2

Patterns

Patterns are the foundryman's mold-forming tool. The mold cavity, and therefore ultimately the casting, is made from the pattern. Even if only one casting is desired, it is necessary to have a pattern, but a great many castings may be made from a single pattern. Obtaining suitable pattern equipment is thus the first step in making castings.

PATTERNMAKING

Patternmaking is divided between that which is done within foundries and that which is done by separate businesses called *pattern shops*. Foundries often have pattern departments. For example, 50 per cent, approximately, of the 5674 foundries in the United States have pattern departments. Some foundries have both wood- and metal-pattern facilities. However, most pattern departments in foundries are more concerned with modifying existing pattern equipment and preparing it for molding (work known as rigging) than with producing new patterns. The vast majority of patterns are made by pattern shops which are independent of the foundry and operate as separate businesses.

Patternmaking, the art of making patterns which will produce the desired casting dimensions, is not within the scope of this book. Certain principles which are applied to patterns, however, should be common knowledge to all who may be concerned with castings.

TYPES OF PATTERNS

Several types of patterns are used in foundries. Depending on the casting requirements, the pattern may conform to one of the following types:

1. Single or loose patterns
2. Gated patterns (loose)
3. Match-plate patterns

4. Cope and drag patterns
5. Special patterns and devices

Each of the pattern types has characteristic uses.

Loose Patterns

Loose patterns are single copies of the casting but incorporating the allowances and core prints necessary for producing the casting. They

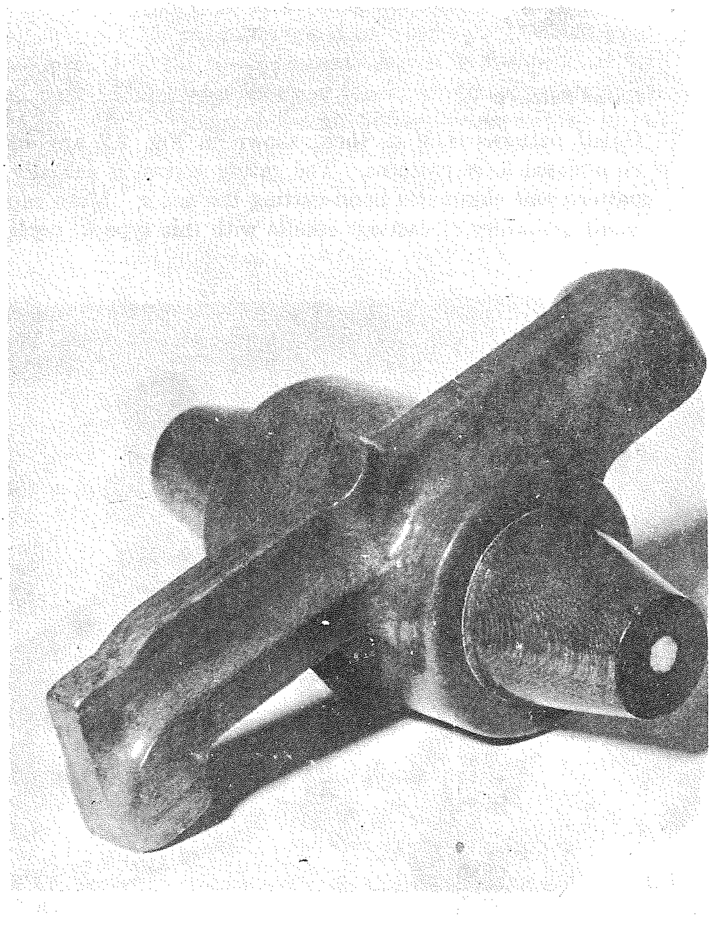


Fig. 2.1 A loose pattern of a rocker arm. (*Courtesy of the Malleable Founders' Society, Cleveland.*)

generally are of wood construction but may be made of metal, plaster, plastics, wax, or any other suitable material. Relatively few castings are made from any one loose pattern since hand molding is practiced and the process is slow and costly. The parting surface may be hand-formed. Gating systems are hand-cut in the sand. Drawing the pattern from the sand, after rapping it to loosen it from the sand, is also done by hand. Consequently, casting dimensions vary. A loose pattern is shown in Fig. 2.1. Such a pattern might be used for producing prototype castings.

Gated Patterns

Gated patterns such as those shown in Fig. 2.2 are an improvement on ungated loose patterns. The gating system is actually a part of the pattern and eliminates hand-cutting the gates. More rapid molding of small quantities of castings results with this type of pattern.

