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A Study of Metal Founding and its Practices and Applications for Information Purposes in Industrial Arts Education

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A STUDY OF METAL FOUNDING

AND ITS PRACTICES AND APPLICATIONS

FOR INFORMATION PURPOSES IN

INDUSTRIAL ARTS EDUCATION

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CHAPTER I

INTRODUCTION

Founding is a trade that involves some knowledge of almost every operation required in the making of machines; and men well versed in the mechanic arts assert that the art of founding demands greater mechanical skill, caution, and good judgement than any other of the allied trades. The art of founding is largely dependent on the hand, eye, and mind for results, machinery having played but a small part in the work of molders compared to workers in most other trades.[1]

A study of the foundry industry develops the fact that there are few other industries where successful operation depends so much upon certain shop techniques and procedural refinements. These essentials of "know-how" and "know-why" have been accumulated through the years and constitute at the present a broad field of information for use in the modern foundry. Notwithstanding the fact that foundry practice is one of the oldest industries of the world and of our nation, it still occupies a most important place in the American manufacturing scene—as respects design, as respects engineering, and as respects materials. Numerous volumes have been written on metal-casting development and production. Most of this information has been compiled and written as a result of years of hard work combining practical experience and exhaustive research.

PURPOSE

It was the purpose of this paper to make a study of metal founding and its practices and applications for information purposes in industrial arts education.

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[1]International Correspondence Schools Reference Library, (International Textbook Company, Scranton, Pa., 1901) Sec. 40-1

[2]Rusinoff, S. E., Foundry Practices, (American Technical Society, Chicago, Illinois, 1955 and 1962) 1

SIGNIFICANCE OF THIS STUDY

"Foundry is a very important metalworking field for it includes almost half a million people."[1] The skilled and semiskilled jobs which exist in the foundry make the foundry shop and its related industries a major employer of young people. A significant reason for making a study of the foundry, then, was information on job opportunities. The production of metal castings is one of the basic processes of the metal-working industry.

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[1]John L. Feirer, General Metals, (McGraw-Hill Book Co., Inc. New York, 1959) 234

TERMS

BELLOWS--Instrument that produces air for the removal of loose sand.[3]

BLAST FURNACE--The chief raw material for cast iron is pig iron, which is produced in a blast furnace by the process of smelting iron ore with coke and a flux.[1]

BOTTOM BOARD--The mold board upon which the drag rests.[2]

CASTING--A metal object obtained by allowing molten metal to solidify in a mold.[3]

CENTRIFUGAL CASTING--The principle of this casting process is that the mold rotates fairly rapidly while the molten metal is poured into it. Due to the rotation of the mold, centrifugal forces are being developed, which direct the incoming liquid metal to the inner surface of the mold with considerable intensity, where solidification occurs.[1]

CORE--A sand form designed to produce a recess in a casting.[2]

CORE BOX--A box in which a sand core is formed.[2]

CRUCIBLE--A clay or graphite container in which metal is melted.[2]

DIE CASTING--Pressure is applied to force the molten metal into the metallic molds or dies.[1]

DRAW NAIL--A metal pin or screw used to draw a pattern from a sand mold.[2]

FLASK--A complete molding box. It usually has two parts, the cope and the drag.[2]

FOUNDRY--It is a commercial establishment for founding or producing castings.[3]

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[1]Rusinoff, S.E., Foundry Practices, (American Technical Society, Chicago, Illinois, 1955 and 1962)

[2]Harvey D. Miner and John G. Miller, Exploring Patternmaking and Foundry, (D. Van Nostrand Company, Inc., Princeton New Jersey, 1959 and 1964)

[3]Richard W. Heine and Philip C. Rosenthal, Principles of Metal Casting, (American Foundrymen's Society, Des Plaines, Illinois, McGraw-Hill Book Co., New York, 1955

GATE--A channel through which the molten metal flows from the sprue to the mold cavity.[2]

GATE CUTTERS--A tool made of sheet metal used to cut the gate in a mold.[2]

INVESTMENT CASTING--Investment casting, sometimes referred to as the "lost-wax" process is used to produce small and intricate parts requiring a high degree of surface smoothness and dimensional accuracy. This process is particularly adaptable in the production of parts for aircraft, ordinance and radar. The pattern is prepared by forcing molten wax or plastic into a metal die. The pattern is then used to make a sand mold after which the mold is fired at a high temperature to remove the wax or plastic. Molten metal is fed into the cavity either by centrifugal force or by gravity pouring.[4]

MOLDING BOARD--A board under the flask, used for molding.[2]

MOLD--The entire sand form in which a mold cavity has been left by the pattern.[2]

NON-FERROUS--Containing little or no iron[2]

PATTERNS--Patterns are required to make molds. The mold is made by packing some readily formed plastic material such as molding sand around the pattern. When the pattern is withdrawn, its imprint provides the mold cavity which is ultimately filled with metal to become the casting.[3]

PERMANENT MOLD CASTING--Unlike the sand and plaster casting, where a new mold has to be prepared for each casting operation, the permanent mold process uses a metal mold which can be utilized repeatedly. Because of their greater precision, metal molds produce more accurate castings than the sand casting method. This type of casting is employed when high production warrents the additional cost of equipment.[4]

PLASTER MOLD CASTING--The plaster mold process is similar to the sand mold casting except that the mold material is plaster or a combination of plaster and sand. This process is confined to the casting of non-ferrous metals. Plaster mold castings have a smoother finish and greater dimensional accuracy than sand castings.[4]

