to this defect. The larger the flat area the great the danger.

Which shape is the most prone to expansion scabbing?

A



(36)

There are many ways to control thermal stability and expansion scabbing with various bonds and additions to the sand. These will be discussed later. Many depend on relieving the expansion in some way when molten metal comes in contact with the sand surfaces of the mold.

(37)

After the casting is poured and begins to freeze, it will contract. Just as most materials expand, or get larger when heated, they contract or get smaller when they cool.

As a casting cools to room temperature it gets _____

smaller

(38)

If the contraction during freezing is hindered, some metals will crack or tear. This is called "hot cracking", or "hot tearing". In order to prevent "hot cracking" or "hot tearing" the molding sand must have collapsibility, that is, to decrease slightly in volume so the metal in the casting may also contract.

In order for the casting to contract without "hot cracking" the molding sand must have _____.

collapsibility

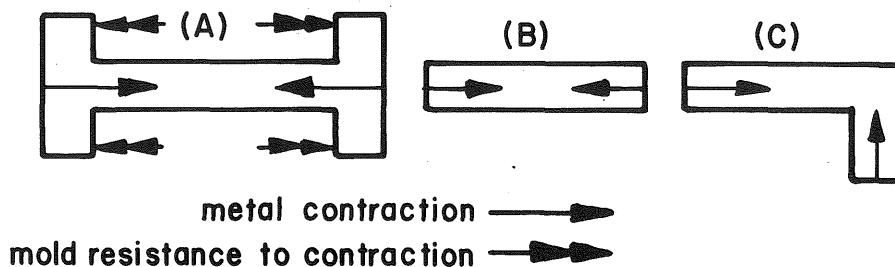
(39)

There are a number of non-sand factors causing hot cracking or hot tearing. Steel, malleable iron, certain copper and aluminum alloys are susceptible to hot cracking. Others like gray and ductile iron are almost immune due to the way they freeze.

The shape of the casting is also important. If the shape is such that it hinders or restricts contraction cracking can occur.

Which shape will be most prone to hot cracking? _____

(A)



(40)

Finally after the casting has solidified the molding sand must be easily removed from the flask when used, fall away from the casting and disintegrate into individual grains (no lumps) so it can be reused. This capability is called, "shakeout".

A sand that meets the above requirements is said to have good s_____ quality.

shakeout

(41)

Let's have a brief review.

Which six of the following properties of a molding sand are of prime importance and should be controlled? _____, _____, _____, _____, _____, _____.

- A. Grain size
- B. Fusion
- C. Compactibility
- D. Strength - Brittleness
- E. Grain surface area
- F. Thermal stability
- G. Collapsibility
- H. Shakeout

A
C
D
F
G
H

(42)

Too large void size may result in casting surfaces that are too r_____, or the sand may _____ to the casting surfaces under certain conditions.

rough
adhere or stick
(either word)

(43)

If the voids are too small, _____ and _____ cannot escape properly through the sand, when the mold is filled with molten metal.

gases
air
(any order)

(44)

The size of the voids in a mold is determined by three factors, the g_____ s_____, the g_____ d_____ and the f_____ of the bonded molding sand.

grain size
grain distribution
flowability

(45)

To help prevent swells and strains of the casting, the molding sand should have adequate _____.

strength

(46)

Excessive _____ can cause cracked molds during the molding operations.

brittleness

(47)

Since the molding sand will come in contact with hot molten metal, it must also have t_____ s_____.

thermal stability

(48)

A sand mold that has poor thermal stability may cause a defect called e_____ s_____.

expansion scabbing

(49)

The sand property that allows the casting to contract without hot tearing while it freezes is called _____.

collapsibility

(50)

After the molding sand has produced a casting it should have good _____ properties so both the sand and the flask can be reused with the least amount of preparation.

shakeout

(51)

In many cases the ideal molding sand may call for the foundryman to make compromises between the various sand properties. Thus, the ideal molding sand for a particular metal, casting or foundry may not work for some other metal, casting or foundry.

COMPACTION, GRAIN SIZE, VOID SIZE

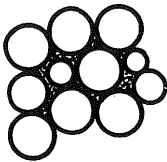
(52)

The preceding frames told what properties and compromises between the properties are needed to produce a satisfactory molding sand.

Now, let's discuss how we can achieve the desired combinations of properties.

(53)

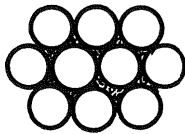
Most sand grains are quite rounded; let's consider them as spheres, or round beads, so they can be pictured on paper as circles. Even when well compacted (rammed), so that the grains touch, there will be voids between the sand grains. See Fig. 1, Appendix C, p A-3.



Shaded areas are voids

(54)

When the sand grains of *about the same size* are well compacted (rammed) so the grains touch, voids will account for 40 to 48% of the volume. Sand grains will occupy only 52 to 60% of the mold volume. It is impossible to have less than 40% voids with *uniform size* sand grains.



Shaded areas are voids

Handbooks tell us that solid grains (fused Quartz) weighs about 180 pounds per cubic foot (180 lbs/cu. ft.) A cubic foot of well compacted sand grains will therefore weigh 52 to 60% of 180 lb/ft³ or 94 to 108 lb/ft³.

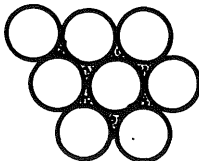
(55)

The size of the sand grains is one variable affecting the *size* of the voids (holes) between the sand grains. The larger the grains the larger the voids, however, total *volume* of voids is changed very little by grain size.

Which group of sand grains has the largest voids? _____

A

(A)



(B)



(56)

Note that there is a fundamental difference between size of voids and volume (amount) of voids. A very important point is that the *volume of voids* (density) is little changed by grain size. Only *void size* is changed by changing grain size.

The density of a well compacted sand mass is _____
changed by a change of grain size.

little

(57)

Grain size and grain distribution are measured by screens with various size openings. Sand is shaken through a series of 6 to 8 screens. Each grain falls through openings larger than it is, until it falls and is caught on the first screen with openings smaller than it is.

Size is usually expressed in the USA as number of openings per linear inch. A 40 mesh screen has 40 openings per inch and will separate grains larger than those caught on a screen with 100 openings per inch. That is the larger the number; the smaller the openings.

A 100 mesh screen has _____ openings than a 50 mesh screen.

smaller

(58)

Void size follows grain size, so a 140 mesh sand has smaller voids than a 100 mesh sand. In other words, the *smaller* the mesh number, the *larger* the grain size.

Which mold made of uniform size grains, has the smallest voids when compacted so the grains touch? _____

(b)

- (a) 40 mesh grains
- (b) 70 mesh grains
- (c) 20 mesh grains

(59)

The following Table summarizes the most commonly used screens for measuring the grain size of foundry sands.

<u>Sieve Number</u>	<u>Size of Openings sq. in.</u>	<u>Size of Openings sq. mm.</u>
12	0.066	1.68
20	0.033	0.84
30	0.023	0.59
40	0.017	0.42
50	0.012	0.30
70	0.008	0.21
100	0.006	0.15
140	0.004	0.11
200	0.003	0.07
270	0.002	0.05

(60)

The usual foundry sand is made up of grains of a number of sizes. An average grain size called AFS (American Foundrymen's Society) Fineness Number can be calculated. An example follows:

Sieve Number	% of Sample Retained on Sieve		Multiplier		Product
20	- 0 -	X	10	=	- 0 -
30	2.0	X	20	=	40
40	15.0	X	30	=	450
50	45.0	X	40	=	1800
70	23.0	X	50	=	1150
100	12.0	X	70	=	840
140	1.8	X	100	=	180
200	0.8	X	140	=	112
270	0.5	X	200	=	100
Pan	0.4	X	300	=	120
TOTAL	100.5				4792

$$\text{AFS Grain Fineness Number} = \frac{4792}{100.5} = 45.5$$

Over 93% of the sand sample was caught on four sieves, the 40, 50, 70 and 100 sieves, and over 10% of the total sand sample was caught on each of the four screens, with the number 50 catching the largest percentage.

(61)

Which of the four sieves caught the smallest percentage of the sand sample? _____

100

(62)

The multiplier of Frame 60 is the number of the last screen through which the sand grains passed. That is, the multiplier for the 30 sieve is 20 etc., or the sand had to pass through the 20 sieve before reaching the 30 sieve.

The multiplier is therefore related to the _____ (size/shape) of the particular sands.

size

(63)

Calculate the AFS Fineness Number for the following sand:

Sieve Number	% of Sample Retained on Sieve		Multiplier		Product
20	- 0 -	x	10	=	- 0 -
30	- 0 -	x	20	=	- 0 -
40	5.0	x	30	=	150
50	6.5	x	40	=	260
70	8.0	x	50	=	400
100	12.0	x	70	=	840
140	40.0	x	100	=	4000
200	20.7	x	140	=	2898
270	7.5	x	200	=	1500
Pan	1.0	x	300	=	300
TOTAL	100.7				10348

$$\text{AFS Fineness Number} = \frac{10348}{100.7} = 102.7$$

$$\frac{(10348)}{(100.7)} = 102.7$$

(64)

The AFS Fineness Number is used a great deal to describe the average grain size of foundry sands.

The average grain size of the molding sand in Frame 63 is _____.

103

(65)

The metalcaster must be careful not to fall into a trap. Study the sieve numbers on which the greatest percentage of the sample of sand was retained. Remember the larger the sieve number the smaller the grain size.

Therefore, a larger AFS Fineness Number tells us that we have a _____ (smaller/larger) average grain size.

smaller

(66)

Note that the sand of Frames 60 and 63 are made up of a number of sizes. This is called sand distribution. Grain distribution is important as it is another factor affecting void size.

Another factor affecting void size is _____.

grain distribution

(67)

Over 93% of the sand grains were caught on four screens in Frame 60, the 40, 50, 70 and 100 screens and each screen caught over 10% of the sample. Because these four screens each caught 10% or more of the sample we call it a sand with a four screen distribution, or a four screen sand.

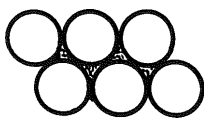
In order for a sand sample to be a five screen sand at least _____% of the sample must be caught on each of _____ screens.

10
5

(68)

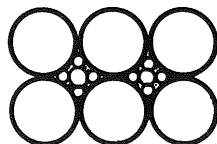
Void size can be changed in two ways:

By changing the size of the grains.



voids

By distribution, that is, by filling the voids with smaller grains.



Void size can be changed by _____ and by _____.

grain size
distribution

(69)

Volume of voids (density) cannot be changed by grain size. Volume (density) can only be changed by distribution. However, the size of the voids can be changed by grain size and distribution.

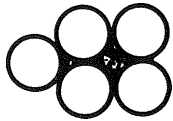
Volume of voids or density of a molding sand _____ be changed by grain distribution.

can

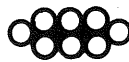
(70)

Two very important points are many times misunderstood:

(1) Changing grain size does not affect density to any extent.

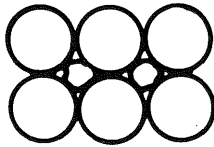


Large grains, large voids, 40-80% voids by volume



Small grains, small voids. Still 40-48% voids by volume.

(2) If voids are filled by grain distribution, void size is not only decreased, but percent voids is also decreased. In other words, density is increased. Silica flour is sometimes used to fill in the voids.



Small grains, small voids. Still 40-48% voids by volume.

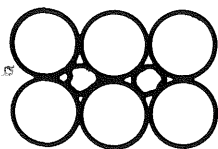
(71)

Some metals like steel and bronze will penetrate the smallest voids under certain conditions, as discussed later. It is therefore necessary in these cases to _____ (increase/decrease) density by f_____ the voids. However, decreasing void s_____ may not solve the problem.

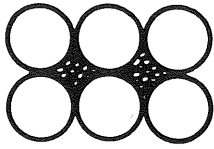
increase
filling
size

(72)

The only practical way both volume and size of voids can be decreased is to have more than one grain size. Two methods of doing this are:



Arrange a series of grain sizes so that each smaller size fits in the voids of the larger. Most sands partially meet this requirement as they are composed of a series of sizes. Precise distribution is needed to attain maximum density.