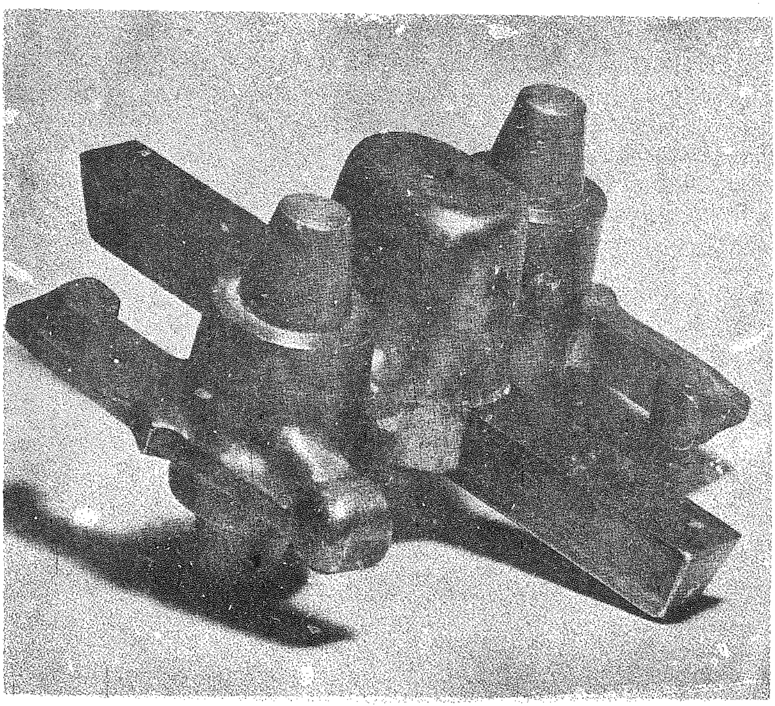


Fig. 2.2 **A gated pattern of the rocker arm shown in Fig. 2.1.** ***(Courtesy of the Malleable Founders' Society.)***

Match-plate Patterns

Large-quantity production of small castings requires match-plate patterns or more specialized types of pattern equipment. The cope and drag portions of the pattern are mounted on opposite sides of a wood or metal plate conforming to the parting line. Match plates are also integrally cast in which cast pattern and plate are cast as one piece in sand or plaster molds. Figure 2.3 shows metal match-plate patterns. Gating systems are almost always attached to the plate. Match plates are generally used with some type of molding machine, as illustrated in Chap. 3, in order to obtain maximum speed of molding. The improved production rate possible with these patterns serves to compensate for their increased cost. Plates also increase the dimensional accuracy of the casting. A limitation of the match-plate pattern arises in the weight of mold and flask which can be handled by the molder. Heavier work is ordinarily put onto larger molding equipment, employing other pattern equipment.

Cope and Drag Pattern Plates

Cope and drag pattern plates are shown in Fig. 2.4. Cope and drag plates consist of the cope and drag parts of the pattern mounted on separate plates. The cope and drag halves of the mold may thus be made separately by workers on different molding machines. The molding of medium and large castings on molding machines is greatly facilitated by this type of pattern equipment. Separate cope and drag plates are more costly, but this type of pattern equipment is usually necessary in

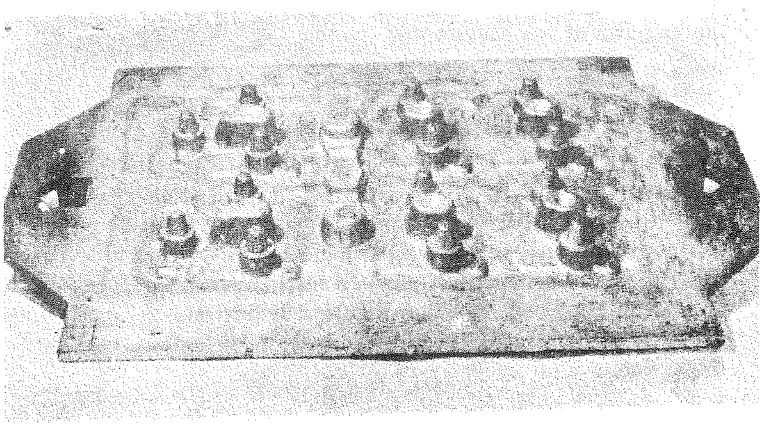


Fig. 2.3 A match-plate pattern of the rocker arm shown in Fig. 2.2. (*Courtesy of the Malleable Founders' Society.*)