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[4]J. W. Giachino and Henry J. Beukema, Engineering-Technical Drafting And Graphics, (American Technical Society, Chicago, Illinois, 1961)

POWDERED METAL CASTING--Although powder metallurgy is not an actual casting process, parts made by this method require the uses of specially made dies. Metal powders are compressed into a form under extremely high pressures varying from 15,000 to 100,000 pounds per square inch. The powder metals most commonly used are copper and tin to produce bronze for bearings, and brass and iron for structural parts. The first operation involves the mixing of the powders to obtain a homogeneous blend. The powder is then compressed into the form by means of briquetting tools with pressure supplied either by mechanical or hydraulic presses. The briquetted compacts are next passed through a furnace here heating bonds the particles firmly together. Upon cooling, the piece is ejected from the die and subjected to various treatments such as sizing, machining, or heat treatment.[4]

RAMMER--A wooden tool used to pack the sand in a mold.[2]

REVERBERATORY FURNACE--The action or process of subjecting something to reflected heat.[3]

RIDDLE--A screen used to sift fine sand over a pattern during the molding process.[2]

RISER--A cylindrical passage in a mold to allow the escape of gases and surplus metal.[2]

SAND MOLD CASTING--In this method a wood or metal pattern is used to make a mold. The mold is prepared by placing the pattern in a wood or metal frame called a flask and packing sand around the pattern. The pattern is then removed and metal poured into the mold cavity.[4]

SLICK--A flat, rounded tool used by the molder to make repairs on a mold.[2]

SPRUE PIN--A conical wooden piece used to mold the sprue hole in a mold.[2]

TROWEL--A flat tool used to smooth the surface of a mold.[2]

CHAPTER II

BRIEF HISTORY OF THE FOUNDRY

"Founding originated before the beginning of recorded history."[1] One of the first metals to be smelted was copper. This occurred in the Near East between 4000 and 5000 B.C. The first casting with copper could have been done by accident. "A metalworker could have spilled molten metal into a footprint, and in picking up the cooled metal he would have noticed that it was shaped like his foot."[2] The earliest foundry shops made castings by pouring molten metal into shallow open molds. The castings were then finished by forging and using abrasive wheels. The closed mold was later developed and with it both the top half and bottom half of the casting had the desired shape. Iron castings were first made by the Chinese in the seventh century B.C. They were the first to provide an efficient bellows to supply a good air draft to their furnaces and were able to get the high temperatures that were required to melt iron.

> About 5000 B.C., the founders in the city of Sumer, in the region between the lower Tigris and Euphrate rivers, made axe heads of copper that had a hollow end into which a wooden handle could be forced. This meant that a cored mold had been used, and the appearance of the casting indicates a closed mold.[3]

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[1]The American Peoples Encyclopedia, (Grolier Inc., New York, 1962) 8-874

2ibid

[3]The Encyclopedia Americana, (Americana Corporation, 1964) 544

Casting was the climax of all the metalworking that occurred in early history. Some of the metals which were used in those times were lead, tin, copper, and bronze. Bronze casting was used to produce some of the most perfect works of art. At first only solid casts were made. This not only made a very heavy object, but also required a lot of metal. "How solid casting was practiced in Egypt is shown in an old picture of 1600 B. C., which came from a temple at Karnak and depicts the casting of a bronze door of a temple."[1]

> Solid casting was later superseded by hollow casting which, however, like the former appeares not to have been known to the Greeks of mythological times and of the immediately succeeding epochs; for when Homer describes how the equipment of his heroes was made, he mentions only forged work, never casts.
>
> Little stone molds of an early date have been found. Schliemann, in his Mycenean excavations found some of these stone molds and regarded them as casting molds. Prehistoric finds prove that stone molds were actually used to make castings.[2]

Weapons have always been important foundry products. Metal hand weapons, many of them made by casting, gradually replaced stone weapons. Casting of gun barrels began about 1300. Bronze, iron, and brass were common materials for early firearms, but have been replaced by steel.

The Master-gunsmiths had much to do with progress in the field of foundry. They had to be very talented in several handicrafts. Some of these handicrafts were casting,

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[1]Albert Neuburger, The Technical Arts And Sciences of The Ancients, (The Macmillan Co., 1930) 54

forging, carpentry, and joinery, and preparation of gunpowder. These men were highly esteemed both by princes and by the townships. "From a document introducing Merckiln Gast a Frankfurt Master-gun-smith of about the last decade of the fourteenth century, we learn something of his ability."[1]

> Merckiln Gast, the gunsmith, can perform the following, First, he can restore spoilt gunpowder to its original state, rendering it again efficient.
> Item, he can separate and refine saltpetre and salt.
> Item, he can make powder that will last 60 years.
> Item, he can shoot with large and small weapons.
> Item, he can cast from iron small-arms and other guns.
> This is the first document in which we hear of an iron founder. Iron casting was one of the greatest inventions of the Middle Ages. It developed in the Rhineland about the beginning of the fourteenth century. It followed the more efficient use than in the early and high Middle Ages, of water power to work the great bellows needed to produce sufficient furnace heat to smelt iron. Only in the second half of the fifteenth century was the iron cast direct from the cupola. The blast furnace for iron began, slowly to develop from the fourteenth century, but not until the sixteenth century can we speak of a true blast furnace. The introduction of the blast-furnace was, to begin with, not directly linked with the invention of cast iron.[2]

Die casting, permanent-mold casting, investment casting, and shell molding were all foundry processes which were invented in the 16th, 17th, and 18th centuries.

