

**A STUDY
ON THE BASIC CONCEPTS OF THE
METAL CASTING PROCESS**



TEACHER LECTURE GUIDE

BY

JERRY R. MILLER

FOUNDRY INSTRUCTOR

MILWAUKEE TECHNICAL COLLEGE

Published by

American Foundrymen's Society

Wolf and Wolf Roads Des Plaines, Illinois 60016

A STUDY ON THE BASIC CONCEPTS OF THE METALCASTING PROCESS



Teacher Lecture Guide
by
Jerry R. Miller
Foundry Instructor
Milwaukee Area Technical College

Published by
American Foundrymen's Society
Cast Metals Institute
Golf & Wolf Roads, Des Plaines, IL 60016

Y. 82
ANADOLU ÜNİVERSİTESİ
Merkez Kütüphane

049660

©Copyright 1975
American Foundrymen's Society
(Incorporated)
Des Plaines, Illinois 60016
Printed in U.S.A.

TS
040660

All rights reserved. This book or parts thereof may not be reproduced without permission of the publishers.

The American Foundrymen's Society as a body is not responsible for the statements and opinions advanced in this publication. Nothing contained in any publication of the American Foundrymen's Society is to be construed as granting any right, by implication or otherwise, for manufacture, sale or use in connection with any method, apparatus or product covered by letters patent, nor as insuring anyone against liability for infringement of letters patent.

PREFACE

The teacher's copy of the lecture guide entitled "A Study on the Basic Concepts of the Metalcasting Process" is part of a system developed after seven years of teaching foundry and always looking for a better method. The method outlined in this course can be used for college, technical, industrial arts and vocational students. It will insure the upgrading of the students' and teachers' understanding of cast metals operations and the overall industry.

In order to attain these objectives, the student's copy of the lecture guide contains little more than page numbers, sub-headings and incomplete drawings, requiring the student to attend all lectures in order to receive, fill in and understand the missing information.

This detailed course information is best presented by the use of an overhead projector and transparencies for each page of the guide. The teacher fills in the transparencies as he lectures and gives shop demonstrations, wherever and whenever possible, to enrich and supplement the lectures. This system insures the teacher of a captive audience and also presents a unique learning situation because of active student participation. However, other methods of teaching can be utilized to suit the teacher and the facilities.

This system has also been used for giving junior high and high school industrial arts teachers a richer background in castings technology. It has been found that the industrial arts teacher must also be taught the principles and basic handskills of castings work to improve his confidence and success in teaching casting processes to his students. The industrial arts teachers can, in turn, use the same system to teach their students cast metals operations and general information.

The material in the teacher's guide is meant to be informative and not highly technical. It can be expanded to meet specific needs. Illustrations, in some cases, may not be complete but are used only to emphasize a point or to present a basic concept. The entire system is meant to be a foundation for encouraging students to continue to learn and to seek out the challenges and career opportunities in this great basic industry.

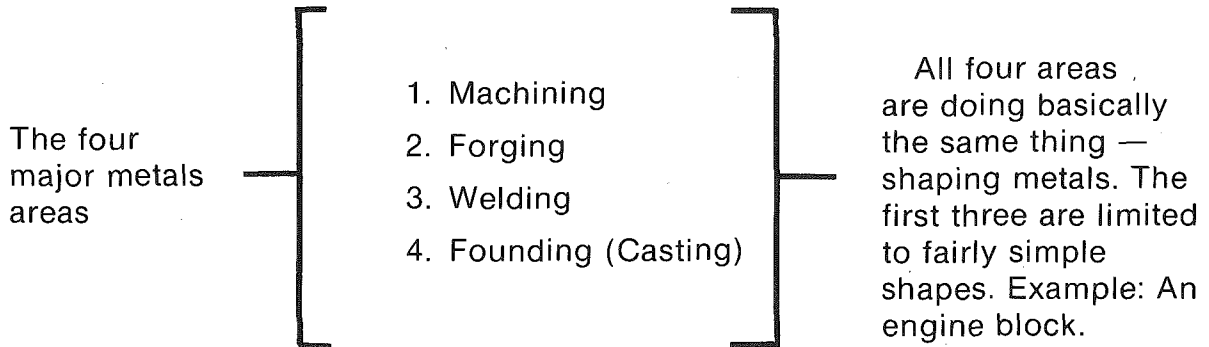
Jerry R. Miller

TABLE OF CONTENTS

TOPIC	TITLE	PAGE
1	Introduction	1
2	History	2
3	Types and classifications of foundries	4
4	Sand molding	5
5	Cores and coremaking	14
6	Binders and additives	30
7	Sand testing	33
8	Patterns	35
9	Gating systems	40
10	Solidification of metals	40
11	Risering or feeding	47
12	Casting design	47
13	Melting	54
14	Casting cleaning	70
15	Inspection	72
16	Casting defects	73
17	Mechanization and automation	79
18	Permanent mold casting	83
19	Die casting	87
20	Centrifugal casting processes	89
21	Investment casting process	92
22	Other special processes	93

1. Introduction

A. The foundry industry - The easiest way to shape metal with practically no limitations.



Practically all metal products start by first being cast. Example: A steel ingot. Therefore, without the casting process, there would be no metals. If there were no metals, what would there be?

B. Foundry products - called castings.

Castings in a home	Castings in a car	Other industries needing castings
plumbing fittings faucets some sinks bath tub sewer pipe radiators furnace parts appliance parts stove parts some cookware piano frame workshop equipment small engines ornamental pieces	engine block transmission housing heads manifolds pistons brake drums master cylinder wheel cylinders crankshaft rocker arms flywheel rear end housing mag wheels ornamental pieces	industrial machinery construction machinery railroads mining machinery aerospace industries petroleum industries chemical industries shipbuilding farm machinery etc.

2. History

A. The beginning

Foundry work began approximately 6,000 years ago. (4,000 B.C. in the Black Sea area.) Gold was the first metal found but copper was the first metal cast. It was a harder metal and therefore better suited their needs. Due to the migratory manner of early masses, the art of founding moved from place to place.

1. **2,000 B.C. to 1,000 A.D.** - Foundry work was noted in the Orient.
2. **1,000 B.C.** - Foundry work also began to appear in the Mediterranean Basin.

B. Developments and progress

1. In the Orient

- a. Mastered bronze
- b. Developed a knowledge of metallurgy
- c. Cast iron about 600 B.C.
- d. India cast crucible steel about 500 A.D.
- e. Chinese used lost wax, closed stone molds and sectional loam molds.

2. In the Mediterranean Basin

- a. Improved on lost wax molding
- b. Refinements in the smelting and forging of iron
- c. First recorded name of a foundryman. Hiram of Tyre (now Palestine) 1066 B.C. - a Phoenician.
 1. Cast King Solomon's pool - 15' in diameter x 7-1/2' deep - mounted on 8 bronze oxen - weight 45 tons.
 2. Cast the pillars for King Solomon's temple in River Jordan valley - 27' high x 4' 6" diam. - total weight 175 tons.
- d. Greek foundrymen cast a statue, Colossus of Rhodes (290 B.C.), statue of Apollo - 105' tall, weight 360 tons, had winding staircase inside, cast in sections and fell during an earthquake in 224 B.C.
- e. Romans cast some bronze bathtubs and statues, but main interest was in weapons

C. The middle ages

1. **Progress** - slow and shrouded in mystery
2. **Technical secrets** - carefully guarded by clergy
3. **Advances during this time**
 - a. Blast furnace with water wheel for power (pig iron)
 - b. Reverberatory furnaces (Furnace that uses reflected heat from roof and walls for melting and refining)
 - c. Improved molding methods (loam and lost wax)
4. **Famous names during this time**
 - a. Leonardo Da Vinci
 - b. Benvenuto Cellini: used loam and lost wax to produce artistic articles
5. **Main products** - (bells, cannons, cooking pots)

D. Advances after the middle ages

1. **Development of coke** - 1730
2. **Invention of cupola** - 1794
3. **Watt steam engine** - replaced the water wheel (for better blast control)

E. Foundry work in colonial America

1. **First successful foundry in the new world** - Saugus Iron Works in Lynn, Mass. in 1642. (Pilgrims landed in 1620)
2. **Mount Joy Forge** - later called Valley Forge - est. 1742
3. **Paul Revere** - operated a bell and cannon factory near Boston. (It became the Revere Copper and Brass Co.)
4. **First cupola** - appeared in 1815 and first drop bottom cupola in 1850

3. Types and classifications of foundries

A. Types - according to metals cast.

1. **Cast iron foundries**
 - a. Gray
 - b. White
 - c. Alloys of gray and white (including ductile)
2. **Malleable iron foundries**
 - a. Annealed white iron
3. **Steel foundries**
 - a. Plain carbon
 - b. Alloys (including manganese steel)
4. **Nonferrous foundries**
 - a. Aluminum alloys
 - b. Copper base alloys (brass and bronze)
 - c. Magnesium alloys (commonly called drow metals)

B. Classifications

1. **Jobbing shops**
 - a. Produce castings for many companies.
 - b. Can be short run or high production.
2. **Captive shops**
 - a. Produce castings only for their own consumption. Example: Ford Motor Company
 - b. Can be short run or high production.
3. **Combination shops**
 - a. Usually a captive shop that takes outside work.

C. Foundry departments (sand)

1. Molding
2. Coremaking
3. Melting
4. Cleaning
5. Control (including heat treatment)

D. Other casting processes

1. Permanent mold casting
2. Die casting
3. Centrifugal casting
4. Investment casting
5. Miscellaneous

4. Sand molding

A. Definition - The construction of sand containers into which molten metal is poured and allowed to solidify. These containers (molds) are destroyed in order to remove the castings.

B. Why sand? - Because sand promotes the following:

1. **Permeability** - referring to porosity, air or gases being able to pass through a mass of sand.
2. **Cohesiveness** - referring to the sticking together of sand grains.

NOTE: See page 9 for more information on the above.

3. **Refractoriness** - meaning heat resistant.
4. **Economical** - meaning cheap, mainly due to being very abundant.
5. **Removability** - referring to the ease of casting removal after solidification and the main reason for practically no shape limitations.

C. What is sand? - Sand can be defined as granular particles resulting from the breakdown of rocks. Sand broken down naturally is better for foundries because the grains end up being smooth and rounded. The most common sand used in foundries is silica sand, SiO_2 (silicon dioxide), better known as quartz.

D. Special sands

- | | |
|--------------|----------------------|
| 1. Zirconite | 4. Carbon |
| 2. Olivine | 5. Staurolite |
| 3. Chromite | 6. Aluminum silicate |

Reasons for using:

1. Most are more refractory than silica.
2. All expand less readily.
3. Some, like zircon, chromite, and carbon sand have a chilling quality.

NOTE: Special sands are more expensive and therefore are used sparingly. Example: Zircon is about 20 times more expensive than silica.

NOTE: More than 10 million tons of silica sand is used annually by the foundry industry. (Even though many foundries reclaim their sand.)

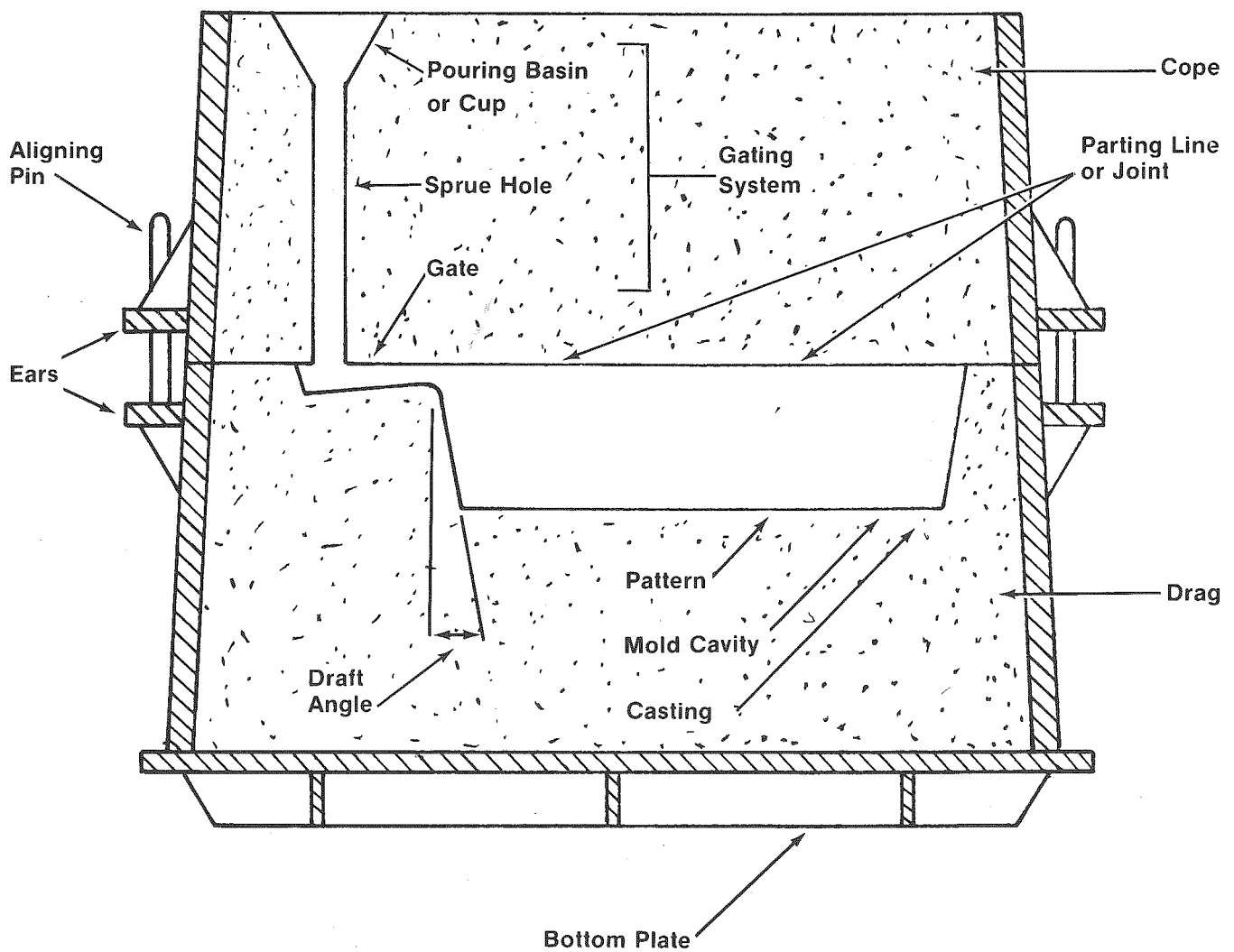
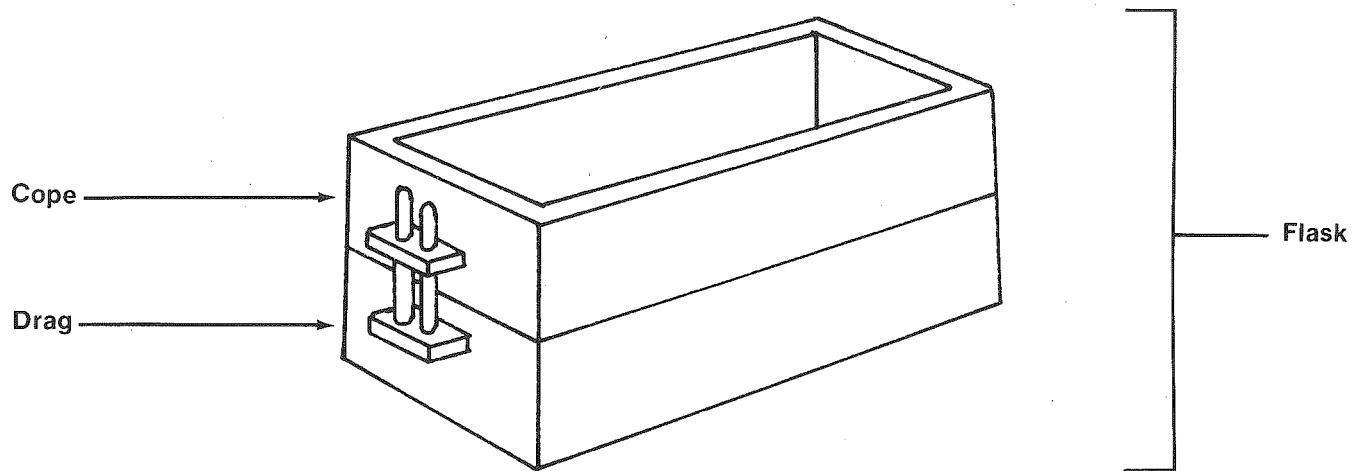
E. Types of sand molds (See picture on page 7)

1. **Green sand molds** - Molds that are made and poured in a moist condition.
 - a. Used for ferrous or nonferrous castings.
 - b. Can be used for small, medium, or large molds. (mostly small)
 - c. Used more than any other type of molding sand. (cheapest)

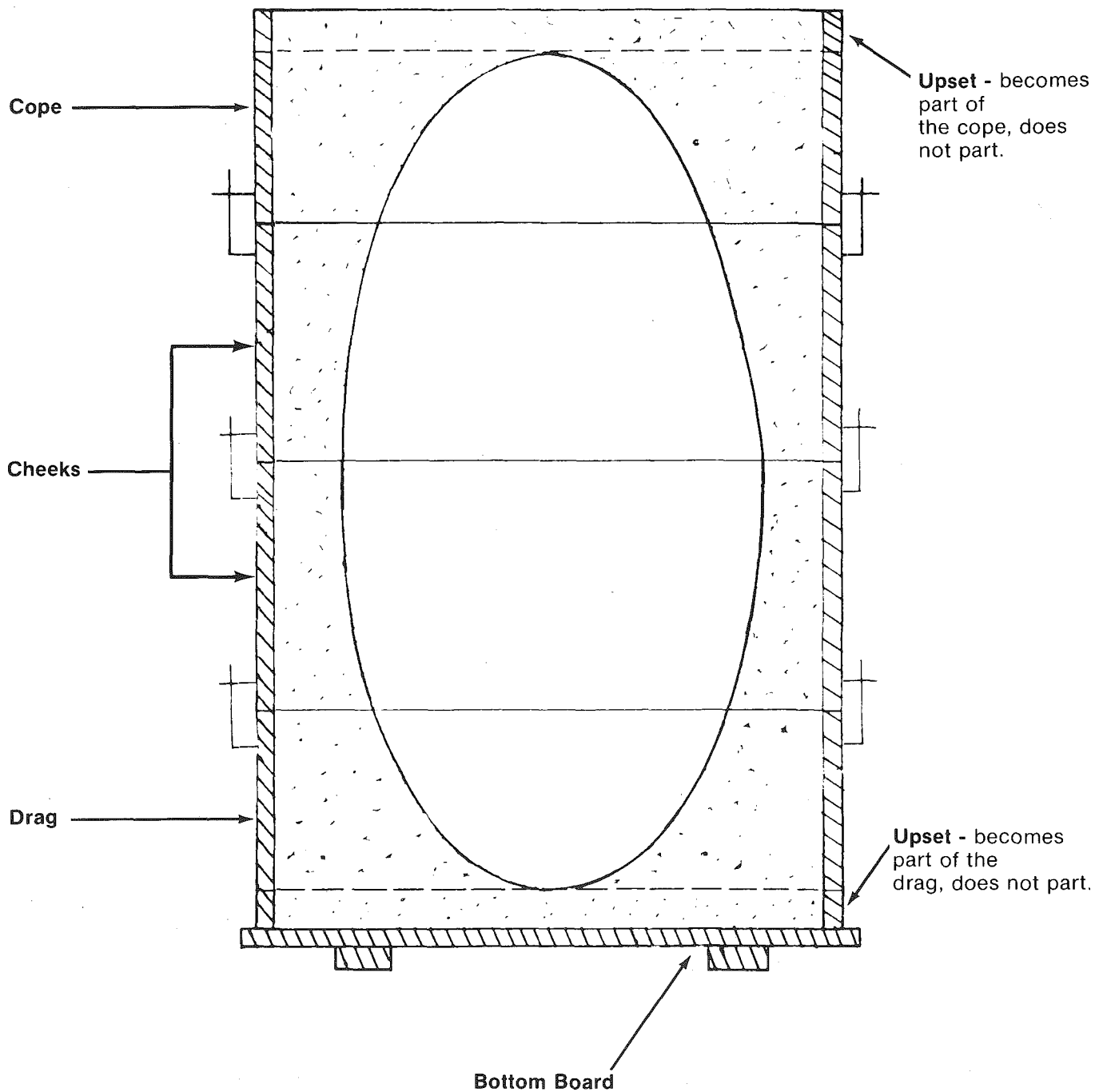
Disadvantages

- a. Not very strong. (can erode, distort, etc.)
- b. Can cause moisture defects. (requires careful control)
- c. Cannot be stored for any length of time.

SIMPLE BENCH SIZE SAND MOLD

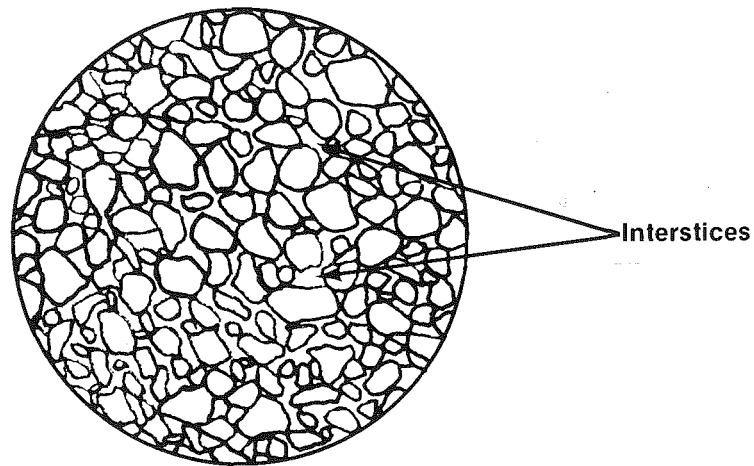


MORE FLASK PARTS



When the height of the cope or the depth of the drag are not adequate, upsets can be used.

SAND GRAINS



Permeability is a result of voids or spaces (called interstices) located between sand grains even though the mass is tightly packed.

Cohesiveness is created by coating each grain with some sticky material (clay, some oils, resins, etc.). Care is taken not to use too much or this could cause plugging of the interstices, which in turn would destroy the sand's permeability.

2. Dry sand molds - all moisture is removed

- a. Molds are very strong after baking (different binder than with green sand; see western bentonite)
- b. Can be used for ferrous or nonferrous casting
- c. Molds resist metal erosion and moisture defects are eliminated
- d. Process is more expensive
- e. Used mainly for large molds

3. Skin-dry molds - made with a dry sand facing and a green sand backing. Mold surfaces are skin-dried by torching or by spraying with a flammable substance and igniting.

- a. Allows the benefits of dry sand only not as expensive
- b. Can be used for ferrous or nonferrous casting
- c. Molds must be poured soon after close-up to avoid moisture migration.
- d. Used mostly for medium size molds.

4. Shell sand molds - sand molds that have a shell-like structure with various thermo-setting resins as binders (See drawing on page 11)

- a. Hot patterns and coreboxes are used with temperatures approaching 1000 degrees Fahrenheit
- b. Advantages:
 - 1. Tolerances of .002 - .015 in./in. (reduces or eliminates machining)
 - 2. Can store indefinitely (do not absorb moisture) which permits more flexible production scheduling
 - 3. Molds and cores cure within minutes of first contact with patterns or coreboxes
 - 4. The process, especially coremaking, lends itself to complete automation
 - 5. Operators require a minimum of training

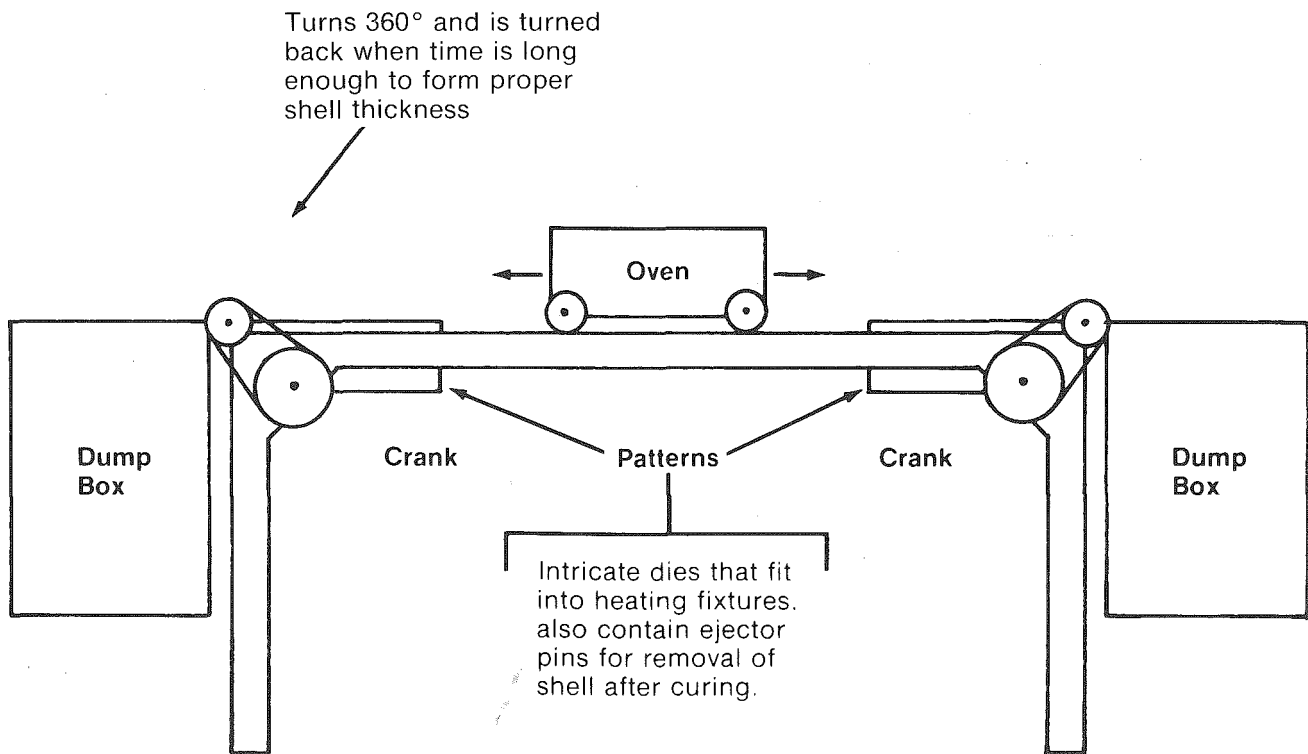
5. Loam molds - made of loam mortar and bricks (no flasks)

- a. Mortar is 50% clay and 50% sand
- b. Sweeps are used instead of patterns (mostly cylindrical castings) - sometimes skeleton patterns
- c. Molds are dried (baked) before pouring
- d. This process not seen much anymore

NOTE: Consult foundry text for more info. and pictures.

SHELL MOLDING

(Originally called the Croning or "C" Process)



Pattern is tilted by turning the crank, when pattern hits dump box, both pattern and dump box are tipped so that resin sand in box falls onto hot pattern - depends on how long sand is in contact with pattern as to how thick shell will be - when tilted back to original position, sand not affected by heat falls back into dump box - oven is moved over shell to help speed up curing cycle.

- 6. Cement molds** - mixture of silica sand and portland cement
- a. Used mainly for large ferrous work
 - b. Produces sharp detail and close tolerances
 - c. Molds air dry (can be a disadvantage due to taking up to 72 hours)
 - d. Materials, generally not reusable

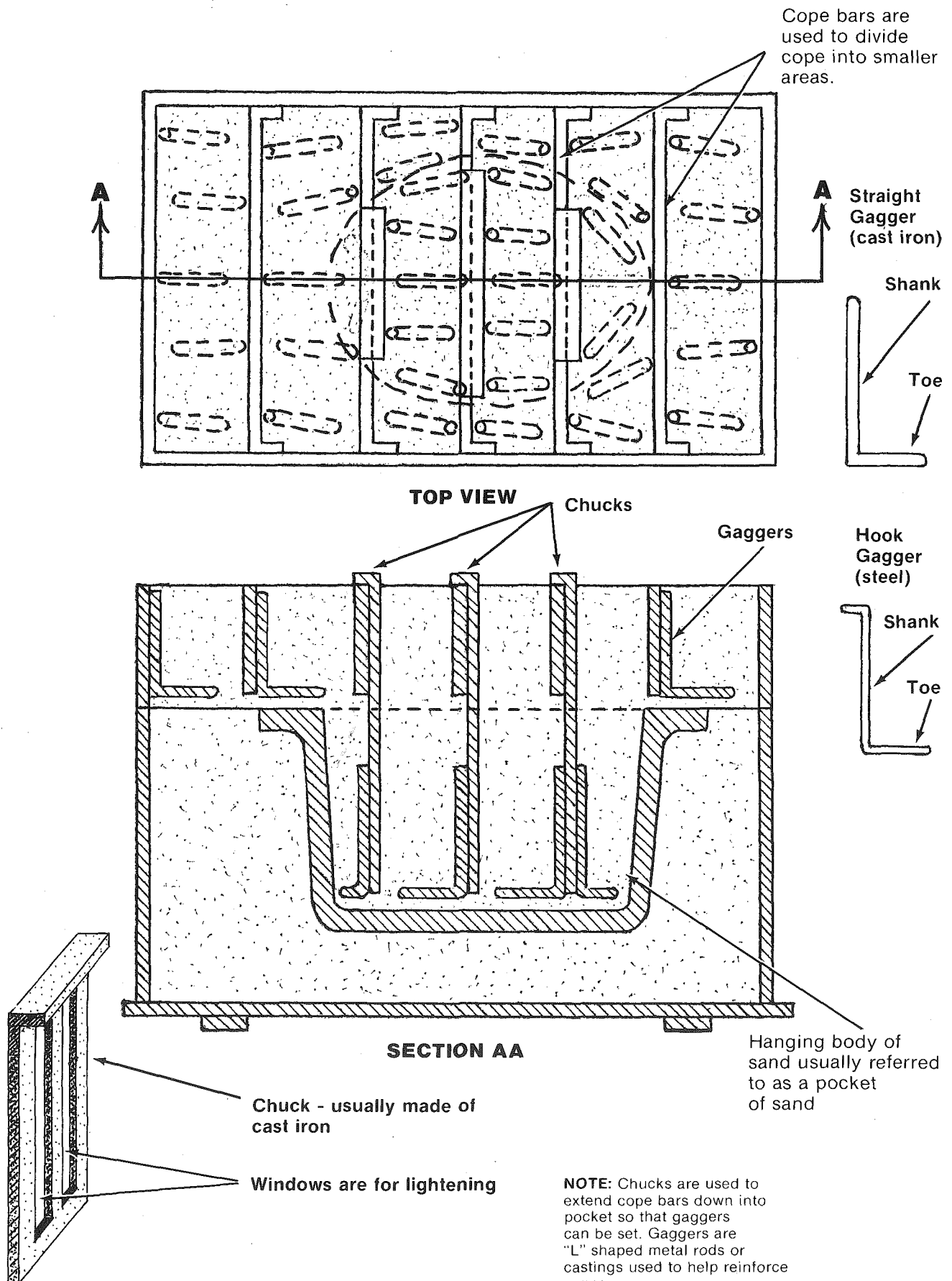
- 7. Chemical cure molds** - compare to dry sand molds in strength and appearance but cure without baking (chemical reaction similar to epoxy glues)
- a. Molds and cores require practically no ramming (usually compacted by vibrating)
 - b. Molds and cores require less reinforcing
 - c. Molds and cores require less skill to construct
 - d. Used mainly for medium and large molds

F. Sand molding methods

- 1. Bench molding (loose)** - See page 7
- a. Small molds
 - b. Can be made green, skin-dry or dry (mostly green)
 - c. Work is slow and laborious
 - d. Requires skilled labor
- 2. Floor molding (loose)** - See page 13
- a. Medium and large molds
 - b. Can be made green, skin-dry or dry
 - c. Work is slow and laborious
 - d. Requires skilled labor

FLOOR MOLDING

Larger molds require reinforcement (cope bars, chucks, gagers, etc.)



NOTE: Chucks are used to extend cope bars down into pocket so that gagers can be set. Gagers are "L" shaped metal rods or castings used to help reinforce copes.

3. **Machine molding** - practically any size mold can be at least partially constructed by means of a machine
- a. Molds can be made green, skin-dry or dry (also applies to shell and chemical cure)
 - b. Molds are more uniform and made much faster
 - c. Most machine molding processes require only semi-skilled labor.