Fill the voids with quite small particles like silica flour or fire clay. Quite large percentages of fine material are sometimes needed (30-40%). For maximum results, the sand grains should be much larger than the silica flour or fire clay grains. See Fig. 2, Appendix C, p A-6.

(73)

Distribution in foundry sands is described by the number of individual screens that have caught over 10% of the sand grains. For example, the sand of Frame 60 is called a 4 screen sand, or a sand with a 4 screen distribution. That is, screens with a sieve number of 40, 50, 70 and 100 have each retained at least 10% of the sand grains.

A sand that is caught mainly on two screens is called a _____ screen sand.

two

(74)

Grain size and grain distribution are factors which are usually determined on the unbonded sand, as received by the foundry. These two factors influence void size even after the sand is bonded, however, flowability of bonded sands must also be considered.

The other influencing factor, besides grain size and distribution, that becomes important with bonded sands is _____.

flowability

(75)

Most foundrymen consider a wide grain distribution, when the sand grains are spread over a number of screens, as beneficial for most foundry sands. A four screen distribution is usually preferred.

There are exceptions. The silica flour sand of Frame 70 is a two screen sand, but has advantages when there is extreme metal penetration.

A four screen sand means that at least 10% of the sand grains are caught on each of _____ screens.

four

(76)

There are definite limitations to filling voids with finer materials. Decreased ability to vent gas is one. Poor thermal stability and collapsibility can also result.

Therefore, the smallest amount of _____ filling materials should be used over that of a normal 4 screen sand.

void

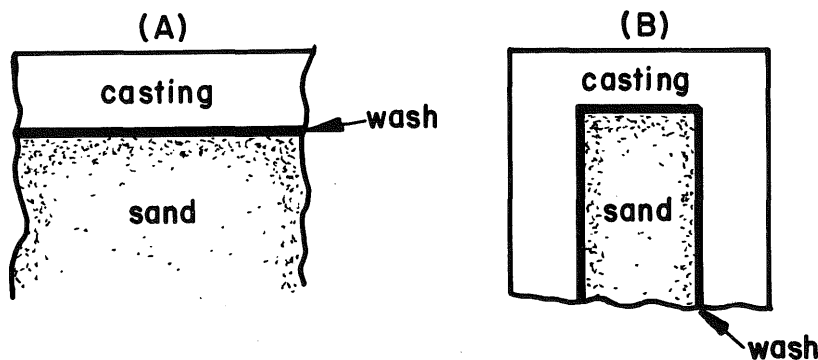
(77)

A "wash" or coating is often used to fill the surface voids and seal the surface. "Washes" are made of small particles of graphite, silica flour, zircon, or other refractory (heat resistant) materials. The particles are suspended in water, alcohol, or other liquids so they can be sprayed, or brushed onto mold surfaces. Some washes must be dried to remove the suspending liquid before molten metal is poured into the mold. See Fig. 3, Appendix C, p A-6.

(78)

Washes are very effective in giving smoother casting surfaces. However, at areas susceptible to severe metal penetration washes should be backed up with a dense sand. In such areas metal will penetrate any crack or bubble in the wash and penetrate the voids in back of the wash. See Fig. 4, Appendix C, p A-6.

On which surface would washes be more effective using a large grain sand? _____



(79)

Let's review Frames 52-78 from a very practical standpoint.

The major *sand* factor affecting metal penetration and gas defects is v_____ s_____.

(80)

There are only three chief sand factors that influence void size.

They are g_____, s_____, g_____ d_____, f_____.

(81)

Complications arise due to nonsand factors, as follows:

- (1) Temperature and depth of sand heated to above the melting point of the metal, as affected by:
 - a. Shape of casting and sand areas.
 - b. Metal temperature.
 - c. Superheat. The temperature above the melting temperature of the metal.

cont'd

(A)

void size

grain size
grain distribution
flowability

- d. Special sands like zircon, olivine and chromite are effective in certain applications because they take longer to heat up.

(2) Metal Pressure.

The two chief nonsand factors affecting penetration and gas are temperature of the sand surface and metal pressure

temperature
metal pressure

(82)

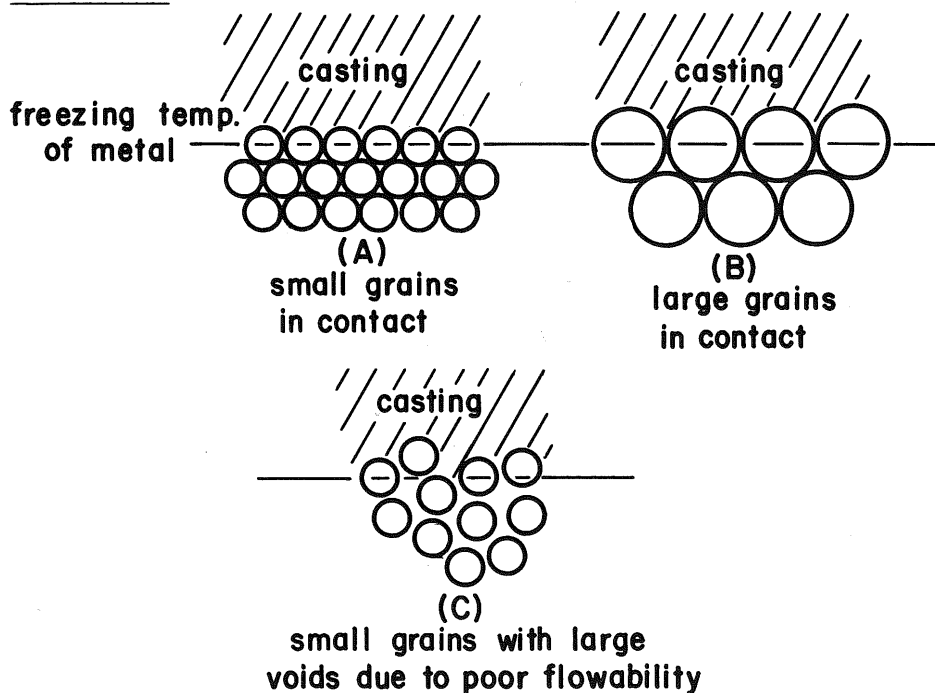
If only the surface of the sand next to the casting is heated to above the melting temperature of the metal, only surface roughness, or slight penetration will occur. Penetration stops immediately when the metal starts to freeze (Fig. 5, p A-6). This type of penetration is most usually found in outer casting surfaces.

Which of the sands will make the roughest casting surfaces?

(C)

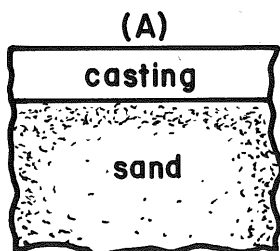
Which of the sands will make the smoothest casting surfaces?

(A)

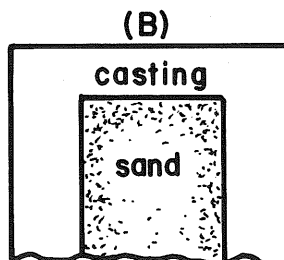


(83)

In the following illustrations:



compare with A of Fig. 6, p A-7



compare with B of Fig. 6, p A-7

cont'd

Which sand mass will heat faster and to a greater depth?

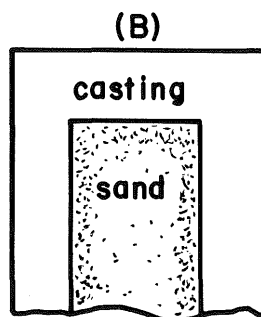
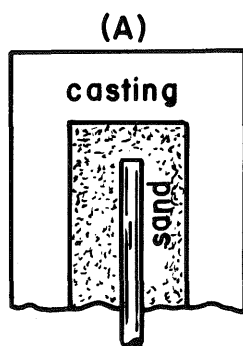
Which sand mass is more susceptible to deep metal penetration,
as much as several inches? _____

Which sand mass is more apt to evolve gas into the casting?

(84)

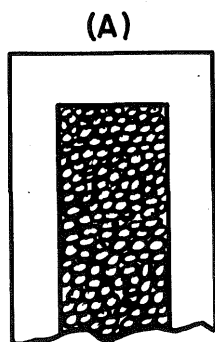
One way to overcome the problem of Frame 83 is to form artificial passages called "vents" to "vent" the gas through dense sand.

Which sand is _____ so gas can escape without building up
excessive pressure that would force the gas through the metal?

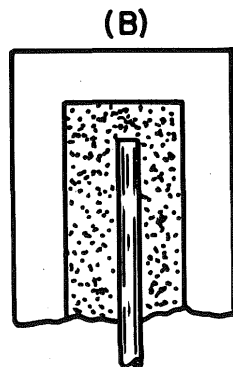


(85)

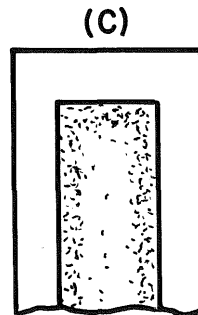
If the problem is both *penetration* and *gas defects*, which would
be the best solution? _____



large
grains



medium grains;
vented, 30%
silica flour



small
grains

(86)

Poor venting or too small void size can cause excessive gas
pressure in the molding sand. This excessive pressure can cause
three types of defects as illustrated in the next frame.

Excessive gas pressure in the molding sand, due to poor
_____ and/or too _____ (small/large) voids can
cause _____ types of defects in the casting.

(B)

(B)

(B)

vented

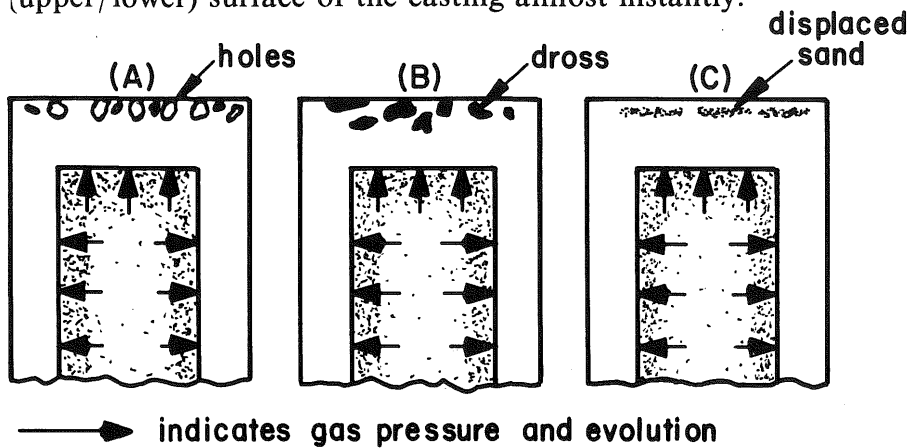
(A)

(B)

venting
small
three

(87)

Study the following illustrations carefully. You will note that due to the gas being lighter than the metal it floats to the _____ (upper/lower) surface of the casting almost instantly.



Gas holes: if metal stays liquid long enough the gas will bubble through the metal and escape, reacting with the metal to form a solid dross or slag. In extreme cases gas pressure is high enough to blow off the top surface forming gas pressure scabs.

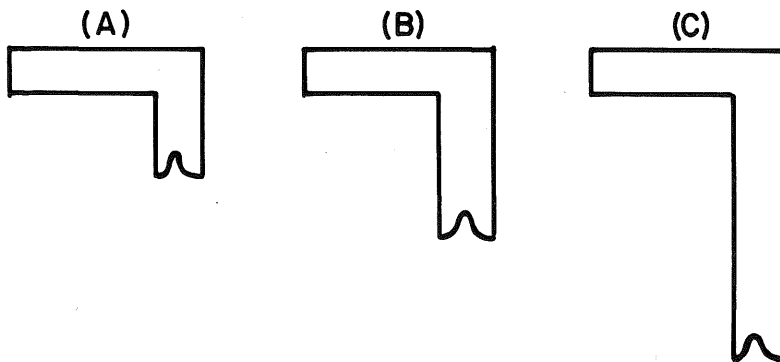
upper

(88)

Metal pressure is another major affecting penetration and gas defects, and is determined by the height of metal in the mold.