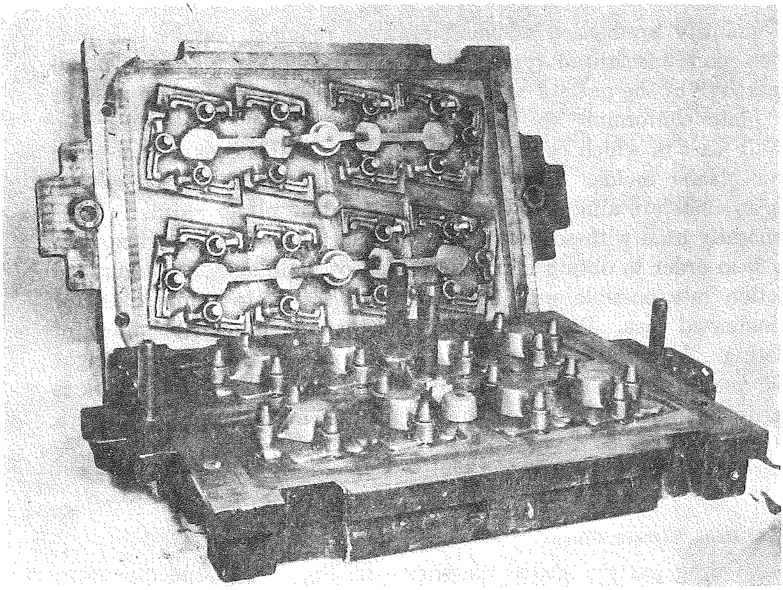


Fig. 2.4 Separate cope and drag pattern plates of the rocker arm shown in Figs. 2.1 to 2.3. (*Courtesy of the Malleable Founders' Society.*)

high-speed mechanized or automated molding. Separate pattern plates require accurate alignment of the two mold halves by means of guide and locating pins and bushings in flasks in order that the upper and lower parts of the casting may match.

Special Patterns and Devices

Specialized pattern equipment is employed when the types discussed above are not suitable. For extremely large castings, skeleton patterns of the kind shown in Fig. 2.5 may be employed. Such equipment is for quite unusual castings where the mold is largely manually constructed. Large work of symmetrical shape sometimes involves the use of sweeps for forming a mold surface. Figure 2.6 illustrates a sweep and shows the type of mold made by this method.

Follow Board

Loose patterns having an irregular parting line are difficult to mold without a follow board, or *match*. The pattern match serves to support the loose pattern during molding of the drag half of the mold and also

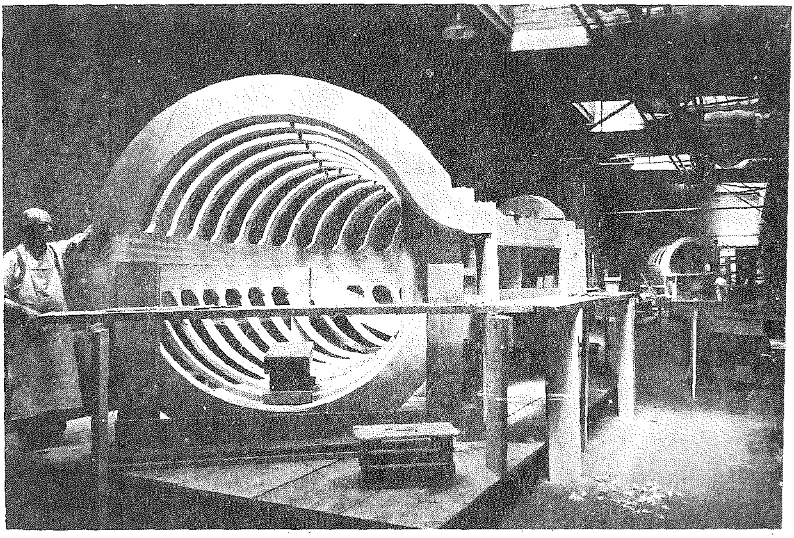


Fig. **2.5** Skeleton pattern of large casting: no. 6 section of spiral casting pattern (no. 5 section in background) for the four 115,000-hp best-efficiency 525-ft-head 150-rpm Francis runners, vertical-shaft hydraulic turbines in cast-steel spiral castings for the U.S. Bureau of Reclamation Boulder Canyon Project. (*Courtesy of Allis-Chalmers Mfg. Co.*)

