McCann Sales, Inc.

CASTING PROCESS INFORMATION GUIDE

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TABLE OF CONTENTS

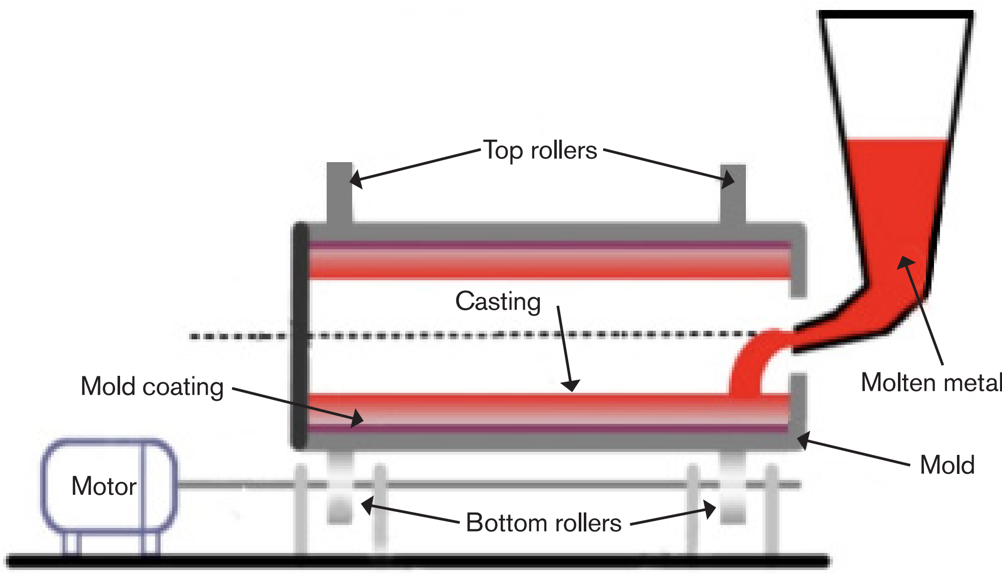
The following casting guide was designed to provide a brief overview of the following 8 casting processes:

Please use this information only as a guide when designing your next casting and contact McCann Sales for a competitive quote.

CENTRIFUGAL CASTING

CENTRIFUGAL CASTINGS

Centrifugal Castings are produced by pouring molten metal into a permanent mold that is rotated about its axis at high speeds (300 to 3000 rpm). The molten metal is centrifugally thrown towards the inside mold wall, where it solidifies after cooling. The axis of rotation may be horizontal or inclined at any angle up to the vertical position. The speed of rotation and metal pouring rate vary with the alloy and size and shape being cast. The casting is usually a fine grain casting with a very fine-grained outer diameter, which is resistant to atmospheric corrosion, a typical situation with pipes. The inside diameter has more impurities and inclusions, which can be machined away.



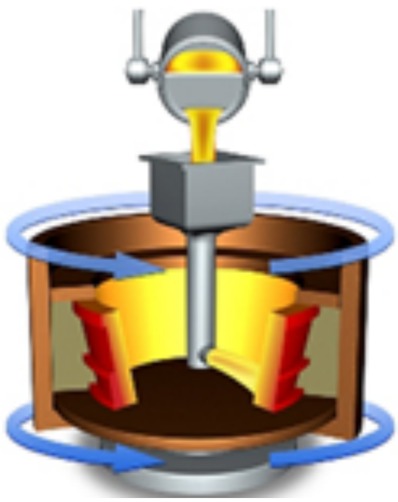
The uniformity and density of centrifugal castings approaches that of wrought material, with the added advantages that the mechanical properties are nearly equal in all directions. Since no gates and risers are used, the yield or ratio of casting weight-to weight of metal poured is high.

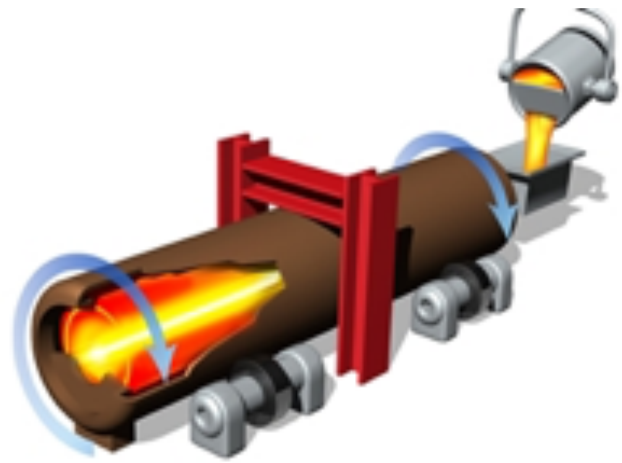
The mold may be made of cast iron or steel, copper, graphite, ceramic, or dry sand. Only cylindrical shapes can be produced with this process. Size limits are up to 10 feet diameter and 50 feet length ranging from ounces to 50,000 pounds.

CENTRIFUGAL CASTINGS

When to use it

- Symmetrical parts that can rotate on an axis
- Static casting material properties are inadequate
- Centerline shrink is an issue using other casting processes
- Limited I.D. features
- Large parts, up to 135,000 lbs./61,235 kg or more
- Net-shaping: Some tooling cost is often justifiable when significant finishing is required





CENTRIFUGAL CASTINGS

Wall thickness can be 0.1 - 5.0 in. The tolerances that can be held on the OD can be as good as 0.1 in and on the ID can be 0.15 in.

Typical Materials

- Iron
- Steel
- Stainless Steels
- Aluminum
- Copper
- Nickel

Typical Parts

- Pipes
- Boilers
- Pressure Vessels
- Flywheels
- Cylinder Liners
- Parts that are Axis-Symmetric