Which of the three castings is most prone to bad metal penetration and adhering sand? _____

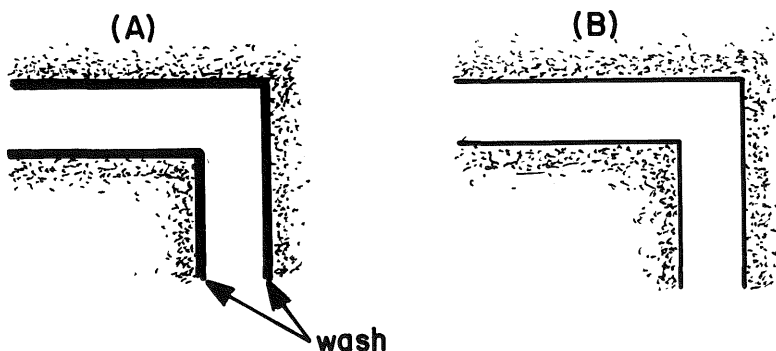
(C)



(89)

Which sand surface will normally produce the smoothest casting surface? _____

(A)



(90)

A number 70 AFS Fineness Number sand denotes a sand with an _____ grain size equal to a _____ mesh screen.

average

(91)

A number 70 AFS Fineness Number denotes a grain size _____ (smaller/larger) than a number 40 AFS Fineness Number.

smaller

(92)

An AFS 50 sand has grains _____ (smaller/larger) than an AFS 100 sand.

larger

(93)

A sand with a _____ (number) screen distribution is usually preferred over a sand concentrated on _____ screens.

four
fewer (or less)

CLAY BONDED SANDS

(94)

The preceding Sections dealt with the more simple conditions when the bond did not interfere to any extent with compaction. The discussion was basic and applies to all sands, core sands as well as molding sands.

When a clay type bond is added to stick the sand grains together, compaction is restricted and the individual grains are not compacted as closely as under the conditions of the preceding section.

(95)

A measure of the void size in bonded sands is permeability. Permeability is the ability to allow gas to flow through sand and is determined by measuring the amount of air that will pass through the compacted sand under standard conditions. The larger the permeability number the larger the voids, and ability to vent gas is better.

Which is the sand with the larger voids? _____

(b)

- (a) 150 permeability
- (b) 320 permeability
- (c) 40 permeability

(The range 40 to 150 covers most production molding sands.)

(96)

The very dense sands of Section II, that are sometimes used to resist penetration have almost zero permeability.

These dense sands must be used with care because of their poor ability to v_____ gas, their poor t_____ s_____ and their poor c_____.

vent
thermal stability
collapsibility

(97)

Four types of bonding clays are most widely used in the United States:

western bentonite — chemically a sodium aluminum silicate. The mineralogical name is sodium montmorillonite.

southern bentonite — chemically a calcium aluminum silicate — calcium montmorillonite.

plastic fire clay — *kaolin clay* — an aluminum silicate with a similar, but larger structure than the bentonites.

illite clay — similar to kaolin clay.

The term “clay bond” is used to denote any of these clays, or a mixture of these clays. The term is also used to denote a bond containing nonclay materials if the clay is the predominant material.

(98)

It is generally agreed that southern bentonite promotes better shakeout properties than western. That is, lumps present when the sand is removed from the castings break up easier if bonded with southern bentonite, or a mixture of southern and western bentonite.

Southern bentonite usually improves _____ properties.

shakeout

(99)

The bentonites have about replaced the fireclays as the primary bonds in American molding sands.

One reason is the greater bond strengths of the bentonites. Compaction (ramming) must be controlled more closely with fireclay bonded sands. These fireclay sands are easily “overrammed” to high compaction and are susceptible to expansion spalling (See Frame 32). Bentonite bonded sands are more difficult to “over ram.” Fireclay is, however, used many times in conjunction with bentonite.

The bentonites resist “o_____ r_____” better than fireclay.

over ramming

(100)

In addition to the basic bentonite bonds, other additions are made to the molding sand for specific applications. Some of the more common additions are listed. Specific applications will be discussed later.

Seacoal

Pitch

Cereal (corn flour) — Dextrin — Lignin Pitch

Cellulose materials

Wood flour

Ground corn cobs

cont'd

Oat hulls
Flax seed hulls
Iron oxide

Many other proprietary materials of unknown composition that are sold by trade names are also used.

(101)

The most important addition is water. Water is absorbed by all binders and is particularly important in the control of bentonite and fireclay bonds.

Many times it is advantageous to consider percentage of water in the bond rather than percent water in the molding sand as a whole. This is done as follows:

$$\text{Percent water in bond} = \frac{\% \text{ water in sand}}{\% \text{ bond in sand} + \% \text{ water in sand}}$$

(102)

Percent water in the bond, as calculated in Frame 101 will be used a lot in the discussion to follow. One advantage is simplification. If water in the sand is used in the discussion, different water contents must be considered with every change in the bond material.

If a molding sand contains 10% bond and 4% water, what is the water content of the bond. (See Frame 101 for equation).

- (a) 28.6%
- (b) 21.2%
- (c) 32.0%

$$\frac{.04}{.10 + .04} = .286 \text{ or } 28.6\%$$

(a)

(103)

There is a sudden and drastic change in all clay bonds from a moist, brittle powder to a plastic putty, or gel at a critical water content of the clay bond. When sands are bonded with clays of this critical water content, the sands are said to be at their "temper point."

At the temper point of the sand the clay bond changes from a brittle, moist powder to a p_____ putty or gel.

plastic

(104)

The change from a moist, brittle powder to a plastic putty or gel occurs at different percentages of water for the various clays. The following chart indicates these percentages.

	western bentonite	southern bentonite	kaolin fireclay
brittle, moist powder	less than 27% water	less than 30-32% water	less than 15-16% water
plastic gel	over 27% water	over 30-32% water	over 15-16% water

(105)

New western bentonite would be considered a plastic putty if it contains _____ water.

- (a) 20% water
- (b) 32% water
- (c) 22% water

32%

(106)

The strengths of the clay bonds are highest at the critical water contents of Frame 104. Molding sands bonded with these clays will show the highest green (undried) strengths.

High clay bond strength causes h_____ strength of the bonded sand.

high

(107)

If the clay bond on the sand grains contains less than the critical water contents of Frame 104 and is brittle, sands bonded with this clay bond will also be brittle.

A molding sand bonded with new western bentonite containing 23% water will be _____.

brittle

(108)

Another property of clay bonds to be considered is that of adhesion or stickiness. As water increases much above the critical point, strength of the clay bond decreases rapidly. At the same time stickiness or adhesion increases just as rapidly, which becomes a major factor preventing sand grains from flowing past each other.

The adhesion of western bentonite _____ with increasing water contents over about 27% while the strength _____ (increases/decreases)

increases
decreases**(109)**

We must now consider a series of compromises and balances in order to obtain the best sand to make the best mold.

If the water content of the clay bond is under the critical percentage of Frame 104, the sand will be flowable because adhesion is low. Strength will be high, but the clay bond and the sand will be brittle.

A sand bonded with new western bentonite containing 25% water _____ (will/ will not) be flowable, but _____ (will/ will not) be brittle and have little adhesion.

will
will**(110)**

Secondly, if the water content of the clay bond goes over the critical percentage (27% for new western bentonite) brittleness decreases rapidly along with the strength. Therefore, resistance to over ramming decreases and the ensuing grain to grain

compaction may cause expansion scabbing.

New western bentonite containing 35% water will make a molding sand that can be easily o_____ r_____

over rammed

(111)

Third, as strength decreases, stickiness increases which decreases flowability. Therefore, a sand bonded western bentonite containing 35% water will have poor f_____.

flowability

(112)

When molds are compacted (made) by the usual molding machine (especially by squeezing) most force is exerted on flat, horizontal surfaces. The force causing compaction is much less against vertical surfaces and the least in pockets of the mold. See Fig. 7, Appendix C, p A-7.

Vertical surfaces are compacted l_____ than horizontal surfaces, and pockets are compacted the l_____.

less
least

(113)

"Sticky" clay bonds with high water content resist compaction when the compaction force is low, similar to that force which is against vertical surfaces and pockets.

Clay bonded sands containing too much water may show large v_____ and generally uneven p_____ in vertical surfaces and pockets.

voids
pockets

(114)

"Sticky" sands with high water contents have low strength clay bonds. This may allow too high a compaction on flat horizontal surfaces, where compaction force is high, which may lead to expansion defects, like expansion scabs, especially if the clay content is low.

Clay bonded sands containing too much water may also cause e_____ defects on flat horizontal surfaces.

expansion

(115)

It is evident that a rather precise balance between b_____ due to too low bond water content and poor f_____ due to too high water content is needed to make the best molds and the best castings.

brittleness
flowability

(116)

There are supplementary bonds (to be discussed later) that will decrease the tendency toward expansion defects if the bond water is increased to give a less brittle, more workable sand. However, there is little that can be done to decrease "stickiness" and poor flowability, except lower the water content.

(117)

When percentage of water in the bond is translated into the percent of water in the bonded sand, the amount of bond must be taken into consideration.

For example, if the bond contains 30% water, a sand containing 10% of the bond will check 4.2% water. A sand containing 15% of the same bond will check 6.4% water.

(118)

The critical bond water contents of Frame 104 can be translated into water contents of the sands containing different amounts of clay. *These values apply only to new clay.* The best combination of properties for best moldability occurs at *just above* the critical water contents given below.

% new clay bond in sand	% water in sand to give 24-16% water in kaolin fireclay	% water in sand to give 25-30% water in western bentonite	% water in sand to give 30-32% water in southern bentonite
5	0.8-1.0	1.7-2.1	2.1-2.4
10	1.6-1.9	3.4-4.3	4.2-4.8
15	2.4-2.9	5.0-6.4	6.4-7.0
20	3.3-3.8	6.7-8.6	8.6-9.5

With the water contents *just above* the critical range, which would be the best molding sand containing 10% southern bentonite? _____

- a. 5.0% water b. 4.0% water c. 6.0% water

a.

(119)

Most production sands do not contain all new clay bond, but also contain a mixture of heated (dehydrated) clay and used supplementary bonds. These materials do not absorb as much water as new clay. Therefore, the optimum water contents will be lower than those of Frame 118.

Production molding sands are usually bonded at a bond water content _____ than required for new clays.

lower

(120)

An average for many reused, production system molding sands that are rebonded with bentonite after each use is 20-25% water in the AFS clay. AFS clay is the amount of all materials in the sand with particle sizes under 5 microns. (See AFS Sand Testing Handbook for methods of determining AFS Clay).

The optimum water content of the AFS clay bond in many, but not all production sands, is _____ to _____ percent.

20
25

(121)

The optimum water content for any given foundry will depend not only on the composition of the sand, but also on pattern and molding equipment. A very important factor is tradition — what the molders are used to.

The percent water in the AFS clay is an important sand factor and should be determined constantly. If the water and AFS clay percentages are known, the water content is easily determined by the equation in Frame 101.

A sand containing 4.5% water, 14.2% AFS clay will have what water content in the AFS clay? _____

- a. 28%
- b. 20%
- c. 24%

$$\frac{.045}{.142 + .045} = .238 \text{ or } 24\%$$

c.

(122)

The 20-25% water content in the AFS clay translates into the following sand water contents for these particular AFS clay contents.

<u>% AFS clay</u>	<u>% water in Sand to give 20-25% Water in AFS Clay</u>
5	1.3 - 1.7
10	2.5 - 3.3
15	3.7 - 5.8
20	5.0 - 6.6

Study the preceding relation. The higher the AFS clay content, the allowable water range becomes _____ (greater/smaller). This point is of major importance.

greater

(123)

Two very important points have just been discussed.