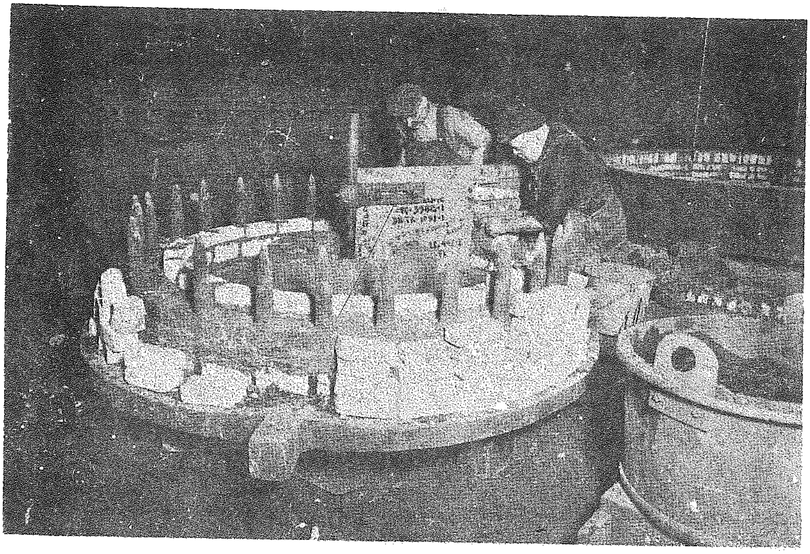
establishes the parting surface when the match is removed. Figure 2.7 illustrates a hard-sand match used for molding a ball. The term *hard-sand match* originates in the material used to construct the match. The frame and bottom are of wood, but the match is sometimes made with a mixture of 25 parts dry molding sand, 1 part litharge, and sufficient linseed oil or core oil to make the sand workable as a molding sand. Plaster is also used to make a match.

Master Pattern

A master pattern, often made of wood, as that in Fig. 2.1, is used as an original for casting metal patterns. Several patterns may be cast from the master and mounted on a pattern plate after they have been finished to the proper dimensions. The master pattern in this case may be the first step in obtaining match plates. A master pattern incorporates certain dimensional allowances, discussed in the following section.

PATTERN ALLOWANCES

Although the pattern is used to produce a casting of the desired dimensions, it is not dimensionally identical with the casting. For metallurgi-



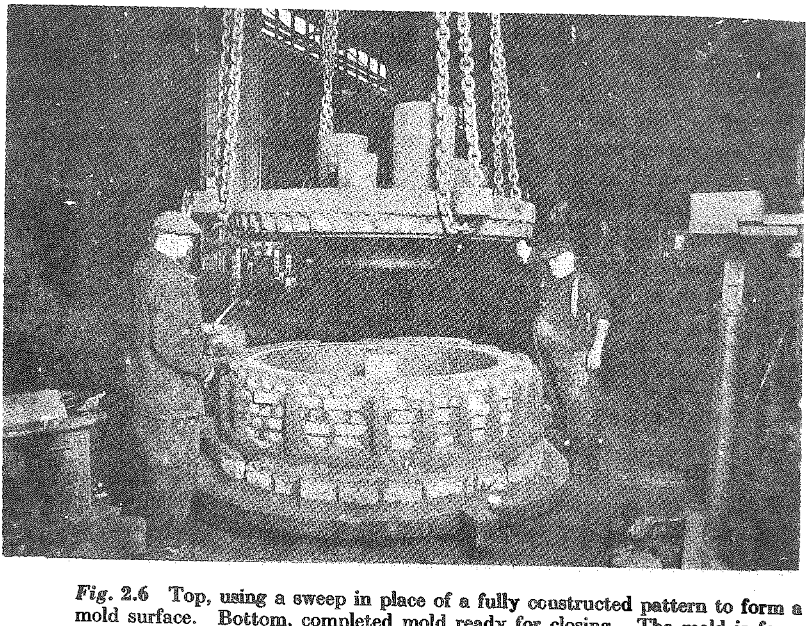


Fig. 2.6 Top, using a sweep in place of a fully constructed pattern to form a mold surface. Bottom, completed mold ready for closing. The mold is for a flywheel sheave casting weighing 8380 lb. (*Courtesy of Allis-Chalmers Mfg. Co.*)

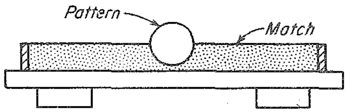


Fig. 2.7 **Hard-sand match used to establish the parting surface when molding a ball-shaped loose pattern by hand.**

cal and mechanical reasons, a number of allowances must be made on the pattern if the casting is to be dimensionally correct.

Shrinkage Allowance

Shrinkage allowance on patterns is a correction for solidification shrinkage of the metal and its contraction during cooling to room temperature. The total contraction is volumetric, but the correction for it is usually expressed linearly. Pattern shrinkage allowance is the amount the pattern must be made larger than the casting to provide for total contraction. It may vary from a negligible amount to ⅝ in. per ft, depending on the metal and the nature of the casting. Typical shrinkage allowances are given in Table 2.1. The linear allowances in Table 2.1 are representative for castings in sand molds. However, special conditions prevail with some metals. White iron, for example, shrinks about ¼ in. per ft when cast, but during annealing it grows about ⅛ in. per ft, resulting in a net shrinkage of ⅛ in. per ft. Spheroidal carbon cast iron may solidify with a contraction of ¼ to ⅛ in. per ft, depending on the degree of graphitization which it undergoes during freezing (i.e., the more graphitization, the less shrinkage).