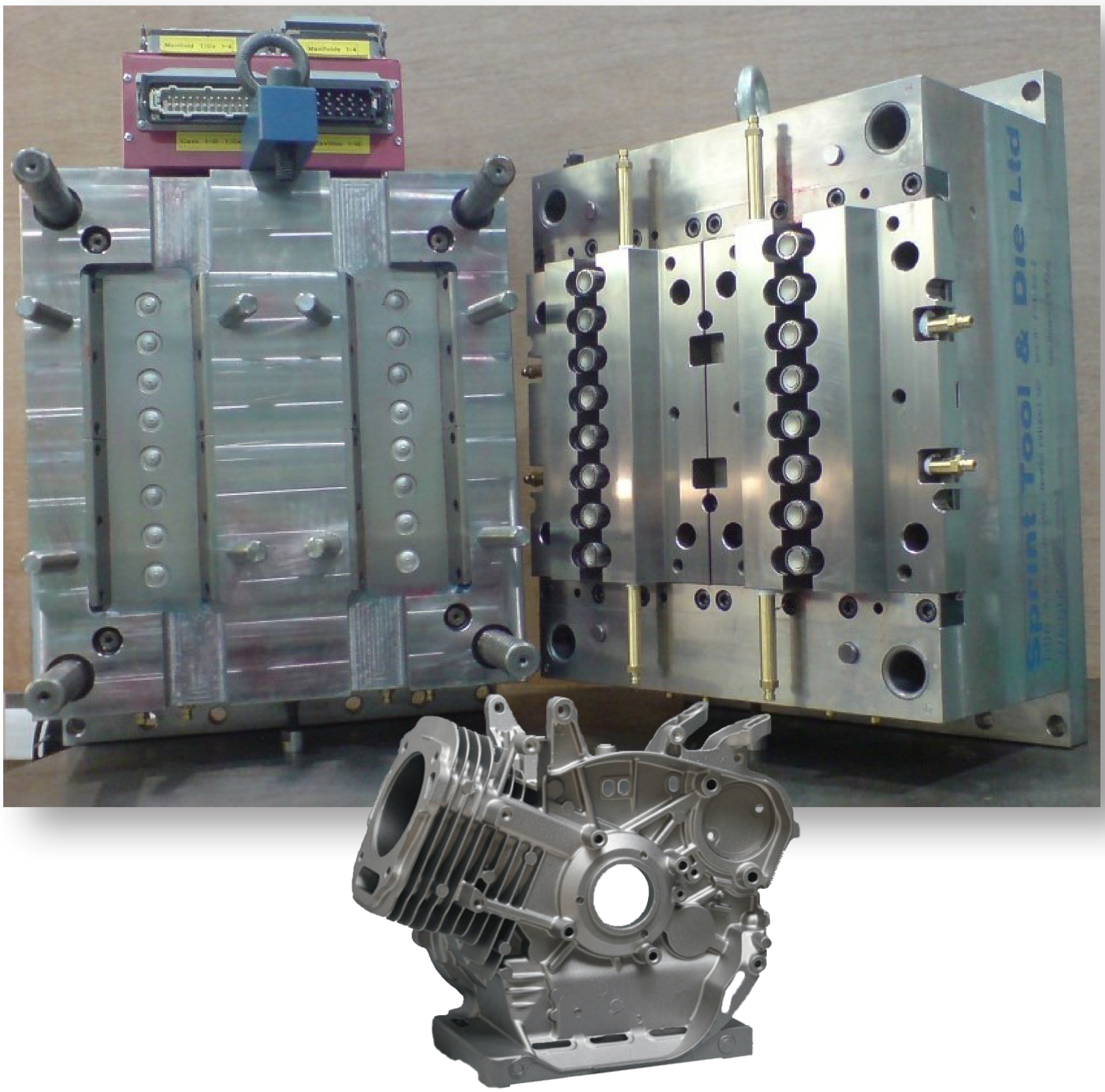
Advantages

- Very high material soundness
- Material properties are equal in all directions
- Part to part repeatability

Disadvantages

- Only able to produce cylindrical shapes

DIE CASTING



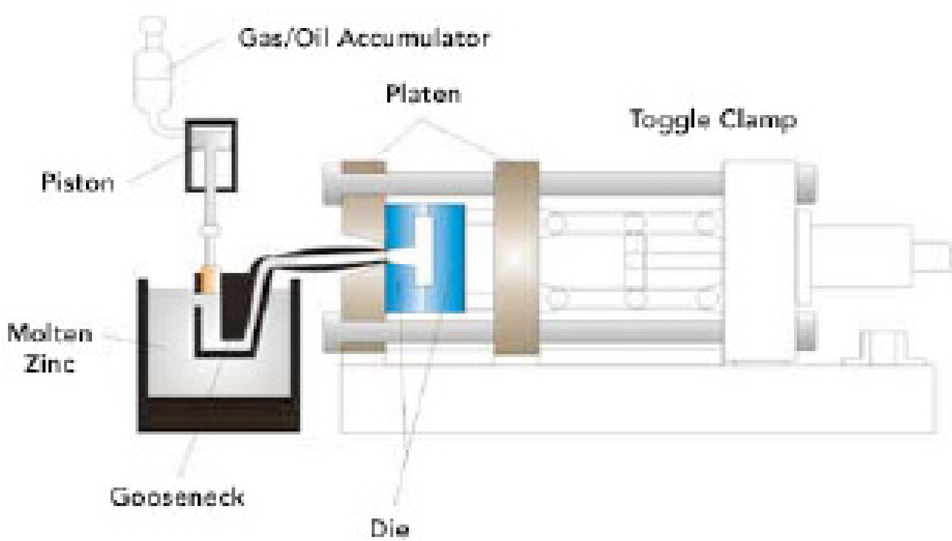
DIE CASTING

Hot Chamber Process

The metal for casting is maintained at an appropriate temperature in a holding furnace adjacent to, if not part of, the machine. The injection mechanism is located within the holding furnace and a substantial part of it is therefore in constant contact with the molten metal. Pressure is transmitted to the metal by the injection piston, which forces it through the gooseneck and into the die. On the return stroke metal is drawn into the gooseneck for the next shot. In this process there is minimum contact between air and the metal to be injected, thus minimizing the tendency for turbulent entrainment of air in the metal during injection. Due to the prolonged contact between the metal and parts of the injection system hot chamber is restricted to zinc-base alloys. The Zinc alloys are the most widely used in the die casting process. They have very desirable physical, mechanical and casting properties. They also have the ability to be readily finished with commercial electroplated or organic coatings.

The mold has sections, which include the “cover" or hot side and the “movable" or ejector side. The die may also have additional movable segments called slides or pulls, which are used to create features such as undercuts or holes which are parallel to the parting line. The machines run at required temperatures and pressures to produce a quality part to near net-shape.

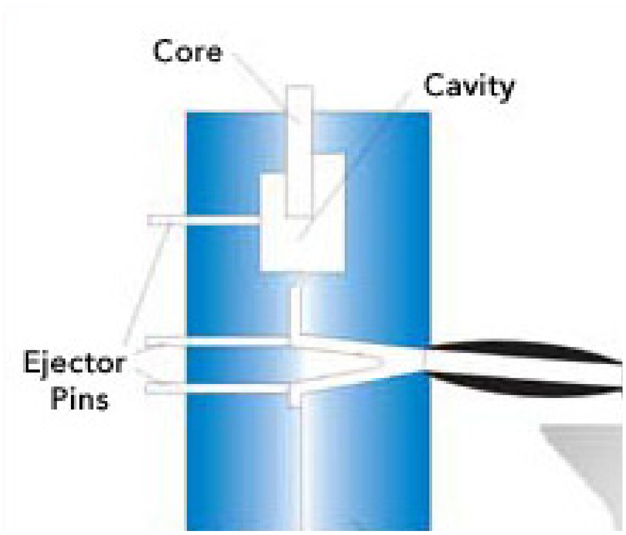
Diagram of Hot Chamber Die Casting Machine