"Benvenuto Cellini used the investment casting technique some 400 years ago to cast his statue Perseus."[3]

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[1]Friedrick Klemm, A History of Western Technology, (Charles Scribner's Sons, New York, 1959) 101

[2]ibid

[3]The American Peoples Encyclopedia, (Grolier Inc., New York, 1962) 4-875

"Die casting is not a 20th century development. The Mergenthaler Linotype machine invented in 1884 is one of the earliest applications of this process."[1] Die casting was not used industrially to any great extent until World War I. The process, as well as the casting made, is called die casting in America and pressure die casting in England.

"The shell-molding or Croning process was introduced into the United States from Germany in 1947."[2]

Powdered metal casting was a development of the 1950's. This type of casting is accomplished by placing tiny grains of unmelted metals into a mold and then heating the mold.

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[1]Encyclopedia Britannica, 7-347

[2]The American Peoples Encyclopedia, (Grolier Inc., New York, 1962)

CHAPTER III

FOUNDRY EQUIPMENT

A foundry needs certain basic equipment. The first piece of equipment that a foundry is concerned with is a pattern which is identical in shape to the desired casting. A foundry needs a heat source of some type to melt the metal. One of the many types of molds is also a necessary piece of equipment. Some facility for removing the sprues and risers from the rough casting is needed.

Some of the different types of furnaces that are used in the foundry are the cupolo, the reverbertory furnace, and the crucible furnace. The fuel that is used to produce the high temperatures that are needed may be coke, coal, oil, gas, or electricity. The molds may be expandable, such as molding sand, or they may be made of iron or steel and used over and over as is done in die casting. Saws, sprue cutters, gas blowtorches, or flexible cutting wheels may be used to cut off the extra metal from castings. Some castings need much machining after they are cast. A good example of this is the engine block in the automobile. Other castings need little or no machining.

Casting may be done in the industrial arts shop with only a small amount of equipment. This should include a flask, molding board, bottom board, bench rammer, sprue pin, riser pin, draw screw, strike-off bar, riddle, spoon and gate cutter, trowel, sprinkling can, shovel, and a few other molders tools.

For light metals such as aluminum, lead, and zinc alloys, either a large soldering or a special melting furnace may be used in the industrial arts shop. An acetylene torch or a forge may also be used to melt some metals.

Some other pieces of equipment that are directly associated with the pouring of the metal are the crucible, the pouring ladle, the tongs, the crucible shank for pouring. Some necessary pieces of equipment to insure safety are goggles, asbestos gloves, leggings, and an apron.

CHAPTER IV

PRINCIPAL CASTING METHODS

A casting is a piece of metal made by pouring the molten metal into a mold. The principal casting methods are sand mold casting, plaster mold casting, permanent mold casting, investment casting, centrifugal casting, and die casting.

SAND MOLD CASTING

In this method a wood or metal pattern is used to make a mold. The mold is prepared by placing the pattern in a wood or metal frame called a flask and packing sand around the pattern. The pattern is then removed and metal poured into the mold cavity.

PLASTER MOLD CASTING

The plaster mold process is similar to the sand mold casting except that the mold material is plaster or a combination of plaster and sand. This process is confined to the casting of non-ferrous metals. Plaster mold castings have a smoother finish and greater dimensional accuracy than sand castings.

PERMANENT MOLD CASTING

Unlike the sand and plaster casting, where a new mold has to be prepared for each casting operation, the permanent mold process uses a metal mold which can be utilized repeatedly. Because of their greater precision, metal molds produce more accurate castings than the sand casting method. This type of casting is employed when high production warrents the additional cost of equipment.

INVESTMENT CASTING

Investment casting, sometimes referred to as the "lost wax" process is used to produce small and intricate parts requiring a high degree of surface smoothness and dimensional accuracy. This process is particularly adaptable in the

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[1] J. W. Giachino and Henry J. Beukema, Engineering-Technical Drafting And Graphics, (American Technical Society, Chicago, Illinois, 1961) 304

production of parts for aircraft, ordinance and radar. The Pattern is prepared by forcing molten wax or plastic into a metal die. The pattern is then used to make a sand mold after which the mold is fired at a high temperature to remove the wax or plastic. Molten metal is fed into the cavity either by centrifugal force or by gravity pouring.

CENTRIFUGAL CASTING

Centrifugal casting consists of a permanent mold which is rotated rapidly while a measured amount of molten metal is poured into the mold cavity. The process is applicable for cylindrical castings made either of ferrous or non-ferrous metals. Centrifugal force holds the metal in the mold and the volume of metal poured controls the wall thickness of the casting. The advantage of centrifugal casting is that it produces smoother outside surfaces, thereby reducing a great deal of machining.

DIE CASTING

Die casting is a process of forcing metal under pressure into metal dies. It is especially applicable for casting soft alloys of zinc, aluminum, magnesium, and copper. Castings formed by this method are extremely accurate and require little or no machining. The process is adaptable to almost unlimited shapes without expensive supplementary operations.

POWDER METALLURGY

Although powder metallurgy is not an actual casting process, parts made by this method require the uses of specially made dies. Metal powders are compressed into a form under extremely high pressures varying from 15,000 to 100,000 pounds per square inch. The powder metals most commonly used are copper and tin to produce bronze for bearings, and brass and iron for structural parts. The first operation involves the mixing of the powders to obtain a homogeneous blend. The powder is then compressed into the form by means of briquetting tools with pressure supplied either by mechanical or hydraulic presses. The briquetted compacts are next passed through a furnace where heating bonds the particles firmly together. Upon cooling, the piece is ejected from the die and subjected to various treatments such as sizing, machining, or heat treatment.