The patternmaker's *shrink rule* is a special scale which makes unnecessary the computation of the amount of shrinkage allowance which must be provided on a given dimension. For example, on a ⅛-in. shrink rule, each foot is ⅛ in. longer and each graduation is proportionately longer than its conventional length. Shrink rules are available with the standard allowances of Table 2.1. Sometimes double allowances are made if a pattern is first made in wood and then in some other metal, as in making master patterns. For example, an aluminum pattern made from a wood master pattern may require a total allowance of ¼ in. per ft on the wood pattern if a gray-iron casting is to be made. The total allowance on the original wood pattern will then provide for shrinkage of the aluminum pattern casting and of gray-iron castings made from the aluminum pattern.

Machine Finish Allowance

Machine finish allowance is the amount the dimensions on a casting are made oversize to provide stock for machining. Typical finish allowances are presented in Table 2.2. It can be seen that these allowances are influenced by the metal, the casting design, and the method of casting

Table 2.1 Pattern-shrinkage allowances Before specifying, consult the patternmaker and foundryman*

Casting alloys	Pattern dimension	Type of construction	Section thickness, in.	Contraction, in./ft
Gray cast iron	Up to 24 in.	Open construction	......	1/8
	From 25 to 48 in.	Open construction	......	1/10
	Over 48 in.	Open construction	......	1/12
	Up to 24 in.	Cored construction	......	1/8
	From 25 to 36 in.	Cored construction	......	1/10
	Over 36 in.	Cored construction	......	1/12
Cast steel	Up to 24 in.	Open construction	......	1/4
	From 25 to 72 in.	Open construction	......	3/16
	Over 72 in.	Open construction	......	5/32
	Up to 18 in.	Cored construction	......	1/4
	From 19 to 48 in.	Cored construction	......	3/16
	From 49 to 66 in.	Cored construction	......	5/32
	Over 66 in.	Cored construction	......	1/8
Malleable cast iron	....	....	1/16	11/64
			1/8	5/32
			3/16	19/128
			1/4	9/64
			3/8	1/8
			1/2	7/64
			5/8	3/32
			3/4	5/64
			7/8	3/64
			1	1/32
Aluminum	Up to 48 in.	Open construction	......	5/32
	49 to 72 in.	Open construction	......	9/64
	Over 72 in.	Open construction	......	1/8
	Up to 24 in.	Cored construction	......	5/32
	Over 48 in.	Cored construction	......	9/64–1/8
	From 25 to 48 in.	Cored construction	......	1/8 –1/16
Magnesium	Up to 48 in.	Open construction	......	11/16
	Over 48 in.	Open construction	......	5/32
	Up to 24 in.	Cored construction	......	5/32
	Over 24 in.	Cored construction	......	5/32–1/8
Brass	....	....	......	3/16
Bronze	....	....	......	1/8–1/4

*From American Foundrymen's Society.[1]

and cleaning. The values in Table 2.2 are for castings made in conventional molding sand. Other casting processes permit different finish allowances to be used, as is pointed out in a subsequent chapter. In general, machine finish allowance may be a minimum if the surfaces to be machined are entirely in the drag half of the mold since dimensional variation and other defects are usually least prevalent there.

Table 2.2 Guide to pattern machine-finish allowances* *Unless otherwise specified*

Casting alloys	Pattern size	Bore, in.	Finish
Cast iron	Up to 12 in.	1/8	3/32
	13 to 24 in.	3/16	1/8
	25 to 42 in.	1/4	3/16
	43 to 60 in.	5/16	1/4
	61 to 80 in.	3/8	5/16
	81 to 120 in.	7/16	3/8
	Over 120 in.	Special instructions	Special instructions
Cast steel	Up to 12 in.	3/16	1/8
	13 to 24 in.	1/4	3/16
	25 to 42 in.	5/16	5/16
	43 to 60 in.	3/8	3/8
	61 to 80 in.	1/2	7/16
	81 to 120 in.	5/8	1/2
	Over 120 in.	Special instructions	Special instructions
Malleable iron	Up to 6 in.	1/16	1/16
	6 to 9 in.	3/32	1/16
	9 to 12 in.	3/32	3/32
	12 to 24 in.	5/32	1/8
	24 to 35 in.	3/16	3/16
	Over 36 in.	Special instructions	Special instructions
Brass, bronze, and aluminum-alloy castings	Up to 12 in.	3/32	1/16
	13 to 24 in.	3/16	1/8
	25 to 36 in.	3/16	5/32
	Over 36 in.	Special instructions	Special instructions