DIE CASTING

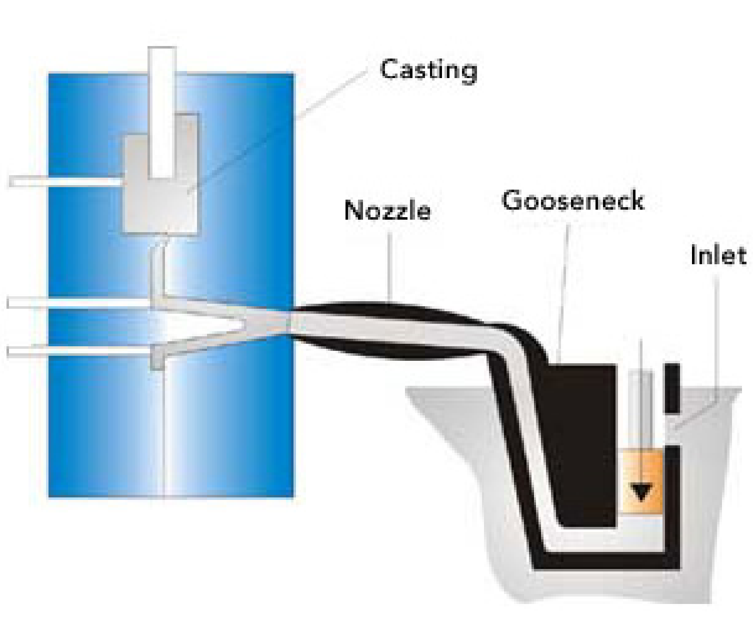
Hot Chamber Die Casting Sequence

STAGE 1



The dies close, the piston rises and the port opens allowing molten metal to fill the cavity.

STAGE 2

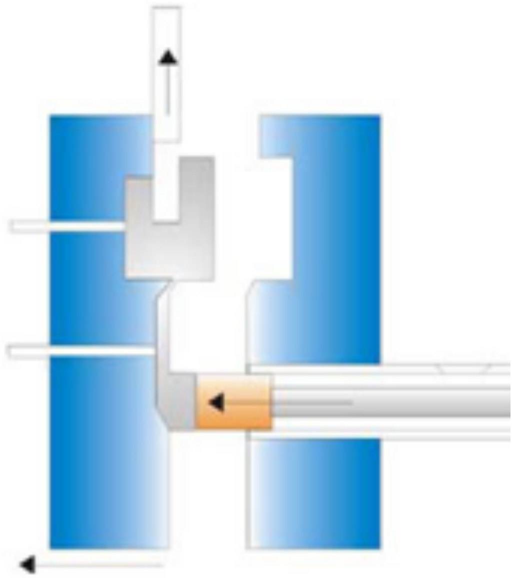


Pressure is transmitted to the metal by the injection piston, which forces it through.

DIE CASTING

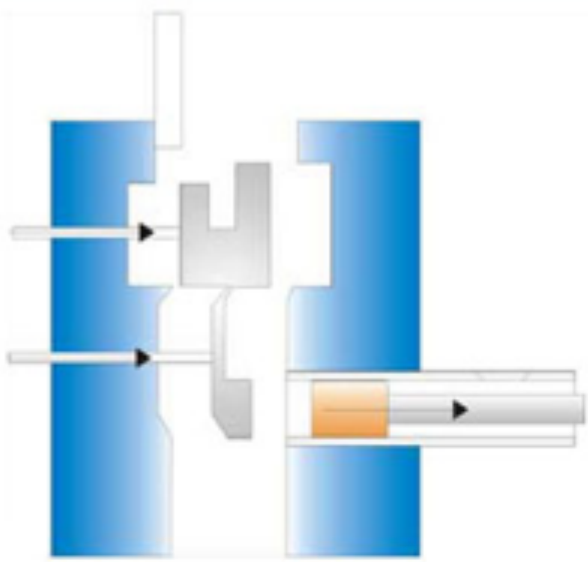
Hot Chamber Die Casting Sequence

STAGE 3



On the return stroke metal is drawn into the gooseneck for the next shot. The cover die opens as well as any core slides or pulls present in the mold.

STAGE 4



The ejector pin side of the mold is retracted and the ejector pins push the casting out of the mold. The plunger is retracted and the process starts all over again.

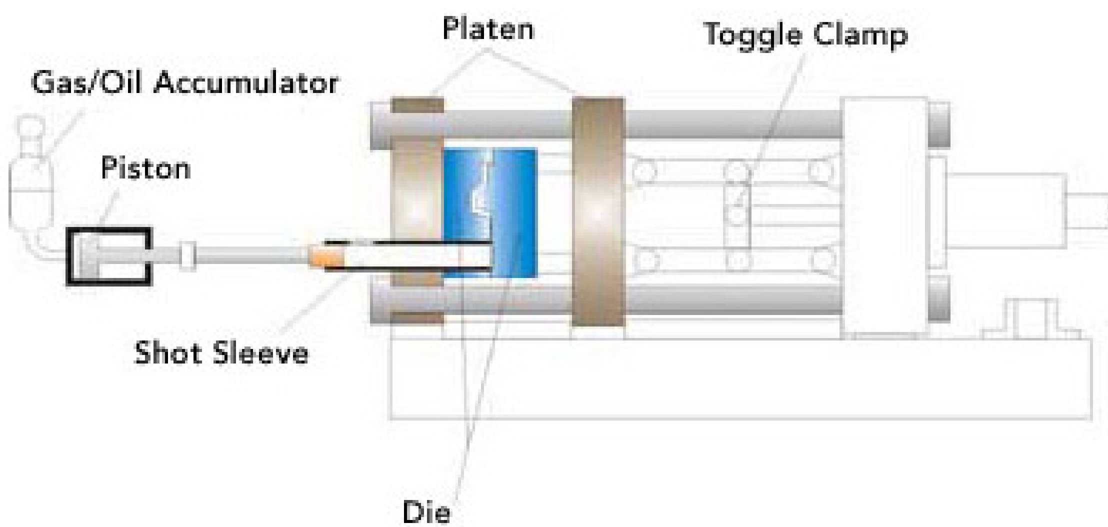
DIE CASTING

Cold chamber process

The essential feature of this process is the independent holding and injection units. In the cold chamber process metal is transferred by ladle, manually or automatically, to the shot sleeve. Actuation of the injection piston forces the metal into the die. This is a single-shot operation. This procedure minimizes the contact time between the hot metal and the injector components, thus extending their operating life. The cold chamber process is used for the production of aluminum and copper base alloys. Next to zinc, aluminum is the most widely used die-casting alloy. The primary advantage is its light weight and its high resistance to corrosion. Magnesium alloy die-castings are also produced and are used where a high strength–to–weight ratio is desirable.

The mold has sections, which include the “cover" or hot side and the “movable" or ejector side. The die may also have additional movable segments called slides or pulls, which are used to create features such as undercuts or holes which are parallel to the parting line. The machines run at required temperatures and pressures to produce a quality part to near net-shape.