CHAPTER V

OPERATIONS IN PRODUCING A CASTING

There are dustinct major operations which are necessary in the production of ordinary castings. The first operation that is involved is patternmaking. This pattern is an exact duplicate of the intended finished casting. It is usually made of wood but can be made of any other material that can withstand the punishment of being packed in the damp sand.

From this pattern a mold is made. This is the second necessary operation in producing a casting. This mold may be made of sand or some other material that can withstand the action of molten metal.

The last operation in the pouring of the metal. This is done by hand in the small foundry, but has taken on a certain degree of automation in the production foundry.

"Each of these operations, requires special skill, and has given rise to special trades, though the molding and founding are often performed by the same person."[1]

PATTERNMAKING

"In the first of these operations, that of the patternmaker, a fair degree of skill in the arts of cabinetmaking and of wood turning is needed, for patternmaking consists

[1]International Correspondance Schools, op. cit. 40-2

largely of fitting joints and making circular forms."[1] The patternmaker must be familiar with the tools of these trades.

A pattern is usually made of wood, metal, rubber, or plaster. The wooden patterns are by far the most common. It is a cheaper material than most others and it is easier to work with. A wood pattern is lighter in weight and its surface is easily treated to withstand the action of the moist sand that is forced against it in the mold. "The use of wood in making patterns is so nearly universal that the patternmaker is always understood to be a wood worker."[2] Clear, dry, white pine is the type of wood that is generally used for patternmaking. Mahogany or cherry or some other hard woods are sometimes used when large numbers of castings are to be made from a single pattern.

One must keep in mind certain allowances when making patterns. Most metals expand when heated and contract when cooled. Shrinkage allowance is therefore one of the basic considerations when constructing any pattern. If a metal is known to shrink 1/8 inch per foot upon cooling from the liquid state after the mold is poured, the pattern must be made a corresponding amound larger than the required casting so that the casting will be correct in size when it is cool.[3]

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[1]ibid

[2]ibid

[3]Miner and Miller, op. cit. 45

A shrinkage scale can be used to calculate the shrinkage allowance.

Another type of allowance is the draft allowance. It is the taper allowance on all vertical surfaces of a pattern to make it easier to draw the pattern from the mold.

An allowance of 1/16 inch is made on all surfaces to be finished on a non-ferrous casting. The standard finish allowance on a ferrous casting is 1/8 inch.[1]

Special patterns are often made of iron, brass, white metal, or aluminum. Ornamental work and statuary are usually modeled in wax or clay.[2]

MOLD

A form into which melted metal is poured to make an object is called a mold. Molds are made of metal, sand, or plaster of Paris.[3]

> The pattern is used to make the mold. The pattern is placed in a box, or flask, as it is called, and then sand is packed around it. Since the flask is made in two parts, it can be taken apart and the pattern removed. After the pattern is removed, a gate is cut to the pour, or sprue hole, and the mold is closed. If the finished casting must have holes or other openings through it, special sand cores are placed in the mold before closing. The molten metal is poured into this cavity. When it cools, the mold is broken to remove the casting.[4]

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[1]ibid

[2]International Correspondance Schools, op. cit. 40-2

[3]Feirer, op. cit. 235

[4]ibid

POURING THE METAL

The cupola is the oldest and still the most used type of furnace for melting cast iron. The electric furnace is being used to an increasing extent because the composition of the iron can be more closely controlled and there is flexibility in the temperature control. It costs more to operate the electric furnace, however, and it is used only when high-quality iron is desired.

The molten metal is taken from the furnace in ladles and is poured into the molds. The rate of pouring is determined by the size of the casting. After the metal has cooled and hardened it is ready to be cleaned.

Castings can be cleaned by brushing, tumbling in a revolving barrel, abrasive or water blasting, and pickling in an acid solution. The gates, risers, and fins which are not broken off in the tumbling barrel must be cut off and the rough places smoothed by grinding.

CHAPTER VI

INDUSTRIAL ARTS FOUNDRY

The application of the foundry in the industrial arts area can be both practical and economical. It is practical from the stand point that each of the four main categories of patterns may be experimented with. It is econimical because much of the equipment can be made by the boys in the shop.

This chapter will be divided into the four necessary, major steps in producing a casting in the industrial arts laboratory. These sections will be patternmaking, molding, pouring, and finishing the casting.

PATTERNMAKING

"The patternmaker is basically a woodworker; therefore, his tool kit will consist of most of the tools used by the cabinetmaker, with the addition of some special tools that are used only by the patternmaker."[1]

A list of these basic tools will be presented here,[2] but the proper use of each tool will not be given as this is material for industrial arts woodworking. This list might be used as a check-list by the student or instructor to see if all the necessary tools are available.