*From American Foundrymen's Society.[1]

Pattern Draft

Draft is the taper allowed on vertical faces of a pattern to permit its removal from the sand or other molding medium without tearing the mold-cavity surfaces. A taper of 1/16 in. per ft is common for vertical walls on patterns drawn by hand. Machine-drawn patterns require about one degree taper. In some cases, even vertical walls 6 to 9 in. deep may be drawn by machine if the pattern is very smooth and clean and the drawing equipment is properly aligned. In the case of pockets or deep cavities in the pattern, considerably more draft is necessary to avoid tearing the mold during withdrawal of the pattern.

Size Tolerance

The variation which may be permitted on a given casting dimension is called its tolerance, and is equal to the difference between the minimum and the maximum limits for any specified dimension. Typical values for heavy castings which require maximum tolerance are given in Table 2.3.

Table 2.3 Typical tolerance for casting weighing 1000 lb or more*

Metal	Tolerance, in.
Gray cast iron	1/16
Malleable iron	3/32
Cast steel	5/32
Aluminum alloys	5/64
Magnesium alloys	11/64
Brass	3/32
Bronze	1/8

*Courtesy of American Foundrymen's Society.

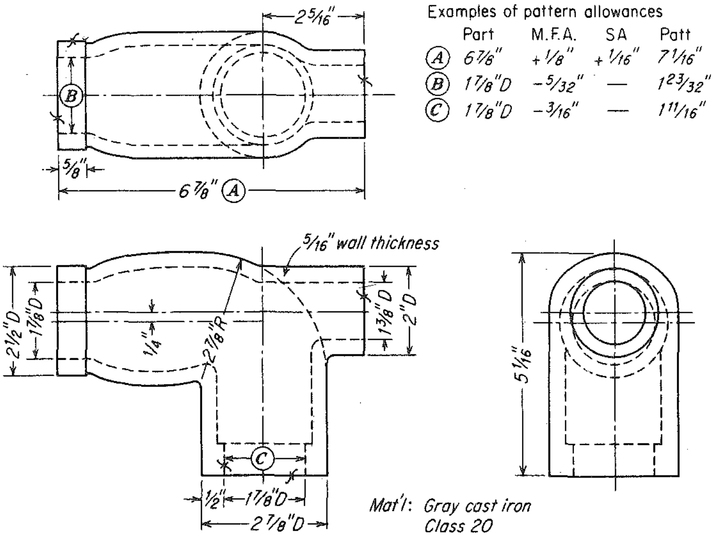
The values in Table 2.3 are approximately maximum values. A common rule states that size tolerance should be at least half the shrinkage allowance. However, where there is considerable experience with a casting, and cooperation between the foundry and the casting purchaser exists, much closer tolerance may be established. Where such conditions prevail, tolerance of only a few thousandths of an inch may be maintained with some casting processes.

Distortion Allowance

Certain objects, such as large flat plates and dome- or U-shaped castings, sometimes distort when reproduced from a straight or perfect pattern. In such cases, the pattern may be intentionally distorted, or "faked." The distorted pattern then produces a casting of the proper shape and size.

Example of Allowances

An example of the application of various pattern allowances to a casting is illustrated in Fig. 2.8. The casting design without allowances is also shown in Fig. 2.8. Core prints must be added to the pattern, and some typical allowances for shrinkage and finishing are indicated in the draw-



Examples of pattern allowances

Part	M.F.A.	SA	Patt
(A) 6 7/8"	+ 1/8"	+ 1/16"	7 1/16"
(B) 1 7/8"D	− 5/32"	—	1 23/32"
(C) 1 7/8"D	− 3/16"	—	1 11/16"

***Fig.* 2.8 Drawing of mixing-value casting shown in Fig. 1.1. Some typical pattern allowances are listed.**

ing. The actual pattern is shown in Fig. 1.1. The core is located by the walls on the ends of the core print. The actual pattern dimensions are not shown in the drawing, but rather a shrink rule is employed by the patternmaker. However, the machine finish allowance is added to the finished dimension, and so should appear in the drawing. The cored ends must be smaller than the finished diameter. The pattern, made as a loose, split pattern, and the core boxes, core, mold, and casting are shown in Fig. 1.1.

FUNCTIONS OF PATTERNS

The main purpose of a pattern is its use in molding. However, to produce a casting successfully and render it suitable for further processing, the pattern may be required to perform other functions besides producing a mold cavity. These are briefly considered as follows:

Molding the Gating System

Good gating practice for castings generally requires that the system of channels and feeding reservoirs (gates and risers) for introducing metal into the mold cavity be attached to the pattern. The gating system may then obtain the benefits of machine molding.