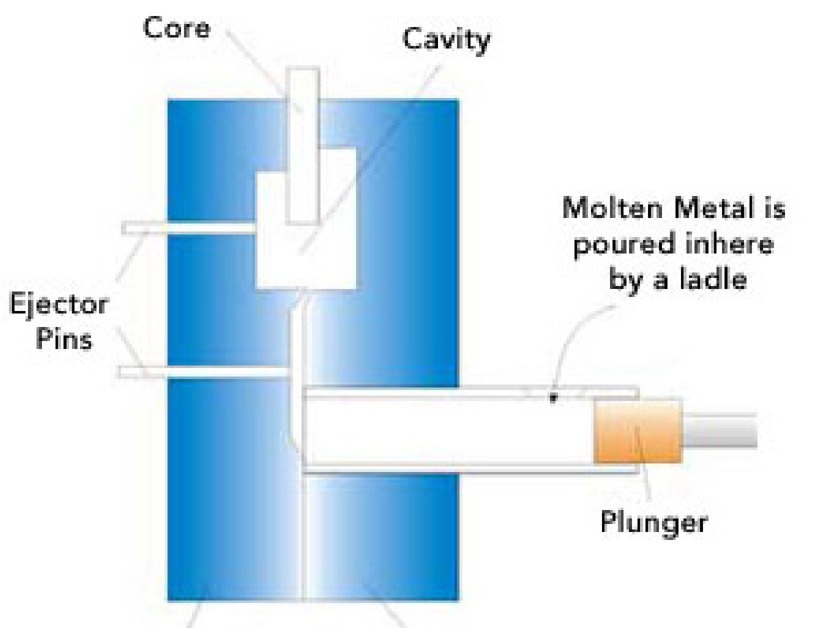
Diagram of cold chamber die casting machine



DIE CASTING

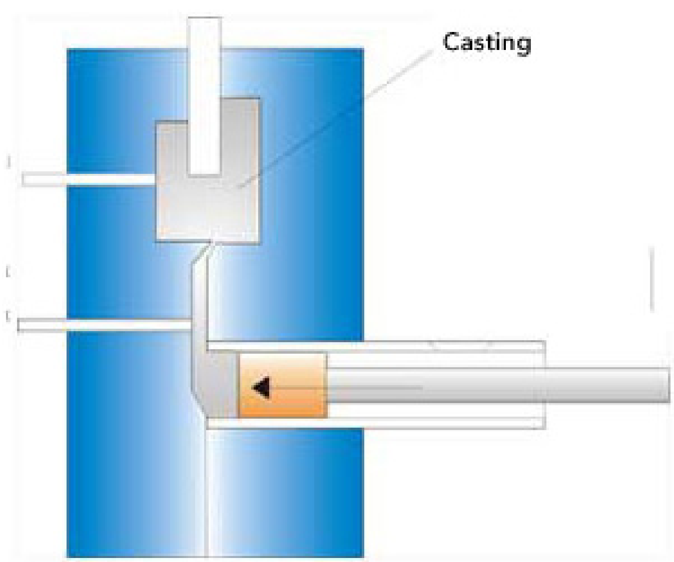
Cold Chamber Die Casting Sequence

STAGE 1



Molten metal is transferred by ladle, manually or automatically, to the shot sleeve.

STAGE 2

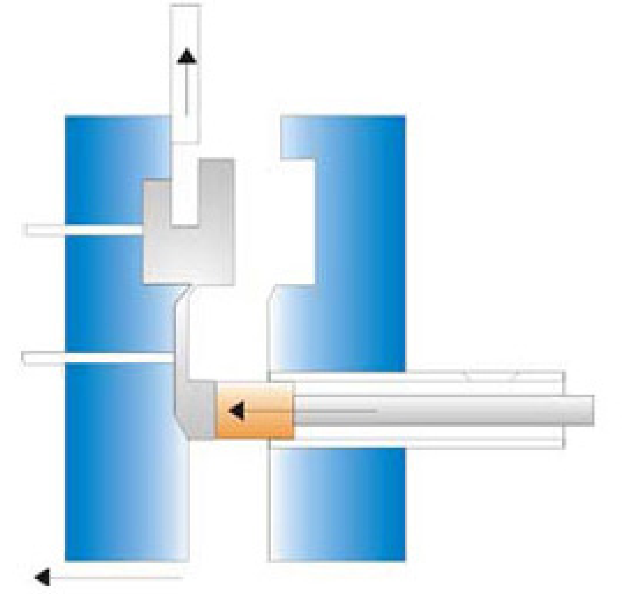


Actuation of the injection piston forces the metal into the die. Unlike the Hot Chamber Process this is a single-shot operation.

DIE CASTING

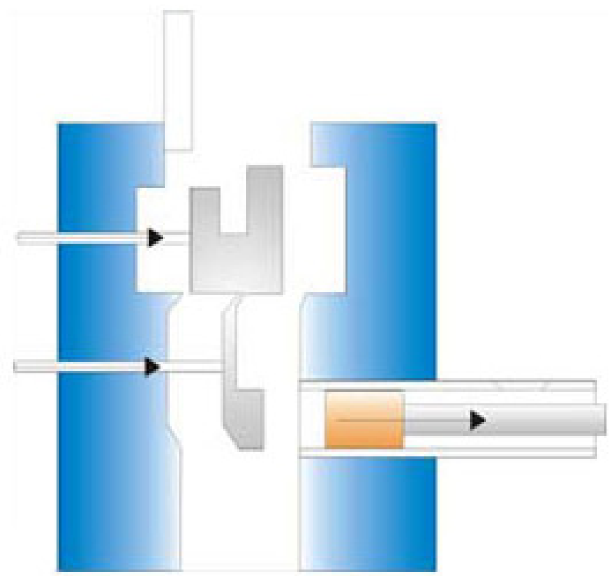
Cold Chamber Die Casting Sequence

STAGE 3

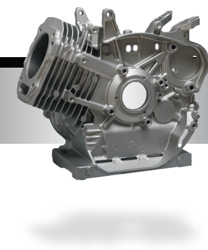


The cover die opens as well as any core slides or pulls present in the mold.

STAGE 4



The ejector side of the mold is actuated and the casting is removed from the mold.



DIE CASTING

Advantages

- The ability to produce castings with close dimensional control
- The ability to produce castings with a good surface finish
- The ability to produce castings with thin walls, and therefore of reduced weight
- The ability to produce castings at a high rate of production

Disadvantages

- High tooling costs
- Restrictions on castable alloys
- Size restrictions of castings that can be cast
- Volume restriction

Definitions:

COVER DIE – The stationary half of a die-casting die, which forms the exterior or appearance surfaces of the casting.

DIE CAVITY – The impression in a die into which pattern material is forced.

LADLE – Metal receptacle frequently lined with refractories used for transporting and pouring molten metal.

GATE – The passage connecting a runner or overflow with a die cavity.

GATE RUNNER – The runner in a die-casting die that is directly adjacent to the gate. The runner feeds the injected metal to the gate.

PLATEN – Portion of a casting machine against which die sections are fastened, or of trim presses against which trim dies are fastened.

PLUNGER – Ram or piston that forces molten metal into a die.

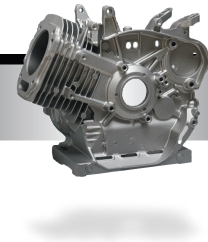
PARTING LINE – The joint between the cover and ejector portions of the die or mold. Also, the mark left on the casting at this die joint.

PARTING LINE, STEPPED – A condition on a die-casting where the parting line changes abruptly from one level to another.