4. **Pit molding**

- a. Very large molds (see page 15)
- b. Usually made of dry sand or cement (sometimes entirely of cores)
- c. Work is slow and laborious
- d. Requires skilled labor

5. Cores and coremaking

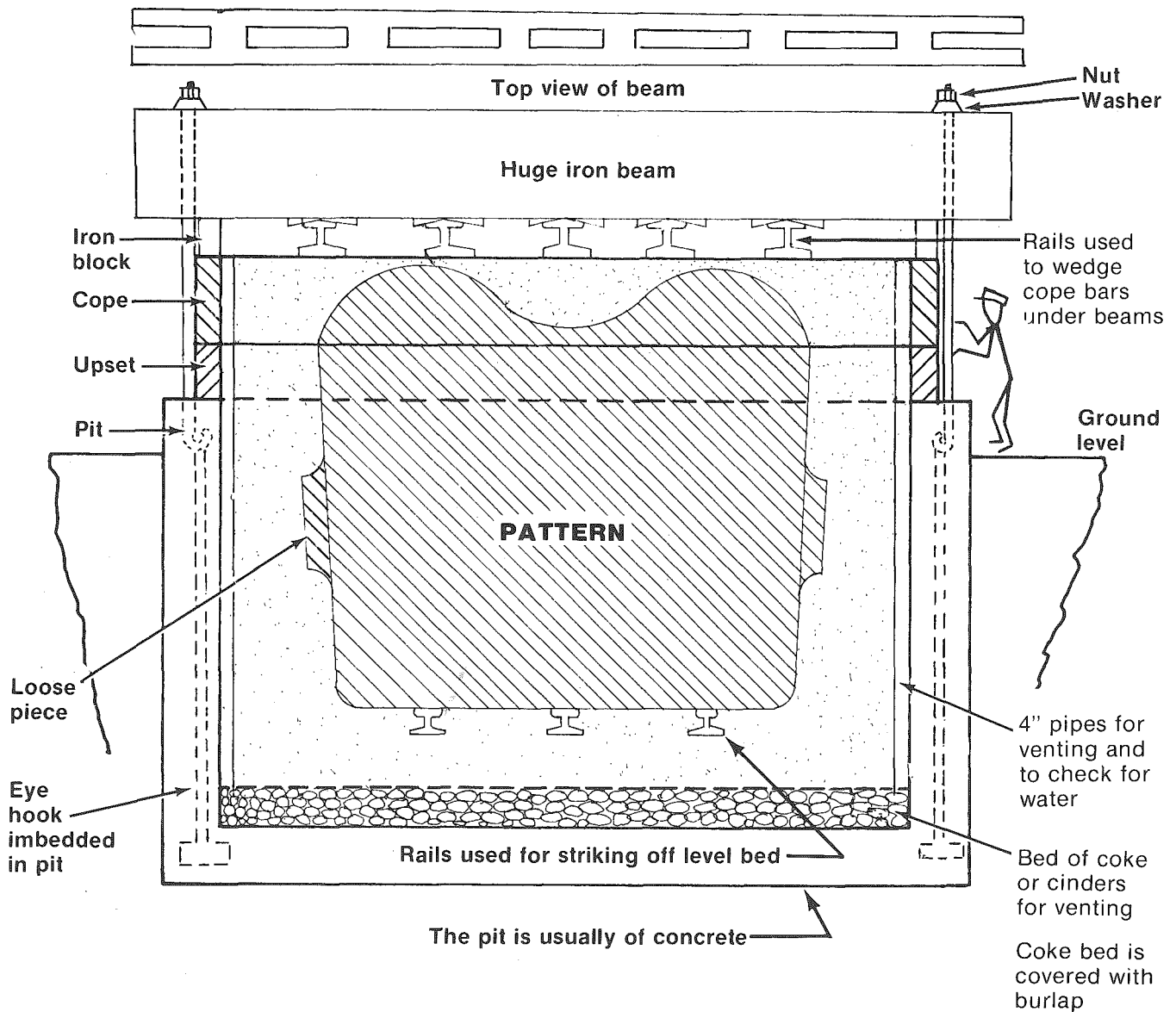
A. Definition - Coremaking generally refers to the construction of sand shapes that will later be positioned in molds to help shape parts of the castings not readily shaped by the mold cavity alone.

B. Core sand mixtures - differ from molding sand mixtures in that they usually are made up from 100% new sand (sharp sand - meaning a sand that is clean or free of all binders) whereas molding sands will usually consist of 2/3 or more old sand (used sand, also known as returned sand). Because of this difference, cores have some problems not usually encountered with molds.

- 1. **Lack of surface smoothness** - due to using sharp sand. Can be improved by:
 - a. Washing - coating the surface of the core (like painting)
 - b. Using a facing made of finer grained sand
- 2. **Need of additional collapsibility** - due to cores usually being surrounded by molten metal, which shrinks during solidification. Can be improved by:
 - a. Using additives (see page 32)

PIT MOLDING

Cope is held in place during pouring by placing huge beams across it and bolting them to the pit with threaded "J" hooks.



NOTE: Long runner boxes are usually used to carry metal to downgates when several ladles are required during pouring. (Not shown in drawing)

C. Core applications

1. **Produce recesses and cavities in castings**
2. **Produce entire molds** (Example: Pit molding, stack molding, coremolding, etc.)
3. **Miscellaneous type cores** (Cores used for purposes other than the normal shaping of a casting.) See page 17

D. Types of cores

1. **Classified by material** - cores can be made as:
 - a. Green sand cores - usually referring to cores that are formed by the pattern during molding. (No coreprints)
 - b. Dry sand cores - generally meaning cores that are baked before using.
 - c. Chemical cure cores - usually cores that set by a curing process other than baking.

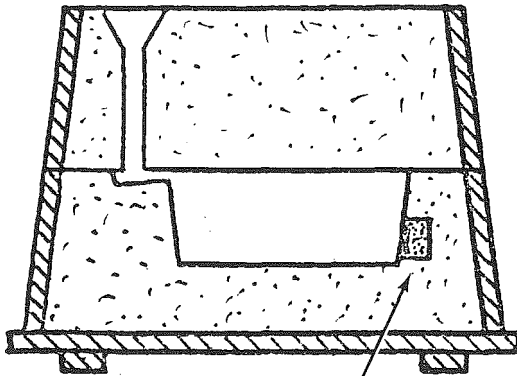
2. **Classified by position or location** - See page 18.

E. Supporting cores in molds

1. **Coreprints** - bearing surfaces in mold to locate and support cores; also extended parts of patterns, coreboxes and cores.
2. **Cope cores** - when cores are located in a cope and extend down, they must be secured. See page 19

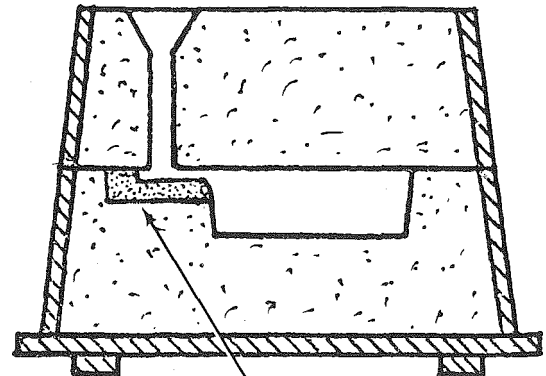
NOTE: Smaller cores can be held in cope with paste, nails, etc.

MISCELLANEOUS TYPE CORES



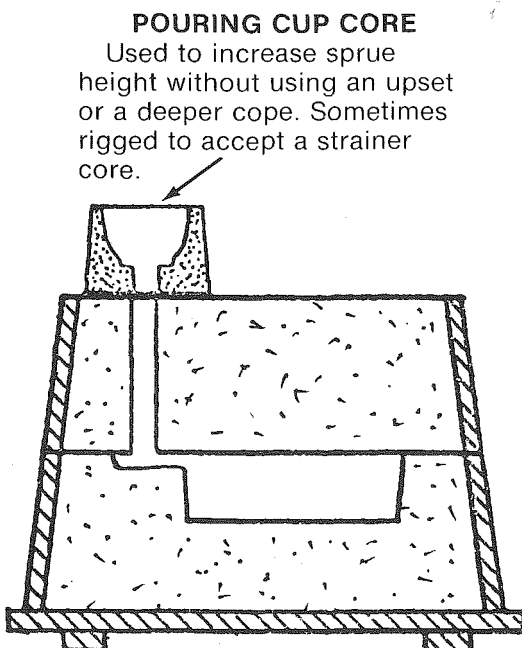
RAM-UP CORE

A core put in place during the ramming process (no coreprint). Could be a name core, etc.



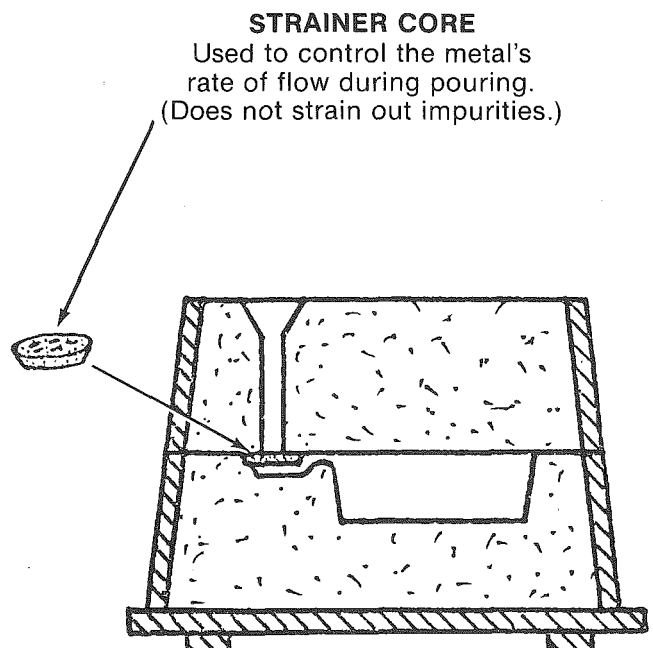
SPLASH CORE

A dry sand core in a green sand mold to prevent erosion problems.



POURING CUP CORE

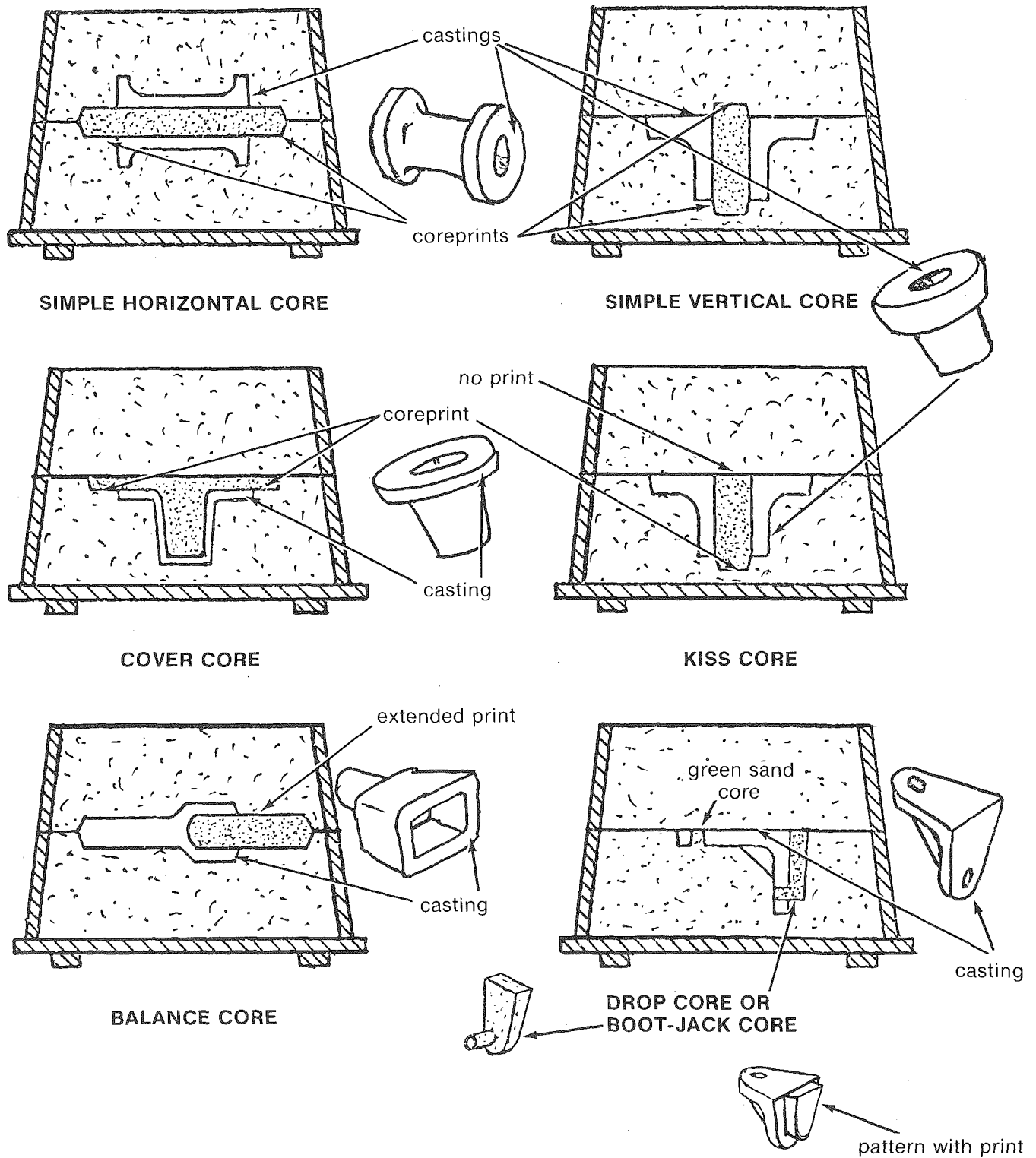
Used to increase sprue height without using an upset or a deeper cope. Sometimes rigged to accept a strainer core.



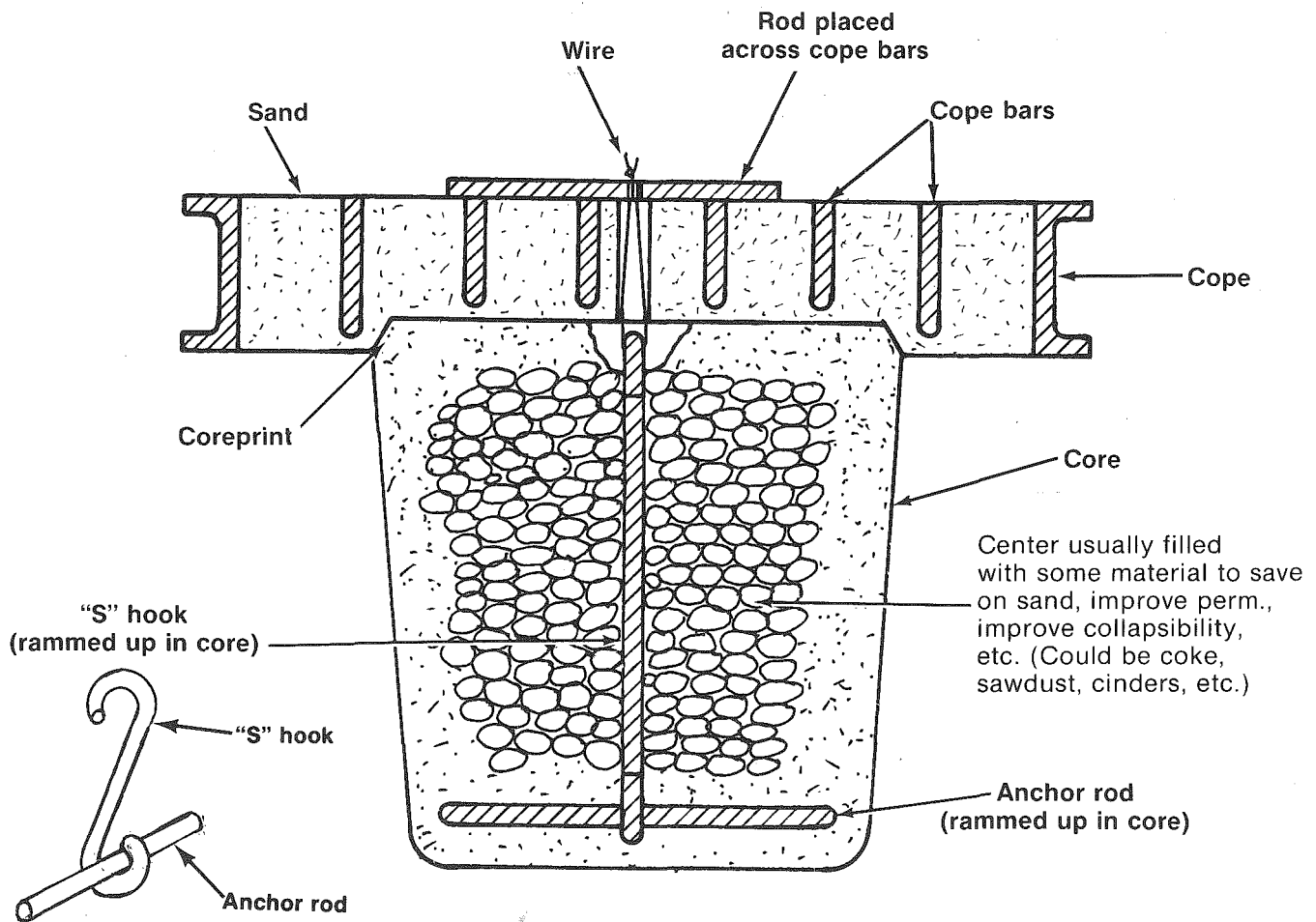
STRAINER CORE

Used to control the metal's rate of flow during pouring. (Does not strain out impurities.)

CORES CLASSIFIED BY POSITION

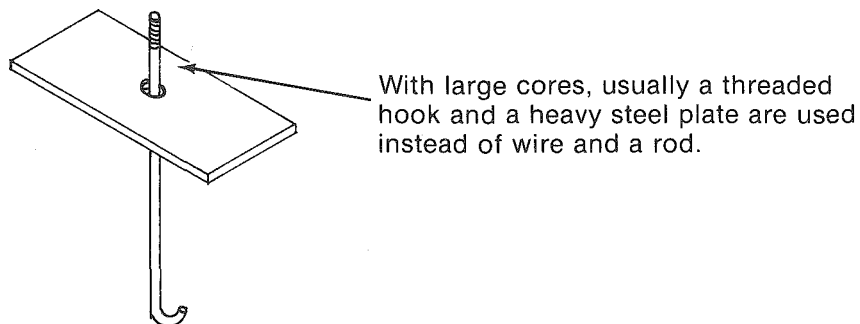


COPE CORES



SECTIONED VIEW

NOTE: Refer back to page 13 and compare.



3. **Chaplets** - are metal supports used in conjunction with or instead of coreprints - usually of a similar metal for they become part of the casting - made in assorted shapes and sizes - should be avoided in machined areas. (See page 21)

4. **Hinge tubes** - are used to produce holes in vertical extensions that would otherwise require the use of drop cores - also used to eliminate drilling small diameter holes in some castings. (See page 22)

F. Operations and methods of constructing cores

1. **Made in coreboxes** - usually wooden or metal boxes that contain a cavity with the shape of a desired core. To produce a core, the corebox cavity is filled with sand which is then rammed (by either hand or machine), the entire assembly is then either rolled onto or with a plate and then the box is drawn to expose the core. Depending on the size or shape of a core, more or less steps might be required. (See pages 23 & 24)

2. Corebox types

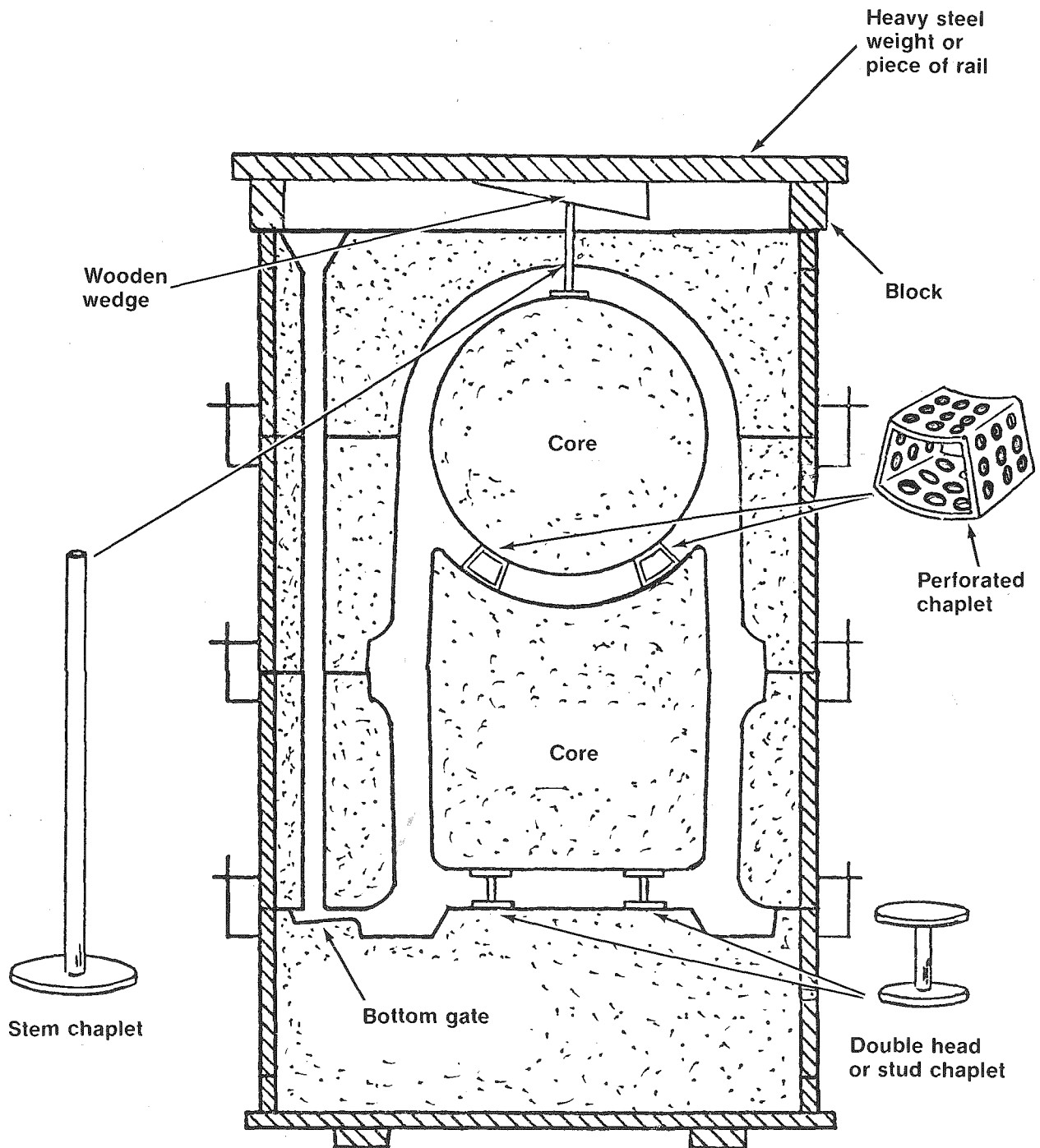
- a. Roll-over or dump coreboxes - the entire core is made in one box in one operation.

- b. Half coreboxes - produces half cores which must be joined in order to produce full cores.

- c. Split coreboxes - consist of two halves, making possible the construction of full cores and the elimination of joining. Because cores made in split boxes usually are of an irregular shape, special plates that conform to their shapes are used to support them during baking. These plates are called core driers.

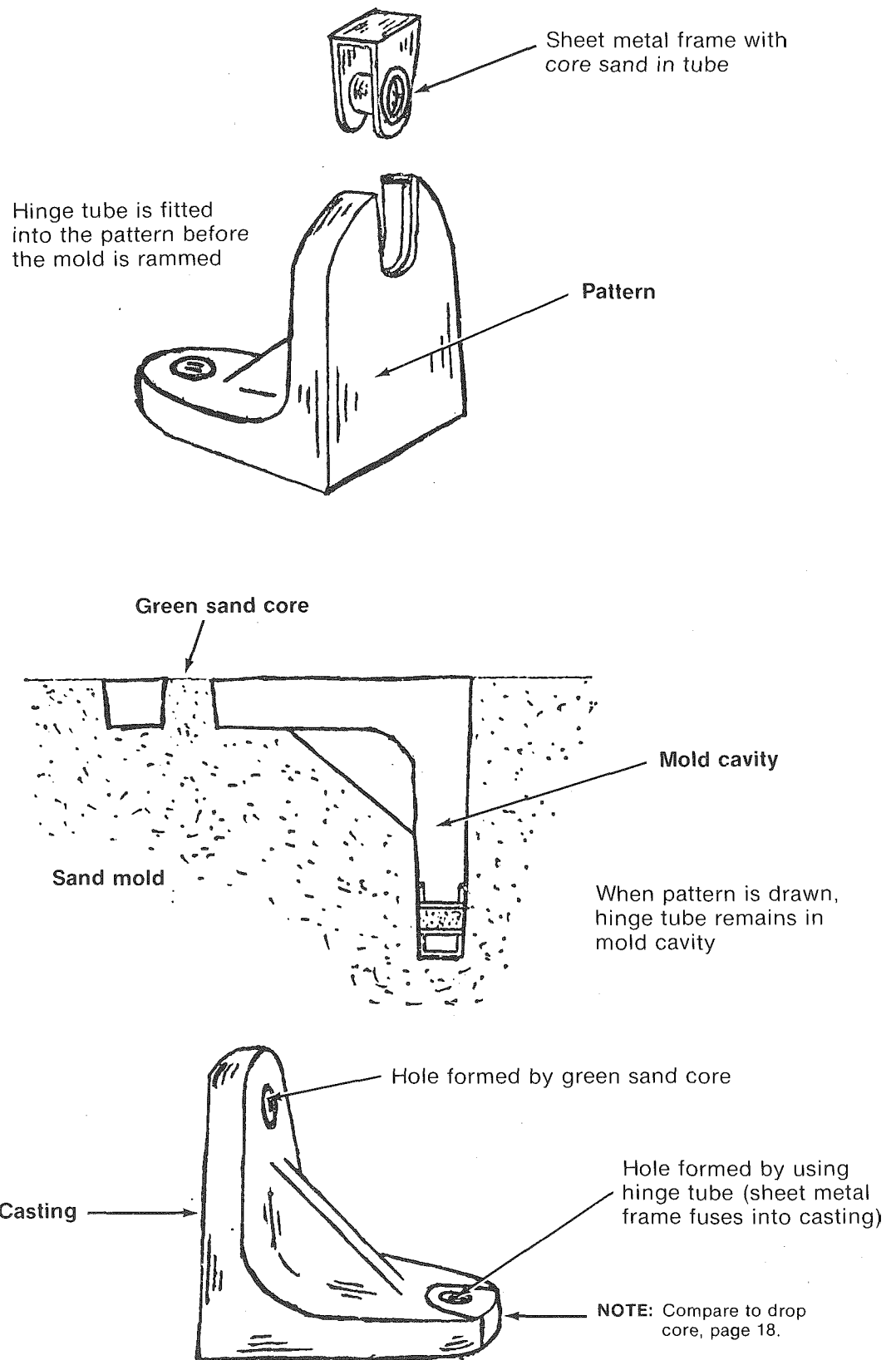
- d. Booked coreboxes - are very similar to split coreboxes except that they are hinged along one side. This allows each half to be rammed separately, struck off, and then joined green by closing the hinged box. Boxes of considerable length can be rigged this way to eliminate the need for joining after baking. Booked cores usually require core driers, too.

CHAPLETS

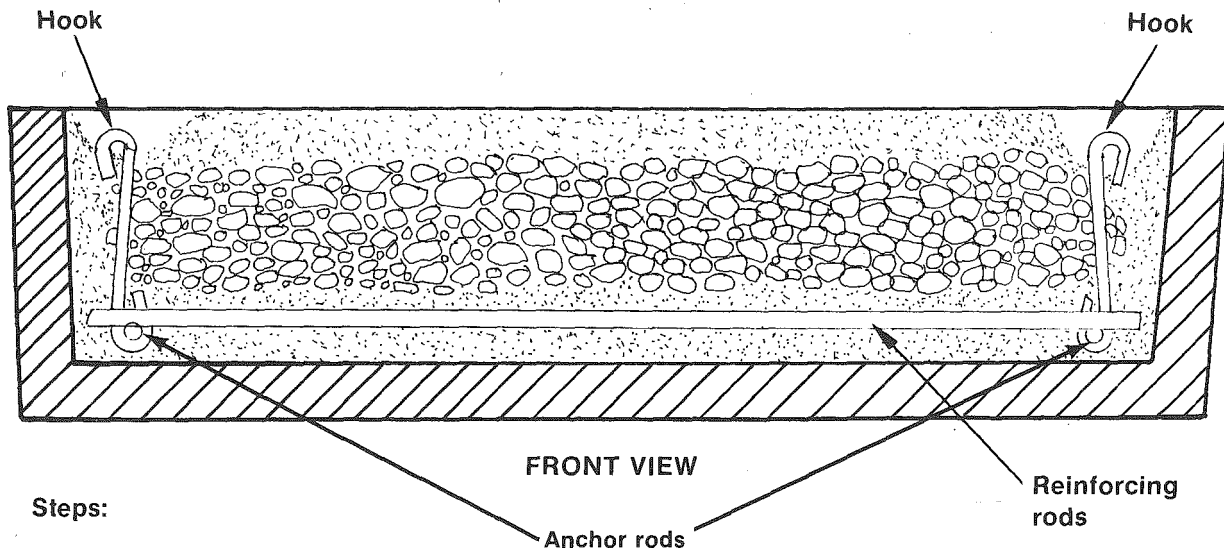


The stem chaplet, in this case, is tightened from outside the mold after the mold is either weighted or clamped. This is to avoid crushing.

HINGE TUBES

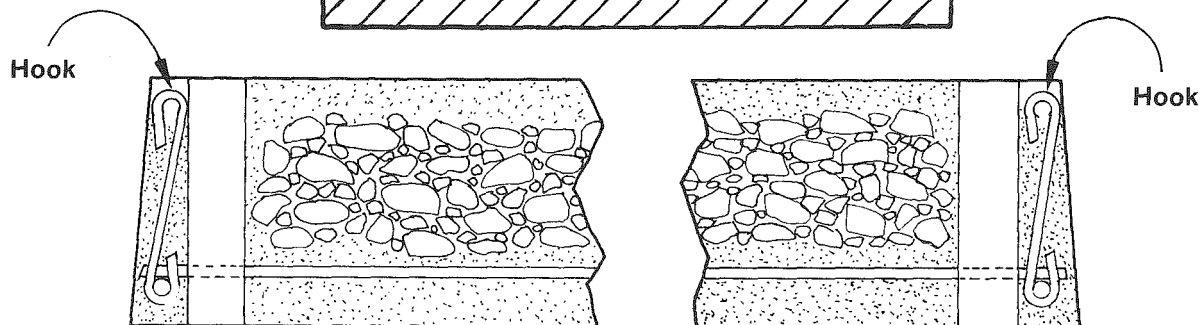
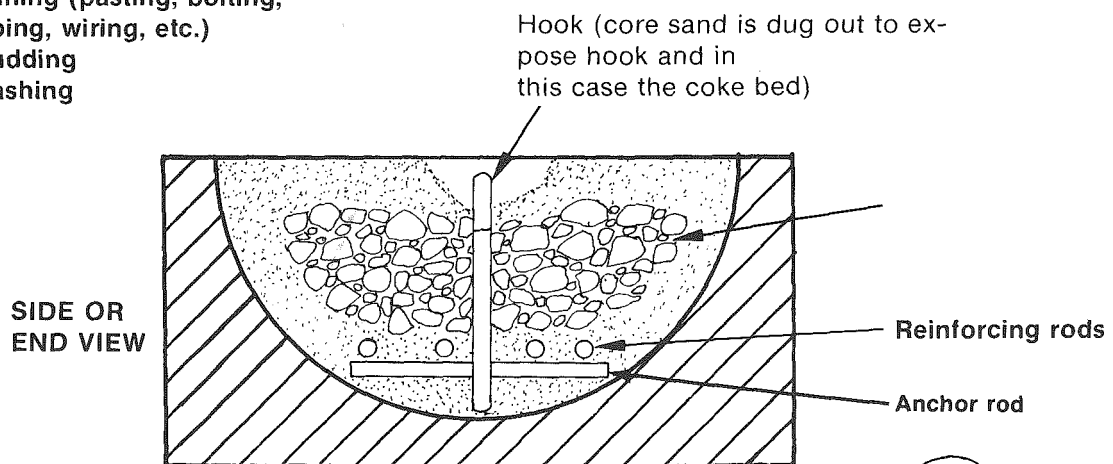


STEPS TO RAMMING A LARGE CORE



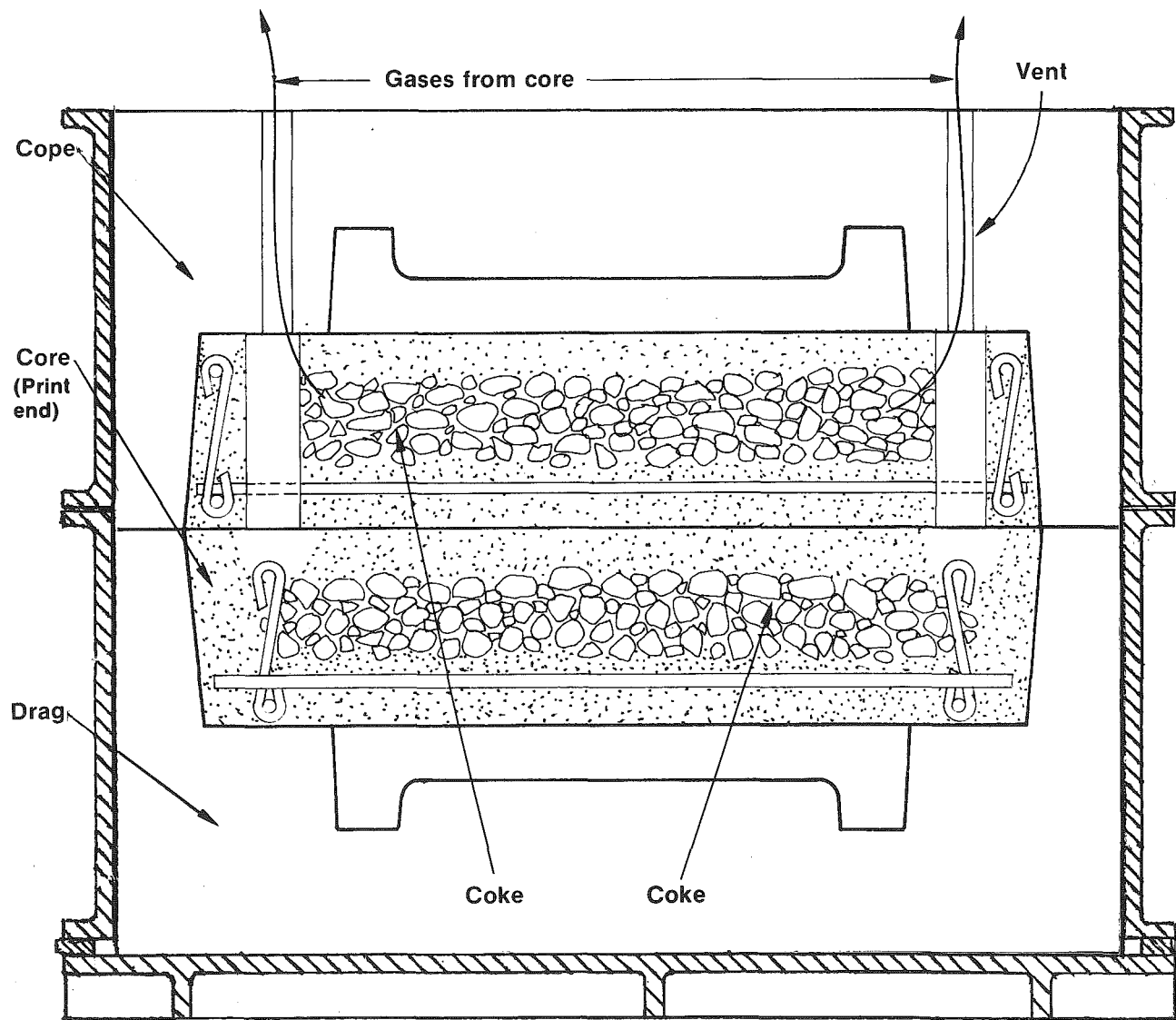
Steps:

1. Ramming
2. Reinforcing
3. Venting
4. Baking or curing
5. Sizing
6. Joining (pasting, bolting, taping, wiring, etc.)
7. Mudding
8. Washing



Cope half of core is made with holes to line up with hooks in drag half after core is joined. Cope half also has hooks to be used during the sizing and joining operations.