First, high bond (clay) contents allow for high water contents. *Moldability depends primarily on the water content of the bond, not on the water content of the sand.* Low bond, low water sands have a number of disadvantages, as well as advantages. One disadvantage is excessive drying out of the sand and the mold surfaces.

Water content of the _____ is not as important as the water content of the _____ in regards to moldability.

sand
bond

(124)

Secondly, the higher the bond (clay) content, the wider can be the range of water content and still hold the same range in bond water content. In many instances, unless the ultimate in sand control is exercised, increasing the amount of additions that absorb water is justified only for control purposes.

(It should be emphasized that this viewpoint is new and is controversial.)

The range in water content for consistent moldability is w_____ as the bond content increases.

wider

(125)

AFS clay is seldom determined frequently enough for production moldability control. A fair, but not perfect, control is possible by using water-green compression strength ratios. These are determined by dividing percent water in the sand by the strength of the green (undried) sand in compression. These are standard, frequently determined tests.

Green compression strength is used as a rough measure of the bond and other water absorbing materials in the sand, *if* mulling is consistent.

(126)

Water-green compression strength ratios throughout the industry vary widely. However, in a particular foundry they are and can be held to fairly close limits and indicate percent water in the bond. Some examples follow:

	% water-green compression strength
production iron sands, castings under 50 lb.	0.15-0.20
production iron sands, larger castings	0.25-0.30
production iron sands, large castings	0.30-0.35
traditional steel sands	0.40-0.50
new production steel sands	0.25-0.30

Water-green compression strength ratios are important in process control as they measure percent _____ in the _____.

water
bond**(127)**

With consistent mulling, green compression strength can be used as a measure of the bond plus other water absorbing materials that are included in the AFS clay. High green compression strength allows a wider range in water for consistent moldability and the ability to consistently make good molds.

Green compression strength can be used as a measure of the bond providing the mulling is _____

consistent

(128)

The preceding ratios between water and bond, although very important, only determine the composition variables. There are other variables affecting moldability. One is how the sand is mixed or mulled. Direct tests are needed to back up the water bond ratios discussed in previous frames.

Tests for compactibility that have just been advanced show great promise in overall control in production. One of the more important determines the amount a sand compacts after it has filled a given space. (See ref. 10)

(129)

It is fortunate that thermal stability, collapsibility, and shakeout requirements do not conflict greatly with the moldability requirements just discussed. Moldable sands usually perform well when in contact with molten metal.

The performance of the sands in contact with molten metal will be discussed in the section to follow.

REVIEW QUESTIONS

(130)

The addition of a clay bond _____ (increases/decreases) ease of compaction.

decreases

(131)

When the sand grains are not compacted to maximum density, void size can be measured by _____. (permeability/tensile)

permeability

Ed Note: Frame (132) is inadvertently omitted. No sequence of information is lost; continue to Frame (133).

(133)

What are the names of the most commonly used clay bonds?

1. _____
2. _____
3. _____

western bentonite
southern bentonite
fire clay
(in any order)

(134)

One advantage of the bentonites over the fireclays is their greater _____.

bond strength

(135)

Southern bentonite differs from western bentonite in its _____ ability.

shakeout

(136)

The most important addition to a clay bonded sand is _____.

water

(137)

Using the equation for percent of water in the bond:

% water in the bond =

% water in sand

% bond in sand + % water in sand

What is the % water in the bond if a molding sand contains 12% bond and 4.8% water? _____

- (a) 28.6%
- (b) 32.0%
- (c) 25.2%

(a)

$$\frac{.048}{12 + .048} = .286 \text{ or } 28.6\%$$

(138)

If the water content of the bond is under the critical amount, as determined with the equation of Frame 137, the molding sand will be _____ (brittle/strong).

brittle

(139)

Strength of the bond and sand is _____ (lowest/highest) at the critical, or temper point.

highest

(140)

When water content increases above the temper point, bond strength _____ (increases/decreases).

decreases

(141)

The decrease in strength of the bond above the temper point is accompanied by an _____ in stickiness or adhesion.

increase

(142)

If the water content of the bond is too high there is danger that the sand bonded with this bond will cause expansion defects on f_____ h_____ surfaces where molding or compaction pressure is _____ (high/low).

flat horizontal
high

(143)

This same sand may make rough surfaces in vertical surfaces and in p_____ where the molding or compaction pressures are _____ (high/low).

pockets
low

(144)

A high percentage of bond will allow a _____ (higher/lower) water content than a low bond content. Such sands will not d_____ o_____ as fast as lower water sands.

higher

dry out

(145)

A high percentage of bond will allow a greater r_____ in water content for the same bond water content.

range

(146)

The important factor affecting moldability is b_____ water content, not the water content of the sand.

bond

(147)

The optimum water content of used bonds is _____ (higher/lower) than for new clay bonds.

lower

(148)

AFS clay is used to estimate the water absorbing materials in the sand. Many production sands containing used bond have an optimum water content of _____ to _____ percent in the AFS clay.

20-25

(149)

Another production control test for bond water content is a ratio between percent w_____ divided by g_____ c_____ s_____.

water

green compression strength

SUPPLEMENTARY BONDS

(150)

Bonds or additions to supplement the basic clay bonds are added to molding sand in some instances to improve moldability. In other instances the additions are made to improve the behavior of molding sands when subjected to molten metal — “thermal behavior” of the sand.

Some supplementary bonds are added in an effort to improve both moldability and thermal behavior.

(151)

Let us first review the various aspects of thermal behavior and expand the discussions of the preceding Sections.

There are three types of scabbing defects due to three entirely different types of thermal behavior. These different scabbing defects must be distinguished because the causes and cures are different.

It is always necessary to define the type of scabbing to prevent confusion as to the c_____ and c_____ of the particular defect.

cause
cure

(152)

First — *Expansion, Scabbing, Rat Tailing, Cope Spalling* are due to expansion of the mold surface when exposed to or contacted by liquid metal. The continued expansion forces that cause the mold surface to lift up must be greater than the strength of the sand for this type of thermal behavior to occur. (see Frame 32 and Fig. 8) Pure expansion defects occur mostly on large flat mold surfaces which can be horizontal or vertical.

Expansion scabbing is due to e_____ of the mold surface and occurs first on l_____ f_____ surfaces.

expansion
large flat

(153)

The cures for expansion scabbing are to compensate for the expansion or increase the strength of the mold surfaces so it does not fail under stress. There are a number of ways of doing this.

Many foundrymen provide room for the sand grains to e_____ so stresses are not built up in the mold surface.

expand

(154)

Second — *Gas Pressure Scabbing* is almost always seen in the top surfaces of sand masses extending into the metal and surrounded by metal. The cause and cure are entirely different than for expansion scabbing. The cause is gas pressure high enough to blow away the sand surface. (See Fig. 9, Appendix C, p A-9)

The cure for gas pressure scabbing is low gas content of the sand and venting, either by larger v_____ between the sand grains, or by artificial v_____ as discussed in previous sections, thus allowing the gas to escape to the atmosphere.

voids
vents

(155)

Third — *Erosion Scabbing* occurs in areas where the velocity of the liquid metal is high or where liquid metal must change direction abruptly. These areas are called areas of high liquid metal turbulence. (see Fig. 10, Appendix C, p A-9)

A combination of expansion and erosion scabbing occurs where the flow of the metal covers and uncovers a sand surface.

Erosion scabbing usually occurs at areas of high metal t_____.

turbulence

(156)

The cures for erosion scabbing are materials that bond at high temperatures or bonds that flux and hold the sand grains

together at high temperatures. Bentonite is a good high temperature bond. High bentonite contents are advantageous for both moldability and thermal stability.

Bentonite is beneficial in expansion and erosion scabbing as it allows for e_____ and also acts as a h_____ t_____ bond.

expansion
high temperature

(157)

It is theoretically possible for moving liquid metal to erode a sand surface, grain by grain, but not to the degree of forming a definite scab.

This type of sand failure is hard to pin down. The turbulence needed to cause this erosion also forms metal drosses or slags. Defects that have been blamed on erosion sand almost always show more dross than sand grains.

(158)

If erosion, not scabs, is suspected, the cure would be high temperature bonds and increased compaction. The compaction must be controlled so that scabs are not produced.

Erosion can be decreased by h_____ t_____ bonds and controlled c_____.

high temperature
compaction

(159)

Collapsibility has been discussed in previous frames, however, supplementary additions will be discussed in this section which are added to the sand to promote collapsibility.

By adding supplementary bonds to the sand we can promote _____ and reduce the possibilities of hot cracking or hot tearing.

collapsibility

(160)

Some supplementary bonds are added to improve "peel", that is to decrease adhesion of sand to the castings.

Grain size control and materials to fill the voids like silica flour, seacoal and fire clay are still the major factors in decreasing sand adhesion.

(161)

The most widely used supplementary bonds or additions are the carbonaceous materials that contain large amounts of carbon and hydrogen. Some of these materials are:

Seacoal (soft coal) gilsonite pitch

These materials form tarlike compounds when heated that act as high temperature bonds.

Seacoal, gilsonite and pitch form t_____ like compounds that become h_____ t_____ bonds when the sand is heated.

tar
high temperature

(162)

Seacoal and its carbonaceous relatives are used almost exclusively in gray iron, ductile iron and to a lesser extent in malleable iron sands. They are seldom used in steel sands due to a reaction between these high carbon materials and low carbon steels causing poor casting surfaces. They are used in a few nonferrous sands.

Seacoal, gilsonite, pitch are used mostly in i_____ sands.

iron

(163)

One of the theories of the behaviour of carbonaceous materials is this:

These materials improve surface finish and they also form reducing gasses when heated by the molten metal. All metals react with the oxygen in the mold cavity to form oxide drosses (slags) that may cause casting defects. The reducing gasses, formed by the carbonaceous materials, will react with at least some of the oxygen, thus leaving less oxygen available to react with the molten metal.

The reducing gases formed by seacoal d_____ dross formation and therefore fewer casting d_____ may result.

decrease
defects**(164)**

The reducing gasses formed when seacoal is heated also decrease the reaction between the carbon and hydrogen in the iron and oxygen which form gas holes in the metal called pinholes.

This seems particularly important with ductile iron. Seacoal contents, as measured by loss in weight on ignition in air at 1600-1800°F, as high as 10% are used to decrease pinholes in ductile iron.

Seacoal is used to prevent a reaction between the i_____ and o_____ in the air which can form p_____.

iron
oxygen
pinholes**(165)**

Seacoal contents in gray iron sands are usually lower, 2 to 8%. It is sometimes claimed that too high percentages of seacoal create so much gas that it hinders metal filling the mold. This causes misruns and rounded corners.

Too high seacoal may cause _____ and _____.

misruns
rounded corners**(166)**

The tarlike products formed when carbonaceous materials are heated are sticky and are good high temperature bonds. Therefore, resistance to both expansion and erosion scabbing is increased. Mold wall movement and strains are also decreased.

Seacoal breaks down into tarlike h_____ t_____ bonds that _____ (increase/decrease) favorable thermal behavior.

(167)

Pitch is used mostly in sands used to make large castings. The molds are dried after the pattern has been removed and the strength of the clay bonded sand increases drastically; 2, 10 or 20 times. Pitch further increases dry strength with an improvement in thermal behavior.

Drying the molds and adding pitch to the molding sand greatly improves t_____ b_____ and increases s_____

(168)

For a given amount of thermal expansion, resistance to expansion and erosion spalling of dried mold surfaces increases many times over the resistance of undried surfaces due to the increase in strength in the dried molds. Mold wall rigidity, resistance to mold wall movement and straining also increase

Pitch further increases dry strength. These high strengths are the chief reason pitch and dried molds are used for _____ (large/small) castings.

(169)

There have been claims that carbonaceous materials, like seacoal, act as lubricants and increase flowability. This claim has not been verified.

(170)

Other materials or additives which can be used to help overcome expansion problems are the cereals.

The cereal binders are grain flours made from corn, milo or wheat. Corn flour is by far the most widely used. Cereal binders are used in practically all steel molding sands in amounts from 0.5 to 1.5% by weight. They are used to a lesser extent in iron sands and nonferrous sands, but can be advantageous in all molding sands.