Establishing the Parting Line

On a flat pattern plate, the parting surface is a simple plane. Many castings, however, require curved parting surfaces (Fig. 2.2) because of their shape, and these are established by the pattern where match plates or cope and drag plates are used (Figs. 2.2 and 2.3). Loose patterns require that the parting surface be cut by hand or that a follow board or match be constructed for establishing the parting surface in successive molds.

Making Core Prints

When a casting requires cores, provision is made on the pattern for core prints. Core prints are portions of the pattern and mold cavity which serve to anchor the core in proper position in the mold. The core print is added to the pattern, but does not appear on the casting because it is blocked off by the core. Core prints are illustrated in Fig. 1.1 and on the pattern in Fig. 2.3.

Establishing Locating Points

The foundry, pattern shop, or machine shop employs locating points or surfaces on the casting to check the casting dimensions. Machining operations may also use the locating points in establishing the position of machined surfaces relative to the balance of the casting.

Minimizing Casting Defects Attributable to the Pattern

Properly constructed, clean, and smooth surfaced patterns are a necessity in making good castings. Patterns with rough, nicked surfaces and undercuts, loosely mounted, and in a generally poor condition contribute substantially to defective castings containing sand inclusions and other imperfections.

Providing for Ram-up Cores

Sometimes a part of a mold cavity is made with cores which are positioned by the pattern before the molding sand is rammed. The ram-up core then is held by the sand which has been packed around it.

Providing Economy in Molding

The pattern should be constructed to achieve all possible savings in cost of the casting. Here such items may be considered as the number of castings in the mold, the proper size of the pattern plate to fit available molding equipment, method of molding, and other factors.

CORE BOXES

Core boxes, although not referred to as patterns, are an essential part of the pattern equipment for a casting requiring cores. Core boxes are constructed of wood or metal. The simplest type of box is the dump box illustrated in Fig. 1.1. The top of the box is flat, and the core is removed by placing a plate over the box and inverting it. A split box is a two-piece box usually having a flat parting surface. A simple gang core box and accompanying pattern are shown in Fig. 2.9. A gang box permits making several cores in the same box simultaneously. More complex multiple-piece core boxes are considered in Chap. 6, which deals with the subject of coremaking. Cores which do not have any flat surfaces impose an additional requirement for the pattern equipment. Support

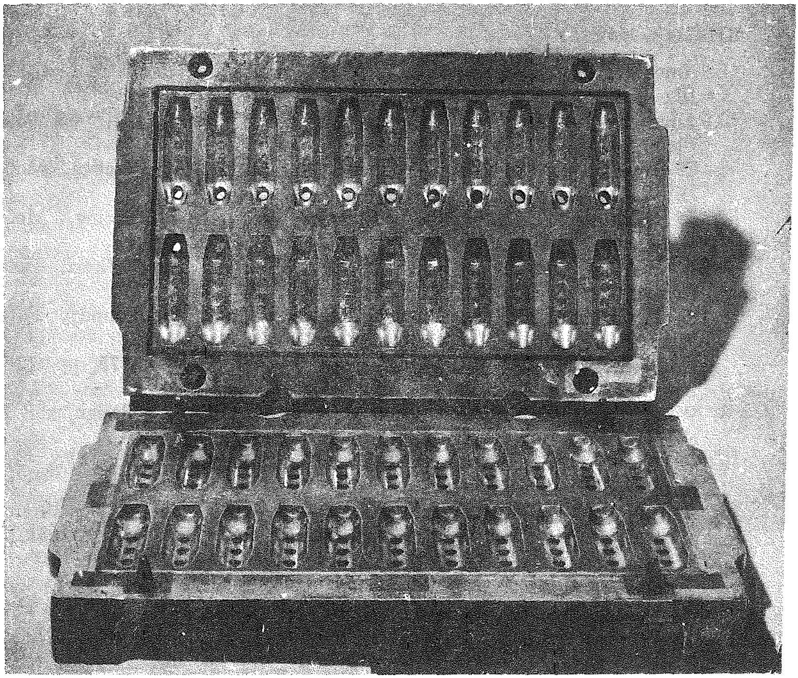


Fig. 2.9 Simple gang core box for making rocker arm cores by core blowing. (*Courtesy of the Malleable Founders' Society.*)

must be provided during the baking of cores since the sand is weak until after the baking process. A flat core surface and flat plate (core plate) can provide such support. When the core has only curved surfaces, however, a support conforming to part of the surface must be provided. The supporting device in which the core rests while it is baking is called a *core drier.* Since the drier is used every time a core is baked, the number of driers needed equals the number of cores baked as a batch. Some core boxes require provisions for electrical or gas heating if they are to be used for shell coremaking or hot-box coremaking (Chap. 6).