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[1]Miner and Miler, op. cit. p. 3

[2]ibid

Measuring and Layout Tools:

Rule	Try Square
Caliper Rule	Combination Square
Shrink Scale	"T" Bevel
Flexible Rule	Dividers
Marking Gauge	Trammels
Steel Square	Calipers

Sawing Tools:

Coping Saw	Dovetail Saw
Compass Saw	Patternmakers Saw
Panel Saw	Miter Box
Back Saw	

Planing Tools:

Block Plane	Circular Plane
Bench Plane	Core-Box Plane
Rabbet Plane	Spokeshave
Router Plane	

Boring Tools:

Brace	Counter Sink
Hand Drill	Multi-Spur Machine Bit
Auger Bit	Bit Gauge
Twist Drill	Doweling Jig

Clamping Tools:

Hand Screw
Patternmaker's Vise
"C" Clamp
Bar Clamp
Pinch Dog

Miscellaneous Tools:

Claw Hammer	Rasp	Fillet Iron
Mallet	Screw Driver	Cornering Tool
Chisel	Nail Set	
Gouge	Brad Awl	
Cabinet File	Brad Pusher	

Machines Used In Patternmaking:

Circular Saw
Band Saw
Jig or Scroll Saw
Jointer
Wood Turning Lathe
Abrasive-Disc Machine
Abrasive-Belt Machine
Drill Press
Grinder
Wood Trimmer

Patternmaking Materials:

Wood
Plastic
Wax
Glue
Pattern Shellac
Colored Shellac
Fillets
Pattern letters, figures, or monograms
Draw Pin, Rapping Bar, and Draw Screw

The first thing a patternmaker is concerned with is accurate layout on paper. "The patternmaker should have a good knowledge of and a developed skill in drawing."[1] Several of the advantages of a layout prior to the construction of a pattern are as follows:

1. It serves as a good reference
2. It brings to light obscure details
3. There is less chance for mistakes
4. Needed materials are easily listed
5. The finished pattern may be more easily visualized
6. Steps of procedure can be better planned
7. Dimensions and pertinent information are brought together.
8. Core prints and other similar parts are not likely to be overlooked.[2]

As one can imagine there are a great variety of shapes and sizes of patterns. "Some are small in size and simple

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[1] ibid

[2] ibid

in nature, while others are large and highly complex, with irregular surfaces, core prints, and loose pieces."[1]

Patterns may be listed in order according to difficulty. The four main categories of patterns are the solid flat-back patterns, split patterns, patterns with irregular parting lines, and cored patterns. The solid, flat-back pattern and the split pattern will be the two described here for they are the ones most used in the industrial arts laboratory.

The following procedure may help a beginning patternmaker to check the sequence of operations in constructing a simple wooden pattern.[2]

> 1. Study the pattern layout and determine the location of the parting surfaces. From the layout, study the shape of the proposed pattern to determine how many separate pieces may be necessary for the pattern. With a basic knowledge of woodworking, the patternmaker may think through the shaping operations that will best suit the particular pattern. For example, cylindrical work is generally shaped by turning on the lathe; rectangular shapes may be cut on the band saw or jig saw; and some small pieces may need to be shaped on the sanding machine or with chisels. Where several separate parts are to be used to construct a pattern, the patternmaker should consider the best method to be used in the assembly of these parts. Here glue, glue and brads, dowels, pinch dogs, and various common woodworking joints may be considered. The best method is one which will result in the most durable pattern with a reasonable amount of time expanded in its construction.

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[1]ibid

[2]ibid

2. Start the pattern by constructing the main part of the body. Select a suitable piece of pattern lumber with consideration for the direction of the grain of the wood. In general, the grain of the wood will run in the direction of the greatest length of the piece being shaped. This provides strength and reduces the chance of inaccuracy due to change in size of the pattern lumber, since wood shrinks and expands in its width and thickness more than in its length. Lay out the shape of the piece from the layout drawing. Use dividers to transfer measurements, and a knife, straight edge, and square to mark accurately the size and shape of the pattern. Several pattern parts may be made from one piece of pattern lumber if they are to be of the same thickness.

3. Cut out the pattern part or parts from this prepared layout. When using the circular saw, band saw, or jig saw, set the table of the machine at a three-degree angle to make provision for draft. Be sure the draft angle is in the right direction. Small pattern pieces may be shaped with ordinary hand tools if the need for draft is kept in mind. Cylindrical parts are turned on the lathe with a slight taper when draft is required.

4. Check each part of the pattern for accuracy by placing it on the layout. Be sure allowances are correct. Check to see that outside corners are rounded as required. Sandpaper each part separately so that it is smooth. Take care not to distort the shape of the pattern when sanding. Joining surfaces should not be sanded.

5. Assemble each part carefully with glue and brads and check its position with the layout drawing. Allow the glue to set and dry.

6. Check the completed pattern with the layout for accuracy. Sand any rough surfaces with fine sand-paper and give the first coat of shellac to the pattern. Observe the color code. Allow the shellac to dry for at least two hours.

7. Place the proper-size wax fillets on all inside corners. Make any necessary waxing repairs at this time.

8. Sandpaper the pattern again with fine sandpaper and apply the second coat of shellac, using the color

combinations as required. When the second coat of shellac is dry, sand the pattern lightly once more with fine sandpaper and apply the final coat of shellac. A final light sanding or a light rubbing with fine steel wool will insure the smooth finish required for drawing the pattern from the sand without disturbing the mold.

Fillets must be placed in most sharp corners and the patternmaker must develop a skill in the forming of these. "Wax fillets are the most common type used in patternmaking."[1]

Prepare or select the glue that is to be used. Many patternmakers prefer to use plastic-resin glue while others use a hot glue. "Hot glue is prepared by adding one part of flake or bead glue by volume to three parts of water."[2]

Split Pattern:

Cylindrical or conical patterns and other shapes that lend themselves to turning on a lathe are often prepared in two halves. The procedure for preparing these patterns is commonly referred to as "split turning."[3]

When preparing stock to be turned for a split pattern, the following procedure should be carefully followed.[4]

1. Select pattern stock of the required size, and make allowance for glued ends if that method is to be used for holding the stock while it is being turned.