(171)

It has been established that cereal is about the most potent "anti scabber" of the common sand additions (additions of 0.5 to 1.5% are usually used). See Ref. 16.

Cereal additions of 0.5 to 1.5% are widely used to _____ (increase/decrease) resistance to expansion and erosion scabbing.

high temperature
increase

thermal behavior
strength

large

increase

(172)

The reason cereal is so widely used in steel foundry sands is the high water content of the bentonite used in these sands. A typical steel molding sand contains 6% bentonite, 3.5% water. The bentonite contains 36.8% water and is quite wet, weak and sticky. The sand would be susceptible to scabbing if no cereal is used. A cereal addition of 1.0% eliminates scabbing but the sand is sticky and is hard to compact (ram).

Cereal is used in many steel molding sands to increase resistance to _____ with _____ water bentonites.

scabbing
high

(173)

A combination of high bond water and cereal has given cereal an undeserved reputation for making "sticky", low flowability sand. If cereal is used with lower bond water sands, thermal stability is further increased along with good flowability.

Cereal decreases flowability only with _____ bond water contents.

high

(174)

The reason cereal imparts scabbing resistance to weak high water clay bonds, seems to be a property best described as resilience or springiness. The bond becomes "spring" and it can be theorized that a resilient bond is difficult to overram.

Cereal seems to impart _____ to a clay bond which theoretically prevents overramming.

resilience or
springiness

(175)

Cereal or corn flour must be distinguished from dextrin, a close relative. Dextrin does not give resilience to a sand is therefore not as effective in decreasing expansion and/or erosion scabbing.

Dextrin causes hard mold surfaces even on air drying. It has been difficult to establish any improved thermal behavior due to these hard mold surfaces. Lignin pitches, wood fiber by-products, are similar to the dextrines.

Dextrin _____ (does/does not) improve resistance to expansion scabbing as much as the cereals.

does not

(176)

Another group of additives are the cellulose materials which include wood flour, flax seed hulls and ground corn cobs. These materials are claimed to improve moldability, thermal stability and collapsibility.

Wood flour, oathulls, ground corn cobs and flaxseed hulls are part of an additive group called c_____ materials.

cellulose

(177)

Cellulose materials seem to absorb water and act as tiny water reservoirs. The improvement in moldability seems to be due to lower bond water content for a given overall water content of the sand. The lower bond water content will improve flowability.

The increase flowability attributed to cellulose materials seems due to their ability to a_____ w_____.

absorb water

(178)

The ability of the cellulose materials to absorb water may mean that they will release water slowly to the clay and therefore decrease drying out.

Cellulose materials are added in percentages of 1% to 5%. One objection to these materials is the increase in gas forming materials in the mold when it is poured.

An objection to high cellulose contents is that they f_____ g_____ when the sand is heated by molten metal.

form
gas

(179)

Improved collapsibility is claimed when cellulose materials are present in the sand, as well as improved resistance to expansion scabbing. The claims are based on these materials burning out, allowing for sand expansion, followed by the ability to accommodate metal contraction in hot tearing temperature range. There is no formal proof to support these claims.

The claim or theory for improved thermal behaviour of sands containing cellulose additions is based on these materials b_____ o_____ and leaving space between the sand grains.

burning out

(180)

Powdered iron oxide is sometimes added to molding sands. This addition is more applicable to the low clay core sands where it will sinter or flux and act as a high temperature bond under proper conditions. It is questionable if iron oxide is needed in molding sands in the presence of bentonite that also sinters.

Iron oxide and similar materials that sinter or flux when heated by molten metal are of greater use in c_____ s_____ than in m_____ sands.

core sands
molding

(181)

There are a number of other additions that are being promoted at present. Most are very costly in relation to the additions just discussed. So little is known as to what they will do that they can only be listed.

Tetra Sodium Phosphosphate
Sodium Acid Pyrophosphate
Carboxyl Methyl Cellulose
Poly-acrylates

There are also many proprietary materials used in the foundry whose composition is unknown. There is no way to discuss these materials in general terms.

(182)

Mention must also be made of the nonsilica sands:

Zirconium silicate

Chromium oxide (chromite)

Olivine (magnesium silicate)

These materials absorb more heat than silica sand when heated by molten metal. Therefore, they heat to above the freezing temperature of the metal slower than silica sand, and resist metal penetration to a greater degree.

The nonsilica sands resist penetration better than silica because they _____ (do/do not) heat up as fast as silica.

do not

(183)

A limitation to the nonsilica sands of Frame 182 is not generally recognized. The higher specific heat makes these materials mild chills, as they can absorb more heat than silica sand. However, if the metal sand ratio is high and these sands are heated to above the freezing temperature of the metal before the metal freezes, they are subject to penetration just like silica sand.

The nonsilica sands are subject to p_____ just like silica sand if the metal sand ratio is too h_____.

penetration
high

(184)

The nonsilica sands of Frame 182 do not expand as much as silica when heated. Therefore, they _____ (should/should not) be more resistant to expansion scabbing as compared to silica sand.

should

(185)

The nonsilica sands have higher sintering temperatures than silica. Therefore, they do not form high temperature bonds as well as silica and may be more susceptible to e_____.

erosion

(186)

A minor advantage, applicable only to certain metals (steel is one), is that the nonsilica sands are not "wetted" as readily by metal oxides that may form. This wetting is similar to flux "wetting" when soldering and may promote penetration, but only if the major factors, void size and pressure, favor penetration as discussed in the first section.

REVIEW QUESTIONS

(187)

Scabs associated with flat surfaces are due to e_____ stresses exceeding the s_____ of the sand surface or the sand immediately in back of the surface.

expansion
strength

(188)

Scabs occurring in top surfaces of sand masses extending into the metal are due to excessive g_____ p_____

gas pressure

(189)

Scabs at areas of high metal velocity and turbulence are due to lack of sufficient h_____ t_____ b_____ as well as excessive e_____.

high temperature bond
expansion

(190)

Bentonite is an effective addition to decrease d_____ slightly and can therefore decrease e_____ scabbing.

density
expansion

(191)

Bentonite is also a good high temperature bond and decreases e_____ scabbing.

erosion

(192)

Most fireclays have quite high sintering or fusion temperatures. Therefore, they are not as effective in decreasing e_____ scabbing as the bentonites.

erosion

(193)

Carbonaceous materials generate r_____ gases when heated by molten metal.

reducing

(194)

These reducing gasses decrease oxidation of the metal surface during pouring of the mold and therefore, decrease defects due to d_____.

dross

(195)

These reducing gasses also reduce, but do not eliminate p_____ defects, particularly in ductile iron.

pinhole

(196)

Too high carbonaceous materials in the sand may cause m_____.

misruns

(197)

Carbonaceous additions form tarlike compounds when heated that are good h_____ t_____ bonds.

high temperature

(198)

Carbonaceous materials are used mainly in i_____ sands and are seldom used in s_____ sands.

iron
steel

(199)

Drying the mold after it is made increases the s_____ of the mold surfaces many times.

strength

(200)

A strong mold surface increases resistance to e_____ scabbing as well as e_____ scabbing and m_____ w_____ movement.

expansion
erosion
mold wall

(201)

Cereal additions are potent additions to decrease ex_____ scabbing as well as the combination of ex_____ - er_____ scabbing.

expansion
expansion-erosion

(202)

Cereal binders are effective in preventing expansion scabbing with h_____ w_____ clays.

high water

(203)

The combination of cereals and h_____ water in the clay bond causes poor f_____.

high
flowability

(204)

Dextrin does not decrease ex_____ s_____ as well as cereal.

expansion scabbing

(205)

One beneficial effect of cellulose materials is their ability to a_____ w_____.

absorb water

(206)

The claim for better flowability due to cellulose materials in molding sand is due to a d_____ in clay content.

decrease

(207)

The claim for decreased expansion scabbing and improved collapsibility is based on the cellulose materials b_____ out and leaving v_____ between the sand grains.

burning
voids

(208)

The nonsilica sands have two chief advantages:

They absorb more h_____ than silica sands and therefore, resist p_____ better than silica sands.

heat
penetration

(209)

Nonsilica sands also expand to a lesser degree than silica sand. Therefore, they *should* resist ex_____ s_____ better than silica sand.

expansion scabbing

(210)

The nonsilica sands do not form high temperature bonds as well as silica sands because they have higher sintering temperatures, therefore, they *may* be more prone to _____ (erosion/expansion) scabbing.

erosion

MIXING, MULLING OF MOLDING SAND

(211)

It is generally agreed that in addition to mixing, some type of mulling that applies pressure is required to coat sand grains with the puttylike bonding additions used to bond molding sand.

Mulling pressure is applied by wheels revolving against the slides or bottom of a container. Plows revolving above the same axis as the wheels are used to mix the sand and binders.

(212)

However, the most ardent advocate of mulling must admit that millions of tons of saleable castings have been produced with molding sands that were prepared by only mixing the sand, bond and water.

Therefore, it is possibly advantageous to _____ molding sand, but mulling _____ (is/is not) absolutely necessary in all cases.

mull
is not

(213)

There are number of mixers that do not mull. These mixers are usually used to introduce limited amounts of bond and water to system sands.

Bonding of new or reclaimed sands usually requires the pressure applied by mulling. This is especially true if the bond is western bentonite.

(214)

The three most popular types of mullers differ mainly in speed. Two use muller wheels revolving about horizontal axles at a relatively low speed. The third uses muller wheels revolving about essentially vertical axles at a higher speed.

All types produce equivalent sands when time and horsepower are taken into consideration. Any advantages of high speed mulling should be considered in relation to the simpler controls possible with lower speed.

Muller types differ mainly in _____ and produce sands of _____ properties.

speed
equivalent

(215)

There are two schools of thought regarding mulling. One advocates "adequate" mulling to obtain maximum benefit from relatively small bond additions.

The other schools consist of a few foundrymen advocating less mulling, more bond. There are many involuntary members of this latter group; those foundrymen who have no mullers or those with insufficient muller capacity.

(216)

"Adequate" mulling is usually determined by taking samples at intervals from the muller. Green strength increases with mulling time. The time when green strength levels off and does not increase appreciably with time is considered "adequate."

Mulling is usually measured by g _____ s _____ and when it stops increasing the mulling is considered a _____.

green strength
adequate

(217)

One advantage of adequate mulling is lower bond cost. A possible disadvantage is more accurate control needed of both bond and water.

The advocates of "under mulling" and higher bond contents claim the advantages of greater allowable ranges of bond and water for equal control offsets the higher bond cost.

Higher _____ content allows a greater range in _____ for equal moldability.

bond
water

(218)

Most illustrations in the literature that show or allude to uniform coats of clay bond on sand are in error. Any practical mixing or mulling gives a very nonuniform coating of the puttylike clay bonds on sand grains. The bond is present as spots and rings or in coatings of varying thickness.

Production mulling does _____ produce uniform coatings of bonds on the sand grains.

not

(219)

It is generally agreed that water should be added first when mulling new bond additions into new sand.

The sequence of additions to system sand containing appreciable bond is not considered critical. However, timing of the water addition in relation to total mulling time is critical if flowability of the sand is important. Mulling time should be counted after all water is added.

(220)

At present, total mulling time is usually considered in relation to the water addition or additions, if water is added more than once. Flowability or compactibility of the sand is little affected by mulling when the water content is under the critical temper percentages of Frame 104, however, they decrease with mulling time when water content is above the critical percentages.

The water content of the sand plays an important part in mulling in determining the _____ and _____ of the sand.

(221)

Subject to wide variations in different foundries, it is usual practice to mull in slow speed mullers for 4-5 minutes, for 40-60 seconds in high speed mullers.