LARGE CORE IN FLOOR MOLD



Shim - to allow
gases to escape
between bottom
plate and flask

NOTE: Holes in cope half of core
line up with hooks in drag half. This
allows core to be picked up with shop
crane during core setting operation.
Also note that the molder allowed for
venting by having holes in cope located
right over hook holes in core.

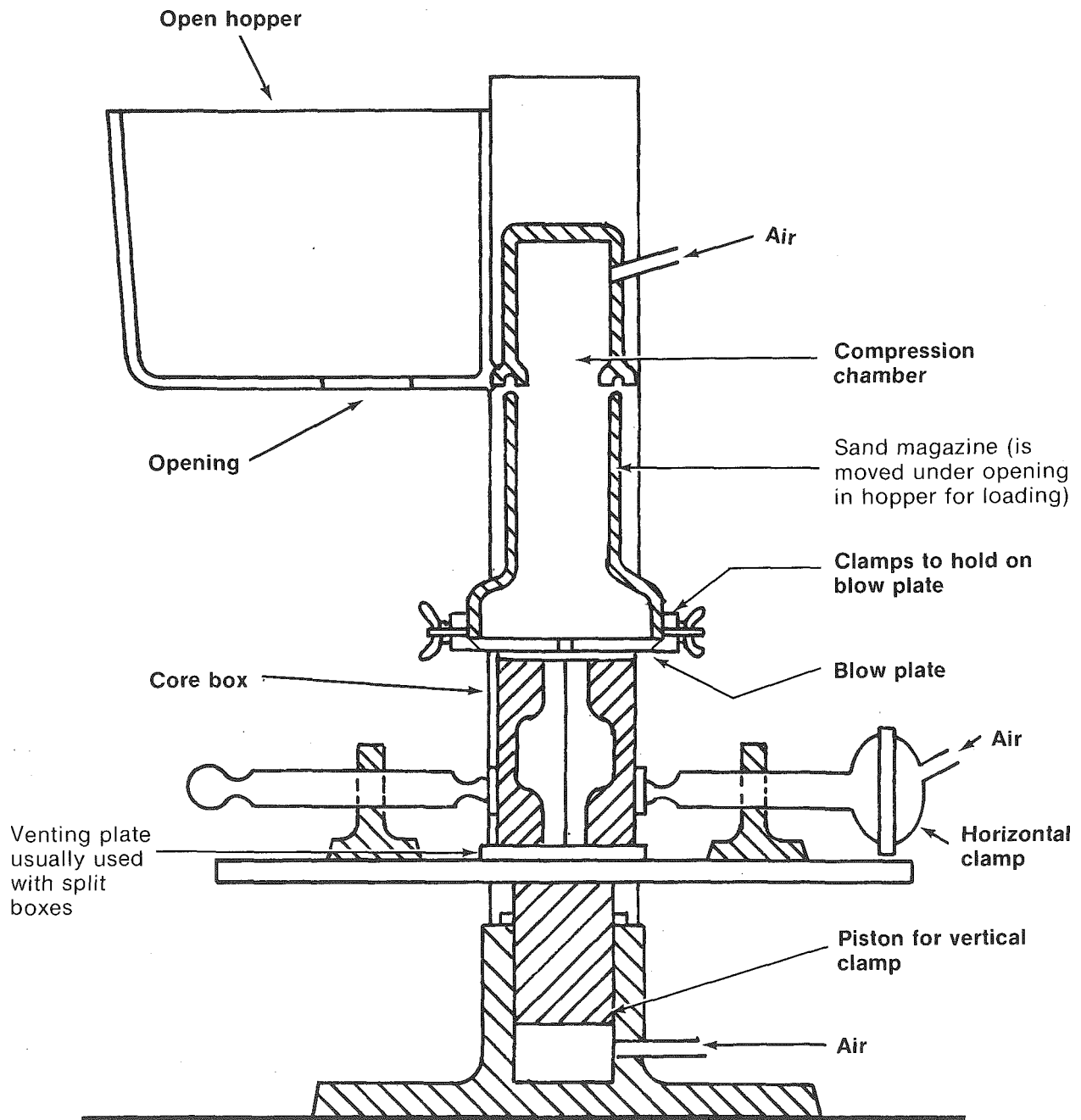
3. Machine methods of ramming:

- a. Jolting - corebox, filled with sand, is placed on a jolt table and repeatedly jolted (bounced) to compact the sand; also called jarring or bumping.
- b. Squeezing - corebox, plus a removable upset, is filled with sand, squeezed (squashed) to compact the sand, upset removed and excess sand struck off.
- c. Blowing - sand is shot into corebox cavity with air pressure - this method probably used more than any other. See page 26
- d. Extruding - sand is forced through dies to produce cores of various diameters. Cores are then baked and stored until needed (called stock cores). See page 27

4. Baking

- a. Ovens - various types to accommodate various size cores.
 - 1. Drawer type - used for small cores and consists of a steel cabinet containing drawers of various heights, designed to support cores during baking.
 - 2. Shelf type - used for small and medium size cores and consists of separate racks of shelves which are moved about with forklift trucks. Ovens are loaded and unloaded according to production requirements.
 - 3. Car type - used for large cores and consist of cars similar to railroad flatcars with arrangements for adjustable shelving to support cores during baking. These cars are usually pulled in and out of huge ovens by using the shop crane and a pulley arrangement.
 - 4. Continuous types - are strictly production type ovens, used by shops having all cores being pretty much the same size and requiring about the same amount of time for baking. See pages 28 & 29

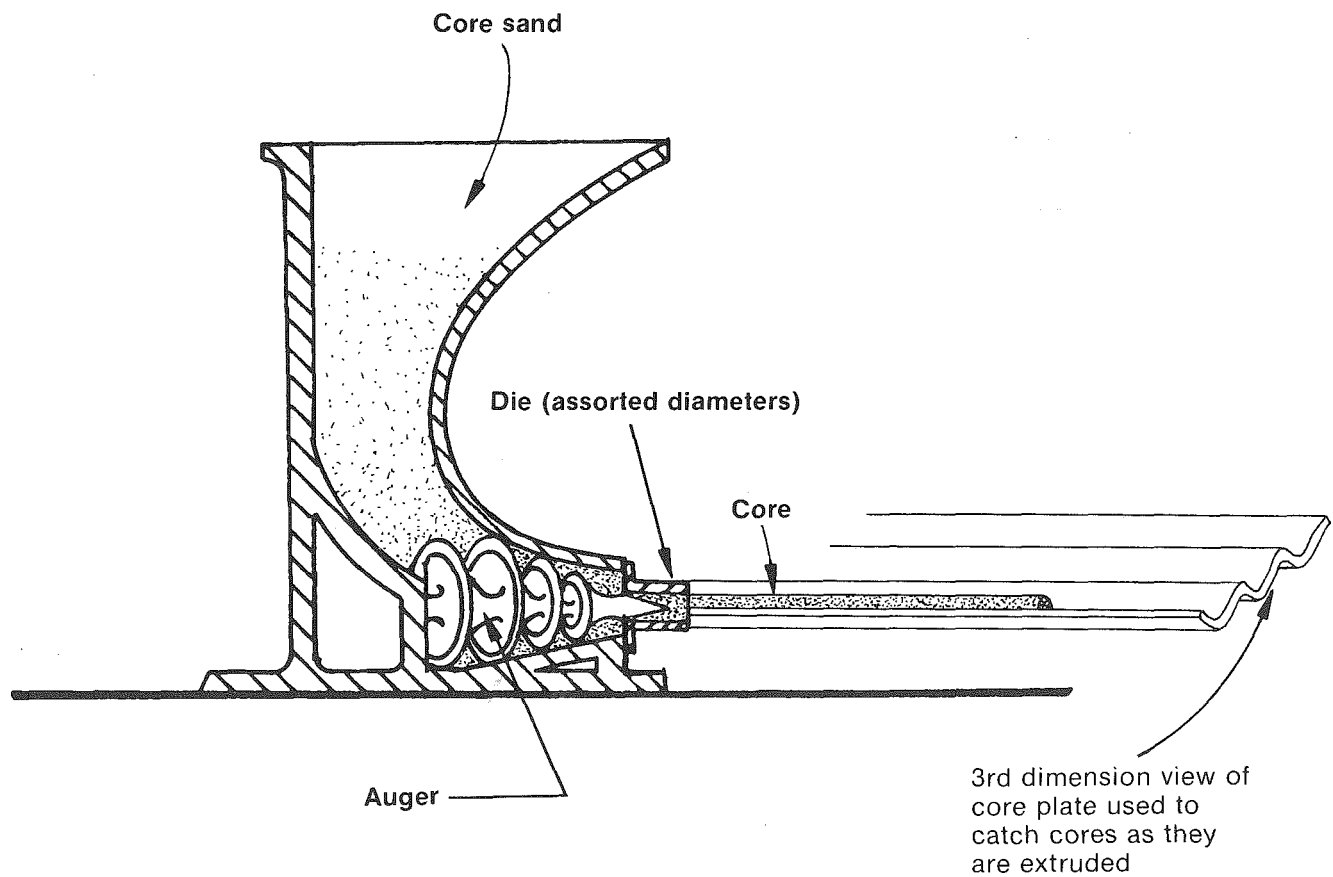
CORE BLOWING MACHINE



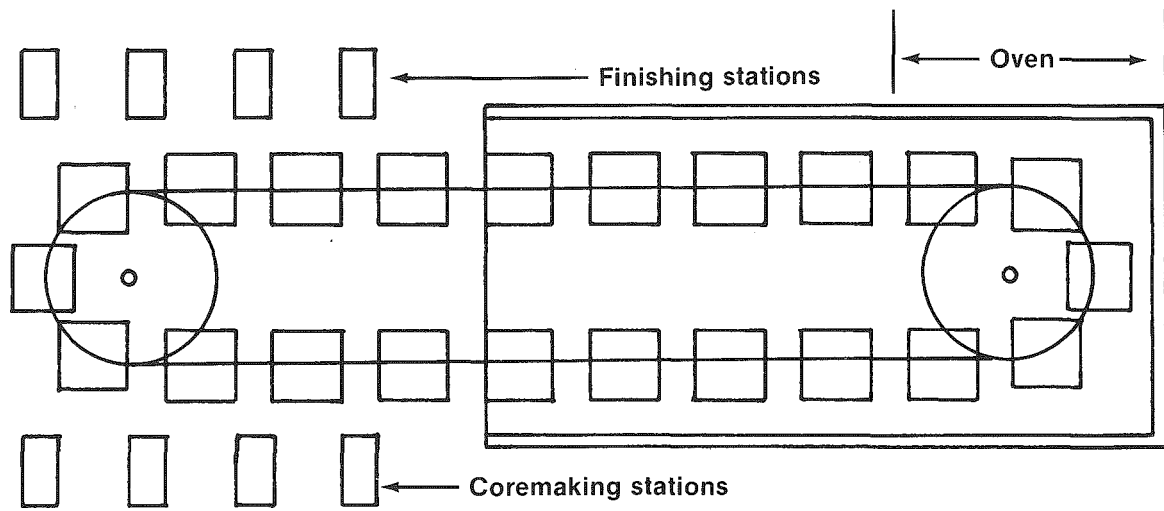
When activated, air rushes in, clamps secure everything horizontally and vertically while sand is shot into the corebox cavity. The production cycle is dependent upon the amount of time taken to remove the core and replace the empty corebox back into the machine.

EXTRUSION PROCESS FOR MAKING STOCK CORES

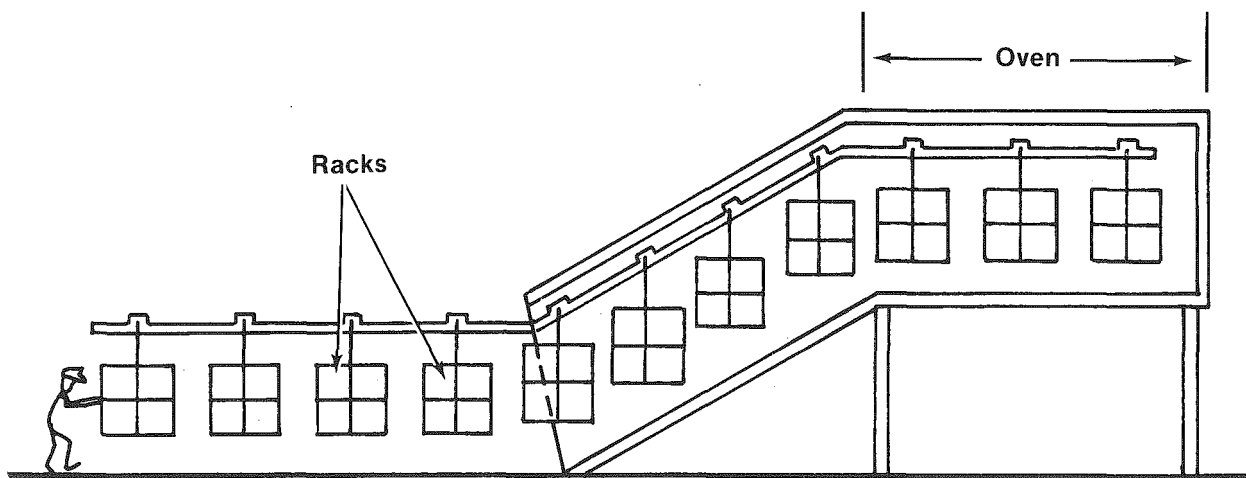
(Also called the stock core machine)



HORIZONTAL CONTINUOUS OVEN



TOP VIEW

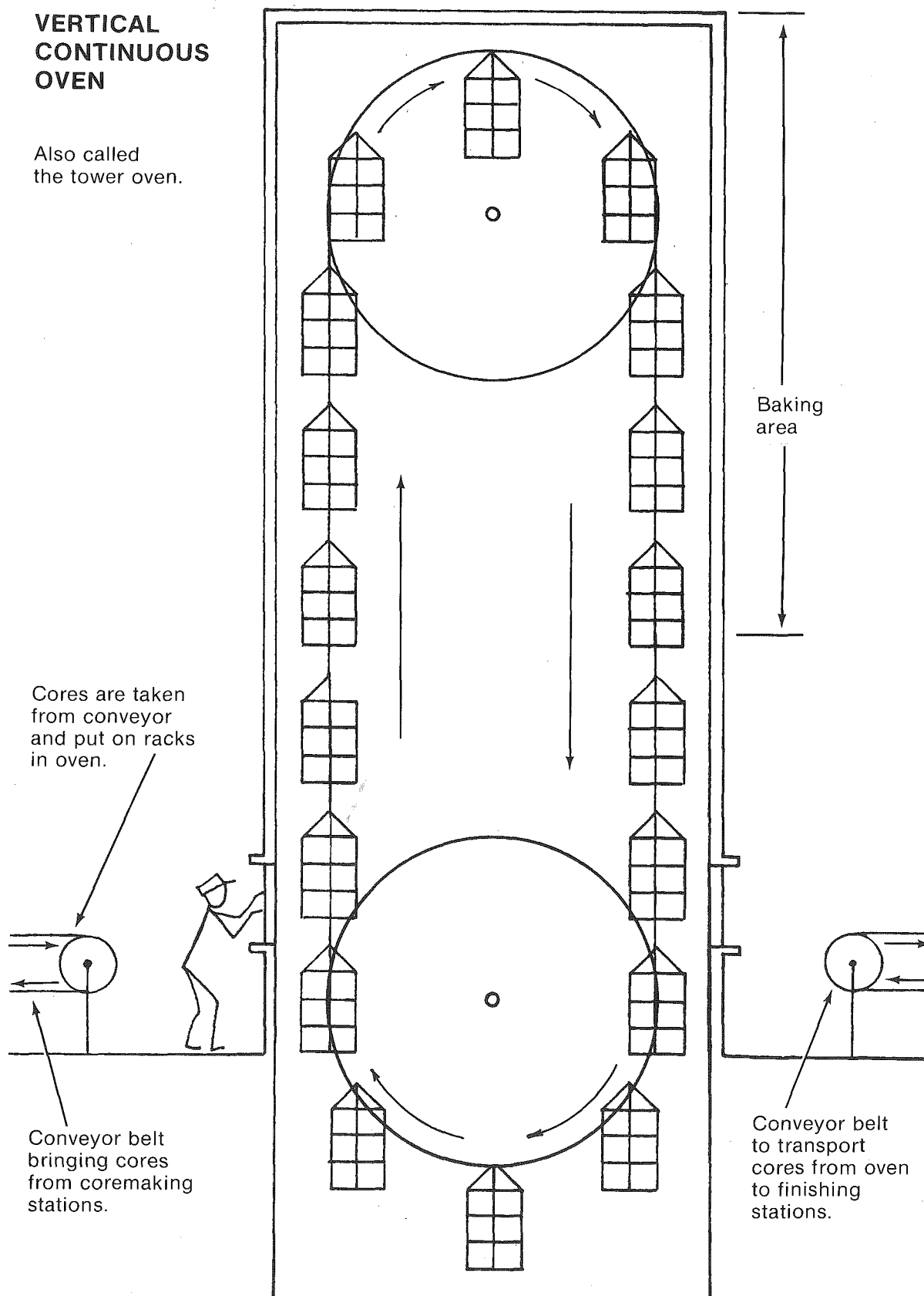


SIDE VIEW

Possible disadvantage: Takes up a lot of room.

VERTICAL CONTINUOUS OVEN

Also called
the tower oven.



6. Binders and additives

A. Definition - Binders are any materials, provided by nature or by man, that impart cohesiveness.

B. Natural and synthetic molding sands - NOTE: Use of the word synthetic is in reference to the sand mixture, not the sand grains.

1. **Natural molding sands** - natural mixtures of sand and clay that can be used for molding just as dug from the ground
2. **Synthetic molding sands** - made by mixing washed, dried and graded silica sand with exact proportions of binders and additives.

C. Clay type binder Natural earthy materials that become plastic when moistened.

1. **Bentonites (montmorillinites)** - the weathered product of volcanic ash and the most common binders of molding sands. There are two types:
 - a. Southern bentonite (calcium bentonite)
 1. Imparts green strength
 - b. Western bentonite (sodium bentonite)
 1. Imparts dry strength as well as a good green strength.
2. **Fire clays (kaolinities)** - the residue of weathered granite and basalt (a kind of marble) and the major clay when all foundry uses are considered.

D. Organic binders

1. **Cereals**
 - a. Wheat, rye and corn
 - b. Usually flour-like materials (sometimes liquid like molasses)
 - c. Inexpensive
 - d. Provide good green strength (seldom used alone)
 - e. Impart good blowability and collapsibility
 - f. Sometimes mixed into molding sands to prevent drying out.

2. Resins and gums

- a. Natural resins (called gums) are derived from the destructive distillation of wood and petroleum - also the exudations of plants.
- b. Synthetic resins (called resins) are derived from reactions of several organic chemicals and are closely related to plastics.
 - 1. Do not require oxygen to cure (a binder for the shell process)

3. Proteins

- a. Derived from milk
- b. Air dry to a strong bond
- c. Core paste

4. Pitch

- a. Residue left in the distillation of tar
- b. Used in iron foundries for hot strength
- c. Used sparingly for it is water resistant and gaseous.

5. Drying oils

- a. Linseed, soybean, some mineral oils, and some animal and fish oils
- b. Liquid when mixed, but changes to a coherent film when baked (not evaporation, but a complex chemical reaction requiring oxygen)
- c. Impart good collapsibility and good dry strength
- d. Produce very little green strength (seldom used alone).

E. Inorganic binders

1. Portland cement

- a. Calcined clay and limestone (name due to appearance - similar to English Portland stone)
- b. A high, early strength cement (8 to 12% cement to sand). See page 12

2. **Sodium silicate** - common water glass
 - a. Binder for the CO² process (also nobake molding)
 - b. Cores or molds may air-set or be set instantly by gassing with CO² (also with liquid or powder catalysts)
 - c. Imparts poor collapsibility (can be improved with additives). See below.

3. **Miscellaneous** - water bond (generally, water is not considered a binder)
 - a. Sand mixed with water and frozen into a shape
 - b. Used to produce some ferrous castings with hard, wear resistant surfaces - also some aluminum castings.

F. Sand additives

1. **Definition** - any materials added to sand that do not promote bond.

2. **Reasons for usage**
 - a. To minimize sand expansion defects
 - b. To improve collapsibility
 - c. To improve finish
 - d. To prevent metal to mold reactions

3. **Additives**
 - a. Seacoal - a finely ground coal used to promote "c" above in iron foundries
 - b. Wood flour - a finely ground wood used to promote "a" and "b" above
 - c. Silica flour - a finely ground silica used to promote "c" above in steel foundries
 - d. Iron oxide - a finely ground rust used to promote "a" above
 - e. Soda ash - a finely ground sodium carbonate used to control a sand's pH to eliminate strength problems
 - f. Boric acid - a finely ground material used to promote "d" above in foundries casting magnesium

7. Sand testing

A. Definition - Methods and equipment are used to examine or test foundry sand mixtures, to either set standards or to locate problems relating to casting defects.

B. Sand tests

1. Moisture tests

- a. Shop method - by weighing out a sample of sand (50 grams) and drying for a set length of time (5 minutes), then reweighing the sample and multiplying the weight loss by two, the percent of moisture can be determined.
- b. Standard method - a 100 gram sample is completely dried in a drying oven, cooled in a desiccator, then reweighed with the weight loss being read directly from the scale as % of moisture. This method is mainly for research.
- c. Speedy moisture checker - a portable unit using a predetermined amount of sand mixed with a set amount of calcium carbide in a closed container that has provisions for measuring the amount of gas produced and relating it to moisture content. Results are read from a gauge calibrated to fall in line with the shop method.

2. Permeability - measured by the time taken to allow a measured amount of air to pass through a standard specimen of sand. (2" high by 2" in diam.) The result is represented by a number. The larger the number, the more permeable the sand.

3. Strength - measured either green or dry for compression, shear, tensile or transverse strengths and usually expressed in P.S.I. (sometimes in ounces per sq. in.)

4. Hardness - measured with a dial indicator that is calibrated to record a surface's resistance to denting. Readings range from 0 to 100. Is also used as an inspection tool.

NOTE: Moisture, strength, permeability and hardness tests are indicators of any serious changes occurring and are run periodically throughout each day. Other tests may only be run on a weekly basis or only when a daily test indicates a problem.

5. Clay content - a 100 gram sample is washed (in a sand washer with water and a cleansing agent) and then put through a series of settling and syphoning until the water is perfectly clear after settling for five minutes. The washed sample is then dried and reweighed with the missing weight representing the % of clay. (A combustible test would have to be run in order to find what's called "true clay.")

6. Grain distribution - a washed and dried sample of sand is put into and agitated through a series of sieves. Sand caught on each sieve is weighed and recorded. These figures can be graphed to show pictorially a sand's distribution. Sieves range from 6 to 270 openings per lineal inch.

7. Miscellaneous tests

- a. Sinter test
- b. Dialatometer tests
- c. pH

8. Patterns

A. Definition - forms of wood, metal or other suitable materials around which molding materials are packed to produce the mold cavity.

B. Major allowances made by patternmakers (See page 36)

1. Shrinkage

- a. An overall enlargement of the pattern and coreboxes to compensate for the normal shrinkage of cast metals during solidification
- b. Accomplished by using shrink rules. Example: The shrink rule for cast iron is 1/8 of an inch longer per foot than a common rule. NOTE: Different metals shrink different amounts. Example: The shrink rule for steel is usually 1/4 of an inch longer than the common rule.
- c. Two metals that do not shrink are bismuth and gallium.

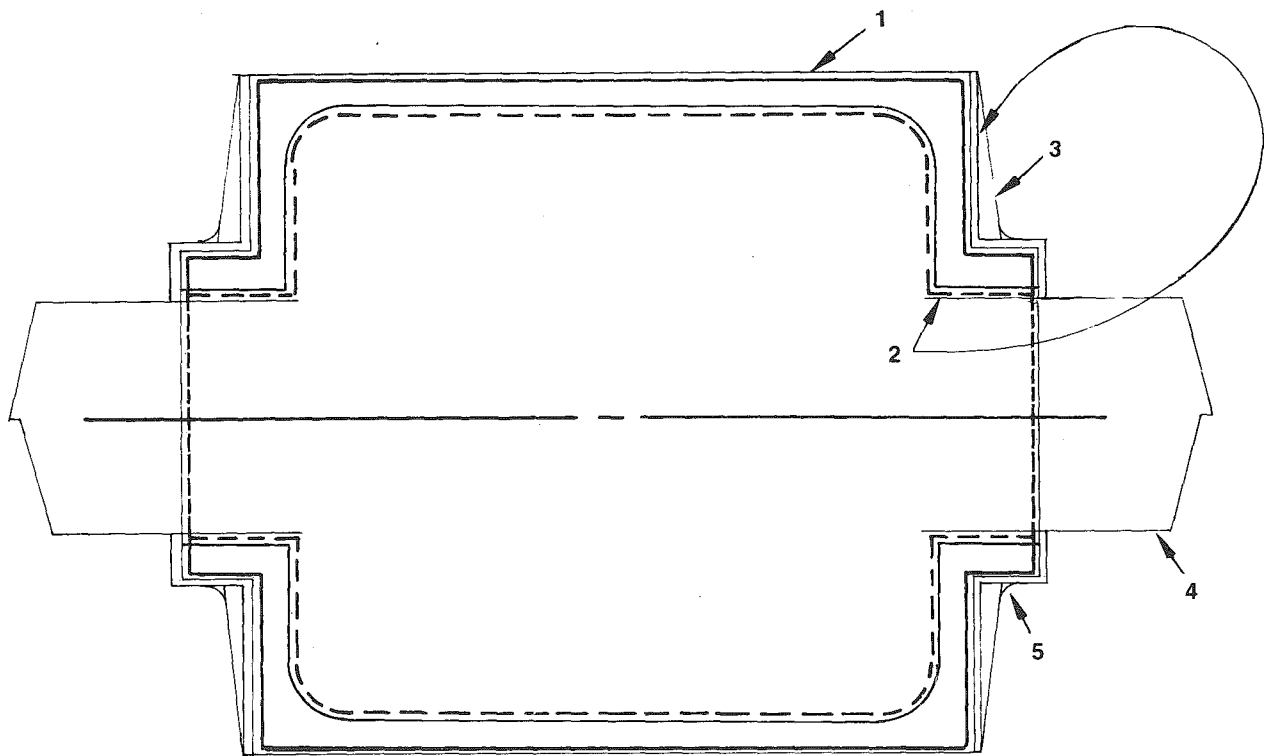
2. Finish - Additional stock, added to the pattern, to compensate for machining.

3. Draft angle - Taper placed on the vertical surfaces of patterns to facilitate ease of removal from the mold cavity.

4. Coreprints - Extended portions of patterns and coreboxes for the locating and supporting of cores.

5. Fillets and rounds - Incorporated to eliminate sharp reentrant angles (sharp corners) which would cause hot spots (areas not solidifying at the same rate as the rest of the casting). The difference in the rate of solidification is due to both increased mass and heated sand.

MAJOR ALLOWANCES MADE BY PATTERNMAKERS



1. Shrinkage
2. Finish
3. Draft angle
4. Coreprints
5. Fillets and Rounds

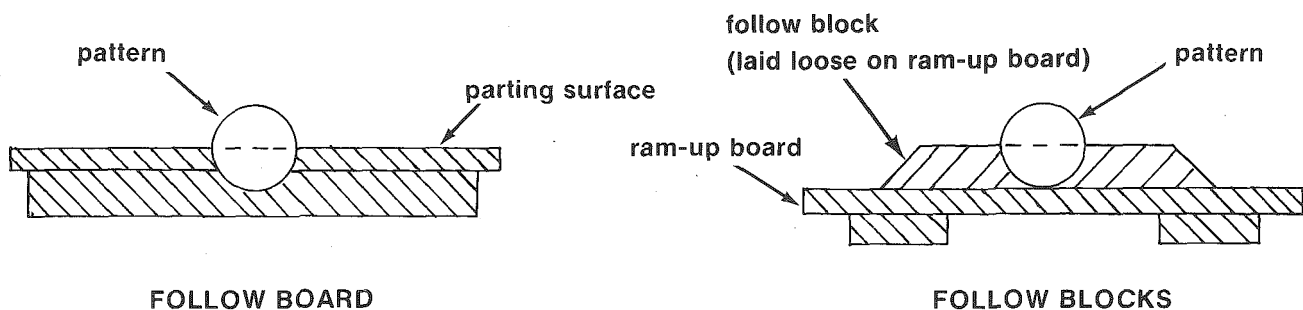
C. Minor allowances

1. **Distortion** - Pattern is sometimes shaped to compensate for a distortion known to occur on some production runs. Example: Flat castings usually have a tendency to pull up on the ends during solidification. Solution: Preshape pattern in reverse.
2. **Shake** - Compensation for the rapping of a pattern.
3. **Location points** - Information put on patterns for molders', manufacturers' or customers' convenience. (Tell-tales on coreprints, vent locations, name core placement, firing order on an engine, etc.)
4. **Machining provisions** - Chucking lugs or other additions to assist machining. Example: Locators for machine shop fixtures.
5. **Color code** - Originally an AFS standard for wood patterns

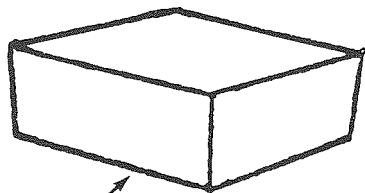
Color	Condition
Clear	Surface left as cast
Red	Finish (surface to be machined)
Black	Coreprint
Alum.	Seat of a loose piece
Green	Stop-off (area on pattern is for strengthening pattern and is not meant as part of casting)

D. Types of patterns

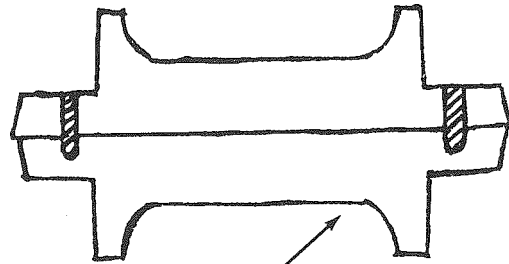
1. **Loose patterns** - (See page 38) Single, split or loose piece
2. **Gated patterns** (See page 38)
3. **Match plates (cast) or mounted patterns** (See page 38)
4. **Miscellaneous** (follow boards, follow blocks, sweep, skeleton, etc.)