SLEEVE – The molten metal chamber of a cold-chamber die-casting machine. This is a hardened steel tube through which the shot plunger moves to inject the molten metal into the die.

EJECTOR PINS – A pin actuated to force the casting out of the die cavity and off the cores.

EJECTOR PLATE – Plate to which the ejector pins are attached and which actuates them.



DIE CASTING

General Design Data

SIZE RANGE: Ounces to 50 lbs.

METALS: Al, Magnesium, Zinc

TOLERANCES: +/- .002" for 1" then add +/- .002 inches/inch

PARTING LINE SHIFT: +/- .015"

AVERAGE TOOLING COST: $25,000 to $100,000

TYPICAL ORDER QUANTITY: 2,500 +

AVERAGE TOOLING LEADTIME: 12 weeks

SURFACE FINISH: 32 to 63 RMS

MINIMUM SECTION THICKNESS: .060 premium /.080" average

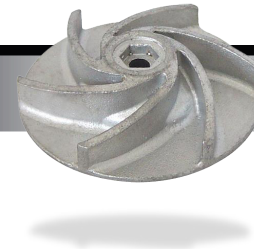
MINIMUM DRAFT REQUIRED: 1 to 3 degrees

This is for comparison purposes only.

Cost Drivers

- Number of impressions per mold
- Number of molds produced per shift
- Amount and complexity of cores required
- Amount of cleaning, grinding, buffing, blasting required
- Weight of casting
- Heat treat specification
- Scrap factor

INVESTMENT CASTING



INVESTMENT CASTING

Where it Started

The Egyptians and Chinese used the process in their early history to make statues and jewelry. The investment casting method was largely ignored as an industrial process for the fabrication of parts until the demand for rapidly finished parts during World War II created the need for near net-shape components that could readily be put into their final form. Then new inorganic high temperature ceramic mold binders were developed to industrialize the process applications to include high strength and corrosion resistant materials such as low to high carbon alloy steel, tool steel, stainless steel, and nickel and cobalt base alloys. Aluminum and brass alloys are available also. It is a process capable of producing intricate shapes weighing from a small fraction of an ounce up to forty pounds or more.

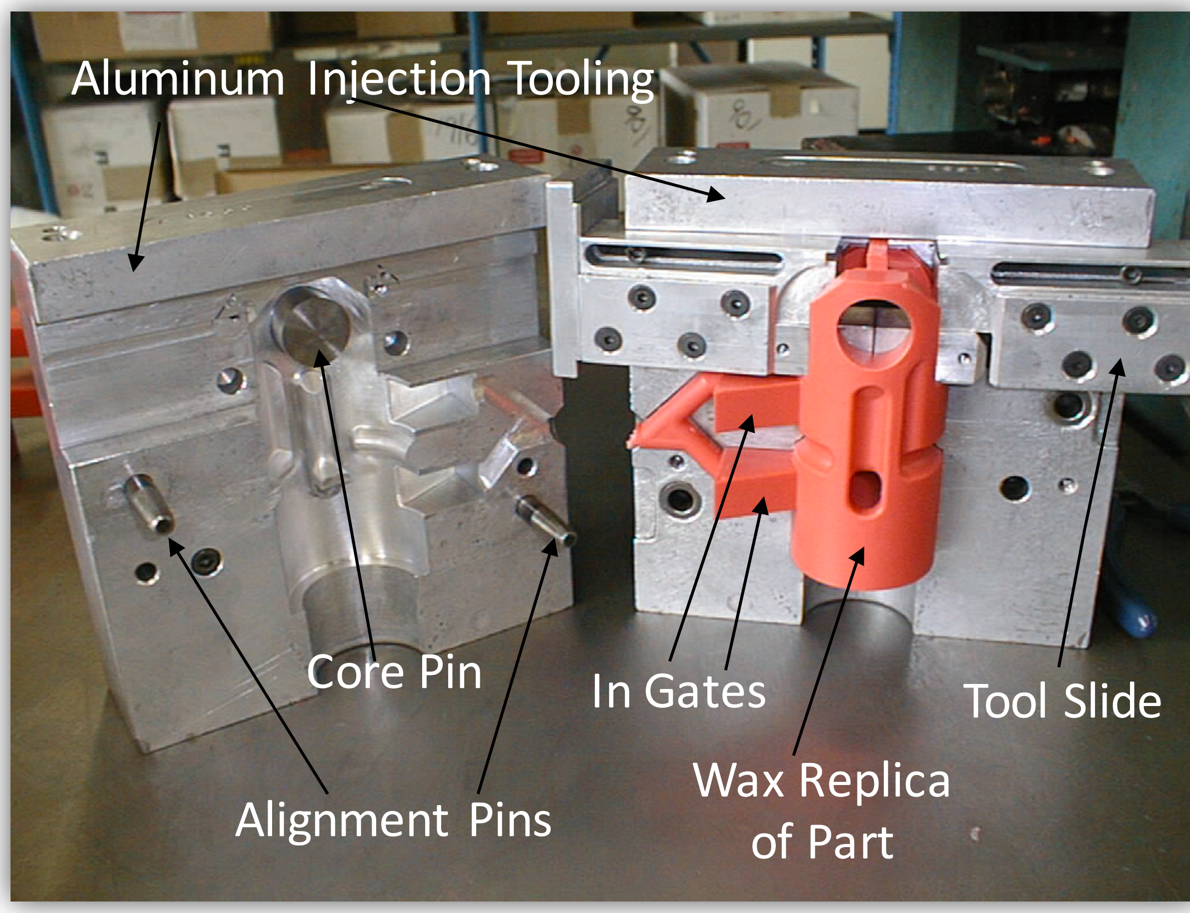
How it Works

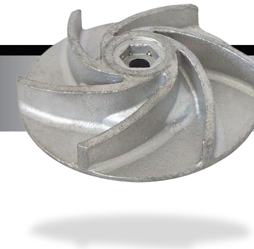
An injection molded wax pattern is used for each part produced which is been encased in multiple layers of ceramic material. The wax pattern is then removed from the ceramic shell mold. The mold is fired in an oven and then molten metal is poured into the cavities left by the evacuated wax pattern. Upon cooling, the resulting precision castings are cleaned and subjected to further processing such as heat treatment. At this point, many parts are in their final form and are ready for use while others may require a small amount of further processing such as machining before reaching their final form.

The word investment, in INVESTMENT CASTING, denotes the mechanical manner of making a mold rather than the material used. This process employs a three-dimensional pattern – using all three dimensions – to produce a one time destructible mold into which molten metal will be poured. A very simple example would be to pour wax into an egg shell, let it cool, then crack away the shell. People, not especially versed in casting terms, on occasion associate this process with financial matters.

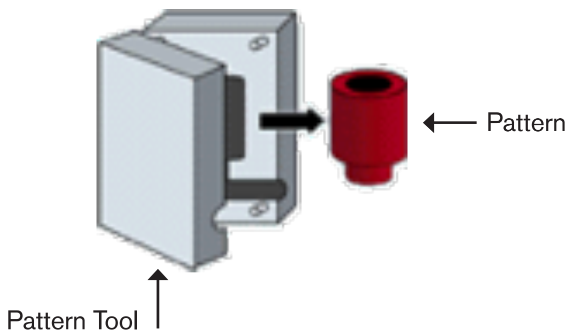
Some examples of usage would be: dental appliances, jewelry, components for the automotive industry, military weaponry, jet engines, aircraft structural parts, machinery components, and many others.