Mulling times vary widely depending on the _____ and _____.

compactibility
flowability (either order)

muller
foundry (either order)

REVIEW QUESTIONS

(222)

Bond and water are usually m_____ onto sand grains by applying p_____.

mulled
pressure

(223)

Sand grains are not u_____ coated with clay bonds by any production mulling procedure.

uniformly

(225)

Degree of mulling is controversial. "Adequate" mulling uses a m_____ amount of bond. Less than "adequate" mulling using more bond requires l_____ precise control.

minimum
less

(226)

Mulling time should be controlled in relation to the time of w_____ addition or additions.

water

REUSED SAND, NEW SAND ADDITIONS, RECLAMATION**(227)**

When the grains of sand in a system are rebonded many times without reclamation, the layers of bond are changed by heating during each reuse. This may make the old bond subject to failure when contacted by liquid metal regardless of how well the last coat bonds. Thus, any amount of new bond may not maintain a good sand system. This mechanism is similar to when a surface that has been painted many times flakes or peels.

Something besides adding new _____ must be done to maintain a satisfactory system sand.

bond

(228)

One method of overcoming the problem of Frame 227 is to add new sands to dilute the old sand in the system. This requires that some old sand be discarded. Between 5% and 20% new sand additions are made by foundries each time the sand is reused. Core sand that is not bonded with clay is considered new sand.

The problem of old clay buildup in molding sand can be overcome by additions of n_____ s_____.

new sand

(229)

One simple way of controlling a system sand is by inventory. Check and plot the additions each day in relation to the amount of sand used and the amount of metal poured. Be sure to include new sand and core sand. Some allowances must be made for core lumps that are discarded and do not enter the system.

System sand can be controlled by i_____ of additions including c_____ s_____.

inventory
core sand**(230)**

The determination of excessive used sand of Frame 227 by testing is very controversial. There are several testing methods that have been advanced in the past few years. Some are chemical, some mechanical. See references for this section.

(231)

Many times it is more economical to reclaim sand that is discarded by the process of Frame 288. There are three main methods of reclamation, that is, removing old bond from sand grains.

Thermal — by heating to over 1200° F. Not applicable to clay bonded sands.

Wet — by abrading off the old clay coatings by agitation while the grains are suspended in water.

Dry — by abrasion when the sand grains are suspended in an air blast.

Reclamation can be an e_____ method of producing the equivalent of n_____ sand for use as molding sand.

economical
new

(232)

Wet reclamation will produce the lowest clay content, under 1% of AFS clay in reclaimed sand. The old bond is abraded off the sand grains as they rub against each other when agitated in water.

A disadvantage to wet reclamation is the difficulty in disposing of the waste water. Elaborate settling basins are needed to meet water pollution codes. Freezing is another disadvantage in the north.

Wet reclamation will remove the g_____ amount of old bond.

greatest

(233)

Dry reclamation removes bond in the same manner as wet, by abrasion, but air is used as the suspending medium. Bond contents as low as those obtained by wet reclamation are not economical. Therefore, dry reclaimed sands are used for molding sand additions, seldom for core sands.

The old bond comes off as a dry powder in dry reclamation and must be disposed of in accordance with pollution regulations.

Dry reclamation does not economically remove as m_____ bond as wet reclamation and therefore, is of more use in reclaiming sand for m_____ sand.

much
molding

(234)

Dry reclaimers are usually adjusted to remove about half the bond when reclaiming for molding sand. This seems sufficient to prevent harmful buildup of the bond. The bond remaining on the sand grains allows a smaller rebonding addition.

It is n_____ necessary to remove all the old bond when r_____ molding sand.

not
reclaiming

(235)

An appreciable percentage of the small particles of the sand being reclaimed is lost as dust. The most practical way to make up for this loss is by introducing new sands as cores.

Cores are an economical and practical way of introducing n_____ s_____ to make up for the material r_____ by the reclaimer.

new sand
removed

(236)

Appreciable amounts of small sand particles are lost with the used clay when sand is reclaimed. If the original grain, void size and permeability are to be maintained, it is necessary to replenish the system with a smaller grain size sand than originally used.

This presents a problem that has not been solved. It is usually not advisable to decrease the grain size of the core sand that is added to the system. Finer sand should be added whenever possible directly to the molding sand system.

REVIEW QUESTIONS

(237)

It is necessary to either a _____ new sand and/or r _____ used system sand to keep the system sand in equilibrium as far as the used bond is concerned.

add
reclaim

(238)

Reclamation of used clay bonded sand grains consists of r _____ the old clay coating.

removing

(239)

Most reclamation is accomplished in the _____ state using _____ to move the sand.

dry
air

(240)

When reclaiming for molding sand only about h _____ of the old clay bond is removed.

half

(241)

The most efficient way to add new sand to a system using reclaimed sand is by means of c _____.

cores

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APPENDIX A — FERROUS SAND FORMULAS AND PROPERTIES

It is impossible to list even a fraction of the compositions and properties of production molding sands in a section. The list is endless. Instead, an attempt is made to list specific applications of the basic properties discussed in previous sections.

A listing of formulas would also be a duplication of effort. Comprehensive listings are available for the asking from a number of suppliers.

A most important point in any discussion of production sands is to never make changes in a sand producing acceptable castings because the sand does not conform to what the books say. There are too many nonsand factors involved to have a universal sand.

Perhaps a change will improve casting quality. Except in a crisis, any change should be made slowly, with continual casting checks. As discussed in previous sections, many casting defects have been erroneously blamed on the sand in the past.

Steel Foundry Sands are discussed first because of their relative simplicity.

Base Sands are usually reclaimed sands or new sands, AFS Fineness Number 50-70. Much sand is used as facing sand placed against the pattern, the mold is then filled with what is known as backing sand. This practice is universal with larger castings. Used sand is sometimes added in amounts up to 50% to reclaimed or new sand to make either facing or system sands for mechanized molding.

Clay Additions are almost always western bentonite to give green compression strengths from 7-9 psi to 12-15 psi. Fireclay is used in addition to bentonite for the larger castings.

Additives — Cereal additions from 0.5 to 1.5% are almost universal. Some cellulose and proprietary materials are used.

Steel Foundry Sands are distinguished by their high water-bond ratios. Bond water contents over 35% are quite common. The resulting sands are quite common. The resulting sands are quite "stiff" with poor compactibility.

The major reason for these high bond water contents is tradition. High bond water contents are needed to make molds for large castings when much finishing of the molds must be done.

Steel foundrymen could learn a lot from iron foundrymen about more compactible sands for mechanized molding with lower bond water contents.

Steel Foundry Sand properties vary as widely as composition. Some standard properties are:

Water — 2.5-4.5% to give bond water contents of 30 to over 40%.

Green Compression Strength — 7-9 psi to 12-15 psi to give water green compression strength ratios of .30 to .40.

Permeability may be quite high at the standard three ram level from 100 to as high as 300 in some foundries.

Compactibility — 45 to 65% denoting low compactibility or flowability.

Deformation seldom below .025 in., usually .030 in. to over .040 in.

Dry Compression Strength — 100 to over 300 psi. The higher dry strengths are shown by sands for large castings made in dried molds.

Gray Iron molding sands are distinguished by relatively high bond contents and low bond water contents when compared with steel sands.

Base Sands are mostly reused system sands with no more than 20% new sand added directly as cores. AFS Fineness Number 60-100 to give 40-100 permeability.

Permeabilities of sands for large castings may be as low as 20. Molds made of these low permeability sands are dried in some manner.

Clay Additions — Either western or southern bentonite, or a mixture. Fireclay is used with western bentonite for large castings.

Additives — Seacoal in amounts to give up to 5% loss on ignition is used almost universally. Cellulose additions of about 1% are used in addition to seacoal or as a partial replacement. Cereal additions of .5 to 1.0% are used if the castings are susceptible to expansion scabbing. Pitch is used in sands for larger molds. Many proprietary materials are in use.

Gray Iron molding sands for small and medium size castings are almost always made up with over 70% reused sand. Facing sands containing more new sand that is sometimes a natural bonded sand are used for larger castings.

Water contents vary widely, from 3 to over 7%, but the bond water contents are more uniform usually between 20 and 25%.

Green Compression Strengths are almost always over 13 psi and range to over 25 psi. Water content varies with strength to give fairly uniform watergreen compression strength ratios of .15 to .30. The range in individual foundries is less.

Permeability for small and medium size castings will range from 30 to 150. Dry sand molds for large castings are made of sand with as low as 20 permeability.

Compactibility is usually quite good, 35-45% for the smaller molds. Sands for larger castings have compactibility values of 50-58% indicating lower compactibility.

Deformation — .015 to .025 in. for sands making small and medium size castings. Values will be higher as casting size increases.

Dry Compression Strengths — 50 to over 300 psi depending on casting size. Low dry compression strengths are claimed to indicate a sand that will erode. Some foundrymen claim that these strengths should be over 100 psi.

Ductile Iron molding sands are similar to the gray iron sands. A major difference in some ductile iron sands is higher seacoal or carbonaceous contents. Losses on ignition at 1800° F over 10% are shown by some sands. High carbonaceous materials are claimed to reduce certain types of porosity in ductile iron castings.

Malleable Iron sands are usually bonded with higher percentages of southern bentonite than used in the other iron sands. Half southern, half western additions are common.

Base Sands are similar to the gray iron sands.

Clay Additions are usually lower than in gray iron sands. Additions are made to system sands to maintain 7-12 psi green compression strength in some foundries. Other system sands are bonded to 10-16 psi.

Additives — Seacoal and similar carbonaceous additions are kept lower than for gray iron sands, usually under 5%. Cellulose additions are quite common in the range 1 to 2%.

Malleable Iron molding sands are practically all system sands with a minimum of new sand additions.

Water contents 3.0 — 4.5% with bond water contents usually 20 to 35%.

Green Compression Strengths — 7-12 psi to 10-16 psi. Water and bond are matched in the individual foundry to give water-green compression strength ratios of .22-.38.

Permeability — 60-120 depending on the individual foundry.

Compactibility — 35-50%, the slightly higher values indicate slightly poorer compactibility on the average than shown by gray iron sands.

Deformation — .015-.028 in.

Dry Compression Strength — 50-150 psi.

By this time the reader must be impressed with the great variations in both composition and properties shown by the

survey of actual molding sands used by any branch of the industry. General recommendations are impossible.

Any expansion of the condensed data of this section would require a booklet for each sand. The interested reader is again referred to the booklets available from a number of suppliers.

APPENDIX B — NONFERROUS SANDS

The basic concepts controlling sand for nonferrous metals are the same as those controlling the sands for ferrous (iron and steel) alloys. However, there are some important differences in details.

One complication is that there are numerous nonferrous alloys that are based mostly on:

Copper — (brass, bronze are the most common.)

Aluminum

Magnesium

Nickel

One fundamental difference of the nonferrous sands is the smaller grain size of the base sand. Many of the sands used for nonferrous metals have AFS grain fineness numbers over 100 versus 50-70 AFS numbers for the sands used for the ferrous (iron and steel) metals. However, there are exceptions. Many magnesium sands have grains equal to AFS fineness numbers of 50-70.

“Natural bonded” sands, sands containing up to 30% natural clay around the sand grains as mined, are used more extensively in the foundries casting nonferrous metals than in ferrous foundries. Many of these sands are used as mined with no additional bentonite or clay added until they are recycled in the foundry.

The “natural bonded” sands from the Albany, New York area have been used for generations and are the best known. Similar sands originate from Windsor Lock, Connecticut and from a number of locations in Tennessee, Ohio and New Jersey. Many of these sands have AFS fineness numbers over 200 and are used with copper base castings that require very smooth surfaces.

Another type of sand used almost exclusively for large bronze castings is bonded with cement. High purity silica sand is bonded with 11-13% high early strength cement, 6-7% water. As this sand has no green (undried) strength, the patterns must be removed from the compacted sand (copes cannot be lifted from drags).

Some iron and steel castings are made with this sand. This sand makes the most rigid molds and most consistent casting dimensions. However, it cannot be used if there is any possibility of the castings hot tearing or hot cracking.