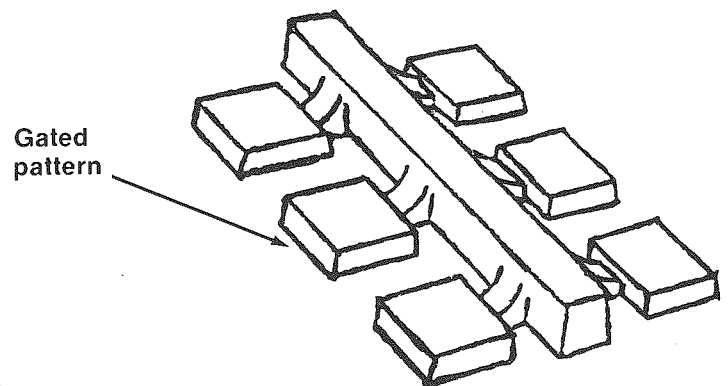
ASSORTED PATTERNS



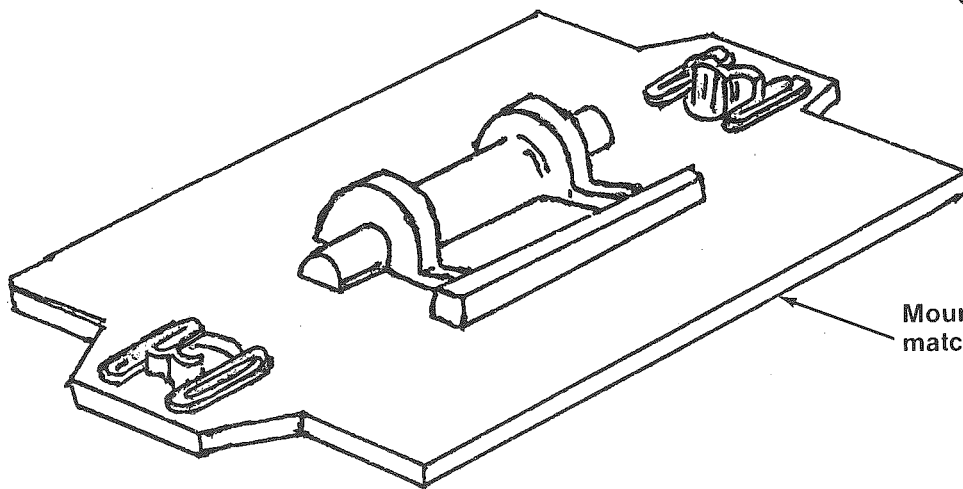
Single (loose)



Split (loose)



Gated pattern



Mounted pattern or
match plate (if cast)

E. Pattern materials - Depends on production requirements.

Castings required	Material
1 to 99	Wood (soft or hard) Soft woods - white pine or sugar pine Hard woods - mahogany or cherry Plaster, Styrofoam etc.
100 to 499	Hard wood, plastics, metal or styrofoam
500 and up	Metal (most prevalent) and styrofoam

F. Pattern materials comparison chart

	Wood	Aluminum	Iron	Steel	Plastic
Machinability	Ex	Good	Good	Fair	Good
Wear resistance	Poor	Good	Good	Ex	Fair
Strength	Fair	Good	Fair	Ex	Good
Weight (fatigue)	Ex	Good	Poor	Poor	Good
Repairability	Ex	Good	Fair	Good	Fair
Corrosion (water)	Ex	Ex	Fair	Poor	Ex
Swelling (water)	Poor	Ex	Ex	Ex	Ex

▲ ————— BEST SCORES ————— ▲

G. Coreboxes

1. **Definition** - A structure made of wood, metal, or other suitable materials containing a cavity with the shape of a desired core.
2. **Construction and materials are the same as with patterns.**

9. Gating systems

A. Definition - Various means of channeling molten metal through the cope and into the mold cavity with modifications for controlling certain energies and forces and trapping damaged metal prior to its entering the mold cavity.

B. Types and classifications (See pages 41-46)

1. Parting line systems (most frequently used)

- | | | |
|-------------|-----------|---------------|
| a. Relief | c. Whirl | e. Shrink-bob |
| b. Skim-bob | d. Branch | f. Strainer |

2. Top systems

- | | |
|-----------|-----------|
| a. Wedge | c. Pencil |
| b. Finger | d. Ring |

3. Bottom systems

- | | |
|---------|------------------|
| a. Horn | c. Ceramic tubes |
| b. Step | d. Cores |

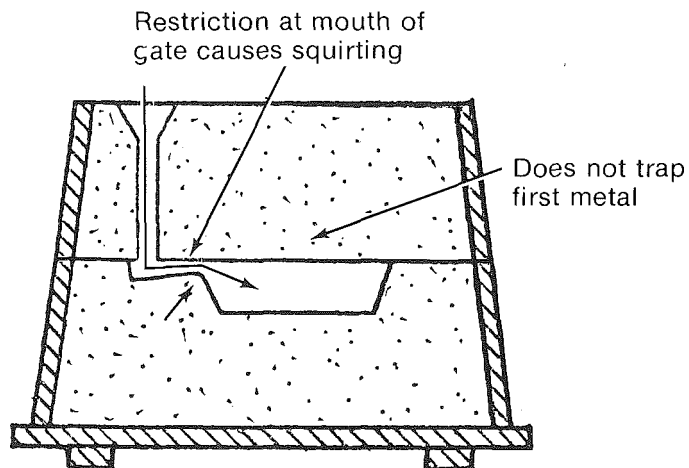
10. Solidification of metals

A. Definition - A physical process of change occurring when a liquid reverts to a solid state.

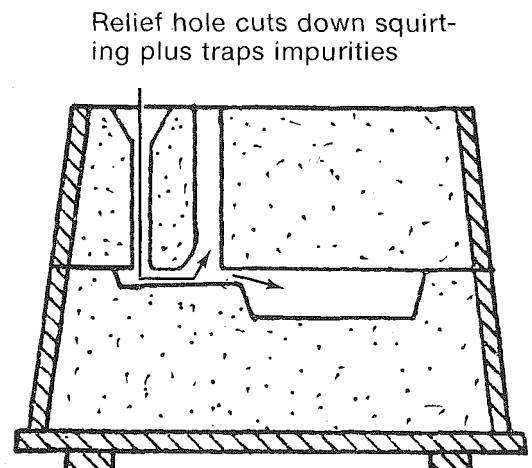
B. The process

1. Begins with the formation of solid nuclei as a result of localized reduction of molecular activity.
2. Nuclei grow, in most cases, as tree-like crystals called dendrites.
3. Nucleation, or crystal growth, continues until all the metal has solidified.

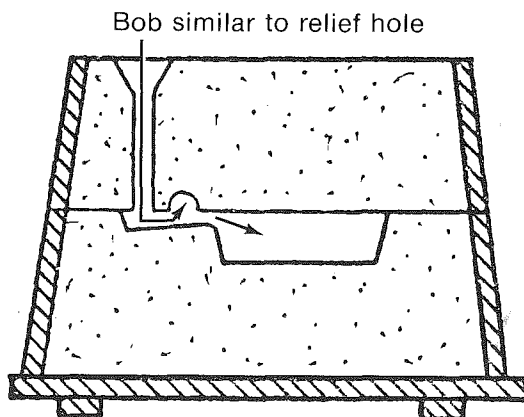
ASSORTED GATING SYSTEMS



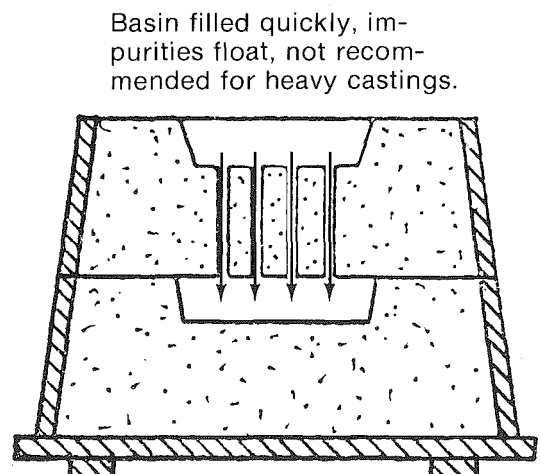
SIMPLE PARTING LINE SYSTEM



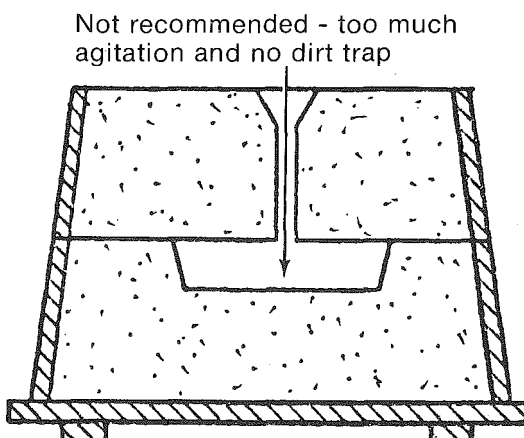
RELIEF SYSTEM (PARTING LINE)



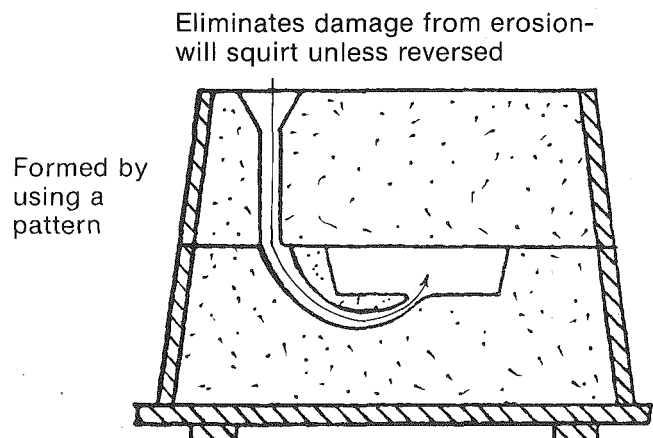
SKIM-BOB (PARTING LINE)



PENCIL (TOP SYSTEM)



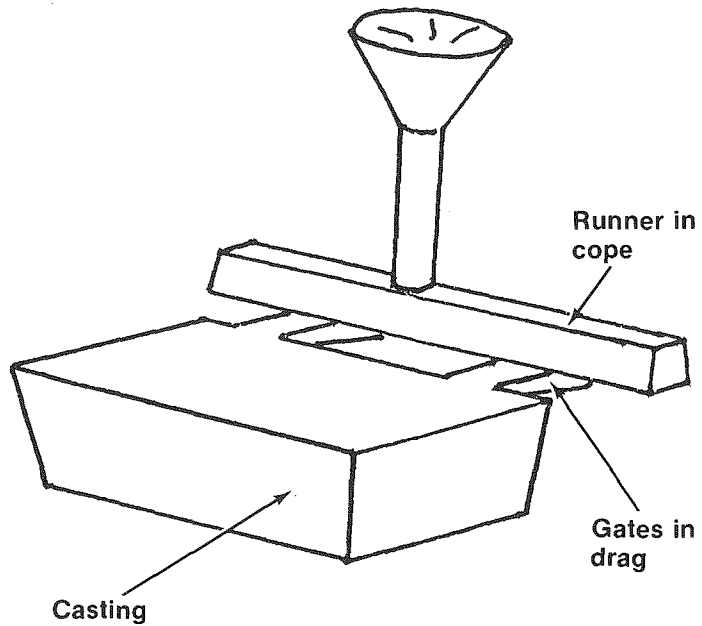
SIMPLE TOP SYSTEM



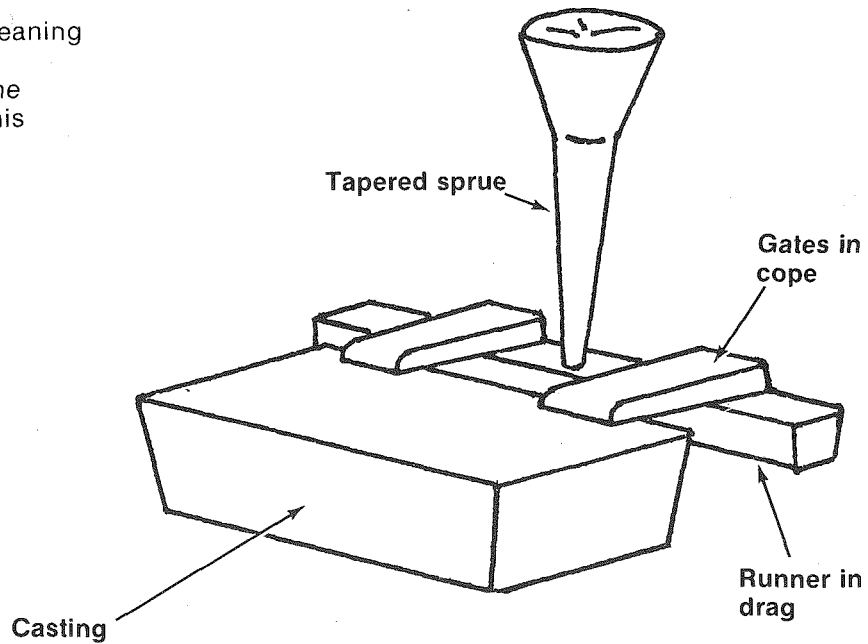
HORN (BOTTOM SYSTEM)

BRANCH SYSTEMS

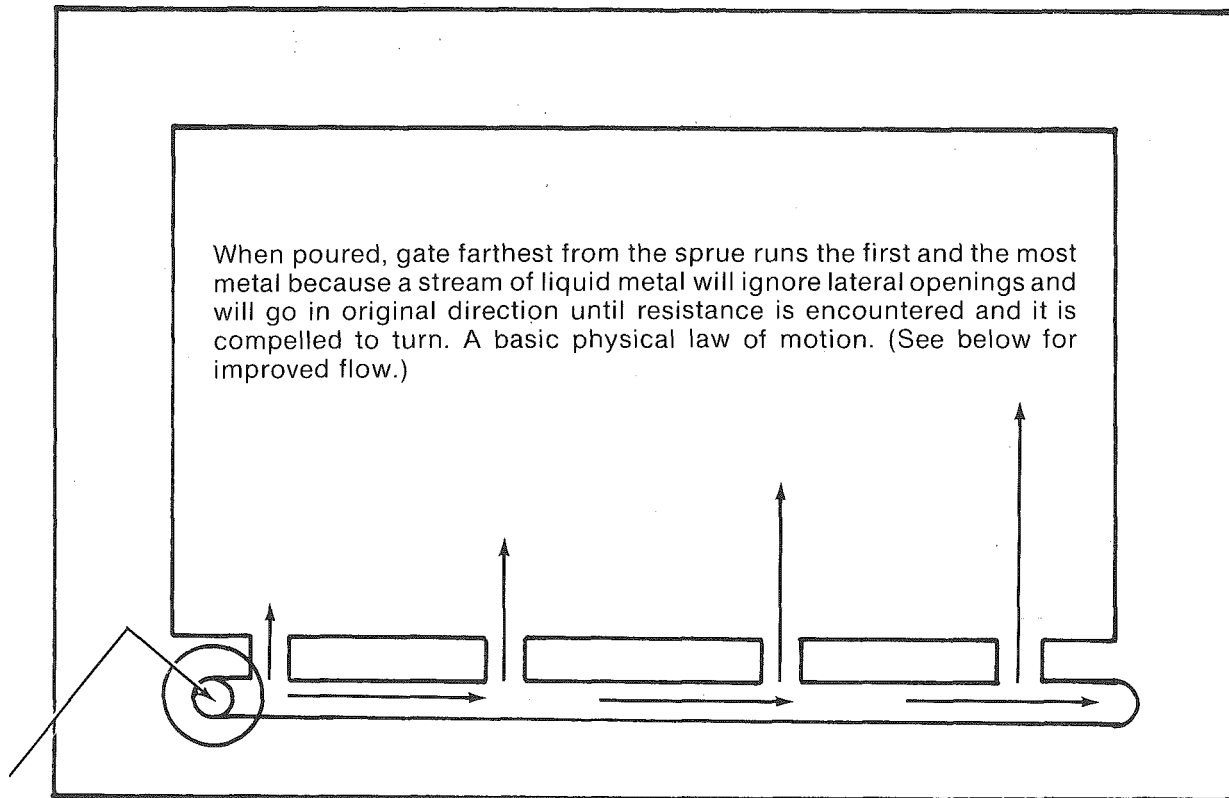
Pressurized System - meaning metal flow is restricted or controlled at the mouth of the gates. A typical ratio for this system would be 1.5 : 1 : 0.5 (area at base of sprue : area of runner : area of gates at mouth).



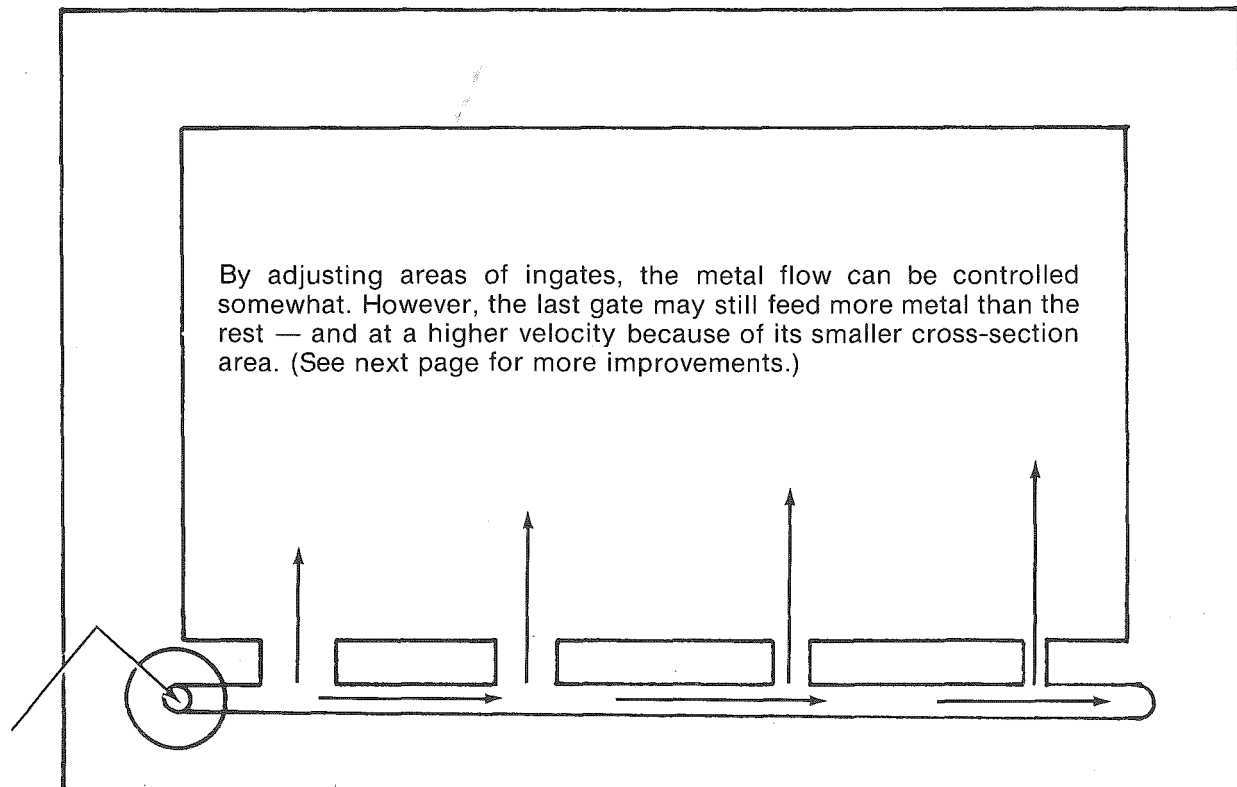
Unpressurized System - meaning metal flow is restricted or controlled at the base of the sprue. A typical ratio for this system would be 1 : 4 : 4.



BRANCH SYSTEMS (continued)

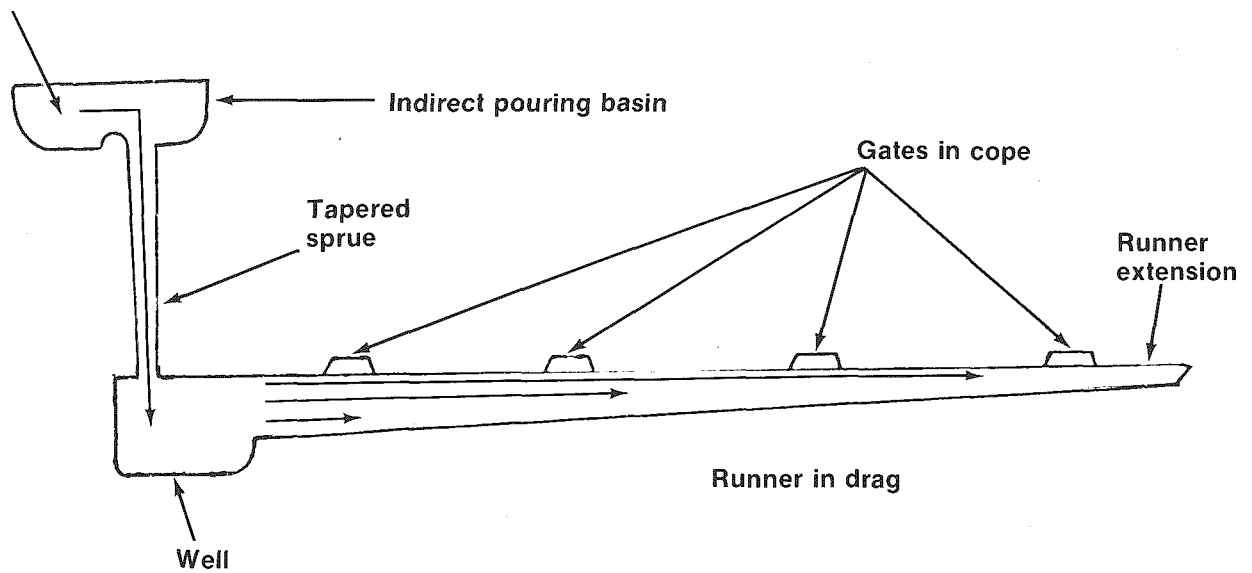


(TOP VIEWS)

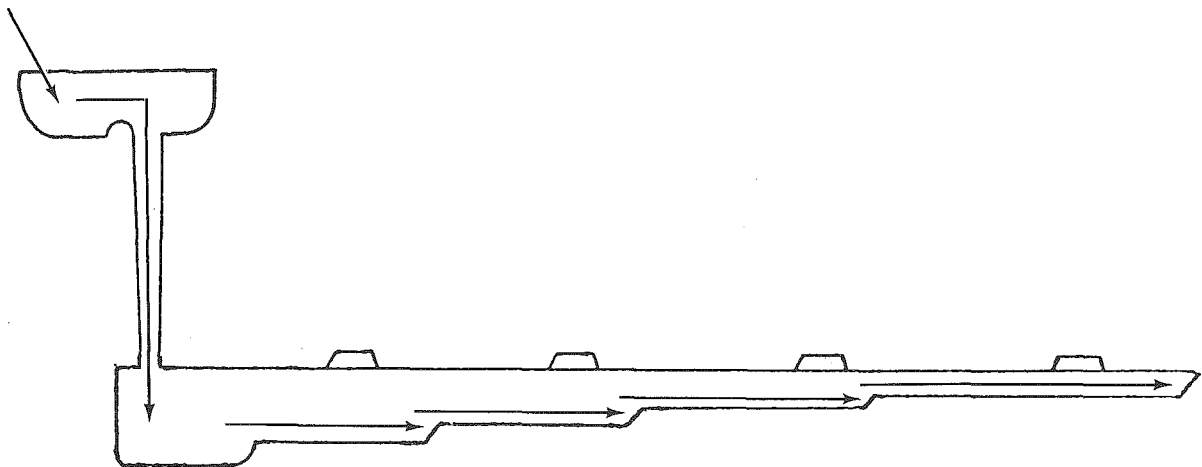


BRANCH SYSTEMS (continued)

Adjusting area of runner is a better way to control amount of metal flow from each gate and equalize the metal distribution in the mold cavity. Note runners in the drag so that all gates can receive metal at the same time and start flowing simultaneously.



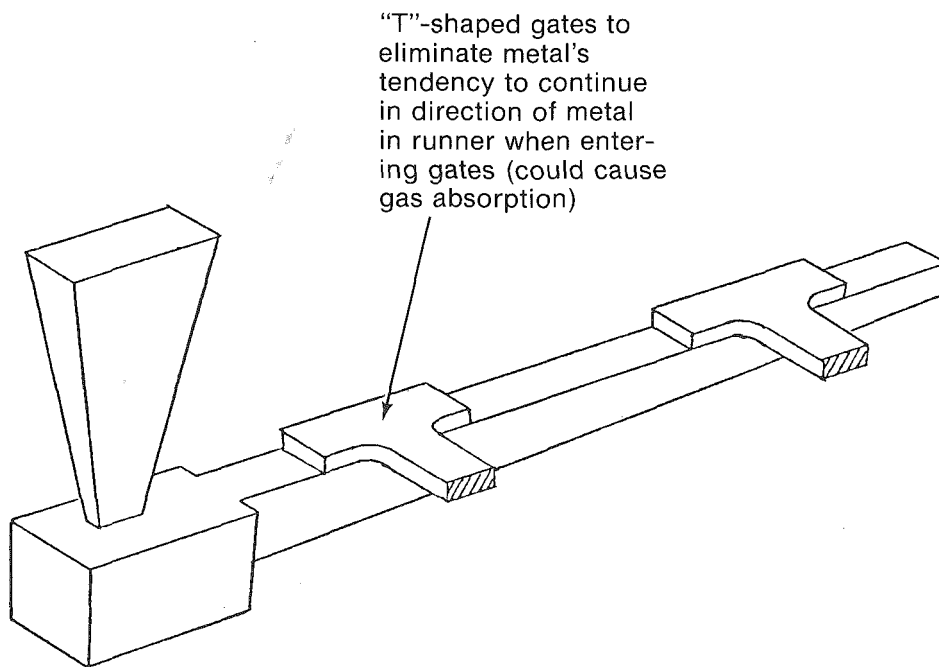
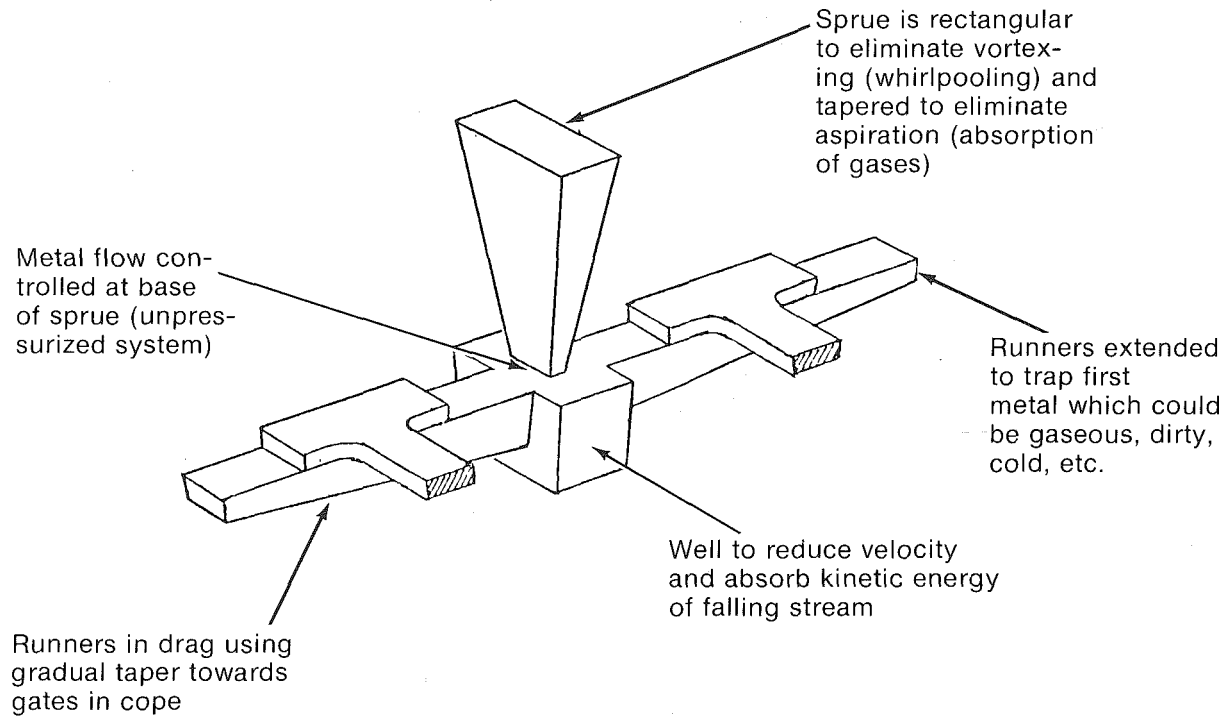
GRADUAL CONCEPT



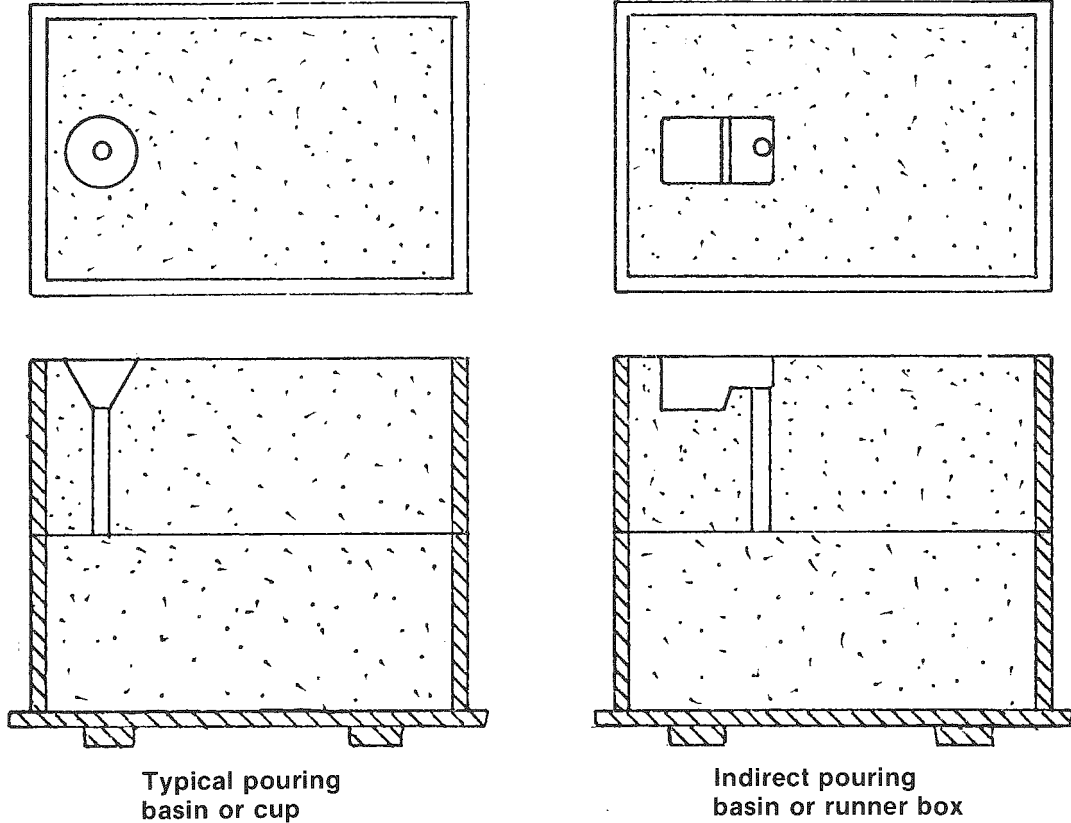
STEPPED CONCEPT

BRANCH SYSTEMS (continued)

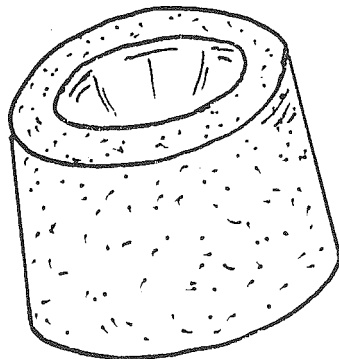
NOTE: These concepts were presented by a lecturer at an AFS meeting and greatly impressed this author.



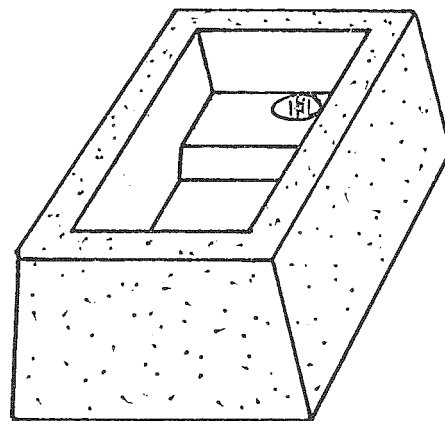
POURING BASINS, CUPS AND RUNNER BOXES



NOTE: An indirect system helps maintain a constant head (height) which reduces chance of vortexing and keeps gating system full throughout pouring operation.