The importance of good pattern equipment cannot be overemphasized. Patterns which take into account the problems of molding and coremaking, proper gating and risering, ease of cleaning, and further processing promote quality in castings. As was pointed out earlier, the subject is one for detailed treatment, beyond the scope of this text. Further information on construction and principles of patterns may be obtained from some of the references listed in the Bibliography.

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Pattern Types

Single free patterns

Free Pattern with runner (loose pattern)

Match plate patterns (The most preferred in foundries)

Special patterns

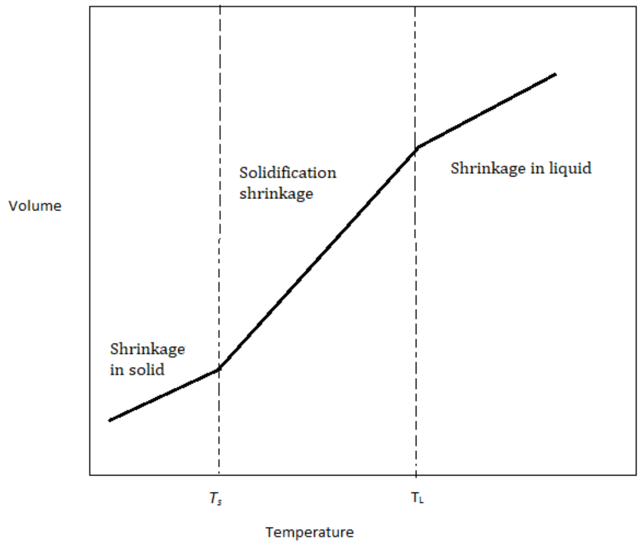
Pattern Materials

Wooden (pine hombeam must be dry and hard with low porosity), metal (Al, Pb-Sn Al-Si-Cu, cast iron) , plaster plastic (phenol epoxy resins) → permanent patterns

Polymeric foam (EPS, EPMMA foam) , Wax (beawax, pure fine, *** , ***)

Metal patterns can be produced by machining or casting. A special plaster material is used for match plate pattern casting.

Stages of Shrinkage Formation

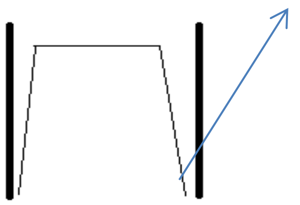


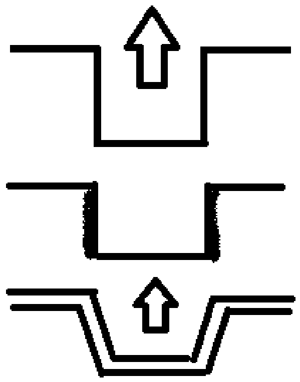
Pattern Allowances (Tolerences)

1) Shrinkage allowance

2) Machining allowance
3) Distortion allowance (special shapes) → Plat, dome, or U shapes can be distert with regular shapes patterns so they can cast with purposely disterted patterns
4)

Taper or Draft 1^{o}-2^{o}inclination for flawless pattern romoval





Volumetric Shrinkage of Some Metal and Alloys

Plain Carbon Steel	2.5-3 %
Steel with 1 % C	4 %
White cast iron	4-5.5 %
Grey cast iron	up to 2.5 % expansion (- 1.8 ⟷ + 2.5)
Cu	4.9 %
70 % Cu 30 % Zn	4.5 %
Al	6.6 %
Al – 4.5 % Cu	6.3 %
Al – 12 % Si	3.8 %
Mg	4.2 %

Zn 6.5 %

In Castings;

Solidification must be directed to feeders, this is called directional solidification.

1) Prepare optimum runner and feeder system for appro thermal gradient
2) Use effective shape feeders
3) If required use chillers
4) Use different type of sands in different place of molds. (These sands must have different thermal properties)

$m = V \div A$ t_s α $(V \div A)^2$ F: feeder C: cast part

$(V_F \div A_f)^2 > (V_C \div A_C)^2$

(N – 15 %)

The following parameters affect the fluidity of alloys

- Casting temperature
- Thermal properties of materials
- Thermal properties of mould and mould material
- Design of runner system
- Mould wetting* ability of cast material
- Section thickness of cast part
- Solidification range

Solidification Shrinkage of Some Alloys

Grey cast iron	3.0 %
Plain carbon steel	7.2 %
Al alloys	5.0 %
Cu alloys	6.0 %