HOW IT WORKS

Investment casting is an industrial process which employs in-process control at every point. Highly refined on-line process control methods are backed up with laboratory skill. Every casting shipped--and this applies equally to orders for a dozen castings or half a million--can be relied on to meet the designer's performance specification.

The principles of investment casting are the same for both the solid mold and shell processes. It is only in the method of forming the ceramic mold that they differ. Both require a pattern, gating to a central sprue, a ceramic mold (either solid or shell), removal of pattern by melting, pouring metal into the cavity left by the melted pattern, removal of mold material from the cast cluster and cutting of castings from the sprue.

Pattern Production

The process begins with the production of a one-piece heat-disposable pattern. This pattern is usually made by injecting wax or plastic into a metal die. These dies may range from a simple, hand-operated single cavity tool to a fully automated multi-cavity tool, depending on production quantities and complexity of the part.

A heat-disposable pattern is required for each casting. These disposable patterns have the exact geometry of the required finished part, but they are made slightly larger, to compensate for volumetric shrinkage (a) in the pattern production stage and (b) during solidification of metal in the ceramic mold.

The pattern carries one or more gates which are usually located at the heaviest casting section. The gate has three functions:

- to attach patterns to the sprue or runner, forming a cluster;
- to provide a passage for draining out pattern material as it melts upon heating;
- to guide molten metal entering the mold cavity in the casting operations; and to ensure a sound part by feeding the casting during solidification.

Pattern Assembly

Patterns are fastened by the gate to one or more runners and the runners are attached to a pouring cup. Patterns, runners and pouring cup comprise the cluster or tree, which is needed to produce the ceramic mold. The number of runners per section and their arrangement on the pouring cup can vary considerably, depending on alloy type, size and configuration of the casting.

Figures 1, 2 and 3 show the sequence of pattern production and assembly. Figure 1 represents the injection of wax or plastic into the pattern die. Figure 2 represents the removal of the solidified pattern from die; it is now ready to be assembled on a cluster or tree Fig. 3.

The Ceramic Shell Mold Process

This process has largely replaced the original block or solid mold process except for some smaller high volume parts and for some aluminum casting where the mold is plaster bonded.

The ceramic shell mold technique involves dipping the entire cluster into a ceramic slurry, draining it, then coating it with fine ceramic sand. After drying, this process is repeated again and again, using progressively coarser grades of ceramic material until a self-supporting shell has been formed. The shell may run from 3/16 to 5/8 in. thick.

The coated cluster is then placed in a high temperature furnace or steam autoclave where the pattern melts and runs out through the gates, runners and pouring cup. This leaves a ceramic shell containing cavities of the casting shape desired with passages leading to them. Figures 4, 5 and 6 show the sequence of ceramic shell build up. In Fig. 4 the cluster is dipped into a ceramic slurry and then, after draining and whilst the slurry coating is still wet, the cluster is coated with dry sand i.e., the stuccoing operation Fig. 5.

This is repeated until the shell reaches the correct thickness Fig. 6.

Casting

The ceramic shell molds must be fired to burn out the last traces of pattern material and to preheat the mold in preparation for casting usually in the range 1600° -2000° F. Because shell molds have relatively thin walls they can be fired and ready to pour after a few hours in the furnace. Figures 7 and 8.

The hot molds may be poured utilizing static pressure of the molten metal head, as is common in sand casting, or with assistance of vacuum, pressure and/or centrifugal force. This enables the investment casting foundry to reproduce the most intricate details and extremely thin walls of an original wax or plastic pattern. Figure 9.

Melting equipment employed depends on the alloy. For non-ferrous alloys, gas fired or electric crucible furnaces are usually used. For melting of ferrous alloys, high frequency induction furnaces are most commonly used.

Cleaning

After the poured molds have cooled, the mold material is removed from the casting cluster. This is done by mechanical vibration and chemical cleaning. Individual castings are then removed from the cluster by means of cut-off wheels and any remaining protrusions left by gates or runners are removed by belt grinding. The casting is then ready for secondary operations: heat treating, straightening, machining and whatever inspection is specified. Then, following any secondary operations, the castings are ready to ship Figures 10 & 11.

Commercial Investment Castings

I. SCOPE

This voluntary standard describes the metal quality of commercial grade castings of the more common alloys to be provided by participating INSTITUTE members in situations where purchasers of such castings do not provide detailed specifications covering all aspects of metal quality.

II. PURPOSE

To define a normal level of metal quality to be furnished by participating Investment Casting Institute member companies as a service to purchasers of investment castings who do not cite detailed specifications. Thus, a casting purchased from one participating Investment Casting Institute member should be of the same basic quality level when purchased from any other member.

III. GENERAL

A. There are nine independent major materials specifications writing groups in the U.S. The trend is for those groups to conform to the American Society of Testing Materials specifications in the hope of reducing the number of specifications thus simplifying the jobs of users and producers of investment castings. The Institute endorses this for non-aerospace castings.

B. For each alloy this standard, wherever possible, uses the chemical range of an existing selected specification in order to avoid a variety of chemical ranges for the same alloy.

C. This publication does not relate to dimensional tolerances of investment castings, covered in the Investment Casting Handbook published by the Institute in 1980. Standard dimensional tolerances given there are met by Institute members.

IV. METALLURGICAL STANDARDS

A. General

1. This section shows the chemical ranges considered standard by the Institute.

2. When chemical analysis is done, it will be done by spectrometric, x-ray fluorescence, or other approved methods using comparative standards traceable to the National Bureau of Standards.

B. Aluminum Alloys

1. Table I shows the trade names for the aluminum base alloys normally cast and the standard chemical analysis ranges. Table II shows some mechanical property ranges these alloys can provide.

2. When heat treatment is required it will be performed in accordance with good commercial practice.

3. Unacceptable flaws may be removed and the metal replaced by a weld deposit using filler of the same alloy prior to final heat treatment The welded area shall meet the quality standards of the base metal.

C. Copper Alloys

1. Table III shows the trade names for the copper base alloys normally cast and the standard chemical analysis ranges. Table IV shows some mechanical property ranges these alloys can provide.

2. If required, heat treatment will be done in accordance with good commercial practice using times and temperatures appropriate for the alloy.

3. Unacceptable flaws may be removed and the metal replaced by a weld deposit using the same alloy as filler prior to final heat treatment (if required). The quality of the welded area shall meet the quality standards of the base metal

D. Iron Base Alloys

1. Heat Treatment and Decarburization

   a. Heat treatment will be done in accordance with good commercial practice. Some, as cast alloys in this group, normally have a degree of decarburization. When surface hardness is required by the application carbon restoration on those alloys should be specified and confirmed by hardness test.

   b. For stainless steels solution annealing is recommended for maximum corrosion resistance

2. Iron, Carbon and Low Alloy Steels

   a. Table V shows the alloy designation and chemical analysis ranges for this group of alloys. Table VI shows some of the mechanical properties achievable from these alloys.

   b. Unacceptable flaws may be removed and the metal replaced by a weld deposit using the same alloy as filler for alloys up to 0.4% carbon nominal and the welded areas will meet the quality standards of the base metal. Above 0.4% carbon nominal, filler of the same alloy is not normally suitable and when it is used the purchaser and foundry should agree on the type, extent and location of welding to assure it is consistent with the intended use. All welding will be done prior to final heat treatment

3. Hardenable Martinsitic Stainless Steels

   a. **Table VII** shows the trade names and chemical ranges considered standard for this group of alloys. For convenience, three age hardenable alloys are included in the table. Table **VIII** shows some of the mechanical properties that those alloys can achieve.