Pouring cup core



Runner box core

11. Riser or feeding

A. Definition - Risers or feed heads are extra reservoirs of metal designed to compensate for excess shrinkage by feeding metal to the casting during solidification.

B. Classifications

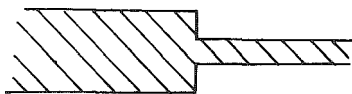
1. **Top risers** - located on the top of a casting and extend through the cope. (See pages 48-50)
2. **Side risers** - located on the side or end of a casting and extend through the cope. (See page 51)
3. **Blind risers** - located on the side or end of a casting and do not extend through the cope. (See page 52)

NOTE: It is possible to gate through side risers and blind risers.

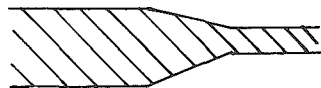
12. Casting design

A. Basic rules - All promote directional solidification

1. **Main basic rule** - all wall thicknesses uniform (no sudden changes in thickness)
Example:



Poor



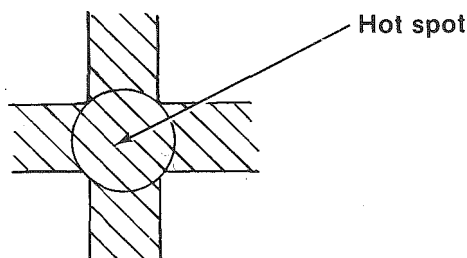
Better



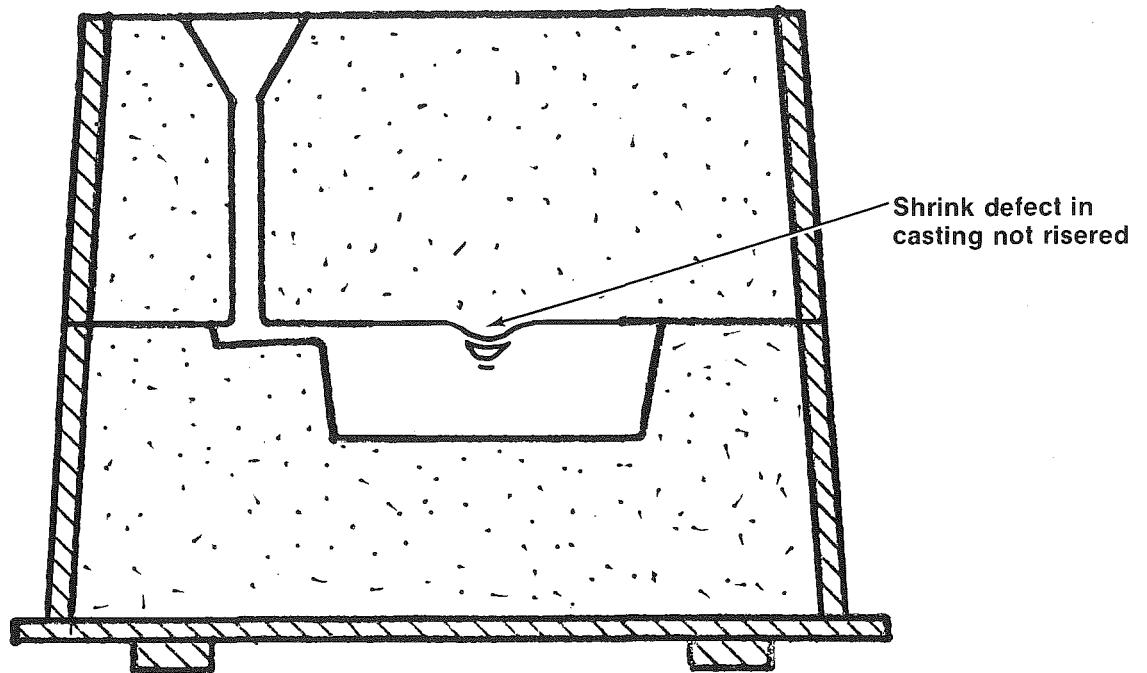
Best

2. Use fillets and rounds

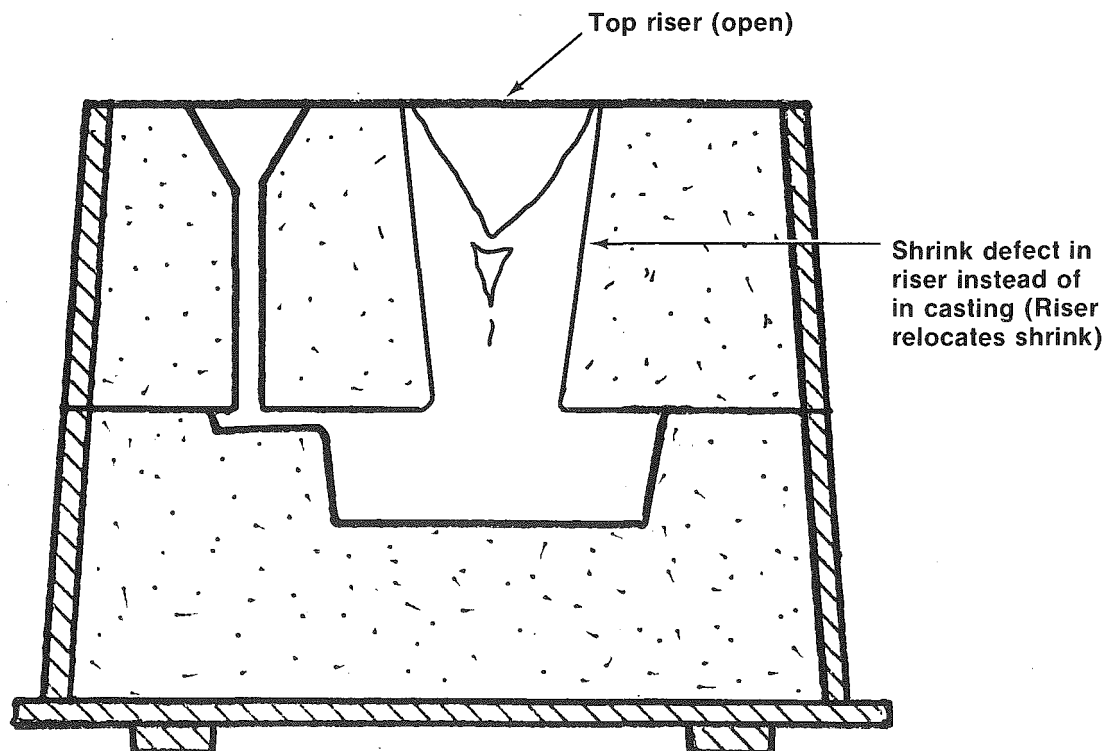
3. Plan for as few sections joining in one spot as possible. Example:



TOP RISERS

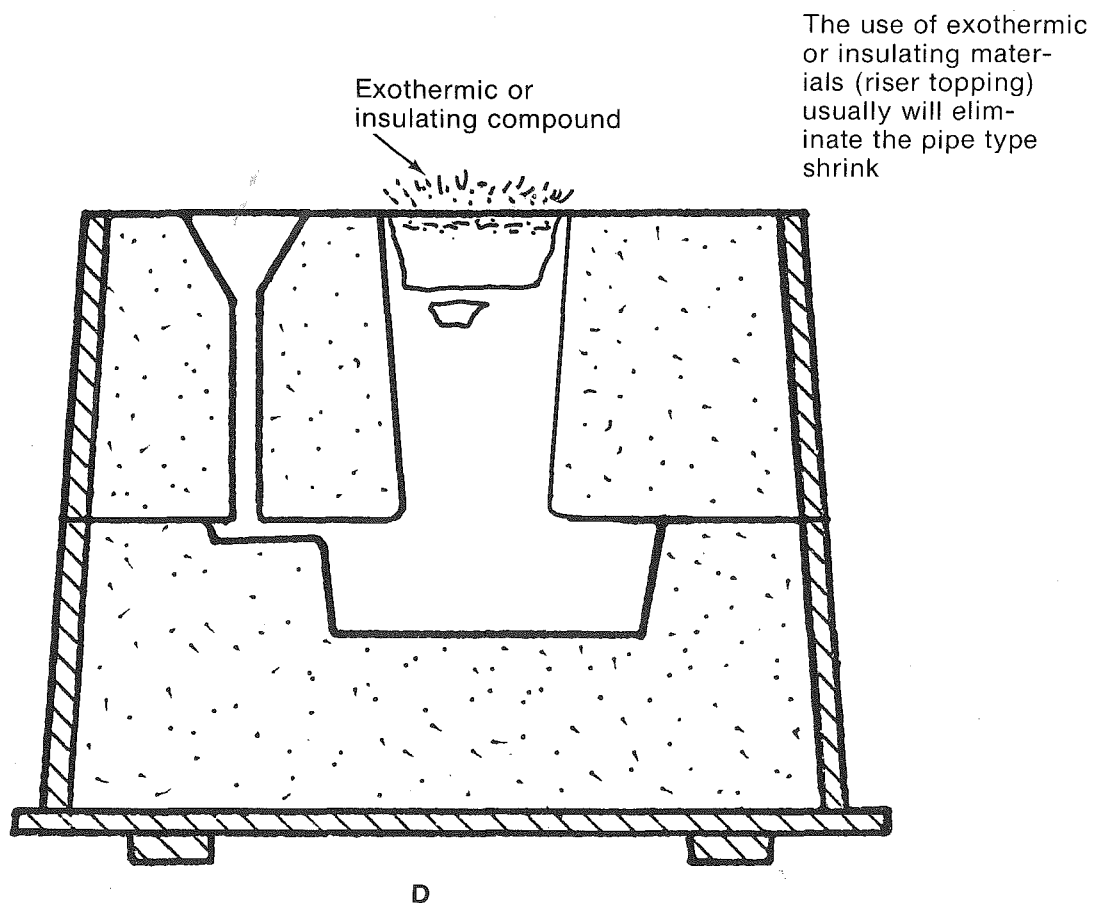
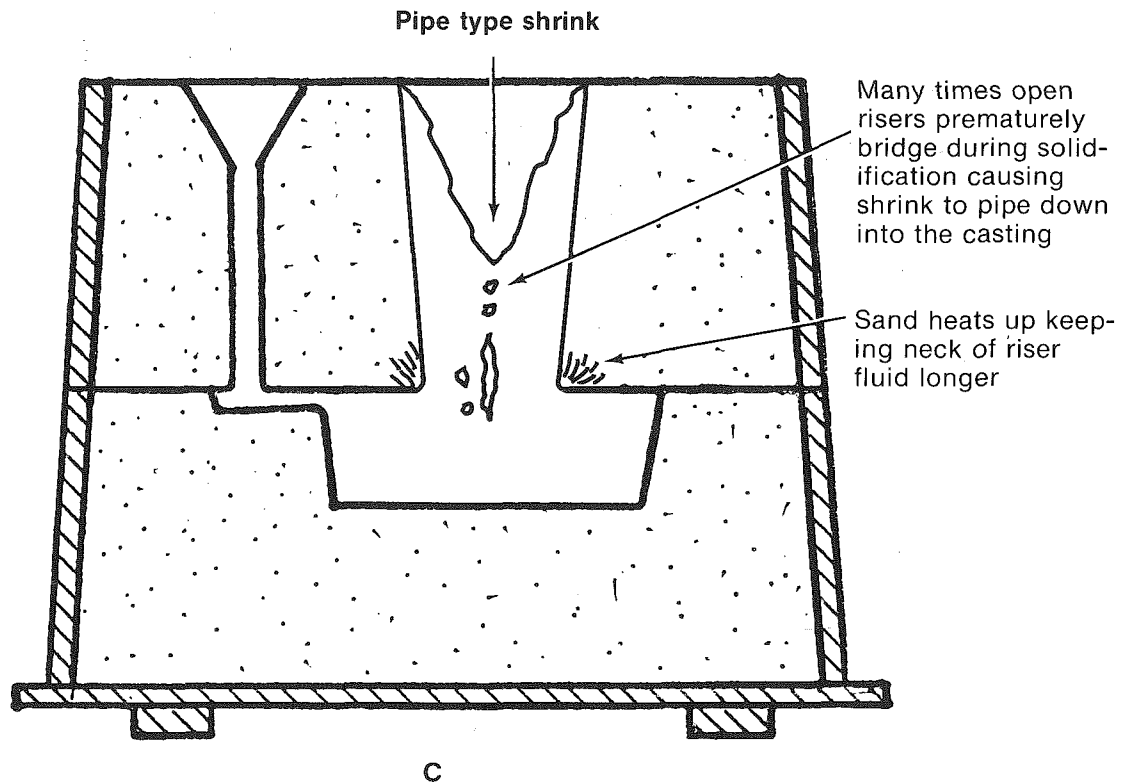


A

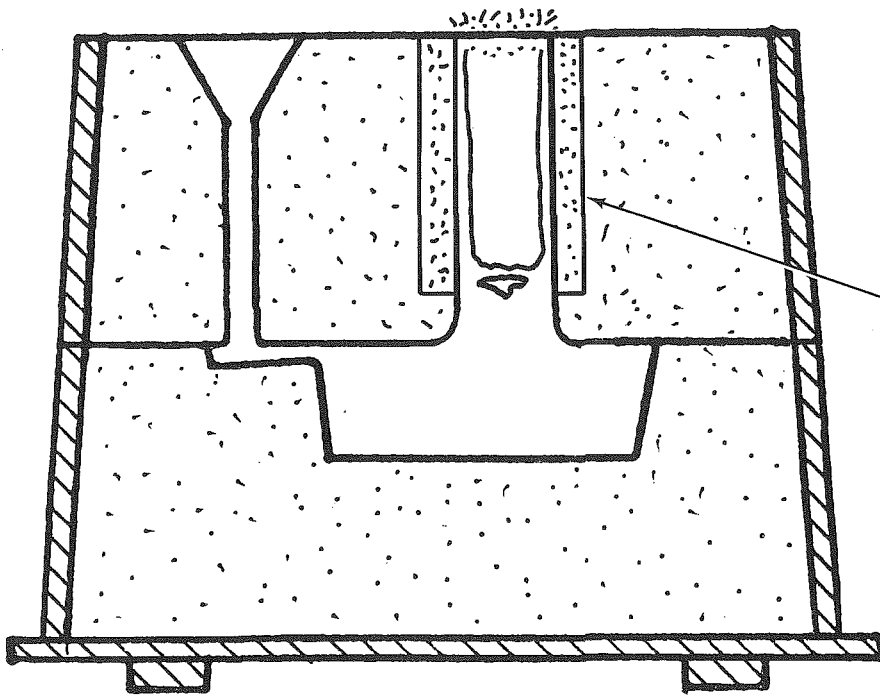


B

TOP RISERS (continued)

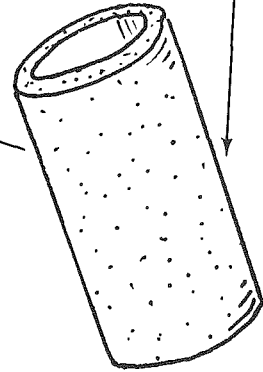


TOP RISERS (continued)

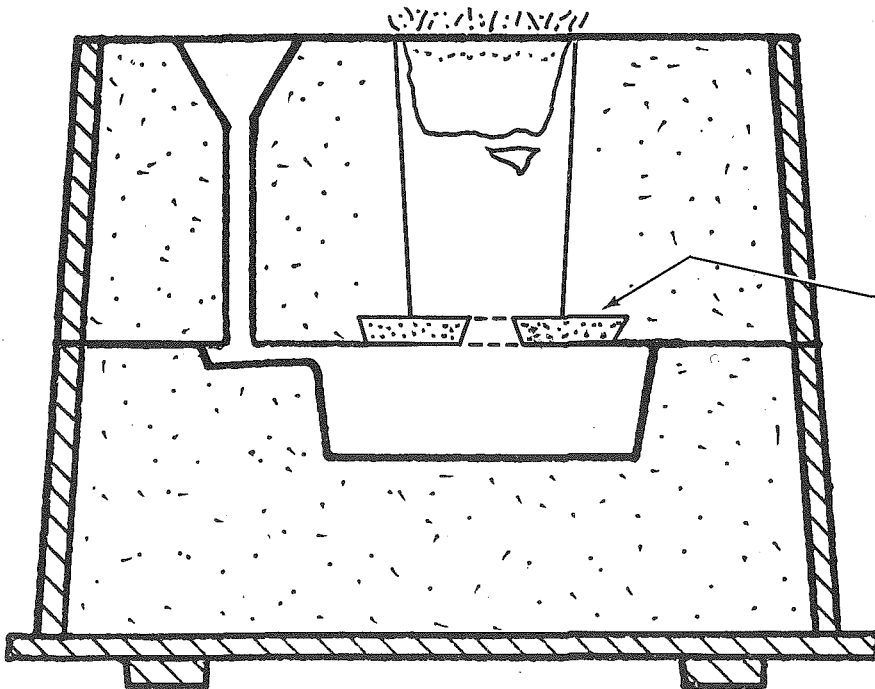


E

Exothermic or insulating sleeve

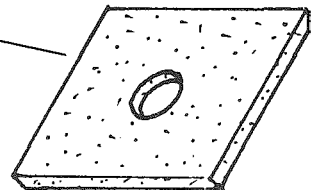


Using sleeves to keep riser fluid longer will also eliminate pipe type shrinks plus will increase yield by cutting down size of riser



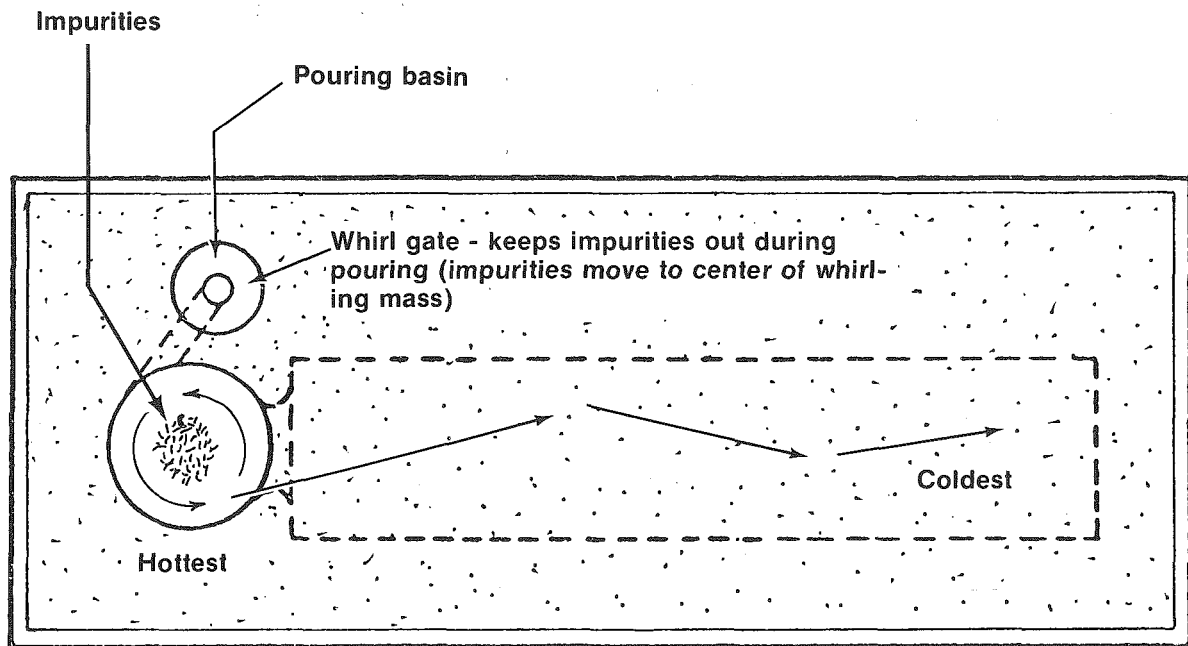
F

Neck-down core to reduce area of riser pad making knock-off possible

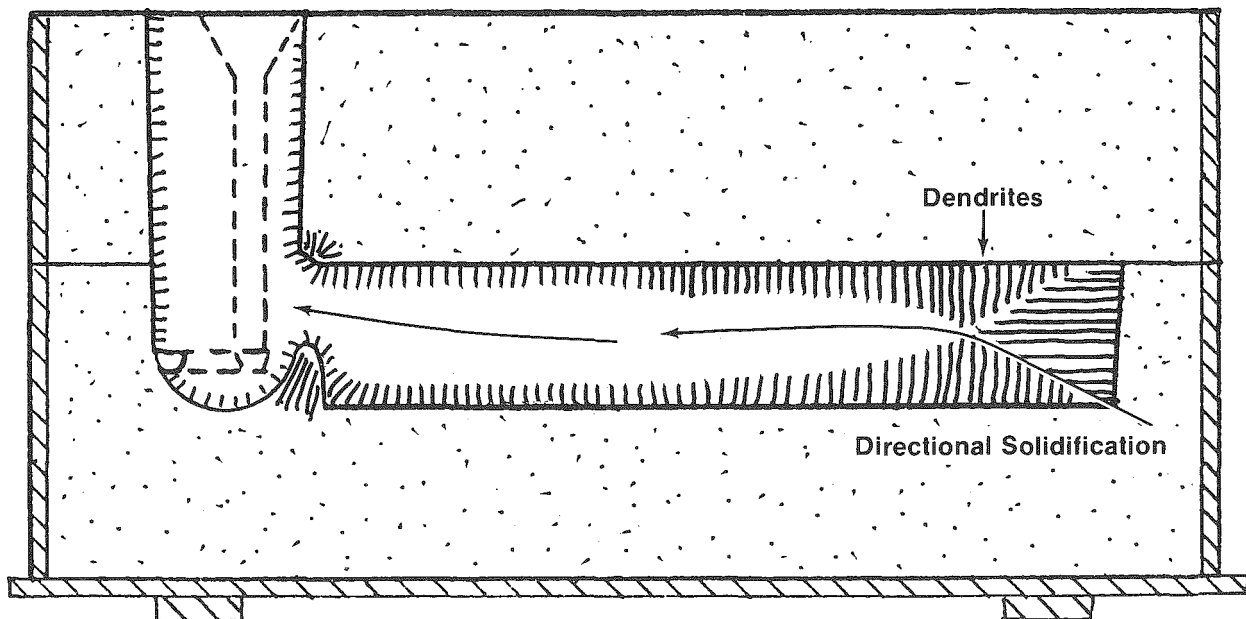


Core heats up allowing riser to feed

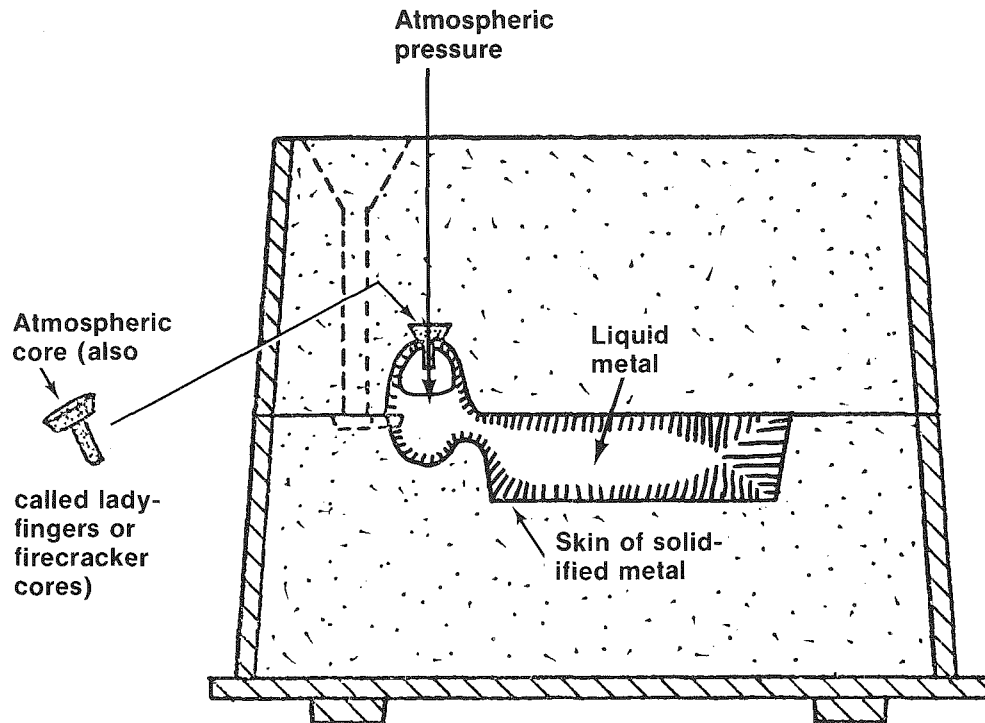
SIDE RISERS



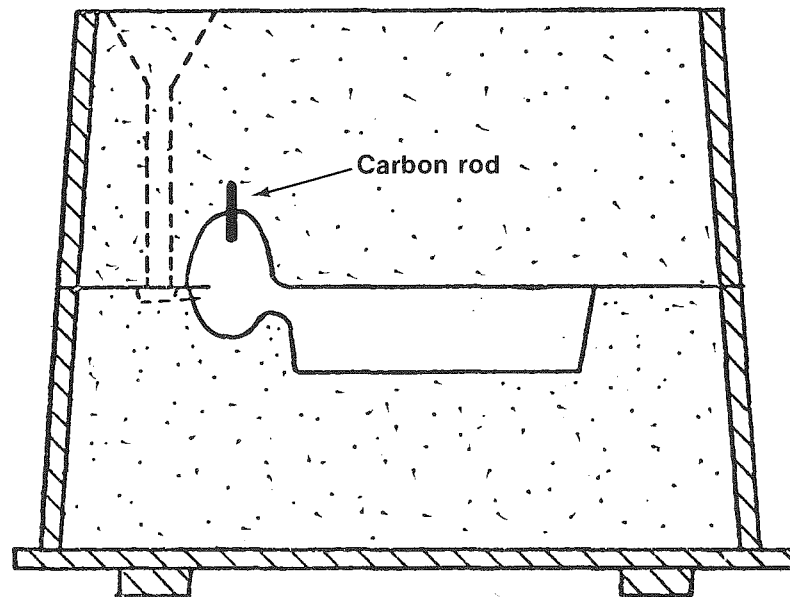
Gating through the riser induces directional solidification (last part of cavity to fill with hot supply of metal)



BLIND RISERS



Hole formed in top of riser eliminates chance of vacuum plus admits atmospheric pressure to riser interior inducing feeding. Directional solidification is induced by gating through the riser. Riser is usually vented to insure proper filling



Used mainly with large steel castings to keep risers fluid longer (a pickup of carbon will lower the point of solidification)

B. Compensating for poor designing

1. **Chilling** - inducing directional solidification by locating heat absorbing materials in strategic areas of the mold.
 - a. Internal chilling - usually done with metal pieces (of similar chemistry) which are designed for locating in problem areas of the cavity and fuse into the casting during solidification. See figure 1
 - b. External chilling - can be accomplished by ramming metal or carbon pieces into areas of the mold, by using a sand with a chilling quality in these areas or nailing these areas after pattern removal, etc. See figures 2 & 3

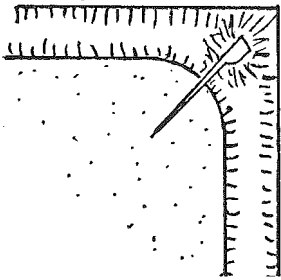


Fig. 1

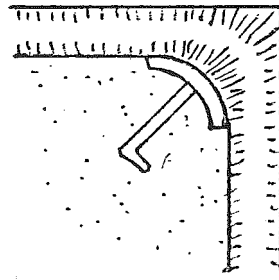


Fig. 2

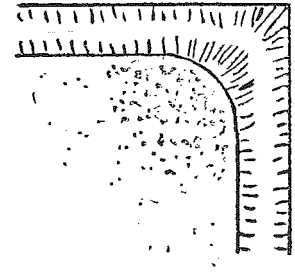
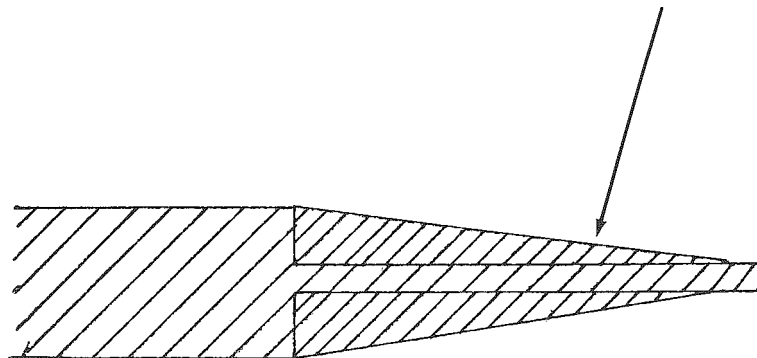


Fig. 3

2. **Padding** - gradual changes in wall thicknesses to improve directional solidification - usually done by foundry engineers or patternmakers - creates excess material which can be machined out if desired.



13. Melting

A. Definition - changing from a solid to a liquid by the application of heat.

B. Melting point vs. fluidity

1. Point of fluidity is several hundred degrees higher than the melting point of most alloys and extremely important to the casting process.
2. Any increment of temperature above the melting point of any metal is considered superheating.
3. Fluidity is a function of superheating and metal composition.

C. Factors to determine selection of melting unit

1. Temperature - to bring about fluidity
2. Quantity - of molten metal required at any one time
3. Quality - of metal composition
4. Economy of both installation and daily operation - Air pollution devices have affected the economy of some furnaces.

D. Cupola furnace (Cast irons) - See drawing on page 56.

1. A vertical, cylindrical, steel plate stack, lined with refractory materials
2. Fastest of all melting furnaces
3. Originally, very economical - installation, maintenance, and operating costs were low (may have changed due to air pollution requirements)
4. Doesn't always give good control
5. Only method of melting that is continuous in operation

6. **Cupolas vary in size** - lined diameters from 18 inches to as large as 13 feet and capable of producing from 1 to about 60 tons of metal per hour
7. **Many times used as the first stage in a duplexing operation (melting in one furnace and refining in another)**

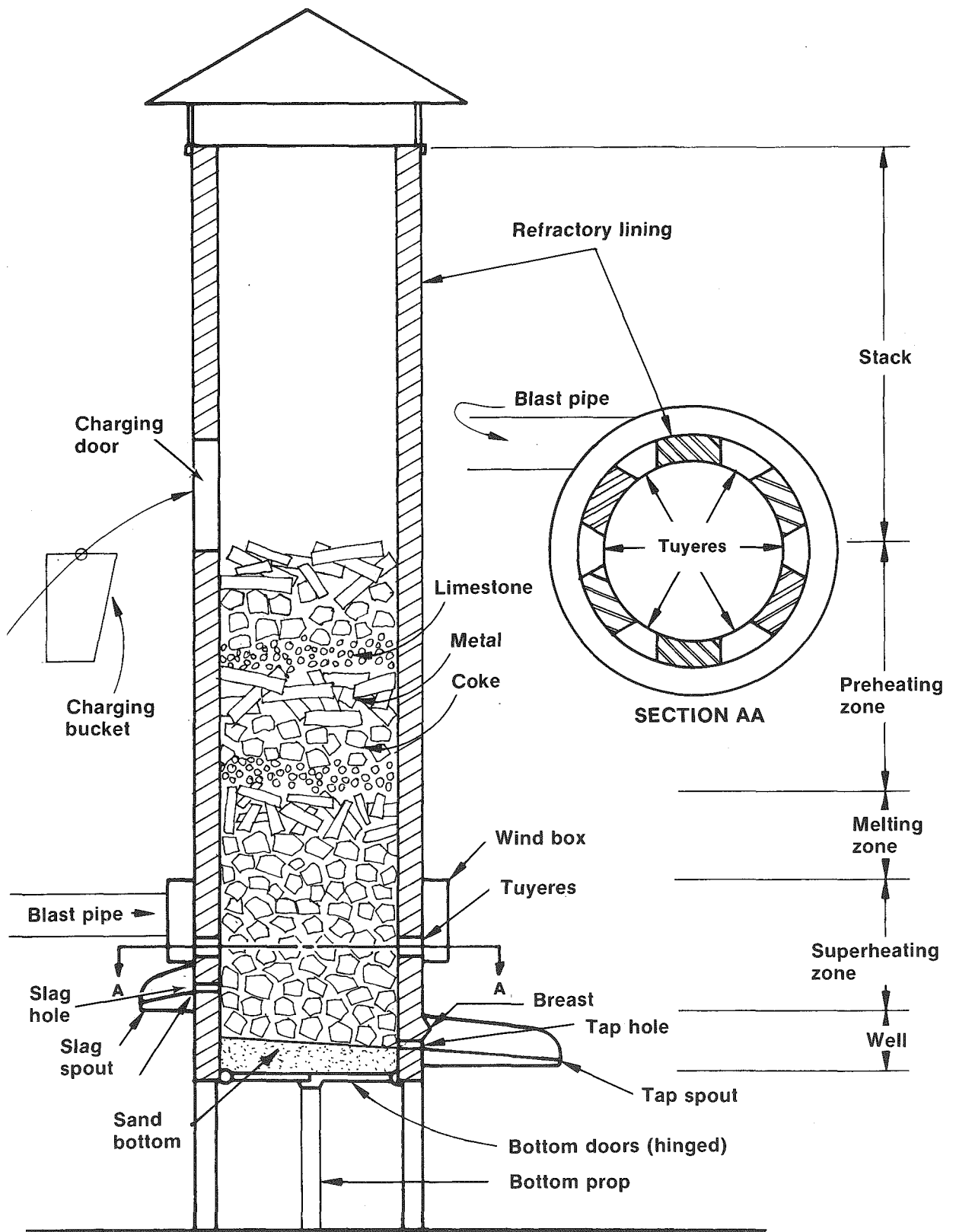
8. Operation of the cupola:

- a. Bottom is rammed with molding sand
- b. Bed charge of coke is put in and fire started
- c. When the bed charge is burned in and at its proper height, alternate layers of metal and of coke and limestone are charged until the furnace is full
- d. Tap hole is closed with a bott (clay ball) and the blast is turned on (air entering through the tuyeres creates enough heat to melt the metal above the bed charge and superheat it as it trickles down through the coke and collects on the sand bottom). When the well is full, slag will begin to trickle out of the slag hole. Before the metal reaches the slag hole, the bott is chipped out of the tap hole and metal is caught in ladles. Just before the well is completely drained, a fresh bott is placed in the tap hole and the well allowed to fill again. Tapping and plugging can be carried on as long as the furnace is charged and no serious trouble occurs.
- e. When no more metal is required the furnace is drained and the bottom prop is pulled. This allows the bottom doors to swing open and the hot materials in the furnace to drop out.