INVESTMENT CASTING

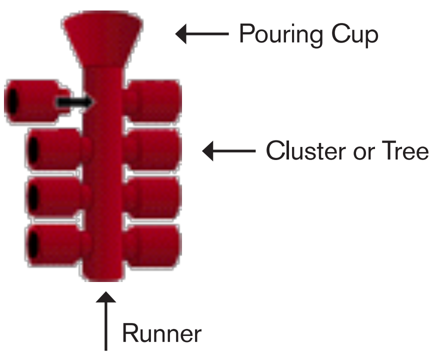




INVESTMENT CASTING



You start by injecting molten wax into an aluminum die to make an exact replica of the part. The tooling can be manual or automated to serve different part configurations and quantities.



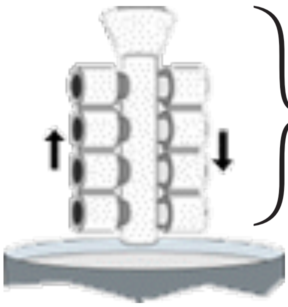
This is showing the parts assembled to the “Tree” or assembly.

This post or sprue is attached to a pouring cup and represents the metal delivery system.

Patterns are fastened by the gates to one or more runners. The runners are attached to the pouring cup. Both are usually made of wax. Patterns, runners and pouring cup comprise the cluster or tree, which is needed to produce the ceramic mold.

INVESTMENT CASTING

Shell Molding (Investing)



Investing

Robotic dipping, the slurry onto the "Tree" or assembly. →

STEP ONE

The cluster (tree) is rinsed in a pattern wash/etching solution. This removes any mold release residue from the pattern. The cluster (tree) is then dipped into a primary slurry/binder. The cluster (tree) is manipulated so that the patterns receive a complete and even coat of binder.

STEP TWO

The cluster (tree) is then stuccoed with a primary refractory grain, this gives us our face coat. After drying, this primary coating process is repeated as necessary. The primary coats determine detail and surface finish.

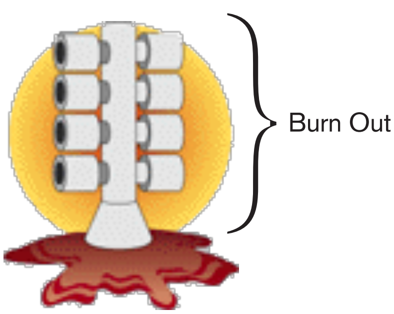
INVESTMENT CASTING

STEP THREE

After completion of the primary coats the cluster (tree) is ready for the secondary or back up coats. This is done in the same manner as the primary coats except the binder composition and viscosity is different and the stucco grain size is coarser. The secondary/back up coating process is repeated as necessary until the shell is strong enough to hold molten metal. After completing the back up coats the cluster (tree) is then given a seal coat by dipping it back into the slurry. The shell, after drying, is now ready for dewaxing.

This is the "Tree" fully invested. Meaning all the coats have been added and it is now ready for the Autoclave. ⟶

Ceramic Shell Dewaxing



The shells are then moved to an autoclave, which is a large pressure steamer. The shells are heated to approximately 500 degrees. This melts out the patterns, gates, runners and pouring cup – creating a ceramic shell containing cavities of the casting shape desired with passages leading to them. This will remove close to 98% of the wax.

INVESTMENT CASTING

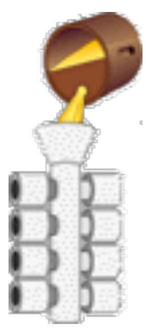
Ceramic Shell Firing (Burn-Out)

The shells are then put in a pre heat oven. Non Ferrous alloys are typically heated to 1,400 to 1,500 degrees. Ferrous alloys are heated to 2,100 to 2,200 degrees.

This is done to:

- Evaporate any remaining wax
- Harden the shell to a ceramic state
- Allow the metal to cool more evenly and not chill off before it solidifies.
- Aid in fluidity for thin sections

Casting



Molten metal is poured into the fired shell at temperatures between 1300˚F - 2950˚F depending on the type of alloy selected, and the casting/part configuration. Pouring temperatures are maintained as cool as possible.

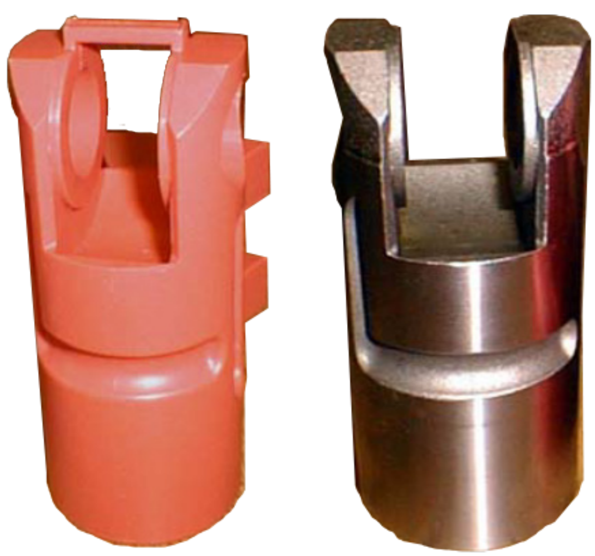
INVESTMENT CASTING

Shell Mold/Investment Removal *(Knock-Out)*

After the poured (molten) metal has cooled, the shell (mold) material is removed from the casting cluster (tree) using high pressure water, vibratory or shot blast methods.

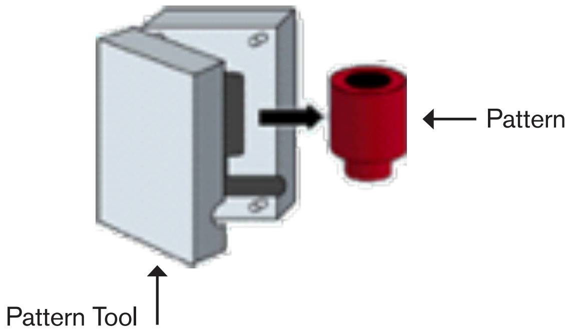
Casting Cut Off And Clean-Up

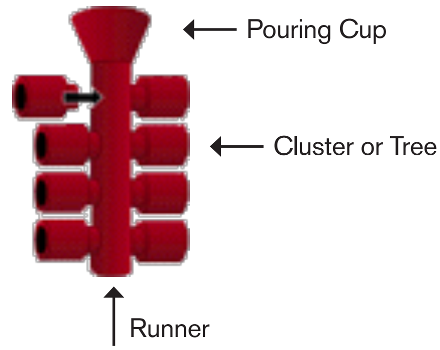
The individual castings are removed (cut-off) from the cluster (tree). Remaining protrusions left by gates or runners, are removed by grinding. Generally the castings are shot, sand or bead blasted for a smoother finish.