2. Plane one true surface of each piece to form the parting surface of the pattern.

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[1]Rusinoff, op. cit. p. 21

[2]Miner and Miller, op. cit. p. 57

[3]ibid

[4]ibid

3, Lay out the position of the dowel pins as planned on your pattern layout. These are usually along the center line of the turning. They are far enough apart to insure alignment when the split pattern is assembled. Avoid placing them too close to the ends of the pattern. Two dowel pins are usually sufficient for alignment.

4. Select the size of dowel depending upon the pattern size. Clamp the pattern halves together so that their parting surfaces are adjacent, and then bore the dowel holes. These holes should be bored completely through one half of the pattern and into the second part to a depth 1/8 inch greater than 1 1/2 times the diameter of the dowel.

5. Cut the dowels to a length equal to the thickness of one half the pattern plus 1 1/2 times the diameter of the dowel, and sand a rounded point on one end of each.

6. Drive the dowel into the bored hole so that the flat end of the dowel is flush with the outside surface of the stock. Usually the patternmaker does not glue these dowels in place until the turning has been completed.

7. Mark the location of the extra stock allowed for gluing on each end, and apply glue to both pieces on these ends. Take care not to have the glue run beyond the extra stock that will be removed after turning. Even a small amount of glue on the parting surface of the pattern may prevent the finished pattern from separating readily. Clamp these pieces and allow the glue to set.

8. Remove the clamps when the glue is dry, and locate the center of the stock on each end exactly on the parting line. Center the stock using the spur and cup centers as you would for spindle turning. A circle may be scribed on each end and the corners may be planed off the square stock to make rough turning on the lathe easier and safer.

Split patterns that are turned in the lathe require little provision for draft. The circular shape formed in the turning process provides plenty of draft except at the ends and shoulders. Be sure to turn a slight taper on the ends and also on any shoulders so that the mold will not be disturbed when the pattern is removed

A pattern may be fastened to a plate to make the molding process more efficient. A good percentage of foundry production is done with patterns mounted on plates. These plates are often called match plates.

OPERATIONS IN MOLDING

As was mentioned before patterns may be classified in four main categories. If the student masters the techniques of making molds of each of these basic types of patterns, he will have a good foundation for further work in the foundry.[1]

The molding of the basic flat pattern and the split pattern will be discussed here because they are the two methods usually used in the industrial arts laboratory.

Molding A Flat-Back Pattern:

In the example to be used here a name-plaque is to be made. A list of the tools, equipment, and materials[2] needed for this exercise is shown to be used as a check list:

Molding flask	Sprue and riser pins	Bulb swab
Molding boards	Molder's bellows	Slick and spoon
Flat-back pattern	Draw pin or screw	Strike-off bar
Riddle	Vent wire	Flask weights
Rammer	Gate Cutter	

Molding sand
Parting compound
Zinc, alloy or casting alluminum alloy

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[1]ibid

[2]ibid

The procedure to be used in ramming up the mold for this exercise is given below.[1]

1. Temper the molding sand thoroughly.

2. Examine the pattern. See that all surfaces are clean, smooth, and dry.

3. Place the drag half of the flask on the molding board with the aligning pins pointing downward.

4. Place the pattern on the molding board near the center of the flask. The pattern should be placed with the flat back of the pattern on the board.

5. Dust parting compound over the pattern and molding board.

6. Riddle fine molding sand over the pattern to a depth of about 1 inch.

7. Fill the remainder of the flask with unriddled, tempered sand from the bin or floor.

8. Ram the sand firmly around the pattern and inside edge of the flask using the peen end of the rammer.

9. Fill the drag again with tempered sand. Ram this firmly with the butt of the rammer.

10. Strike off the excess sand flush with the surface of the drag using the strike-off bar.

11. Place a second molding board on the drag and roll the drag over so that the pins point upward.

12. Carefully remove the molding board. This will expose the flat back of the pattern.

13. Using the foundry trowel, level off the parting surface of the mold.

14. Place the cope on the drag. Be sure that the guide pins fit properly and slide easily in the guides.

15. Carefully push the sprue pin into the sand in the drag about 3/4 inch from the pattern. Opposite the sprue pin and near the heaviest section of the pattern insert the riser pin in the drag about 3/4 inch from the pattern.

16. Sift parting compound over the pattern and the parting surface of the mold. Parting compound contains a nonwetting agent, which will prevent the tempered sand from sticking to the pattern when the cope is rammed and will enable the mold to be separated at the parting surface without the sand in the cope sticking to the drag.

17. Riddle molding sand over the pattern to a depth of about 1 inch.

18. Fill the cope with unriddled sand directly from the bin and ram the sand firmly in place. Care must be taken not to ram the cope as hard as the drag. If the cope is rammed too hard, it will force the sand from the cope into the drag and spoil the mold.

19. Strike off the excess sand at the top of the drag.

20. Most molds require venting. Use the vent wire to pierce a series of holes over the pattern to permit gases to escape. These vent holes should be of such depth that they will almost but not quite reach the pattern.

21. With extreme care, lift the cope from the drag and stand it on edge at one end of the molding bin or on the floor.

22. Carefully remove the sprue and riser pins from the cope. Form a funnel at the top of the sprue with your fingers; this will aid in pouring the casting. Be sure there are no loose particles of sand around the sprue or riser holes.