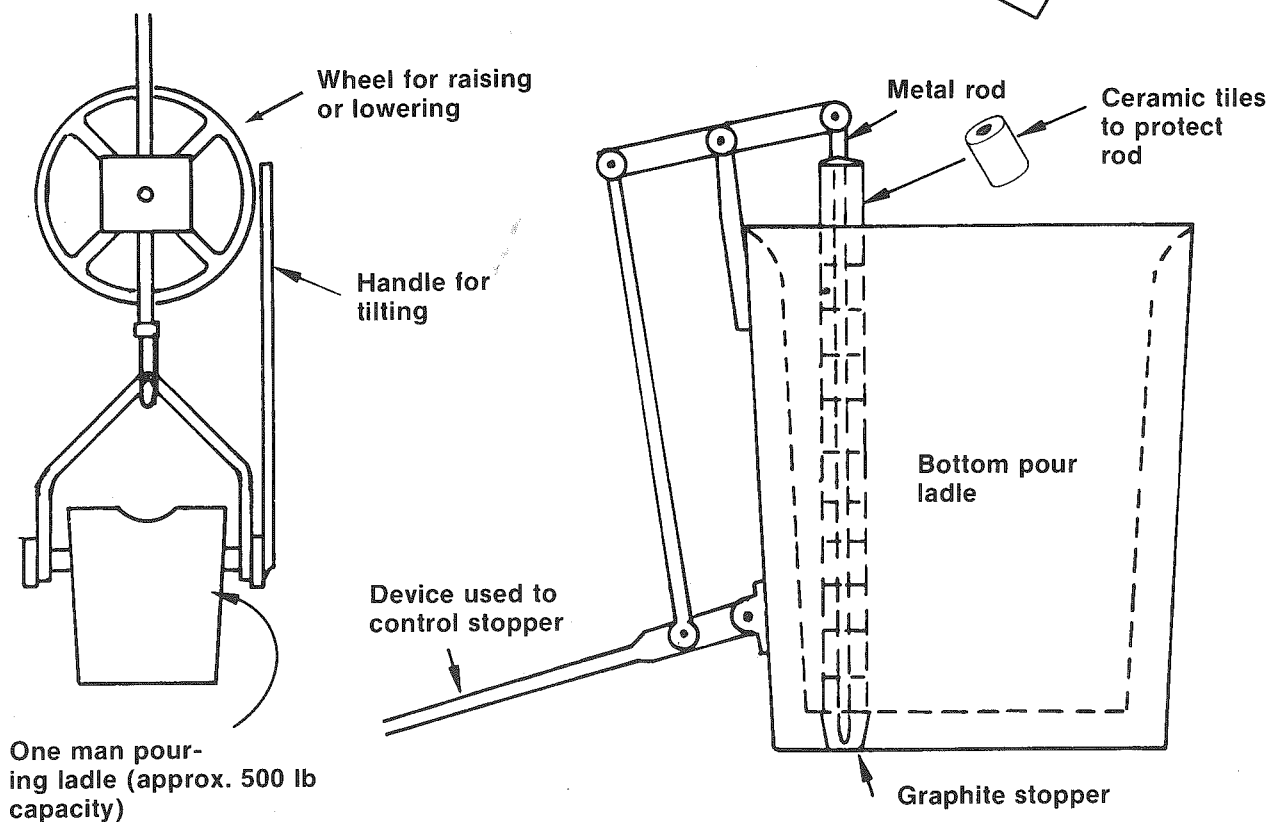
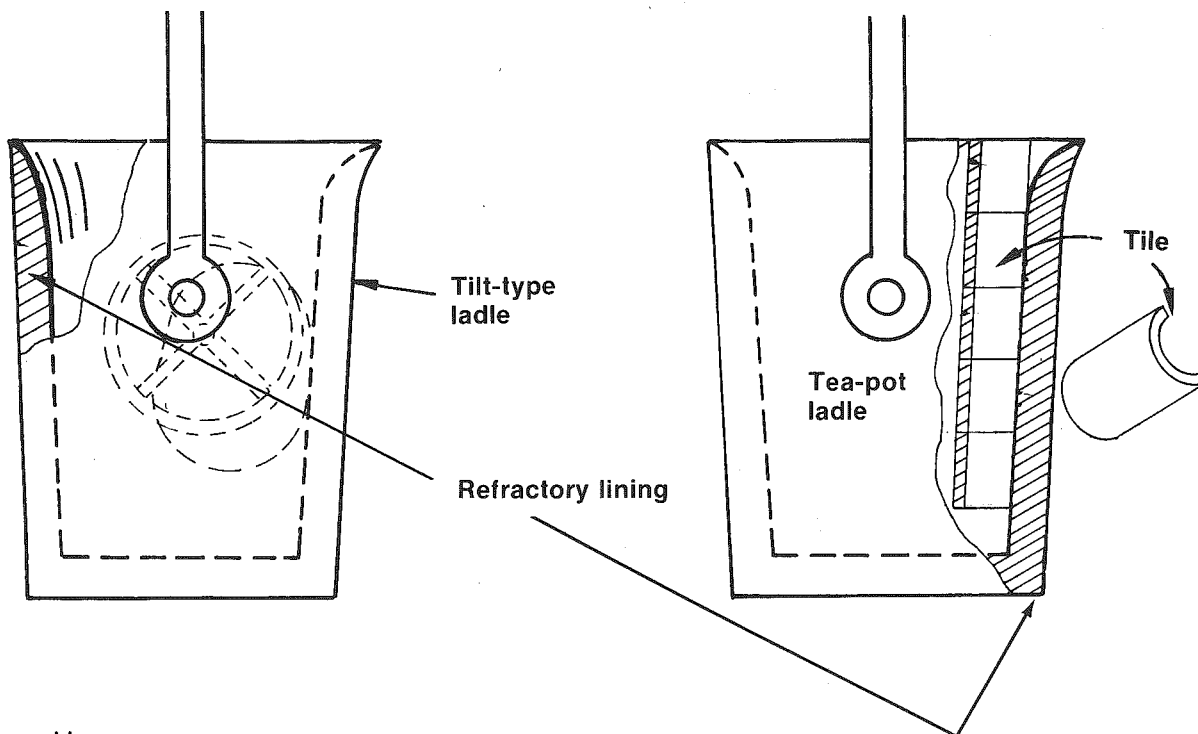
9. Other cupolas

- a. Hot blast
- b. Water cooled
- c. Front slagging

CONVENTIONAL CUPOLA



POURING DEVICES



E. Open-hearth furnace (Acid or basic steel) (See drawing on page 59)

1. A squat, rectangular brick structure having a shallow elliptical hearth to hold the metal charge, with provisions for charging metal and blowing hot gases over the charge.
2. A batch type furnace and reverberatory (most common fuel is oil)
3. Capacities range from 10 to 125 tons per batch (as big as 300 tons in the steel mills)
4. When using scrap low in sulfur and phos. an acid lining (silica) can be used - when using a cheap scrap the basic lining (magnesite, etc.) must be used.

NOTE: This furnace is fast being replaced by electric furnaces to speed up melting and to eliminate air pollution problems.

F. Air furnace (Malleable iron) (See drawing on page 60)

1. Like a modified open hearth.
2. Can melt direct or duplex using the cupola as the first stage.
3. Sizes range from 15 to 75 tons per batch (batch type and reverberatory)
4. Most common fuel is powdered coal.
5. Takes approximately 7 hours to melt and tap a 20 ton batch.

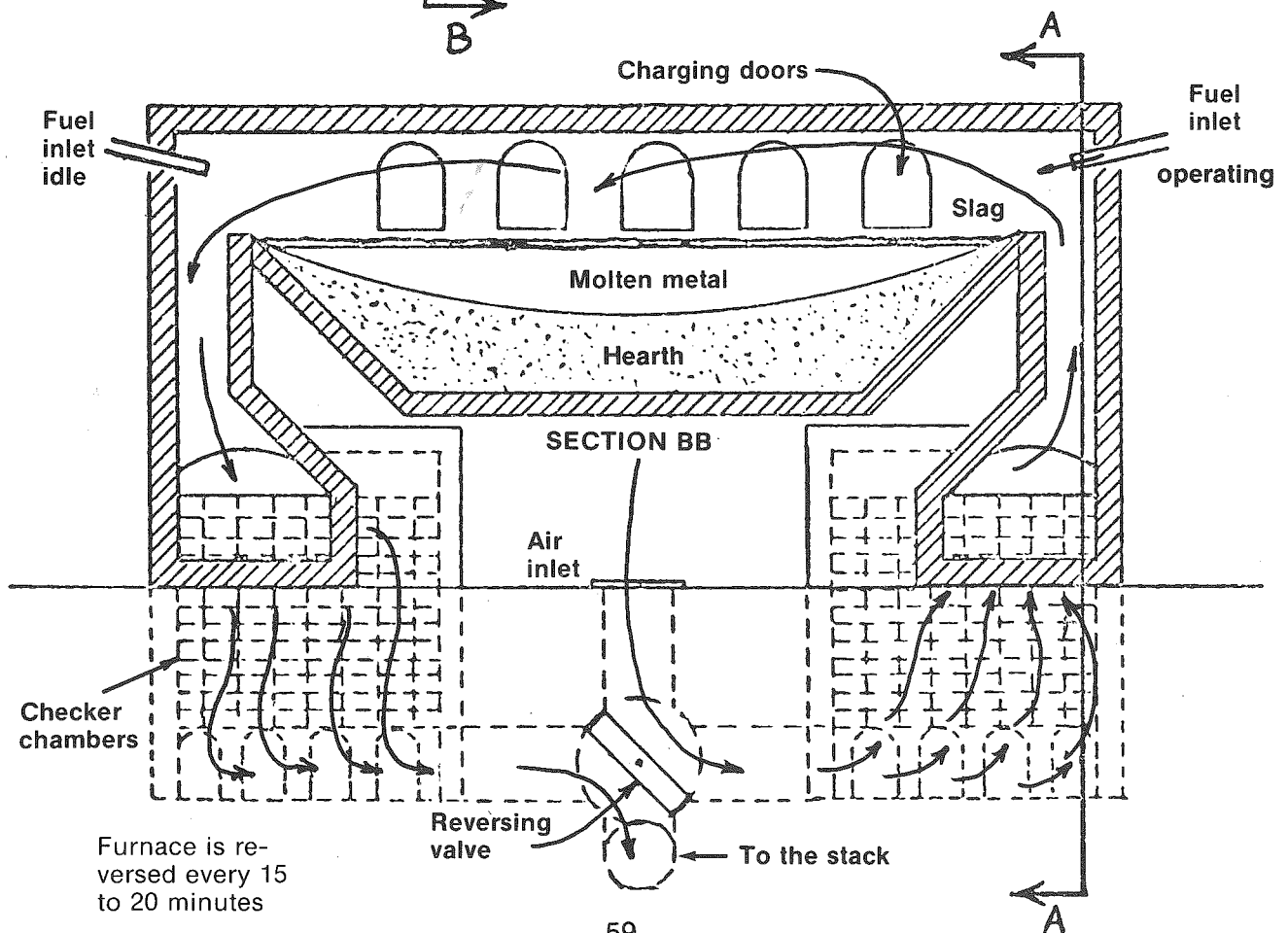
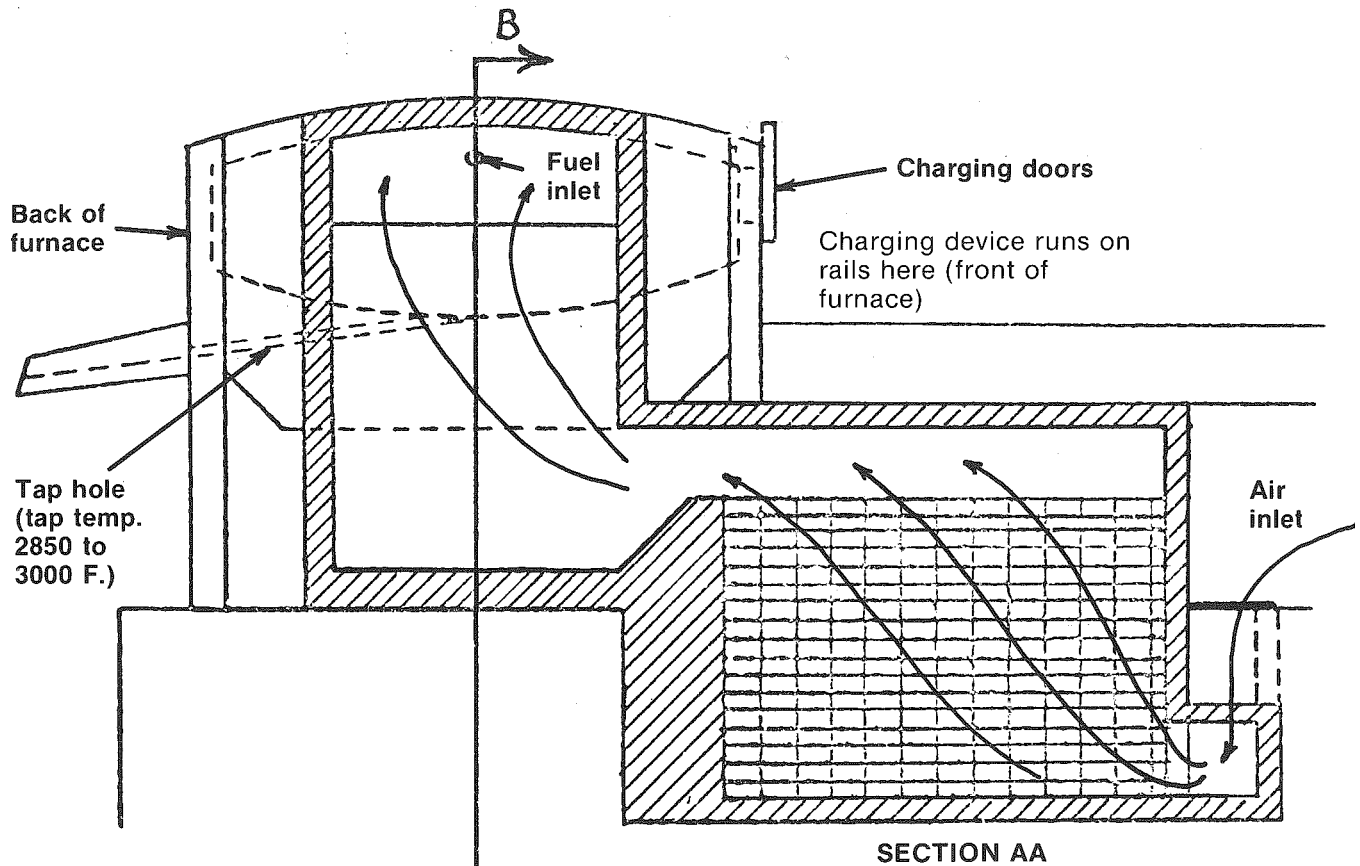
NOTE: This furnace is also fast being replaced by electric furnaces to improve on melting rates and pollution.

G. Reverberatory furnace (High grade cast irons) (See drawing on page 61)

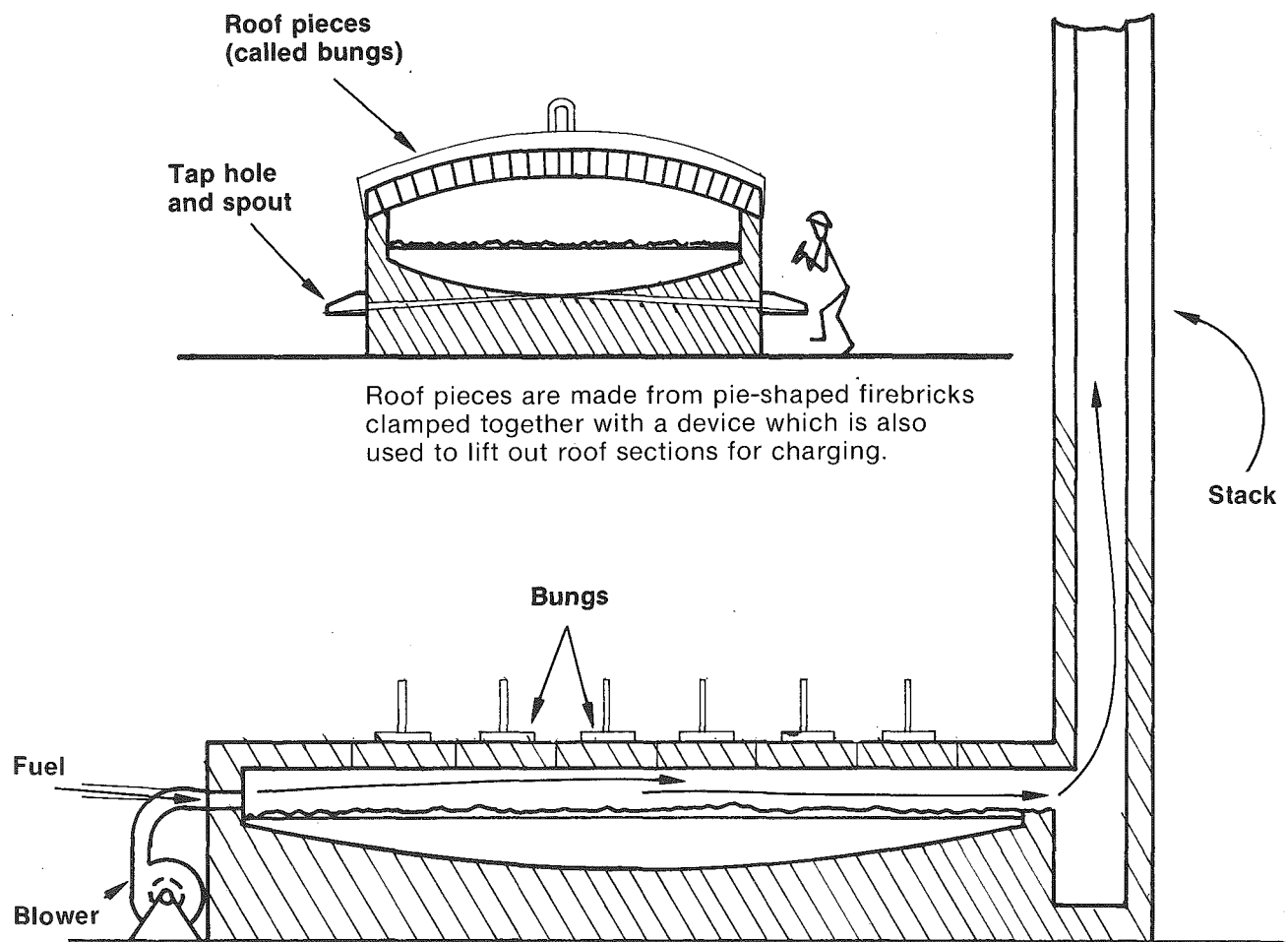
1. A small air furnace, set on trunnions for tilting and fired with oil or gas.
2. Charging can be through the top or through the chimney.

NOTE: Reverberatory or air furnaces are also used for many nonferrous metals.

OPEN HEARTH

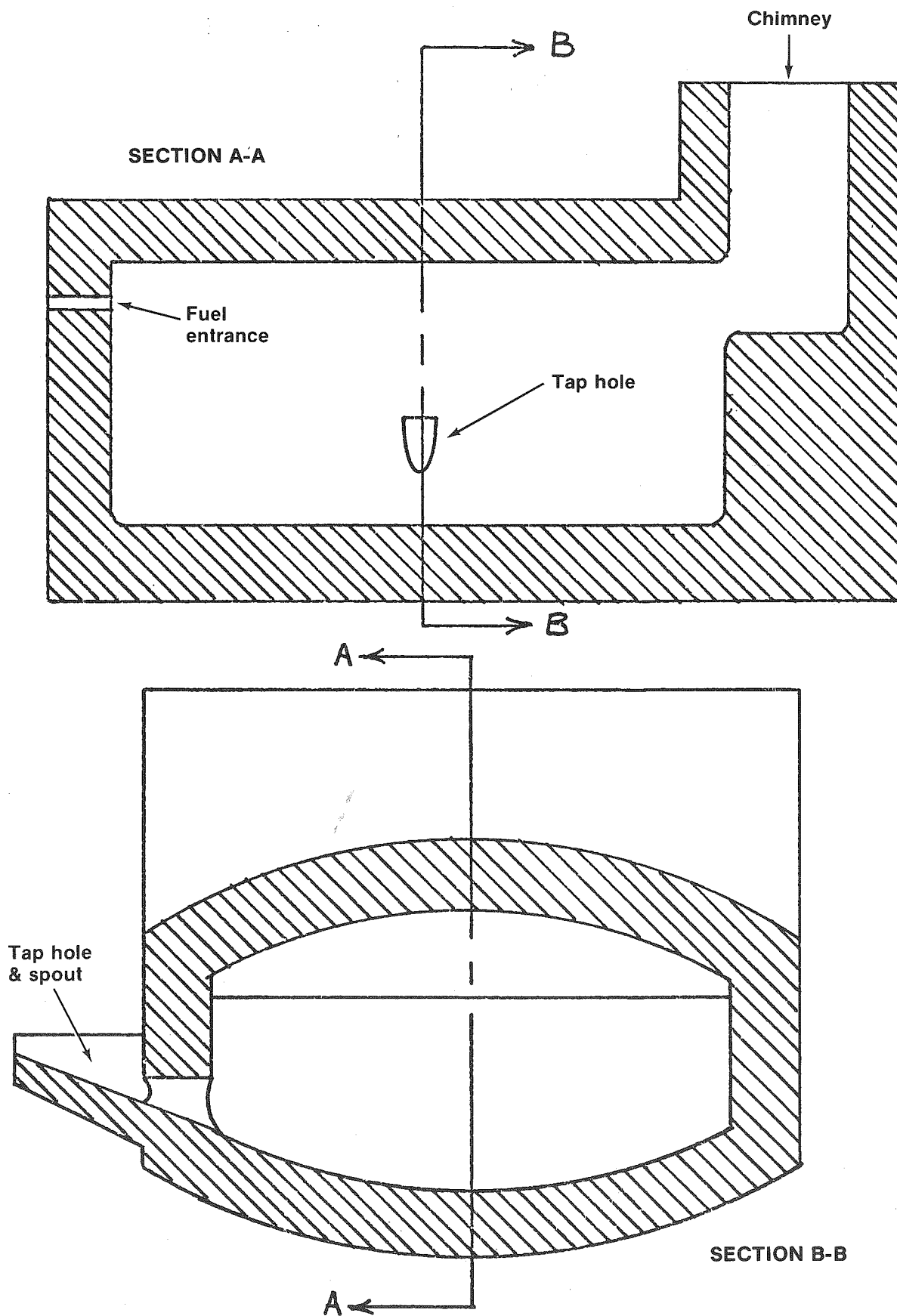


AIR FURNACE



This furnace can have a dozen or more tap holes which are opened and closed like the tap hole on a cupola. This insures swift removal of the metal once the analysis is right.

REVERBERATORY FURNACE



H. Electric furnaces

- 1. Direct-arc furnace (High grade steel)** (See drawing on page 63)
 - a. Capacities from a few pounds to 100 tons per batch
 - b. Batch type but not dependent upon reverberatory action for melting
 - c. Can be lined, acid or basic
 - d. Advantages: High melting rate, high pouring temps. (as high as 3200 degrees F.) and excellent control of analysis.

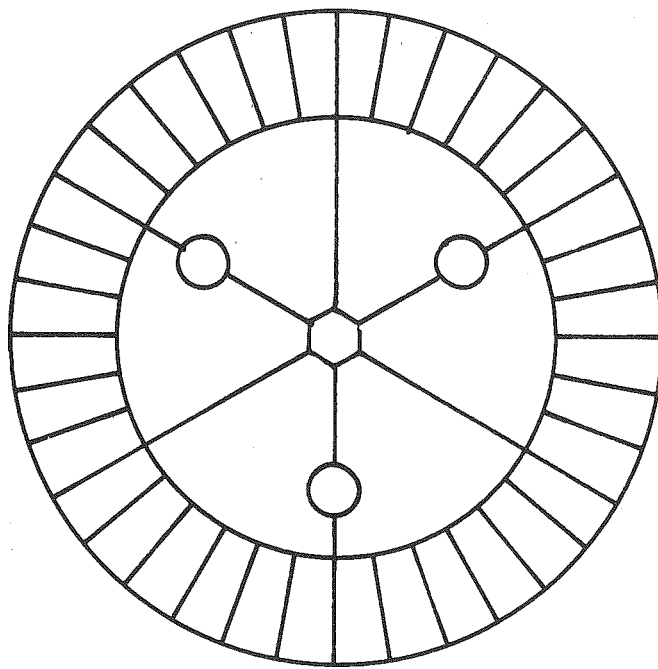
- 2. Indirect arc furnace (Copper base alloys)** (See drawing on page 64)
 - a. Also called the "Rocking arc" because furnace revolves 180 degrees, back and forth.
 - b. Rocking action helps prevent a localized slag attack on the lining, aids the reverberatory action and helps maintain a uniform temperature and composition.
 - c. Sizes: From a few pounds to about 12,000 pounds.

- 3. Coreless induction furnace (Special steel alloys, malleable iron and high grade cast irons)** (See drawing on page 65)
 - a. Copper coil built into furnace carries high frequency current and water for cooling (also low frequency furnaces)
 - b. Sizes: From about 10 pounds to as much as 65 tons per batch
 - c. Care must be taken to clean and know the analysis of each charge plus each charge must be preheated if charging into a molten bath.

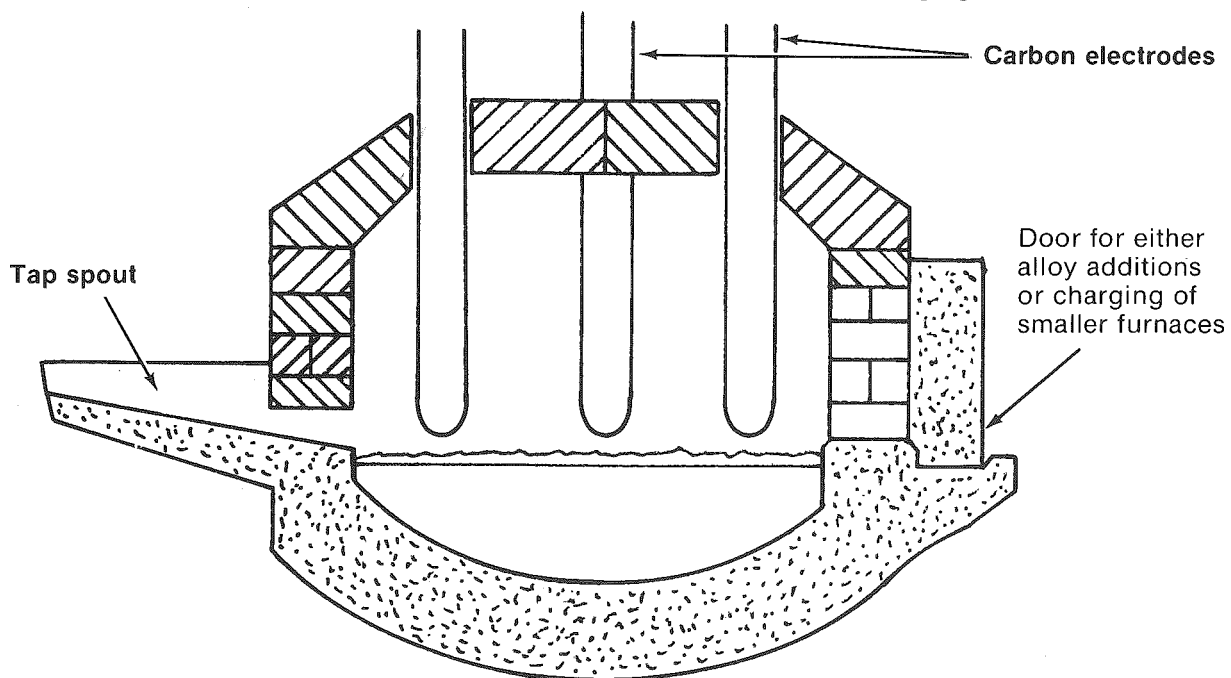
- 4. Channel induction furnace (Cast irons and aluminum alloys)** (See page 66)
 - a. Also called the cored induction furnace
 - b. Mainly a holding device, not a melting furnace (can be used for melting by charging in small quantities of scrap during off shifts)
 - c. Many sizes and many uses (like for die casting)
 - d. Becoming very popular in iron foundries for holding furnaces (melting being done in either cupolas or coreless furnaces)

DIRECT ARC FURNACE

Top view of roof,
approx. brick loc-
ation and holes
for electrodes



On large furnaces the
roof swings aside for
charging.

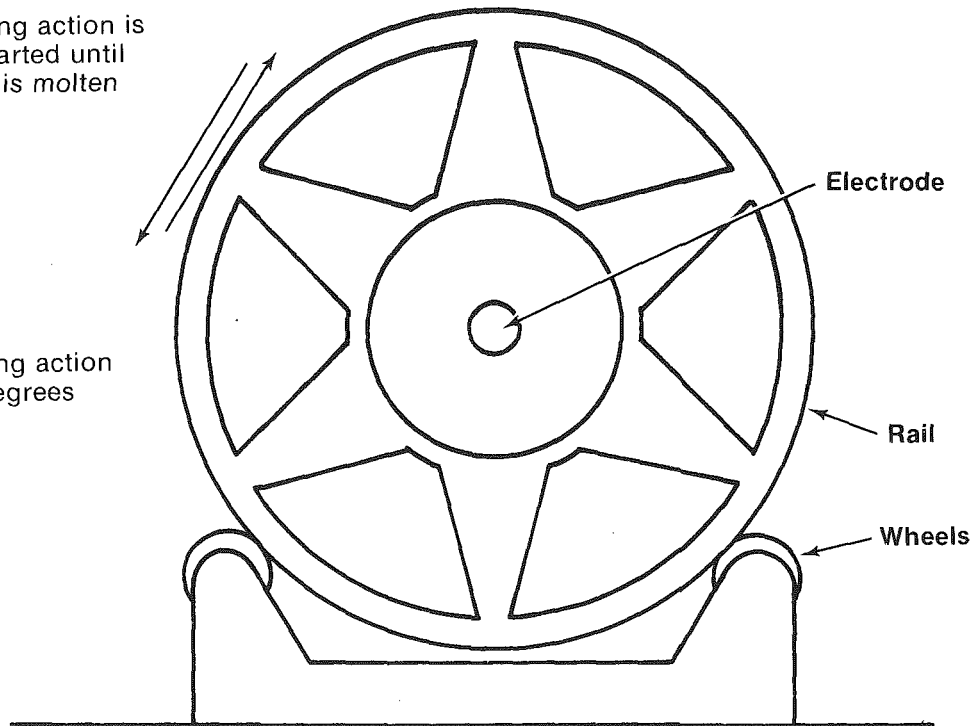


Three phase alternating current travels in or out via the three carbon electrodes - an arc is created when the current jumps from either electrode to melt or from the melt to an electrode. The arc does all the melting (not dependent upon reverb. action). The entire furnace tilts for tapping. Electrodes advance and retract automatically (controlled by amount of current draw).