Molding sands for aluminum and magnesium usually contain distinctive "protective agents" to inhibit reactions between these reactive metals and the mold atmosphere. Some of the agents are:

- Ammonium and potassium fluoride and fluoroborates
- Sulphur
- Boric acid
- Diethylene glycol and similar glycols
- Benzene hexchloride

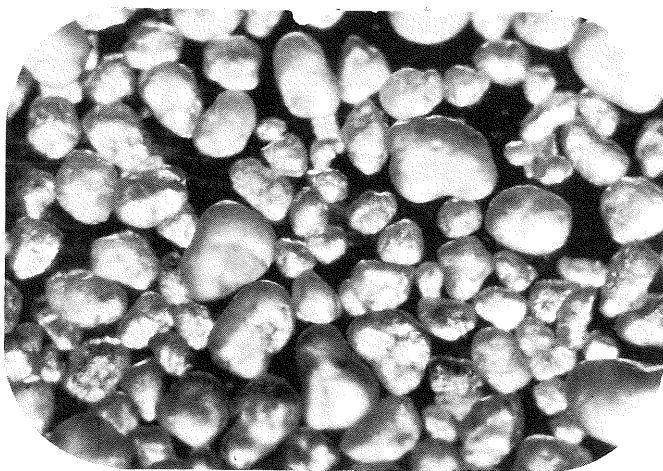
The primary bonds used for the synthetic nonferrous sands are the same as used for similar ferrous sands, such as:

- Western and southern bentonite
- Cereals, cellulose materials
- Some seacoal is used.

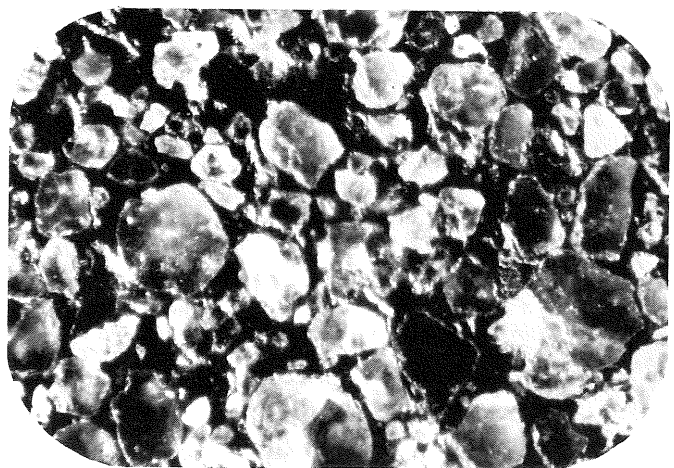
Bentonite contents are usually lower (2-5%) than used in ferrous sands, 2-5%. AFS Fineness Numbers of the base sands are usually over 100 to give 10-40 permeability, but there are many exceptions.

Sands used for nonferrous castings, particularly for the copper base alloys are less standardized than those used for ferrous castings. The formulas for many nonferrous sands are actually recipes based on experience rather than technology. For additional information regarding specific nonferrous sand formulations, it is recommended you contact your supplier.

APPENDIX C



Rounded Sand Grains



Angular Sand Grains

Figure 1 - Illustration of Sand Grains - Magnification 25X (Frame 53)

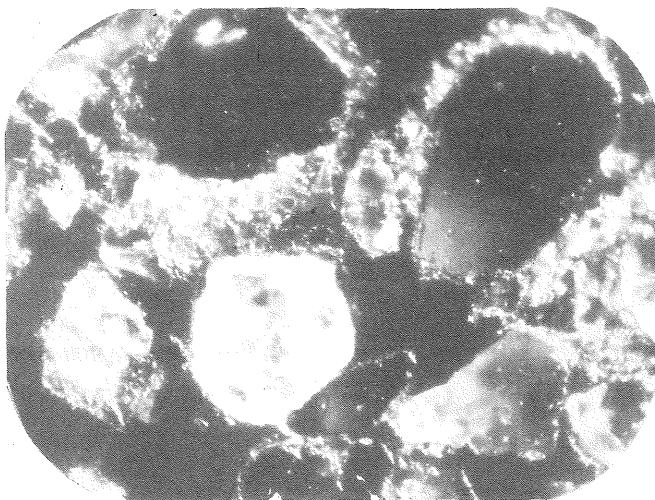


Figure 2 - Sand Containing 30% Silica Flour - 125X (Frame 72)

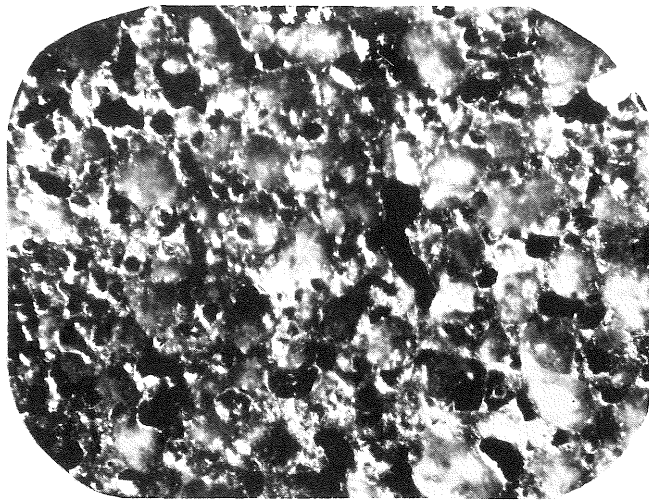


Figure 4 - Surface Coated with Silica Wash after Contact with Molten Steel at 2900°F. Note Small Voids (black) 25X (Frame 78)

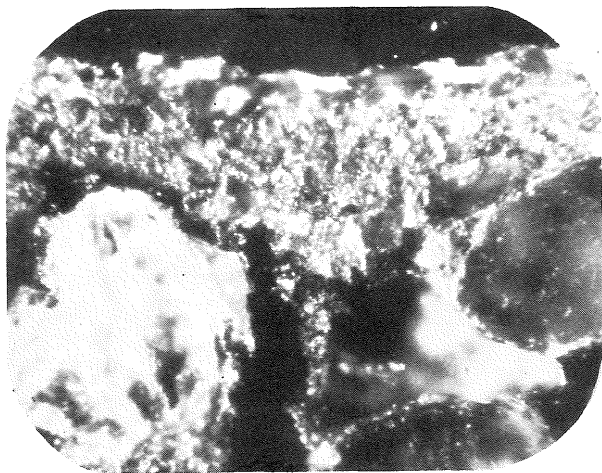


Figure 3 - Coating of Silica Flour (top) on Sand Surface 125X (Frame 77)

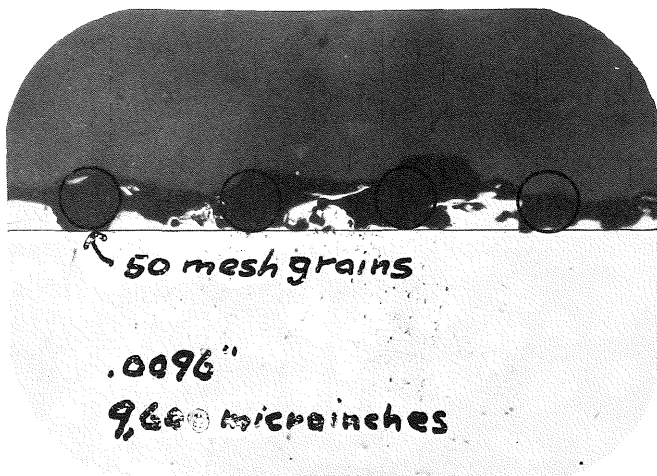
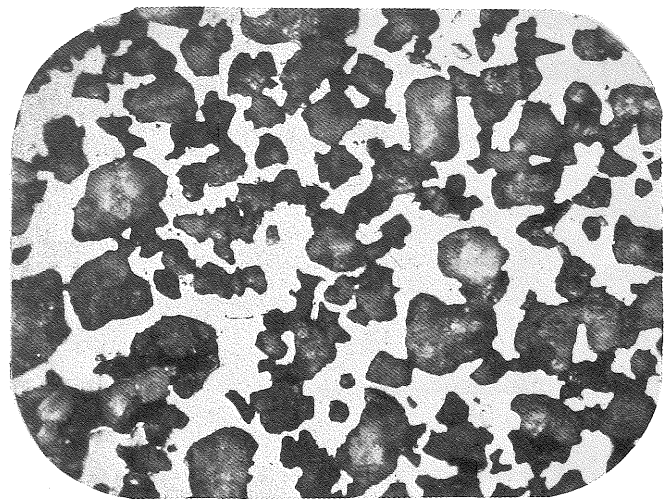


Figure 5 - Cross Section of Sand - Metal Interface Showing Penetration less than One Sand Grain 25X (Frame 82)



(A) Partial Penetration into Dense Sand Mass

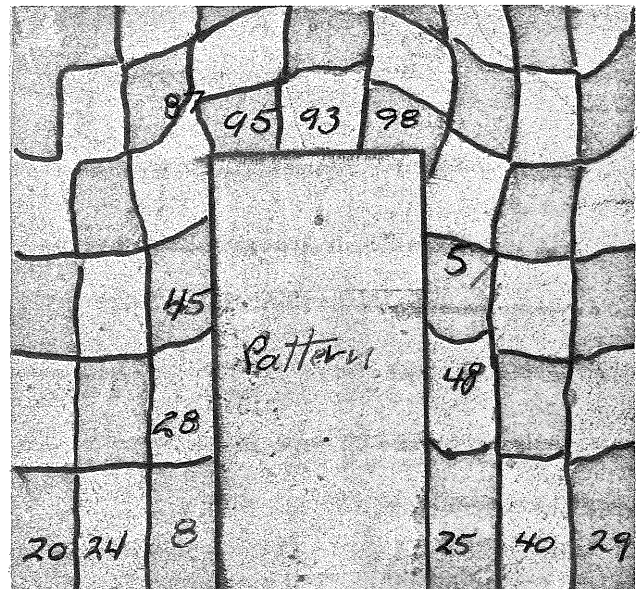


(B) Complete Penetration into Poorly Compacted Sand Mass

Figure 6 - Examples of Metal Penetration (Steel) Metal - light; Sand Grains - dark (Frame 83)

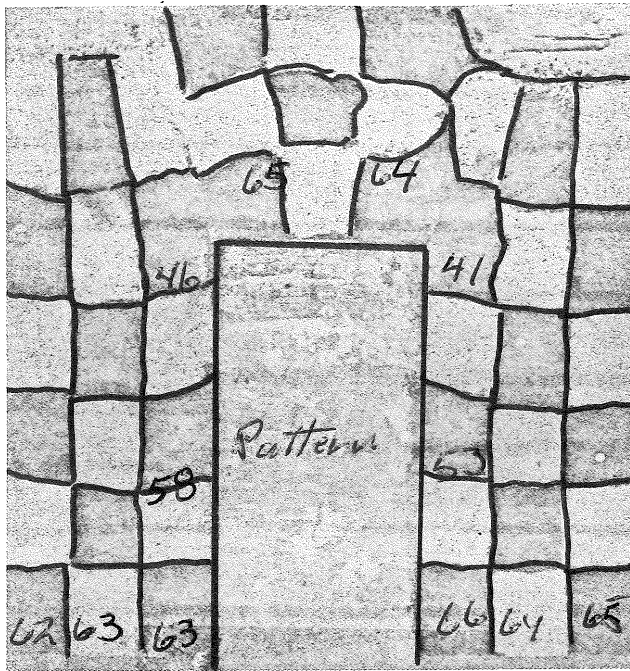


(7A) Mold made of Alternate Blocks of Light and Dark Colored Sand Grains before Compaction Pattern Height - 6 in.
Sand Height - 12 in.