23. Dampen the sand around the edge of the pattern using the bulb swab. This will keep the sand from breaking away when the pattern is drawn.

24. Insert the draw screw in the back of the pattern near the center. With the rapper, tap the screw on its head and then rap the pattern lightly from side to side. This will loosen the pattern from the mold.

25. Carefully draw the pattern from the mold by lifting the draw screw. Steady your hand on the side of the flask while drawing the pattern. Remove the draw screw from the pattern, and then clean and store the pattern in a safe place.

26. If any defects occur in the mold, repairs may be made with the trowel or the slick and spoon.

27. Cut a gate from the mold to the sprue hole and also from the mold to the riser. Use the gate cutter for this operation. Make the gates about 3/8 inch deep and 1/2 inch wide at the mold end, and have them become deeper and wider as they approach the base of the sprue and riser holes. Smooth the surface of the gates with your fingers or with a slick. Soose particles of sand may spoil the casting.

28. Examine the mold for loose bits of sand and remove any sand particles carefully with the molder's bellows.

29. Replace the cope on the drag carefully. Be sure the pins line up properly.

30. Place the mold on the floor and allow it to dry for a few minutes. It is then ready to pour.

Molding A Split Pattern:

The project to be made in this exercise is a miniature anvil which can be used as a paper weight.

This pattern will not be molded entirely in the drag as the flat back pattern was. A split pattern is molded with the upper half in the cope and the lower half in the drag.

The same tools, equipment, and materials are needed as for the flat-back pattern.

The procedure for ramming up a mold for a split pattern is shown below:[1]

1. Place the drag half of the split pattern flat on the molding board.

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[1]ibid

2. Proceed to ram up the drag as described for a flat-back pattern. Refer to steps 5-12

3. After removing the molding board, dust the parting surface of the mold with molder's bellows and place the cope half of the split pattern in place. Be sure that the aligning pins and holes are clean.

4. Dust parting compound over the pattern and the parting surface of the mold.

5. Place the cope on the drag and continue ramming the mold as described for a flat-back pattern. Refer to steps 17-22

6. Vent the mold

7. After removing the sprue and riser pins, place a molding board on the top of the cope and invert the cope, setting the cope and molding board on the molding bench.

8. Swab around the edges of the mold in the cope and the drag with the bulb swab.

9. Rap and draw each half of the pattern from its section of the mold.

10. Cut the gates in the drag with a gate cutter.

11. Assemble the mold and cut a pouring basin. The mold is now ready to be poured.

MELTING AND POURING THE METAL

When the mold is ready it is placed on the floor near the furnace and the student is ready to do the melting and pouring of the metal. The instructor should give very close supervision and many times help the student at this time. The student must be made "aware of the proper procedure to be followed and the safety precautions to be observed when lighting the melting furnace and handling the molten metal."[1]

Considerable difficulty is often encountered by beginners when learning to operate the gas fired crucible furnace. The following instructions will aid in the operation:[2]

Preheating The Furnace:

1. Turn on the exhaust fan in the hood above the furnace as the first operation as a safety precaution against asphyxiation.

2. Start the air blower and turn on the air valve of the furnace to drive out any gas accumulation which may be present in the furnace. Turn off the air valve after this operation.

3. Place a lighted paper inside the furnace near the gas-jet inlet port and turn on a small amount of gas. Use a flow of gas which will just envelop the crucible and yet burn without excessive smoke.

4. Cover the furnace with the lid and allow the furnace and crucible to preheat for 15 to 20 minutes.

Turning On The Blast:

1. At the conclusion of the preheat time, swing the cover off the furnace. Turn the gas valve about two-thirds open.

2. Be sure that the valve to the air blower is closed.

3. Slowly open the air valve until a clear roar is heard in the furnace. Practice will help you to distinguish this roar. Your eyes will serve as a check for the correct color of the flame, your ears will detect the correct and characteristic rumbling sound, and your nose will detect an excessive rich mixture of gas and air.

4. Close the furnace cover carefully and slowly adjust the flame until a short, hard, blue-green flame projects above the vent hole in the cover.

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[1]ibid

[2]ibid

5. Remain at the furnace for a few minutes after this operation, and be prepared to shut off the gas in case the flame goes out.

6. If relighting is necessary, purge the furnace again with a blast of air to clear it of unburned gas.

Shutting Off The Furnace:

1. Shut off the gas valve
2. Close the air valve
3. Shut off the power at the blower
4. Shut off the exhaust system in the hood

Pouring:

If the casting is to be poured the same day that the mold is rammed, the operator may start the furnace while he is ramming the mold, so that the metal will be at the correct temperature at the time of pouring. There are several basic considerations to be kept in mind at the time of molding and pouring:[1]

1. Be sure that the metal is at the correct pouring temperature and thoroughly melted. Cast iron melts at temperatures between 1900 F and 2200 F, but must be brought to 2460 F for best pouring results. Refer to a Melting Temperatures Table in a good foundry text for melting and pouring temperatures of other metals.

2. Make sure that all ladles are prepared and all handles are secure. The tongs and shank must be preheated.

3. All ladles and equipment used to handle the molten metal must be preheated before being used.

4. Never remove a ladle or crucible from the furnace until you have a firm grip on it.

5. The mold should be placed on a dirt or concrete floor for pouring. Never perform the pouring operation on an unprotected wooden floor.

6. Clamp or weight the flask before pouring the metal. The molten metal may cause the cope to raise or float, thus separating the mold at the parting line.

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[1]ibid

7. It is always a desirable practice to wear asbestos leggings, shoe guards, and goggles or a face shield when pouring molten metal.