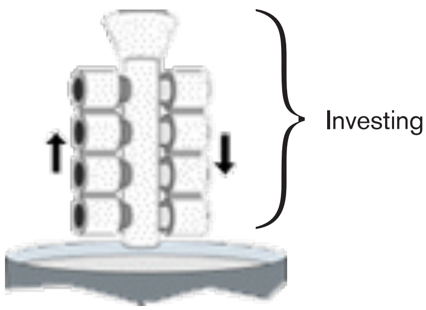


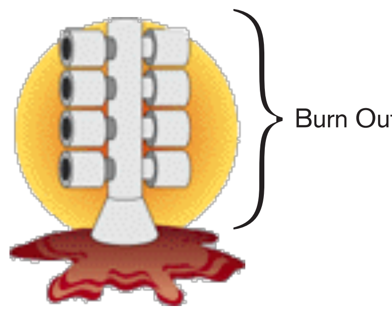
← You are left with a replica of the wax piece you started with.

INVESTMENT CASTING









Definitions

PATTERN TOOL: An aluminum die that is used to produce an exact replica of the finished part in wax.

PATTERN: An expendable wax replica around which molding material is placed to produce a finished casting.

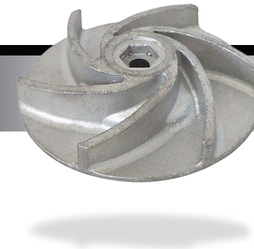
POURING CUP: Where the molten metal is poured.

CLUSTER OR TREE: A group of expendable patterns on runners for casting purposes.

RUNNER: The portion of the tree assembly that connects with the casting ingate.

INVESTING: The coating of an expendable pattern with a ceramic material so that it forms the surface of the mold that contacts the molten metal when the pattern is removed and the mold is poured.

BURN-OUT: Firing a mold at high temperature to remove pattern material residue.



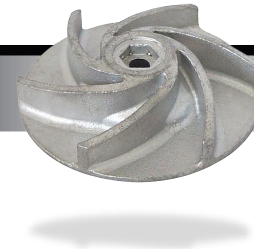
INVESTMENT CASTING

Advantages

- ALLOY FLEXIBILITY: All alloys both ferrous & non ferrous
- SUPERIOR SURFACE FINISHES: 60 to 90 RMS
- THIN WALLS: As thin as .060"
- TIGHT TOLERANCES: +/- .005" to 3"
- NEAR NET SHAPES: On average, investment castings offer 90% or more of the requirements of the finished part in an as-cast state. Investment casting can incorporate complex undercuts, slots, holes, lettering, and bevels into the design.
- DESIGN FREEDOM: Investment casting offers the fewest design restriction of any metal working process.

Disadvantages

- LONG LEAD-TIMES
- SIZE LIMITATIONS
- EXPENSIVE



INVESTMENT CASTING

General Design Data

SIZE RANGE: Up to 18" square / 75 lbs. typical

METALS: All

TOLERANCES: +/- .005" for 3" then add +/- .003 inches/inch

PARTING LINE SHIFT: N/A

AVERAGE TOOLING COST: $4,000 to $12,000

TYPICAL ORDER QUANTITY: All

AVERAGE TOOLING LEADTIME: 6 to 8 weeks

SURFACE FINISH: 90 to 125 RMS

MINIMUM SECTION THICKNESS: .060" non-ferrous /.080" ferrous

MINIMUM DRAFT REQUIRED: Zero

FLATNESS: +/- .005 per inch

RADII: .030 to .060

Note: The above information is meant to be a basic guideline for comparison purposes only.

Metal Density/Part Weight

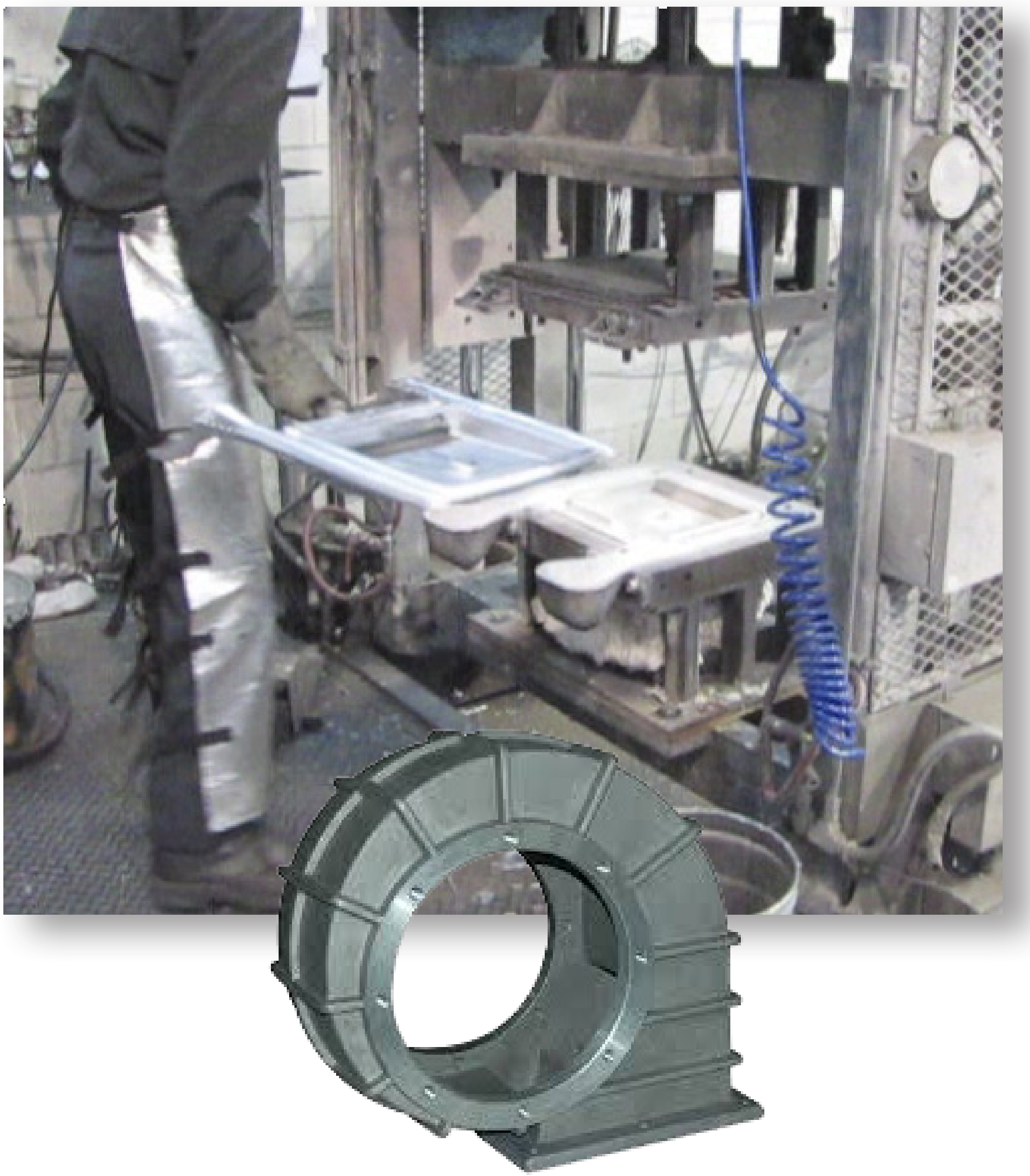
ALLOY	FACTOR
ALUMINUM	.0926 lb/in cubed
BRASS/BRONZE	.3125 lb/in cubed
FERROUS ALLOYS	.2906 lb/in cubed
ZA-3	.2400 lb/in cubed
ZA-12	.2180 lb/in cubed

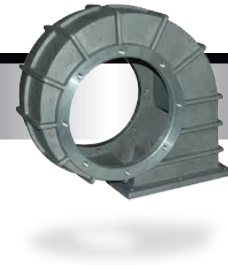
Multiply the part volume in cubic inches by the factor to determine the part weight in pounds.