INDIRECT ARC FURNACE

Rocking action is
not started until
metal is molten

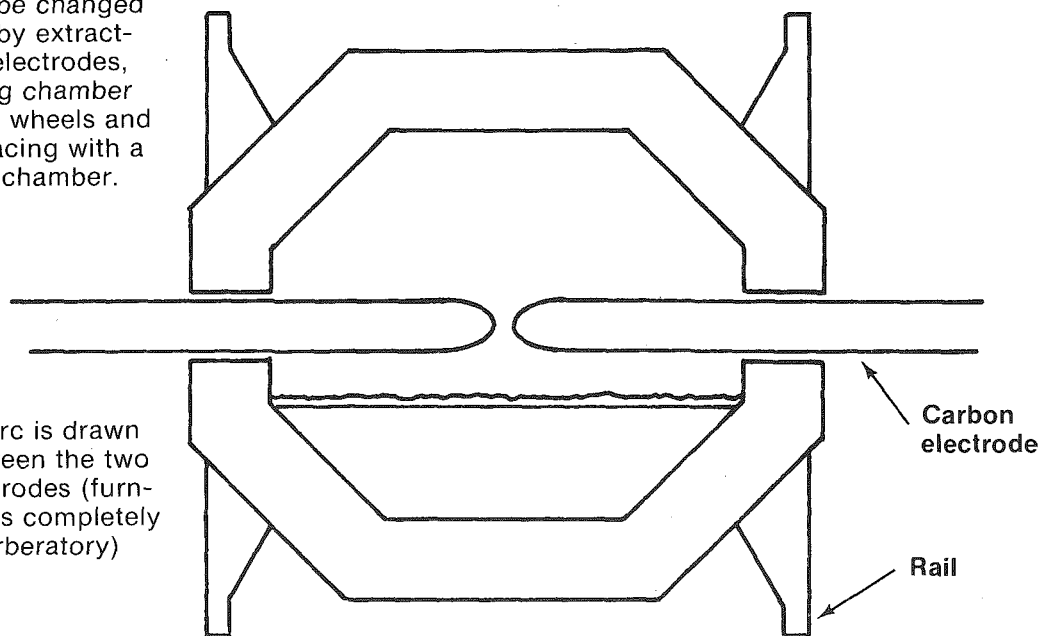
Rocking action
180 degrees



SIDE VIEW

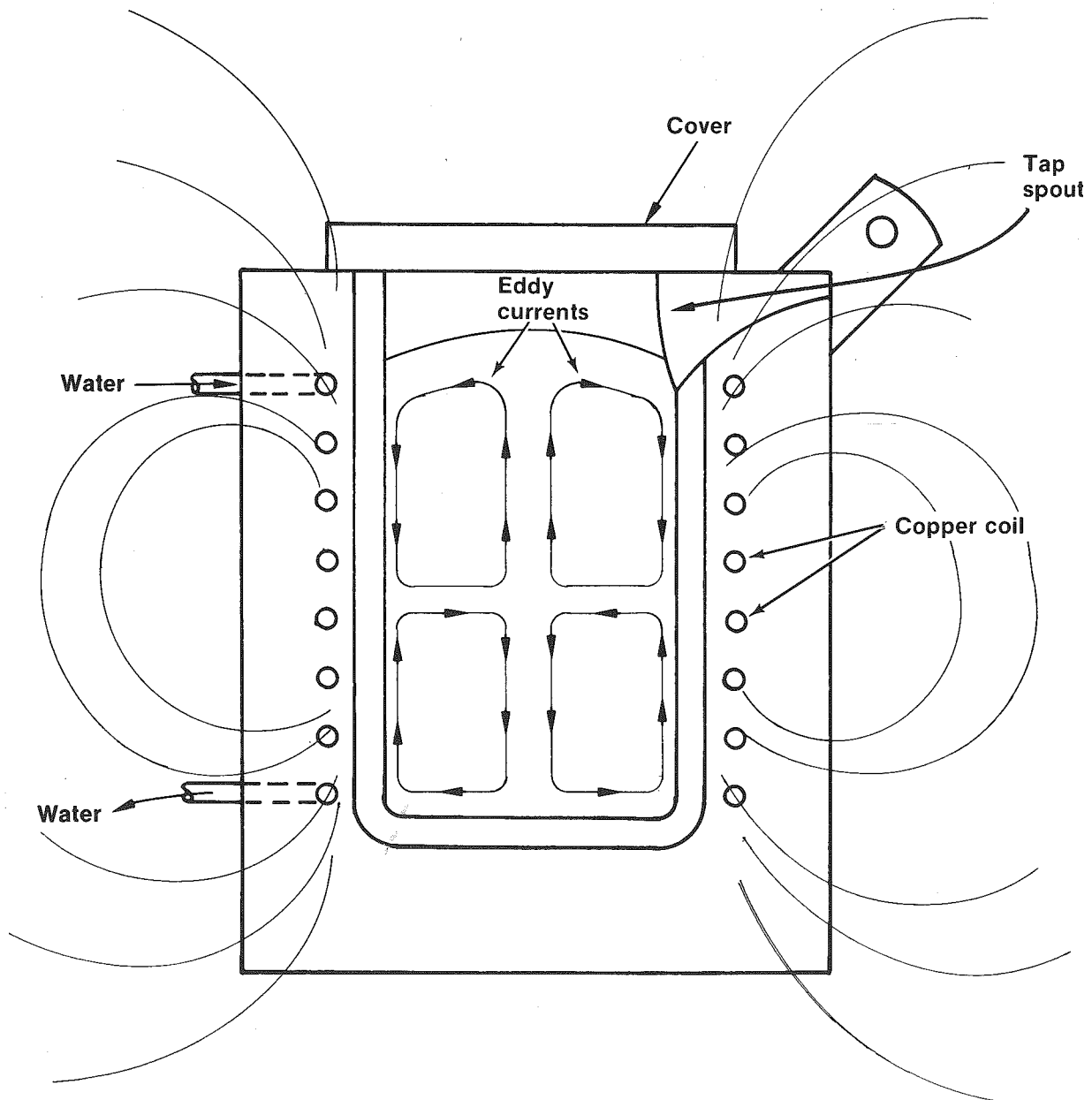
Furnace chamber
can be changed
just by extract-
ing electrodes,
lifting chamber
from wheels and
replacing with a
new chamber.

An arc is drawn
between the two
electrodes (furn-
ace is completely
reverberatory)



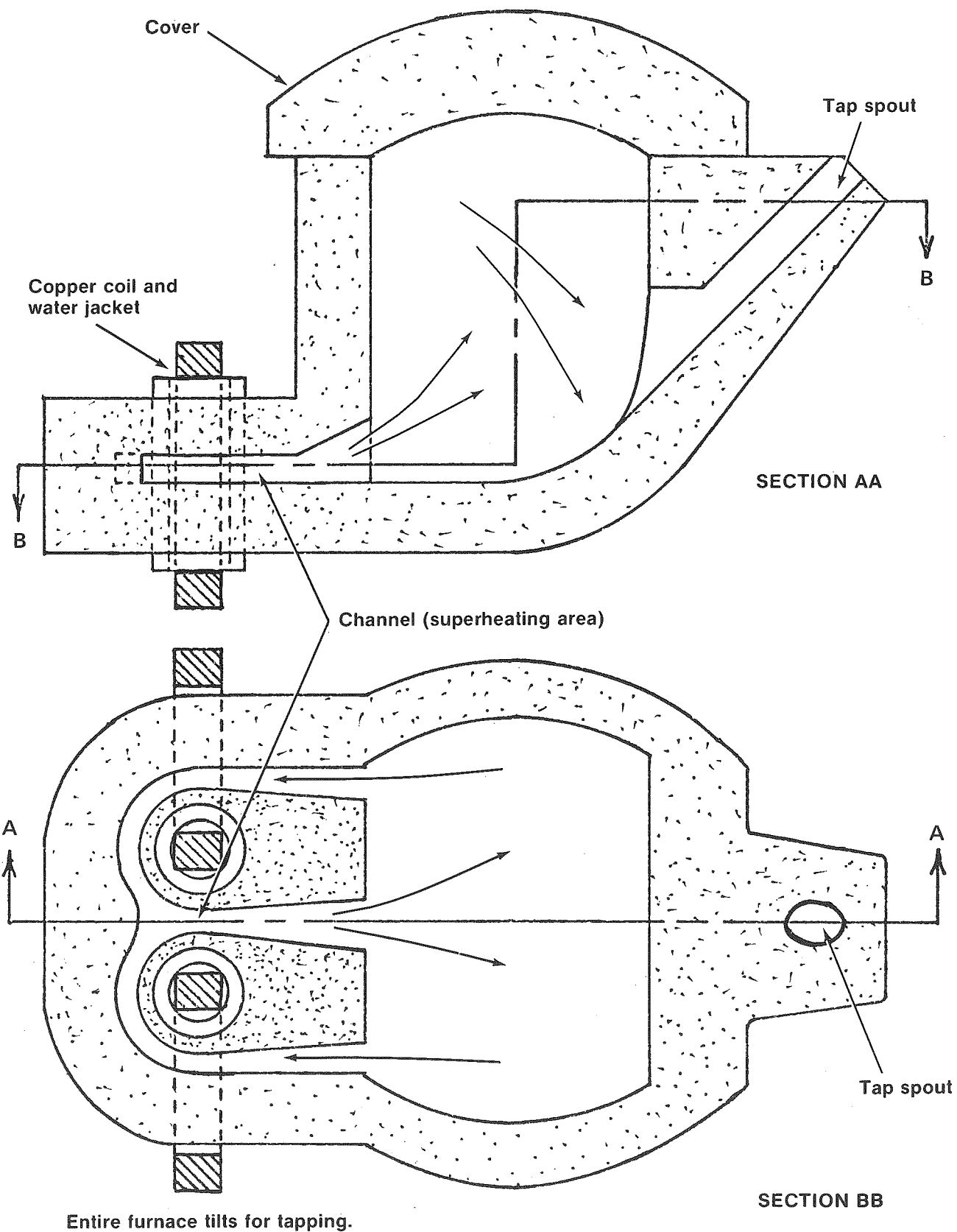
FRONT VIEW

CORELESS INDUCTION FURNACE



High or low frequency current in coil, induces a secondary current in the metal charge, exciting molecules and creating heat.

CORED OR CHANNEL TYPE INDUCTION FURNACE



I. Crucible furnaces (Nonferrous alloys)

1. Stationary (See page 68)

- a. Crucible sets on a base block and is picked out of the furnace with fitted lift-out tongs for pouring.
- b. A crucible is a refractory pot and capacities are based on the amount of aluminum the pot will hold. Example: A #40 crucible holds 40 pounds of aluminum.
- c. Common fuels are gas or oil.

2. Tilt-type (See page 69)

- a. Crucible is cemented to the base block and has a pouring spout which is also cemented into the furnace.
- b. The entire furnace is tilted to extract the molten metal.
- c. Limited to one metal due to using the same crucible for each melt.
- d. Fuels - same as stationary furnaces.

3. Pit-type

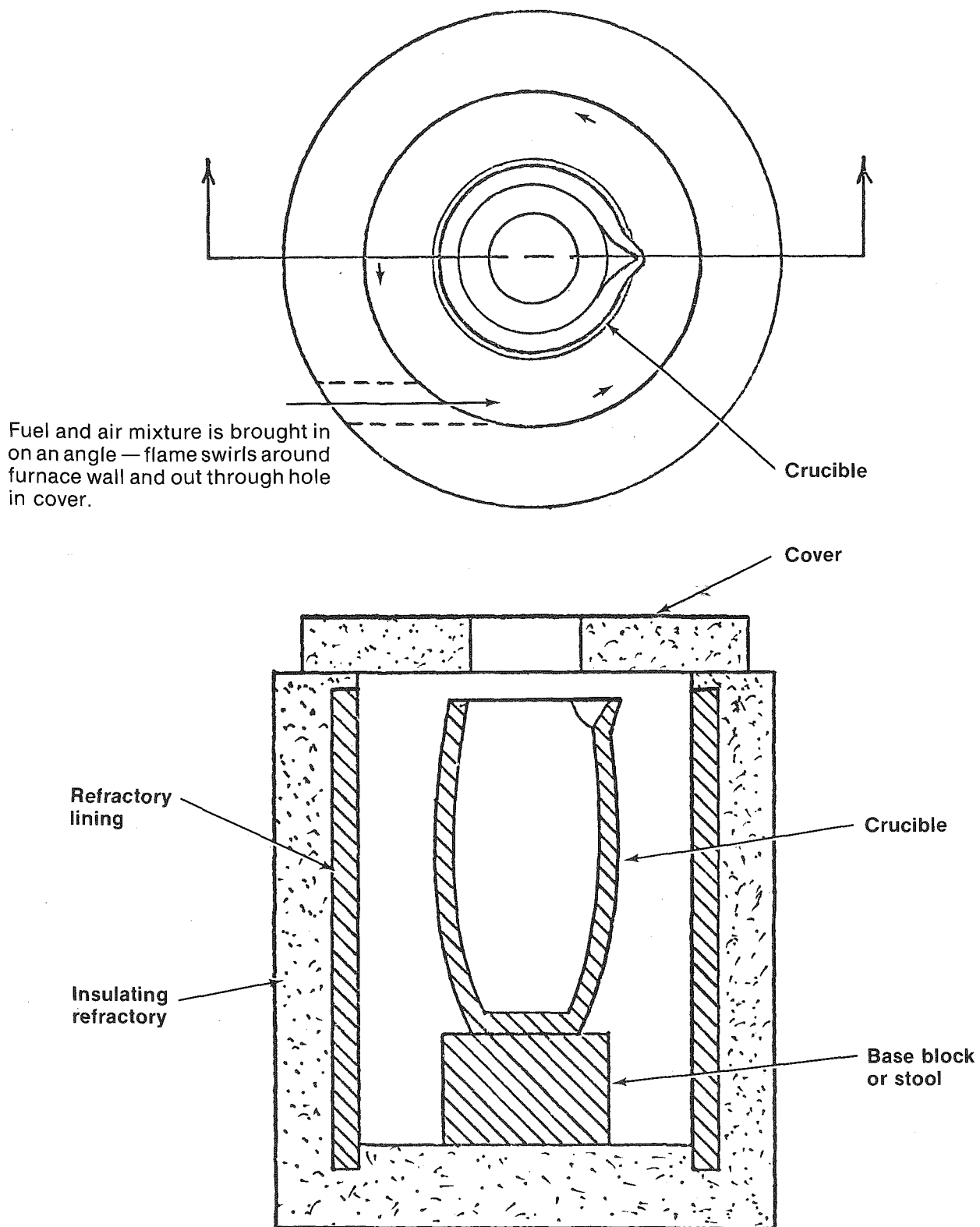
- a. Usually built below floor level (like an underground air furnace) and designed to accommodate a number of crucibles.
- b. Are not very popular today (originally used to produce crucible steel)

J. Converters

1. Are not melting furnaces - require molten metal to start process.

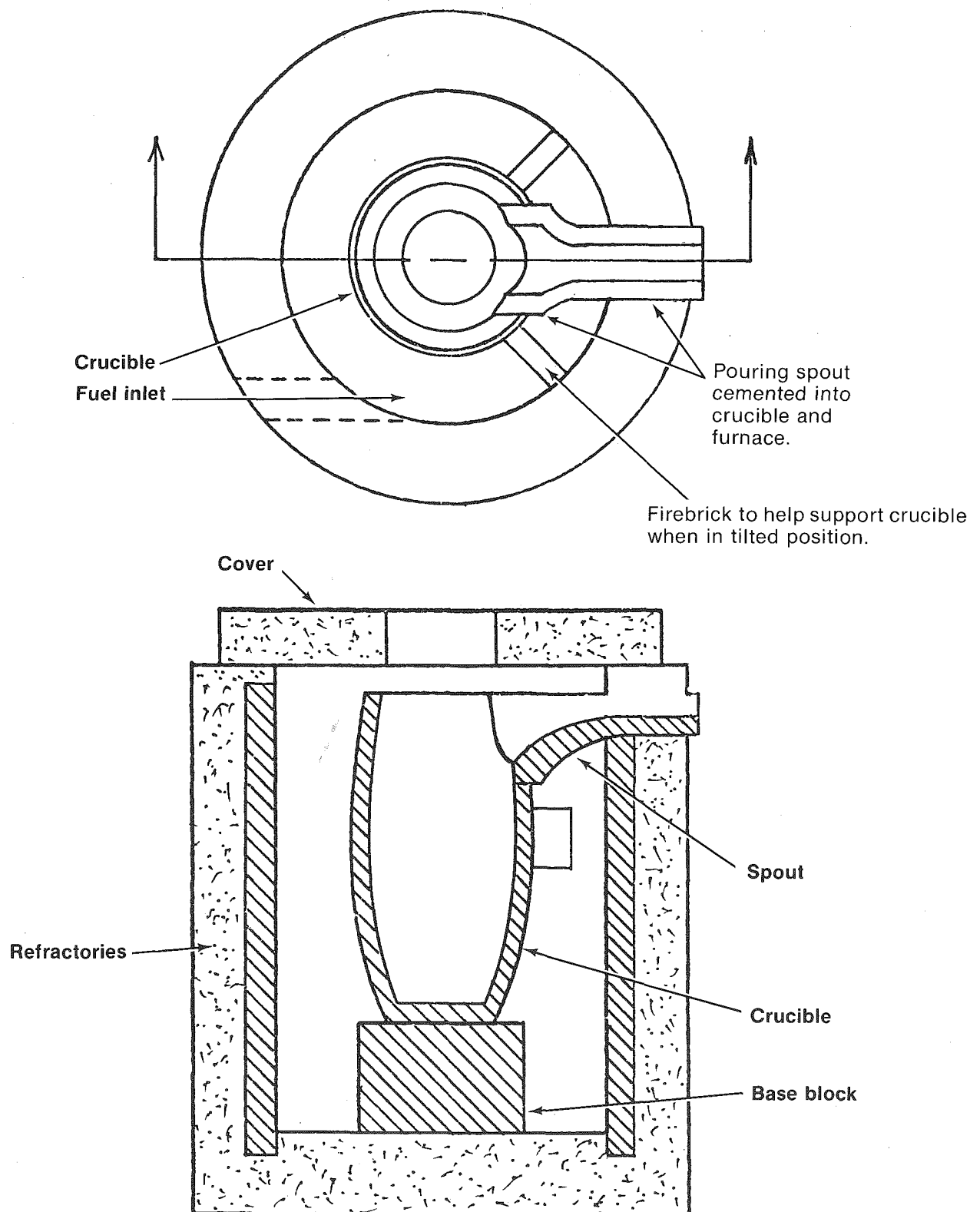
- a. Used to convert iron to steel by blowing air or oxygen into or through the molten iron.
- b. At one time the only way to produce steel in large quantities.
- c. Are seldom used in foundries.

STATIONARY CRUCIBLE FURNACE



SECTION AA

TILT-TYPE CRUCIBLE FURNACE



SECTION AA

14. Casting cleaning

A. Definition - The removal of adhering sand, gates, risers and other protuberances not considered as part of the casting.

B. Rough cleaning - The removal of gates and risers

1. **Flogging** - done with a hammer (brittle castings)
2. **Mechanical cut-off** - done with saws, cutting wheels, shears, etc. (more ductile castings)
3. **Burning** - done with torches (steel castings)

C. Surface cleaning - To clean interior and exterior surfaces of sand, scale, and other adhering materials. (See drawings on page 71)

1. **Tumbling** - castings are put into a horizontal barrel-like structure along with some abrasive material (hardened metal bits, sand, etc.) - entire assembly rotates causing castings and abrasives to rub together - some machines just vibrate causing only the contents to revolve - end result; shiny, clean castings.
2. **Blasting** - casting surfaces are blasted with sand, shot, etc.

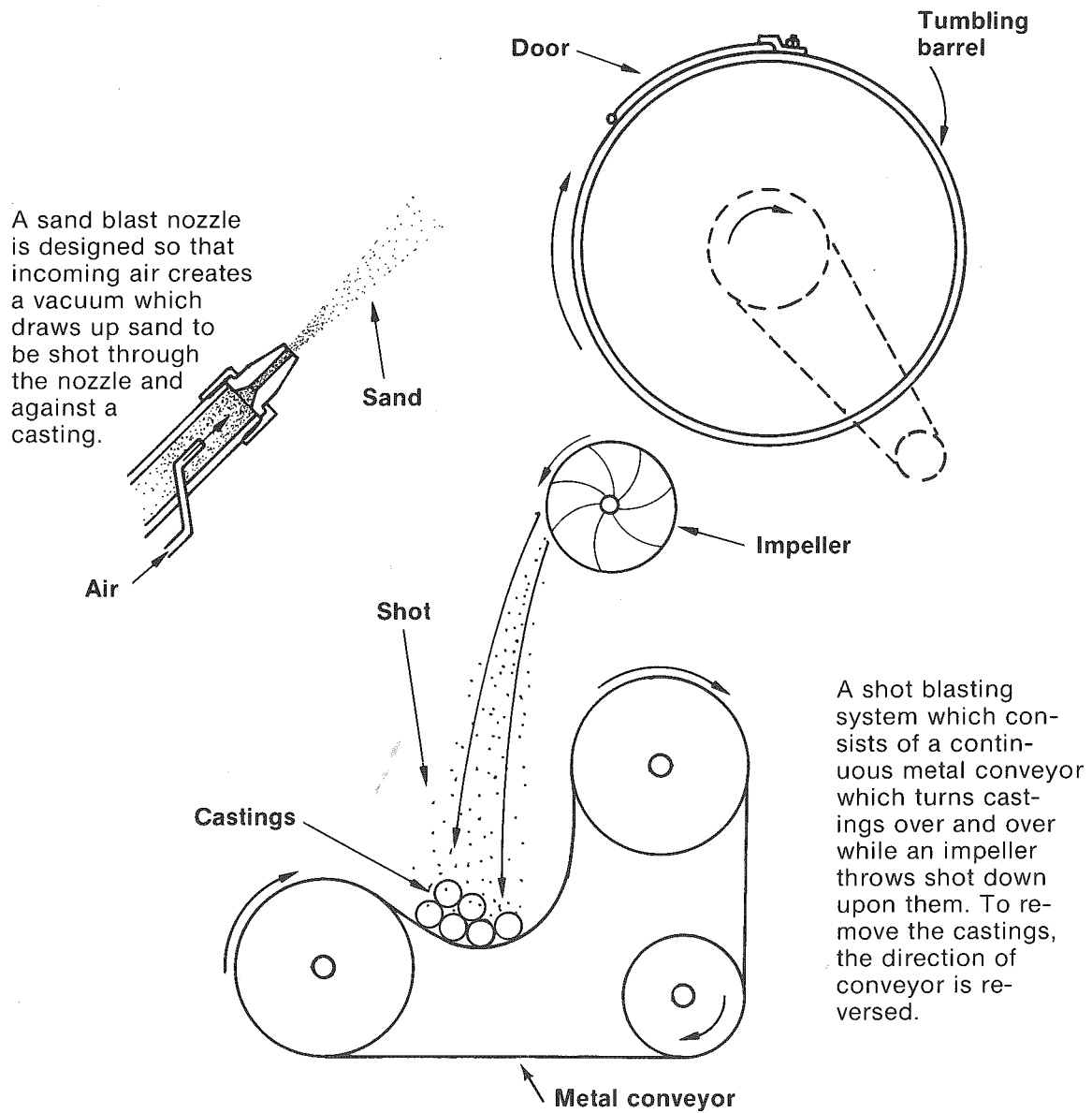
D. Trimming - Removal of fins, gate pads, riser pads, and chaplets.

1. **Chipping** - done with chisels and pneumatic hammers.
2. **Rough grinding** - done with portable hand grinders, stand grinders or swing grinders.
3. **Scarfig and welding** - bad spots are bled out with torches and resulting holes welded (steel castings)

E. Finishing - Final treatments

1. **Chemical treatments** - pickling, plating, etc.
2. **Painting**
3. **Machining** - to insure proper location in a customer's fixtures, etc.
4. **Heat treating**

TUMBLING, SHOT BLASTING AND SAND BLASTING



15. Inspection

A. Definition - Various means of finding deficiencies or imperfections in castings prior to shipping.

B. Destructive inspection - After inspection the casting is no longer usable.

1. **Sectioning or dissecting** - castings are cut up to expose areas most susceptible to defects.
2. **Pressure testing** - either internal or external pressure is applied until failure of cast part or far beyond a customer's specifications.
3. **Tensile strength and percent of elongation** - only if sample is taken from an actual casting and made into a test bar is this form of inspection destructive.

C. Nondestructive inspection - Inspection has no ill effects on the castings.

1. **Visual inspection** - many defects can be spotted by eye.
2. **Dimensional inspection** - castings are measured or gauged to detect any variations.
3. **X-ray and gamma ray** - used to radiograph the internal areas of castings in search of defects.
4. **Magnetic particle** - used to find surface cracks in castings that can be magnetized.
5. **Dye and fluorescent penetrants** - used to find surface cracks in castings that cannot be magnetized. Dye penetrants can be used in daylight whereas fluorescent penetrants require darkness and a black light.
6. **Sonic inspection** - sound waves are sent through castings to show up internal defects. Waves are read on an oscilloscope.
7. **Hardness** - usually used to inspect chemistry (hardness is a basic property related to a metals chemistry) and to inspect for proper heat treatment.

16. Casting defects

A. Definition - Any characteristics that create a deficiency or imperfection in a casting.

B. Types

1. **Major defects** - definitely scrap.
2. **Minor defects** - usually no structural problem - based on appearance or acceptable standards.
3. **Intermediate defects** - a decision must be made as to whether it would be cheaper to repair or to remake.

C. Defects (See drawings on pages 76-78)

1. **Shift** - Misalignment of cope and drag or of a core (coreshift). Usually caused by poor equipment, rough handling, etc.
2. **Swells** - Bumps or uneven surfaces due to soft ramming, excessive pouring pressures, etc.
3. **Shrinkage** - Sunken surfaces or internal voids due to poor design, poor gating, poor risering, poor foundry engineering, etc.
4. **Blows** - Bubbles in the casting usually located on the cope surface, right under a thin skin of metal and sometimes fairly large, smooth voids. Due to moisture in any form like moisture content of the sand, wet chills, wet chaplets, wet inserts, also from low permeability, insufficient venting, hard ramming, green cores, etc.
5. **Hot tears** - Ripping during solidification due to poor design, poor collapsibility, poor foundry engineering, etc.
6. **Cold cracks** - Breakage after solidification due to shaking out too hot, rough handling, etc.
7. **Cold shut** - Metal fronts meeting without complete fusion due to pouring too cold, pouring too slow, poor permeability, poor venting, or oxides forming on metal fronts, etc.
8. **Misrun** - An incomplete casting because of cavity not filling out during pouring - for the same reasons as cold shuts except for oxides forming on metal fronts.

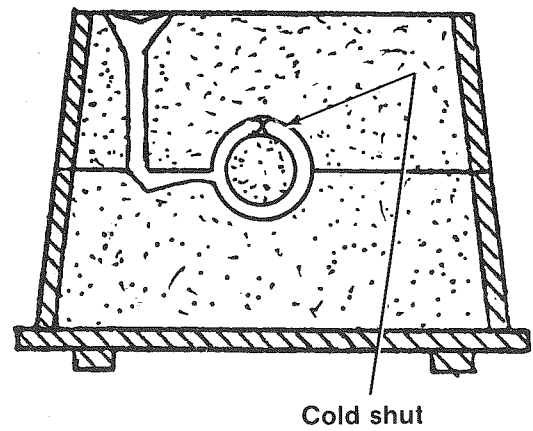
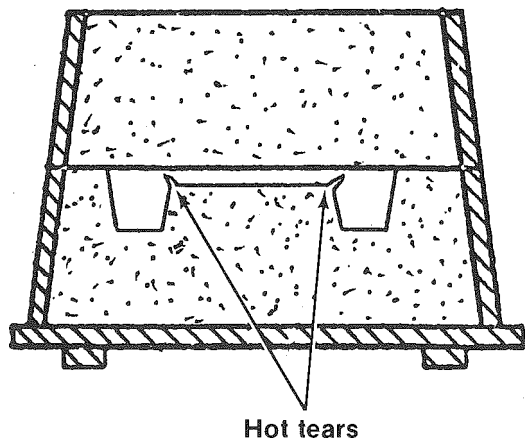
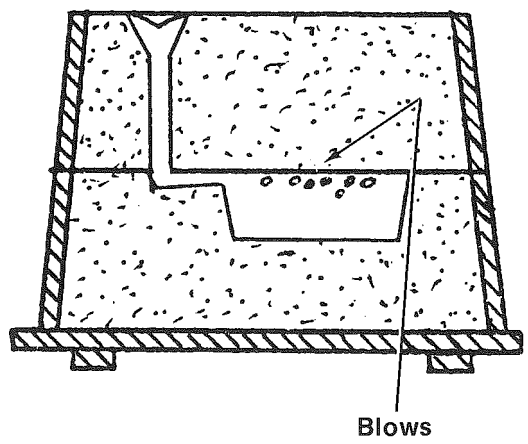
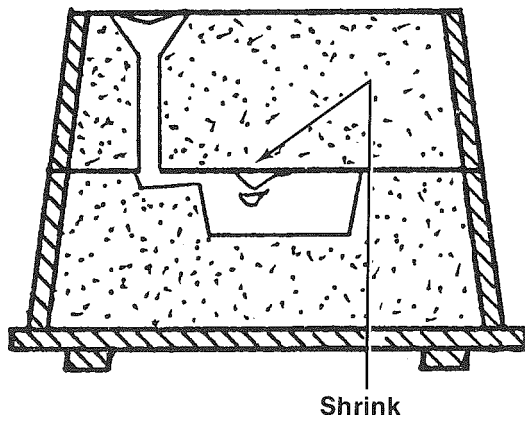
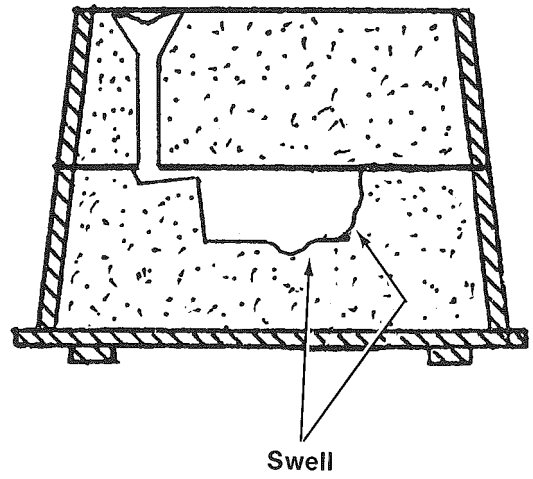
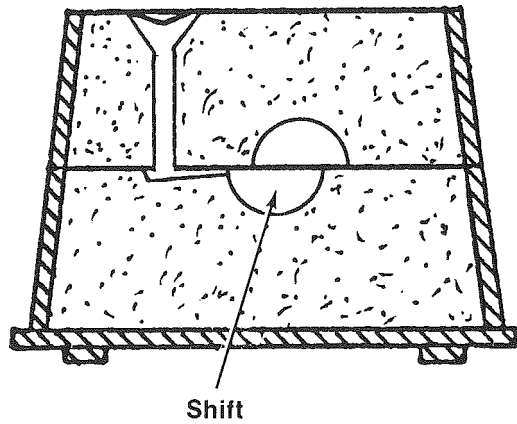
Defects (continued)

9. **Cold shot** - "BB's" solidified in the metal and usually located on the cope surface - caused by splashing of molten metal due to poor gating.
10. **Short pour** - An incomplete casting due to not having enough metal during pouring.
11. **Run out** - Metal runs out at the joint due to using too small of a flask, soft ramming, insufficient weights or clamps, etc.
12. **Bust out** - Metal runs out of the bottom due to not properly bedding the bottom board or plate.
13. **Metal penetration** - Metal enters interstices due to excessive fluidity (which is usually due to being too hot) also from pouring pressures being too high, poor venting, soft ramming, sand grains too large, not riddling, etc.
14. **Rough surface finish** - Similar to metal penetration only not as severe.
15. **Fins** - Metal enters the joint (flash) usually a very minor defect due to not being completely closed (could be the start of a runout) also from slicking around pattern after the cope is made - many times done on purpose by floor molders to avoid crushing.
16. **Rattails, buckles, and scabs** - Expansion defects that start out as a crack-like appearance (rattails) and progressively worsen into an eruption on the casting surface (buckle) which could then progress into breaking loose and the molten metal running behind it (scab) due to poor grain distribution, poor pH, poor strength, not using a cushioning additive, etc.
17. **Sand or slag inclusions** - Dirty castings usually due to just plain sloppiness or an "I don't care" attitude.
18. **Porosity** - Pinholes in the metal throughout the casting usually due to poor melting or pouring practices, poor gating, poor control of moisture in melting, pouring and sometimes in molding.
19. **Drops** - Part of the cope breaks off and falls into the drag due to rough handling, low strength, poor pH, insufficient reinforcement, etc.

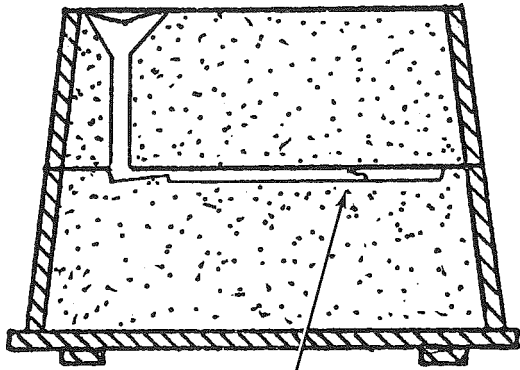
Defects (continued)

- 20. Crushes** - Parts shearing off due to poor fit at the parting line or on the coreprints, etc.
- 21. Cuts and washes** - Erosion of the mold surface due to poor gating, low strength, poor pH, etc.
- 22. Tear-ups** — Parts of mold cavity missing due to back draft, damaged pattern, draw pattern crooked or too fast, etc.