Before the casting is poured, an understanding of the preceding information is essential. The following is a list of suggested steps to be followed when pouring molten metal into the mold:[1]

1. Place the mold on the floor. Care must be exercised to eliminate the posseble collapse of the mold.

2. With a firm grip on the handle and a steady movement, remove the ladle from the furnace.

3. Begin pouring the metal into the sprue hole or pouring basin at a level as near the flask as possible without touching the mold with the ladle.

4. Once the metal has started to flow into the mold, continue pouring until the metal fills the mold, the sprue, and the riser.

5. If the mold is large, it may be desirable to pour from two locations using two or more ladles.

6. Do not touch the casting until it has had ample time to solidify and cool. Fifteen to thirty minutes are usually sufficient time for aluminum or zinc alloys to cool. Metals with higher melting points require several hours to several days depending upon the size of casting.

7. Never touch the casting with the fingers until it has thoroughly cooled. If it is necessary to move the casting before it is cool, handle it with tongs or clamps.

8. Best results are obtained if the casting is allowed to cool slowly. Do not quench it in water.

9. The casting is now ready to transfer to another shop area for final finishing.

FINISHING THE CASTING

No project is complete until it has been finished and conditioned for its particular purpose. The following are

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[1]ibid

several suggestions for finishing a casting:[1]

1. Remove all loose sand from the casting with a wire brush.

2. Remove the sprues, risers, gates, fins, etc., with a hacksaw and file.

3. If the specifications do not call for a machined finish on a surface, remove surface imperfections with a file. Sometimes special grinding wheels or abrasive-belt machines are used. Never use the tool-grinding wheels or abrasive- for removing excess material from a soft-metal casting. Such practice will load the grinding wheel and spoil it for its intended use.

4. Soft-metal castings may be satisfactorily finished with a file, abrasive cloth, and steel wool.

5. Before polishing a casting, be sure that all tool marks are removed with abrasive cloth or steel wool. Such marks would mar the appearance of the finished project.

6. Sand holes are often found in a casting. These may be filled with solder, babbitt metal, metal putty, or other metal filler.

7. Machine tools are often used to finish iron, steel, brass, or bronze castings. Check this possibility with your instructor.

8. Many rough castings require little or no finishing for completion. These may be cleaned with a wire brush.

9. On some castings of special nature, greater accuracy may be attained by scraping after machining. This requires a very high degree of hand skill.

10. A texture may be added to the surface of a casting by so-called "spot-facing" or peening.

CHAPTER VI

FOUNDRY OCCUPATIONS

Foundries may be divided into two distince types. One type is a small local foundry which is called a jobbing foundry. In this foundry many different kinds of castings of all sized are made. If a machine shop needed only one casting to fill a certain order this is the type of foundry that would be consulted. Occupations in a jobbing foundry consist of two types. The first of these types is the job of the engineers and technicians. These men would do all the preliminary planning which is necessary before production work begins and be on hand to inspect the castings and make sure the plant is running smoothly. One of these men would have to be a metallurgist who could control the quality of the metal. The rest of the help would be skilled and semi-skilled laborers who would do the patternmaking, make the molds, and pour the metal into the molds. Some of this group of workers would be coremakers. Others would operate the furnaces and would be called melters. Other men would be busy cleaning the castings after they are taken from the molds and these men would be called chippers, grinders, and finishers.

The other type of foundry is called a production foundry, which is usually larger. The work is generally limited to a few patterns from which thousands of castings are made.

A good example of a production foundry woudl be a division of an automobile industry that produces engine block castings. Here one would find more of the engineers and technicians than in the jobbers shops, but their jobs would be similar to those in the jobbing foundry. Many of them who do the actual molding and pouring would be skilled and semiskilled workers. Their jobs would be very much like those in the jobbing foundry except that every phase of the work would be on a broader scale, and there would be more automated pieces of equipment to make the plant more efficient.

> Altogether, close to one-half million men work in foundries throughout the nation. Of this number about 70,000 are employed in professional, office, managerial, and sales jobs. There are more than 7,000 engineers, chemists, metallurgists, and other scientists in the foundry industry.[1]

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[1]Feirer, op. cit. 237

CHAPTER VIII

SUMMARY

There is no way of knowing when the earliest casting was made. It was before the beginning of recorded history. It is estimated that it was as early as 4000 or 5000 B. C. The first castings were probably made by pouring molten metal into shallow open molds. The first iron castings were made by the Chinese. An important current development is the powdered metal casting and the automated equipment now in use in the foundry.

The principle casting methods are sand mold casting, plaster mold casting, permanent mold casting, investment casting, centrifugal casting, and die casting.

The elementary requirements for a foundry are patterns corresponding to the desired casting; a furnace or a container in which to melt the metal; fuel to provide the heat energy required; molds into which to pour the molten metal; and facilities for removing any extraneous metal from the finished casting.

Three major operations are needed to produce a casting. The first of these is patternmaking. The patternmaker makes a pattern of wood or other suitable material which has the same shape that the finished article will have. The second operation is the making of the mold. A cavity is made in sand or some other suitable material into which the metal is poured. The third operation that is necessary is the pouring of the metal. The metal is melted in a blast furnace or electric furnace or some other heat source. The melted metal is then poured into the sprue of the mold and allowed to harden.

Foundry occupations are of various kinds; engineers, technicians, skilled workers, semiskilled workers, and laborers. Althgether, close to one-half million men work in foundries throughout the nation.

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