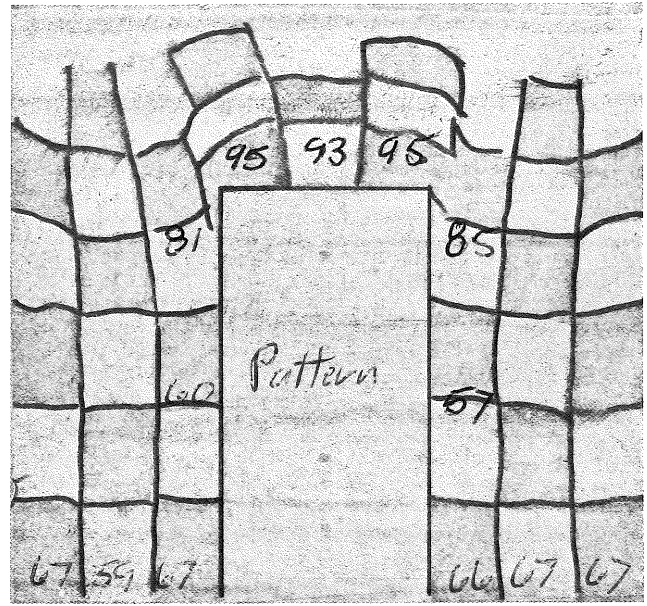


(7B) Deformation of Sand Grid and Hardnesses caused by Squeezing with a Flat Squeeze Plate
Final Sand Height - 8 in.

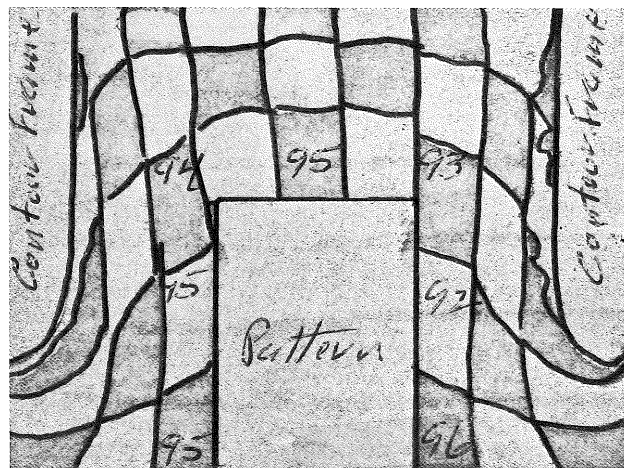
Figure 7 - Illustrations of Compactions Caused by Different Compaction Methods. See reference (9) for more details. The numbers superimposed on the grids indicate green (indentation) hardness. The numbers are relative. The higher the number, the greater the hardness. (Frame 112)



(7C) Deformation of Sand Grid and Hardness caused by 20, (3 in. stroke) jolts.
Final Sand Height - 9 in.



(7D) Deformation of Sand Grid and Hardness caused by a Combination of Jolting (Figure 7C) and Squeezing (Figure 7B)



(7E) Deformation of Sand Grid and Hardness caused by Squeezing with a Specially Designed Contour Frame

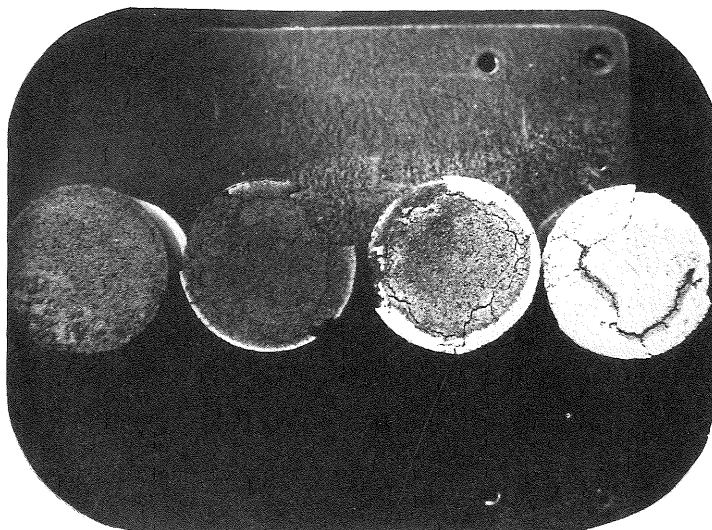


Figure 8 - Two Inch Diameter Test Specimens Showing Expansion Cope Spalling. Time of Exposure to radiant Heat Increases from Left to Right. (Frame 152)

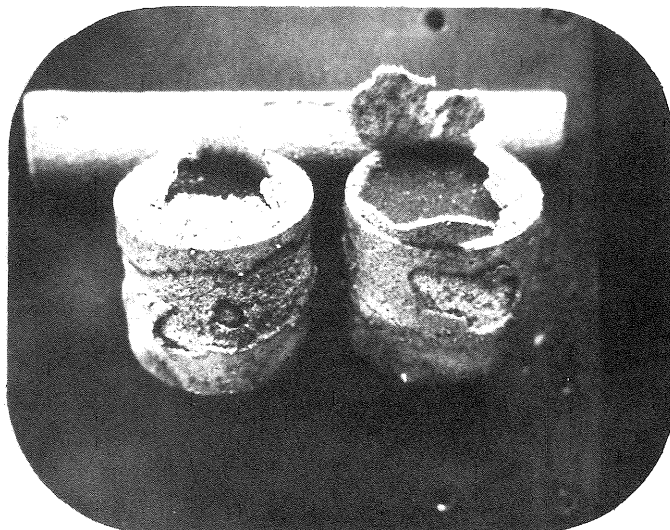


Figure 9 - Test Specimens Showing Extreme Gas Pressure Spalling after Immersion in Liquid Steel. (Frame 154)

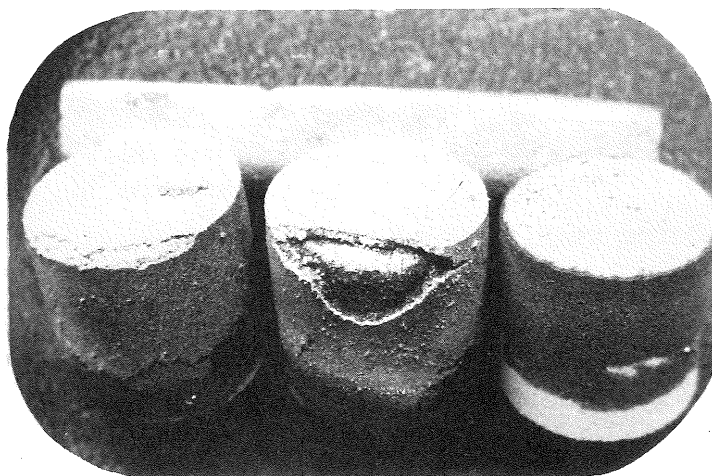


Figure 10 - Test Specimens Showing a Combination of Expansion and Erosion Scabbing after Contact with Liquid Steel. (Frame 155)

TEST

The first 25 statements are either True or False. Read each statement carefully and place an X on the proper letter, example:

Texas is a state.

Water freezes at 212° F.

Answer Sheet

X	F
T	X

1. Green sand molds are normally dried before pouring.
2. Clay is the most common binder in molding sands.
3. Most molding sands are supported by flasks and bottom boards.
4. Molding sand can be compacted so that no voids exist between the grains.
5. Surface roughness of the casting depends, in part, on the void size in the mold.
6. Voids are desirable to allow gases to escape.
7. A major factor affecting gas pressure in a mold is the collapsibility of the sand.
8. Molten metal exerts pressure only in one direction.
9. A strain or swell can be caused by a low strength sand.
10. Expansion scabbing is directly related to thermal stability.
11. Sands with uniform grain size will have 40-48% voids.
12. Changing sand grain size will change void size.
13. A 100 mesh screen has larger openings than a 50 mesh screen.
14. A one screen sand is considered best for green sand molding.
15. Silica flour can be used to fill void spaces in a molding sand.
16. Voids can be reduced to less than 15% with proper grain distribution.
17. Using silica flour to fill voids reduces permeability.
18. Gas holes in the casting can be caused by lack of venting.
19. Mold washes are used to reduce hot tears.
20. The most common clay binder is silica flour.
21. Fire clays give better strengths than bentonites.
22. Chromite sand absorbs more heat than silica sand.
23. Cereal additions promote scabbing.

24. Carbonaceous additives generate oxidizing gases when heated by molten metal.
25. One beneficial effect of cellulose materials is their ability to absorb water.

MULTIPLE CHOICE

The following statements, 26-50, are not complete. Following each is a list of words, one of which will best complete the statement. In some cases, none of the words listed will complete the statement; then the term, none of the above, should be used.

Example:

Answer Sheet

The sum of $5 + 2 =$ ____.

A B ~~C~~ D

- (A) 6 (C) 7
(B) 9 (D) 10

26. The most common clay binder for steel sands is ____.
(A) Western bentonite
(B) Kaolin fire clay
(C) Silica flour
(D) None of the above
27. The method of sand reclamation which is not suitable for clay bonded sands is ____.
(A) Dry
(B) Wet
(C) Thermal
(D) None of the above
28. The most common sand aggregate is ____.
(A) Zircon
(B) Silica
(C) Chromite
(D) None of the above
29. The additive which is a cellulose material is ____.
(A) Silica flour
(B) Wood flour
(C) Iron oxide
(D) Pitch

30. The most refractory of these materials is _____.
(A) Pitch
(B) Iron oxide
(C) Silica
(D) None of the above
31. The material which should be added to the muller first is _____.
(A) Cereal
(B) Bentonite
(C) Iron oxide
(D) Water
32. Old bond is removed in wet reclamation by _____.
(A) Dissolving
(B) Abrasion
(C) Chemical reaction
(D) None of the above
33. New sand may be introduced into a system as _____.
(A) Cores
(B) Silica flour
(C) Iron oxide
(D) None of the above
34. Nonsilica sands reduce scabbing because they exhibit lower _____.
(A) Penetration
(B) Refractories
(C) Expansion
(D) None of the above
35. An additive which reduces void size is _____.
(A) Cellulose
(B) Silica flour
(C) Dextrin
(D) None of the above
36. Metal penetration depends on _____.
(A) Void size
(B) Metal pressure
(C) Washes
(D) All of the above
37. The sintering temperature of silica is _____ zircon sand.
(A) Higher than
(B) Lower than
(C) The same as
(D) None of the above

38. The defect *not* related to thermal expansion is _____.
(A) Expansion scabbing
(B) Cope spalling
(C) Pinholes
(D) Rat tails
39. A cure for expansion scabbing is to _____.
(A) Increase expansion
(B) Increase strength
(C) Increase permeability
(D) None of the above
40. The test which measures void size is _____.
(A) Green tensile
(B) Permeability
(C) Dry shear
(D) None of the above
41. A reasonable new sand addition to a system sand is _____.
(A) 10%
(B) 0.5%
(C) 50%
(D) None of the above
42. The property which measures ease of ramming is _____.
(A) Permeability
(B) Flowability
(C) Thermal stability
(D) None of the above
43. The most favorable situation for reducing metal penetration is _____.
(A) Small grains
(B) Large pins
(C) Small grains plus wash
(D) None of the above
44. Reasonable values for green compression strengths are _____.
(A) 0.15-0.25 psi
(B) 15-25 psi
(C) 150-250 psi
(D) None of the above
45. Washes are primarily used to prevent _____.
(A) Metal penetration
(B) Hot tears
(C) Slag inclusions
(D) None of the above

46. A probable solution to a gas hole problem would be ____.
- (A) Increasing hot strength
 - (B) Increasing cereal content
 - (C) Increasing venting
 - (D) None of the above
47. A probable solution to a metal penetration problem would be ____.
- (A) Increase dextrine content
 - (B) Decrease hot strength
 - (C) Decrease permeability
 - (D) None of the above
48. The material which best resists wetting by molten iron oxide is ____.
- (A) Silica sand
 - (B) Iron oxide
 - (C) Chromite
 - (D) None of the above
49. The property relating to ease the shakeout is ____.
- (A) Collapsibility
 - (B) Hot strength
 - (C) Permeability
 - (D) None of the above
50. The sand with the largest voids is ____.
- (A) 40 permeability
 - (B) 100 permeability
 - (C) 300 permeability
 - (D) None of the above

ANSWER SHEET

True or False

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

Multiple Choice

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

ANSWERS TO TEST

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