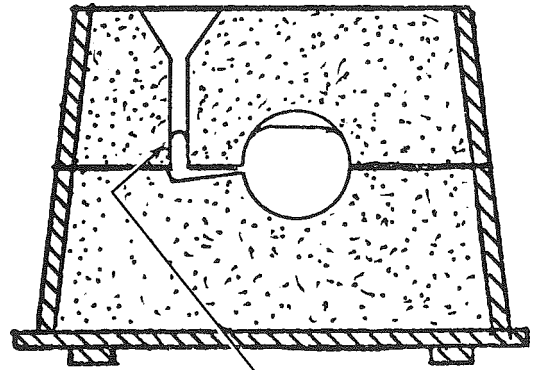
CASTING DEFECTS



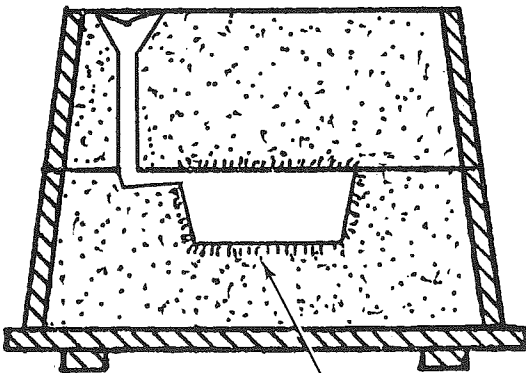
CASTING DEFECTS



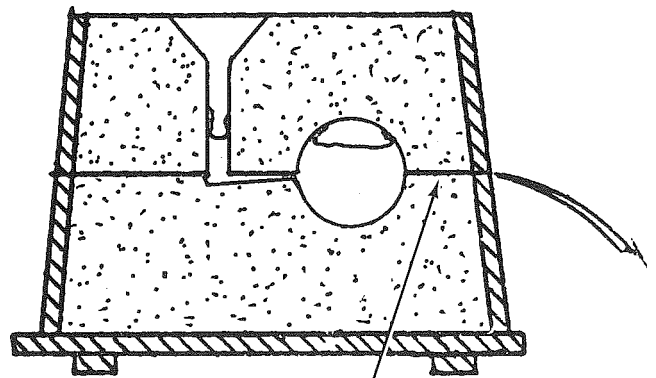
Mis-run



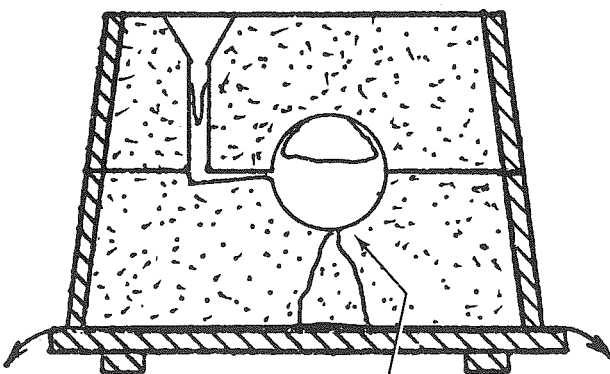
Short pour



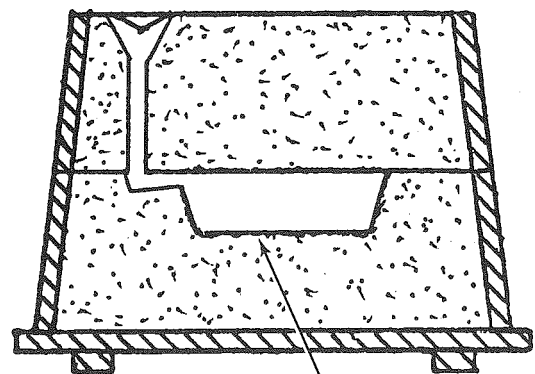
Metal penetration



Run out

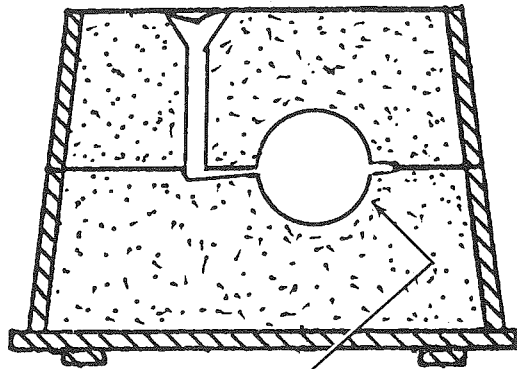


Bust out

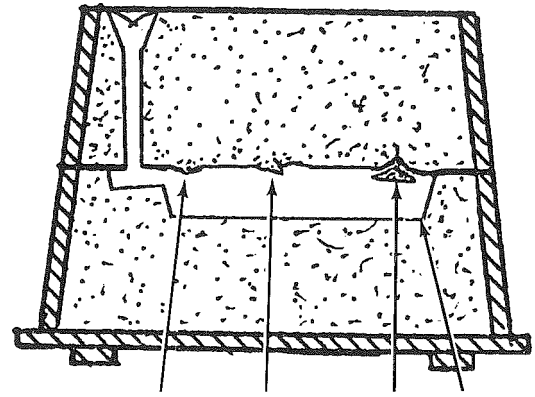


Rough surface finish

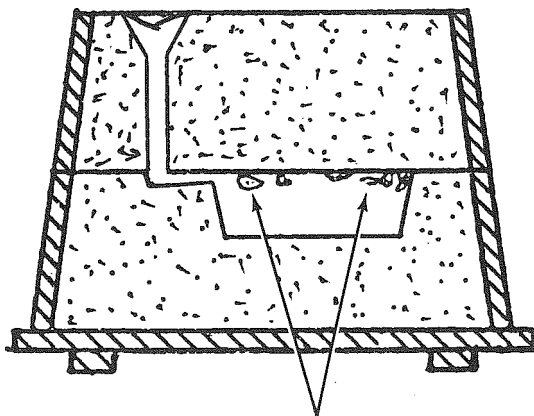
CASTING DEFECTS



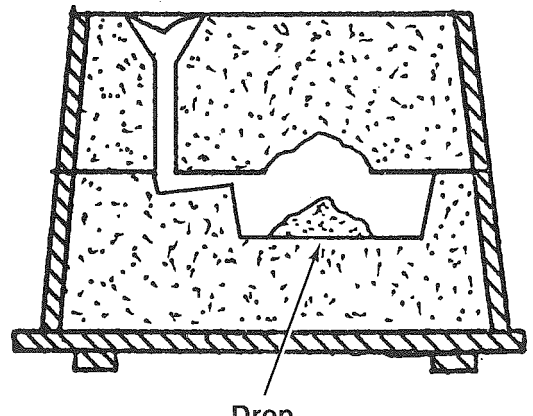
Fins



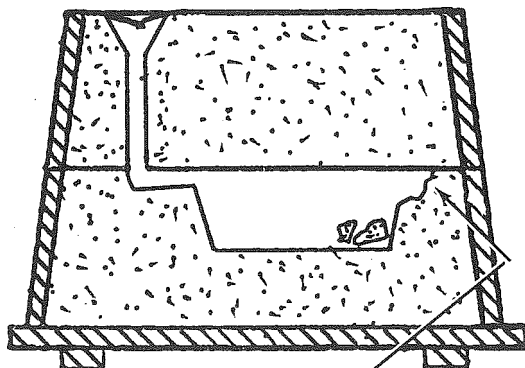
Rattle tails, buckles, and scabs



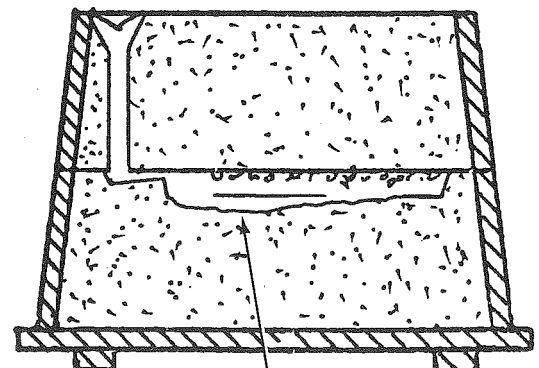
Sand or slag inclusions



Drop



Crush



Cuts and washes

17. Mechanization and automation

A. Definition - Mechanization refers to machines doing some of the work men used to do entirely by hand, whereas automation refers to doing all of the work automatically.

B. Sand handling

Because more sand is handled in a foundry operation than any other material, it is probably the most important area to automate. All sand handling, from incoming to final discarding of used sand, can be completely automated. See drawing on page 80.

C. Molding machines

1. Definition - Devices that consist of several interrelated parts, whose function is to transmit and modify various forces and motions so as to aid in the construction of sand molds.

2. Mechanized Basic operations

1. Ramming of sand (See page 81)
2. Inverting of mold section
3. Rapping and drawing of pattern (some lift cope)

NOTE: Machines can consist of one or any combination of the above operations and are generally named accordingly. Example: Jolt-squeeze machine.

3. Automated Expanded operations

1. Metering sand into mold sections (some invert, some don't)
2. Opening of mold
3. Setting cores

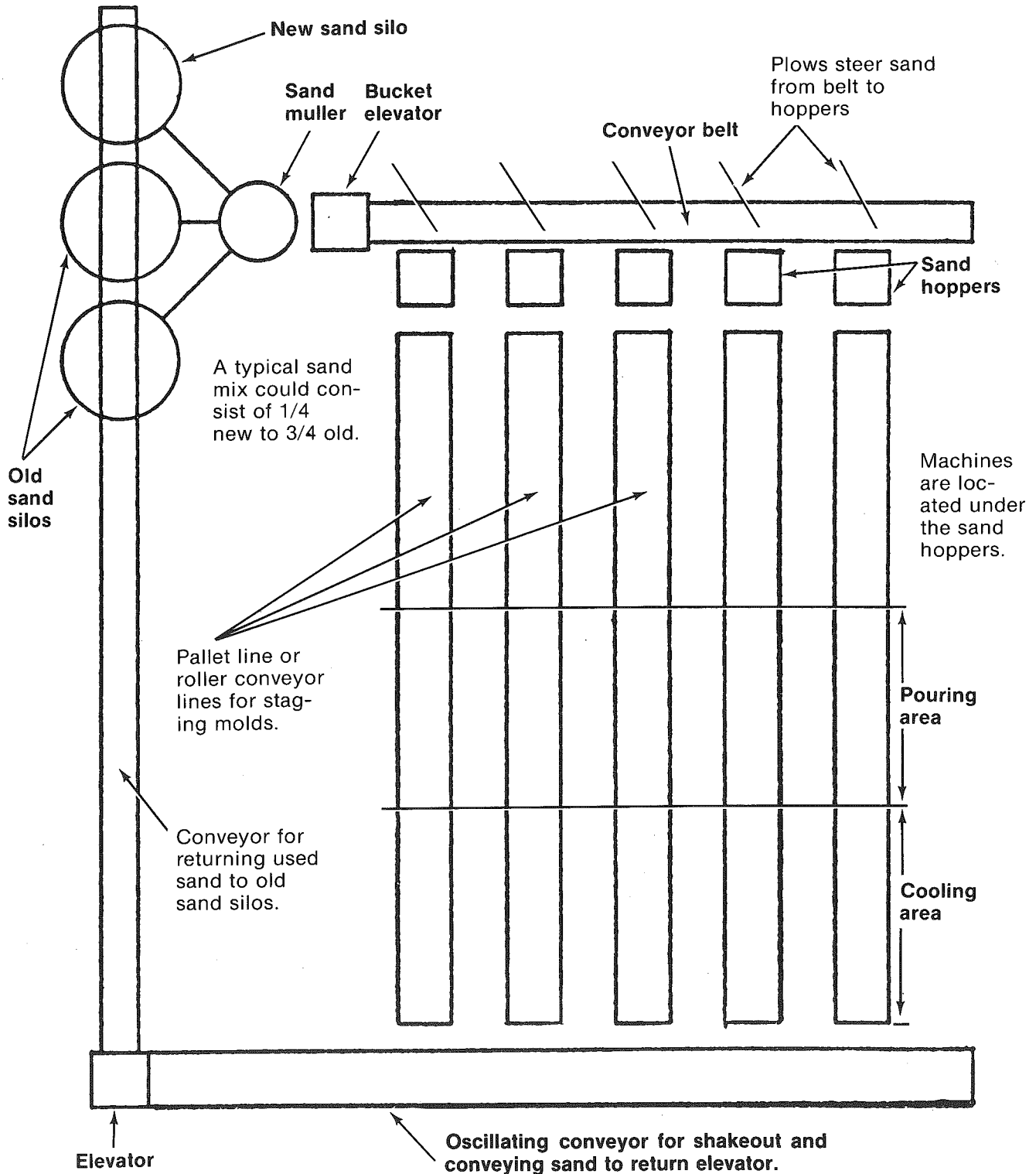
NOTE: These machines are usually known by brand names and model numbers.

D. Mold handling - refers to operations performed after close-up and before shake-out.

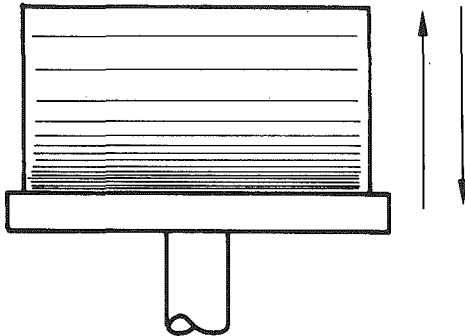
- 1. Transporting molds from the production area to the staging area** - Done with rollers, pallets, cars, hanging racks, etc.
- 2. Staging, which includes jacketing and weighting.** (Exception is a machine which produces molds with vertical parting lines)

FLOW PATTERN FOR A TYPICAL SAND SYSTEM

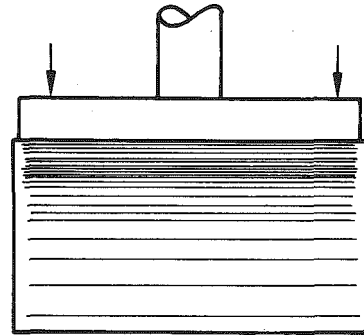
Incoming sand is transferred from boxcars or trucks to the new sand silo. (Usually blown)



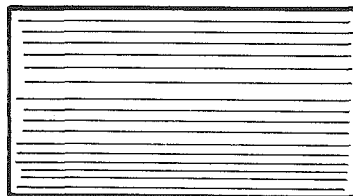
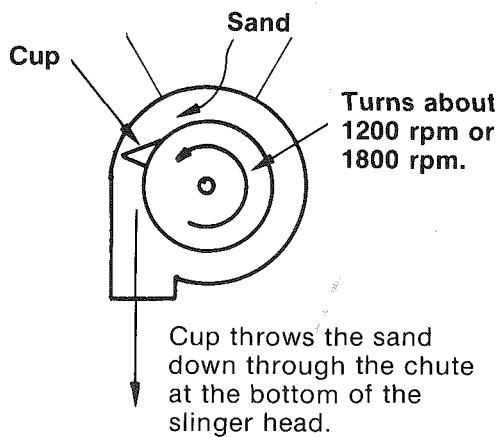
ISO FIRMS: LINES OF MOLD HARDNESS



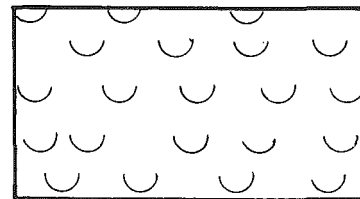
JOLT RAMMING (hard close to the table)



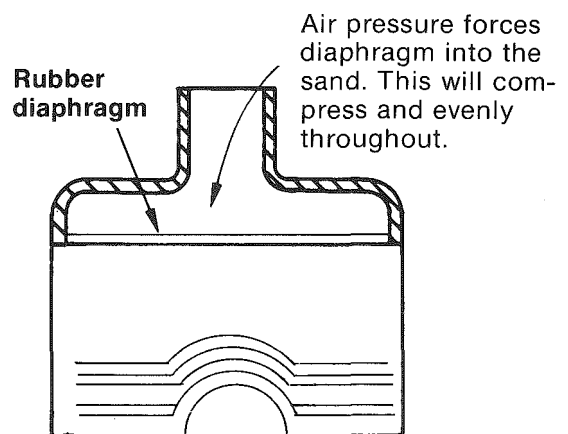
SQUEEZE RAMMING (hard close to the squeeze head)



SLINGER RAMMING (not a true picture - usually has soft spots at the end of each pass.)



HAND RAMMING



PRESSURE MOLDING (isofirms will conform to the shape of the pattern)

E. Pouring - filling the mold cavity with molten metal.

1. Much scrap is attributed to the human error involved during the pouring operation. Variables of rate of flow (speed), steadiness, interrupted pour, etc. are all good reasons for trying to automate this area.
2. Some foundries do pour automatically (highly automated, high production shops) but most are simply mechanized to one degree or another using cranes, easy-tilt ladles, etc.

F. Shakeout - removing the castings from the molds

1. Being a hot, smoky, dusty process has accelerated the automating of this area.
2. Many foundries shakeout automatically and in areas well hooded for ventilation purposes (also insulated to cut down noise and heat)
3. The smaller the molds and castings, the easier to automate.

G. Cleaning - with its many phases is well mechanized, but not too well automated

1. Some automobile foundries have automated some cleaning by using robots and coining dies for gate and riser removal (high production).
2. Others have eliminated much cleaning through design of riser and gate connections.
3. Some surface cleaning is automated.

H. Layout - refers mainly to product flow.

1. From incoming raw materials to the shipping department the product (castings) should flow freely
2. Because most foundries began as small business ventures and later expanded, they usually have poor flow patterns (due to becoming landlocked, etc.). This increases production costs.

18. Permanent mold casting

A. Definition - Castings made by pouring molten metal into molds made of some metallic alloy or other material of permanence. (Also called gravity die casting.)

B. Mold materials

1. **Gray iron** - most popular because of ease of machining and will withstand high temperatures.
2. **Steels** - must be heat-treated to improve refractoriness and lessen chance of erosion.
3. **Aluminum** - has good chilling quality, is easy to machine, but must be anodized to improve refractoriness.

C. Mold life

1. **Pouring temperatures are the most critical factors.**
2. **Refractory washes can prolong the life of molds.**
 1. Core oil and graphite
 2. Water and clay
 3. Dry coatings of carbon (soot)
3. **Mold failure occurs as a surface crazing which hampers removal of castings and also causes the castings to have a rough surface finish.**
4. **Gray iron molds can produce up to 100,000 aluminum castings or up to 15,000 iron castings.**

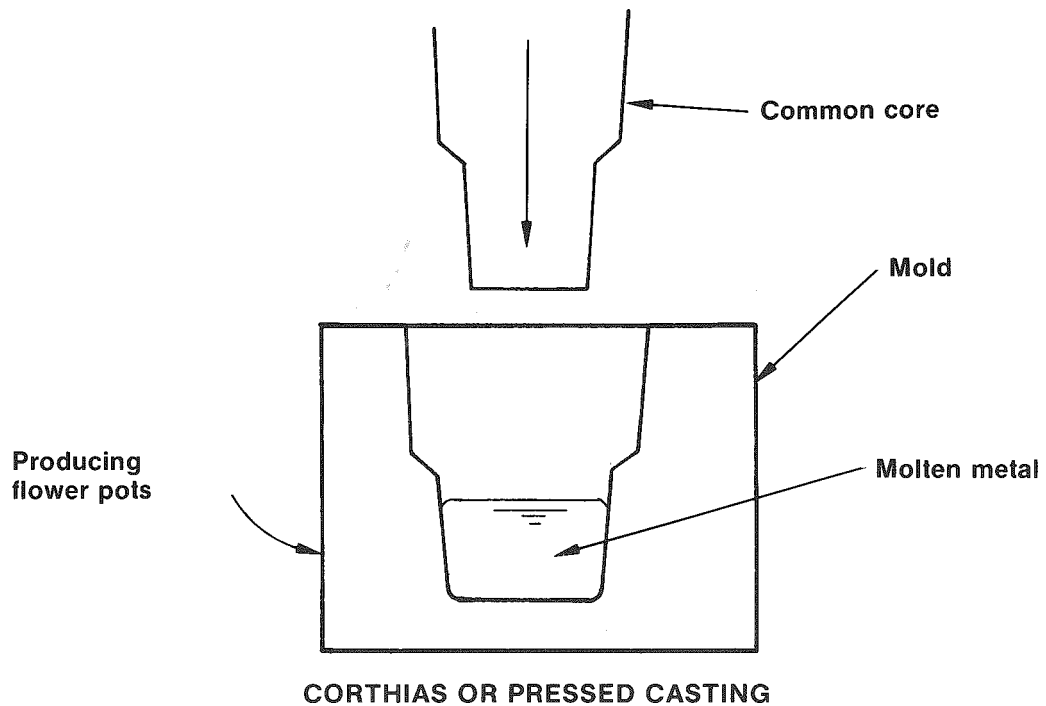
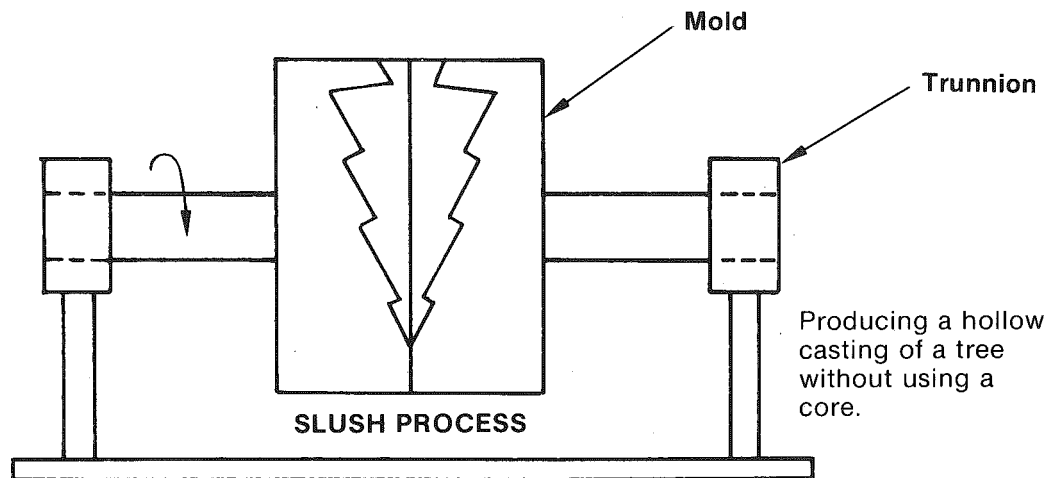
D. Casting alloys

1. **Gray iron (never steel)**
2. **Aluminum** - (most common) the chilling effect from the mold is of an advantage with aluminum alloys plus aluminum melts at relatively low temperatures and can possess good strength.
3. **Magnesium** - limited to simple shapes due to cracking characteristics.
4. **Copper base** - (not extensively used) have poor fluidity and high melting points- aluminum bronze the most common.
5. **Zinc alloys** - easiest to cast, but used more as a die casting alloy.

E. Special applications

1. **Slush casting** - a process for making hollow castings without the use of cores. A permanent mold is filled with molten metal and as soon as metal has formed a skin of solid metal, the mold is inverted allowing all metal still fluid to drain out.
2. **Corthias or pressed casting** - a common core is used after the mold cavity is poured half full to force the metal to fill out the rest of the cavity. (Similar to deep drawing, only with fluid metal instead of sheet metal.)

SPECIAL APPLICATIONS FOR PERMANENT MOLDS



F. Advantages

1. Requires less skill.
2. Requires less floor space.
3. Better tolerances. (0.010 - 0.050 in.)
4. Improved surface finish.
5. Not susceptible to the typical sand mold casting defects.

G. Disadvantages

1. Cost of mold (die) construction.
2. Lack of refractoriness of molds tends to limit types of casting alloys.
3. Chilling effect of the metal mold can create undesirable metallurgical and stress problems with some alloys.
4. The rigid nature of the mold limits the complexity of casting design.
5. Casting size.

19. Die casting

A. Definition - The use of a permanent mold (die) into which molten metal is introduced by means of pressure.

B. Hot chamber

1. The melting unit is an integral part of the machine. Example: a linotype machine.
2. Pressures are much lower than those attainable with the cold chamber process.

C. Cold chamber

1. The melting unit is usually separate and molten metal is transferred to the injection mechanism by ladle.
2. Usually hydraulic pressure is used to inject the metal into the die.
3. Some machines are completely automatic (use robots).

D. Casting alloys

1. Alloys of zinc, aluminum, copper, magnesium, lead and tin are commonly die cast.
2. At one time it was unheard of to die cast any ferrous alloys but now steel is being die cast by using aluminum insert molds which are ejected along with each casting.

E. Advantages

1. Reduction in machining costs.
2. Makes possible the casting of thin sections in fairly complex shapes.
3. Low labor cost per casting along with a minimum of job training.
4. Greatly improved surface finish.
5. Castings are less defective.

F. Disadvantages

1. Relatively high die and equipment costs.
2. Size limitations.

20. Centrifugal casting processes

(See drawings on page 90)

A. Definition - any process in which molten metal is poured and allowed to solidify while the mold is revolving.

B. True centrifugal

1. The mold is spun about its vertical or horizontal axis.
2. The force produced by spinning holds the metal against the walls of the mold until solid.
3. Produces bushings, pipes, and other castings that would normally require cores without the use of cores.

C. Semi-centrifugal

1. Differs from true centrifugal in that cores are required to give the castings their final shape.
2. Castings are gated at their axis.
3. Produces dense, strong castings (sometimes spongy at axis).

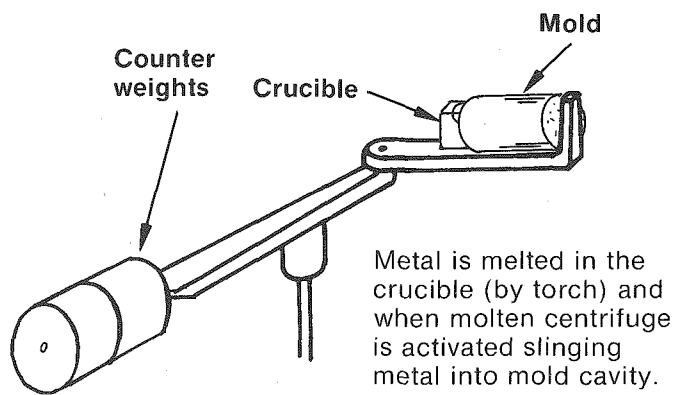
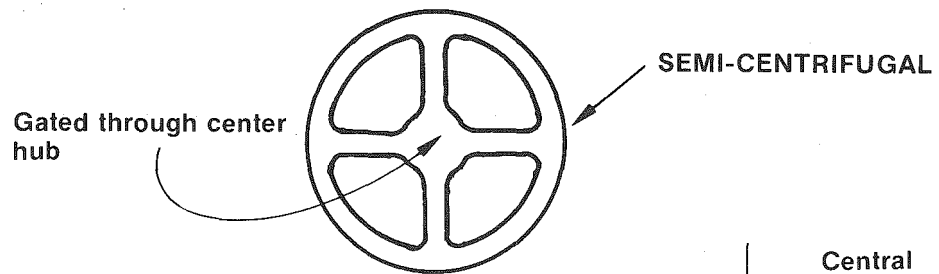
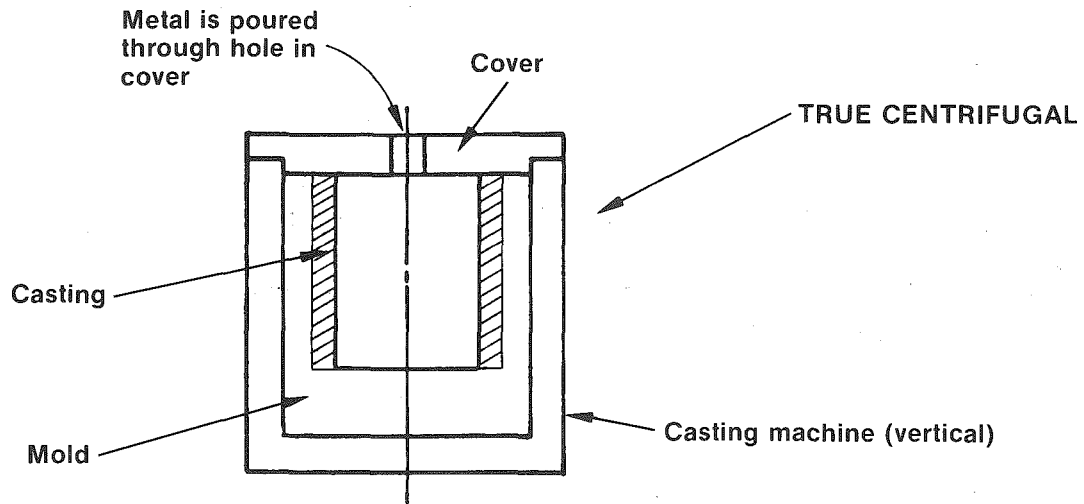
D. Centrifuging

1. Centrifugal force has nothing to do with the castings shape.
2. Used to increase pouring pressures.
3. Many castings can be poured at one time or one at a time, depending on the method used.
4. This process has been used for many years by dentists and jewelers to produce very thin, intricate castings.

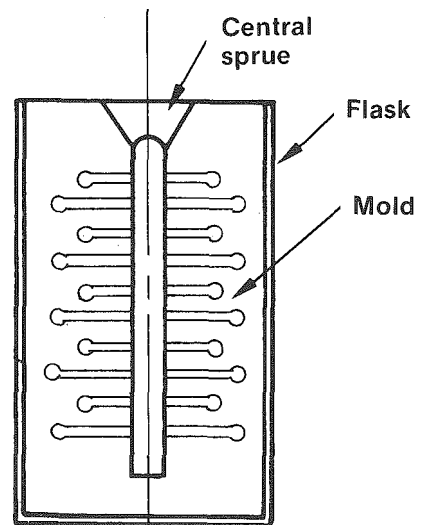
E. Mold materials

1. Sand
2. Metal
3. Graphite
4. Casting plasters

CENTRIFUGAL CASTING



Metal is melted in the crucible (by torch) and when molten centrifuge is activated slinging metal into mold cavity.



Many castings on one sprue - entire mold is spun during pouring to increase pouring pressure.

F. Speeds - 50 to 100 times the force of gravity with 75G's being very common.

G. Alloys cast - Practically any alloy that can be melted.

H. Finished products

1. Cast iron pipe
2. Gun barrels
3. Automotive cylinder walls
4. Jet engine rings
5. Piston rings
6. Brake drums
7. Gear blanks

I. Advantages

1. The elimination of foreign inclusions.
2. Production of sounder, more dense castings.
3. Elimination of cores (true centrifugal).

J. Disadvantages

1. Shape limitations.
2. Size limitations.

21. Investment casting process

A. Definition - Molds are one piece (no cope or drag) and patterns are removed by a melting or burning out process. Also called precision casting or the lost wax process.

B. Mold materials

1. Fine grained silica sand with a suitable binder.
2. Binders can be plaster of Paris and other gypsum products (sometimes sodium silicate or chemical cure binders).
3. Molds are single purpose.

C. Pattern materials

1. Various waxes.
2. Plastics that burn without leaving a residue.
3. Frozen mercury (process called "Mericast").
4. Patterns are also single purpose.
5. For production purposes, patterns can be made by casting or forging in dies made of metal, plastic, rubber or wood.

D. Casting alloys

1. Practically any alloy that can be melted.
2. Poured three different ways:
 - a. Simple gravitational force.
 - b. Air pressure or steam.
 - c. Centrifugal force.

NOTE: When increased pouring pressures are used, thinner sections can be produced.

E. Advantages

1. Extreme precision. (Tolerances as low as 0.00025 of an inch per inch.)

F. Disadvantages

1. Cost - all materials are single purpose.
2. Size
3. A slow production cycle.

22. Other special processes

A. Plaster Molding - cope and drag molds made of plaster instead of sand.

1. Used mainly for nonferrous alloys.
2. Mold parts are dried in ovens with temperatures varying from 350 to 1600F, and time from 45 minutes to 72 hrs. (Some are dehydrated in an autoclave prior to drying)
3. Produces castings with very smooth surfaces and good dimensional accuracy.
4. Used to produce match plates, tire molds and other castings requiring fine detail.

B. "D" Process

1. Shell-like molds are produced by using fast-acting drying oils mixed with sand and blown using complicated blow-box equipment.
2. Although similar, the "D" process has not enjoyed the same popularity as the shell process.

C. Full Mold Process

1. Patterns are made of styrofoam. (Can be produced in quantity with dies)
2. Sand can be used without binders, just vibrated into place around the pattern.
3. Metal is poured directly into the styrofoam which disappears with the metal taking its place. (Gating systems are also of styrofoam)
4. Good for short run jobs. (Cuts down pattern costs)
5. Also used for placing blind risers on some jobs.
6. With no reason for drawing the pattern, no cope, drag, parting line or draft angle is needed. (Better tolerances)