Cost Drivers

- Number of Impressions per mold
- Number of molds produced per shift
- Amount and complexity of cores required
- Amount of cleaning, grinding, buffing, blasting required
- Weight of casting
- Heat treat specification
- Scrap factor

PERMANENT MOLD CASTING





PERMANENT MOLD CASTING

Permanent Mold refers to the tooling used to produce the castings. The molds or dies are usually made of high alloy iron or steel (both very dense) and have a production life of over 100,000 castings.

How it Works

The gravity process begins by preheating the mold to 300 - 400ºF to ease the flow of the metal and reduce thermal damage to the casting. Once to temperature a very close thermal balance is maintained.

The cavity surfaces of the mold are then coated with a thin layer of heat resistant material such as clay or sodium sulfate, which prevents the casting from sticking to the mold.

The metal molds that consist of two or more parts are then assembled. Cores are added if needed.

Once to temperature the molten metal is poured into a sprue at the top of the mold, or pouring cup (Tilt Pouring).

The metal flows into the mold cavity through the runner system by the pressure and velocity induced by gravity.

When the metal has solidified, the mold is opened and the casting is removed.

The gating system is then trimmed from the casting; it is ground and prepared for shipping.

Subsequently, another casting is poured in the same mold cavity.

Casting Properties

Due to the chilling nature of the steel tooling the castings are very sound. This lends the process to parts that need to be pressure tight and that need to have very little porosity.

PERMANENT MOLD CASTING

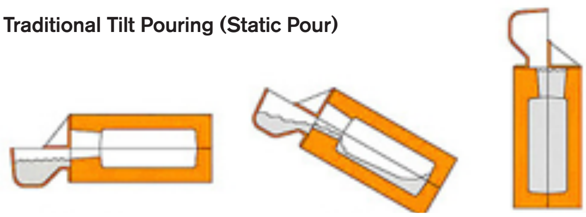
Tilt Pouring Permanent Mold

Pour Cup

The tilt pouring process was developed to eliminate top pouring and pouring down vertical gating systems that could generate dross in the casting.

In the tilt-pour process, with the parting line of the mold in the horizontal position, molten aluminum is ladled into a 'pour cup' attached to the mold. The tilt-pour casting machine then rotates 90 degrees at a slow and controlled rate. As the metal travels down the runner system, it enters the mold cavity smoothly reducing turbulence and oxide.

Traditional Tilt Pouring (Static Pour)

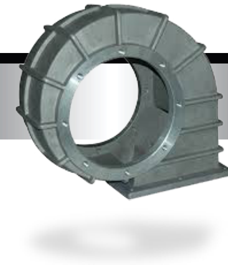


Pouring Position | Filling | Solidification Position

Tilt – Pour Casting Machine

Static Pour Permanent Mold

The Static Pour process is the process in which molten metal is poured directly into the mold cavity. The metal is allowed to solidify in a stationary position. Gravity forces the metal into the mold where it is allotted a set amount of time to solidify before the mold is opened and the casting is removed. The Static Pour process normally has a center-feed pouring method. A center-feed pouring method results when the molten metal is poured directly into the mold from the top, through the gating or a sprue system. This method of Permanent Mold Casting allows for all of the above characteristic, but the main benefit of such a process is the wide range of sizes that can be cast in this format. The size of the parts can range in weight from quite small to very large



PERMANENT MOLD CASTING

SEMI – PERMANENT MOLD Casting

The Semi-Permanent Mold Casting process uses the same general procedures as Permanent Mold Casting but in this process expendable cores of sand or other materials are added to the molding process to create a desired shape or an internal passage. In many cases, the practicality of having a solid casting does not exist. Many customers require that a product have passageways for materials to flow through; therefore a method of creating such passageways must be incorporated. In Semi-Permanent Mold Castings a pre-formed core is inserted into the Permanent Mold cavity. The metal flows around the insert and creates the desired shape or passageway. By using a sand core it allows for the easy removal of the insert to create the desired effect

Advantages

- Able to produce complex shapes and designs
- Fine grain structure
- Superior mechanical properties including strength of casting
- Able to produce pressure tight casting
- Reusable mold

Disadvantages

- High tooling cost
- Limited to low melting point metals
- Limited mold life

Cost Drivers

- Number of Impressions per mold
- Number of molds produced per shift
- Amount and complexity of cores required
- Amount of cleaning, grinding, buffing, blasting required
- Weight of casting
- Heat treat specification
- Scrap factor

General Design Data

SIZE RANGE: Up to 100 lbs.

METALS: Al, Bz, Iron, Lead

TOLERANCES: +/- .015" for 1" then add +/- .002 inches/inch

PARTING LINE SHIFT: +/- .010 to .030"

AVERAGE TOOLING COST: $10,000 to $25,00

TYPICAL ORDER QUANTITY: 500 +

AVERAGE TOOLING LEADTIME: 8 to 16 weeks

SURFACE FINISH: 150 to 300 RMS

MINIMUM SECTION THICKNESS: .125" premium /.187" average

MINIMUM DRAFT REQUIRED: 2 to 4 Degrees

Note: The above information is meant to be a basic guideline for comparison purposes only.

Local Contact: Michael Cellerino • 860-614-0992 • cellcastings@comcast.net

PLASTER MOLD CASTING

PLASTER MOLD

The plaster mold casting process is a specialized process used typically for short run and prototype castings. The plaster molds are made from a mixture of metal casting plaster, talc or other refractory materials and water, once combined they form a slurry.

The slurry is poured manually from the mixer into a flask containing the pattern. The slurry takes less than 15 minutes to set and form the mold. The mold is then vented and removed from the pattern. To prevent the mold from sticking to the pattern, a parting compound is applied, allowing for an easier release.

The molds must then be dried in an oven until there is no more moisture present. As a result, no gases or steam form when molten metal is poured into the mold.

The mold halves are then assembled along with any cores (Cores are used to form hollows and undercuts in the casting) that are needed to form the final mold that will produce the casting.

Metal is then poured into the molds and after the casting solidifies, the plaster is broken away and the cores are washed out. The gating system is then removed and the casting is finish ground.

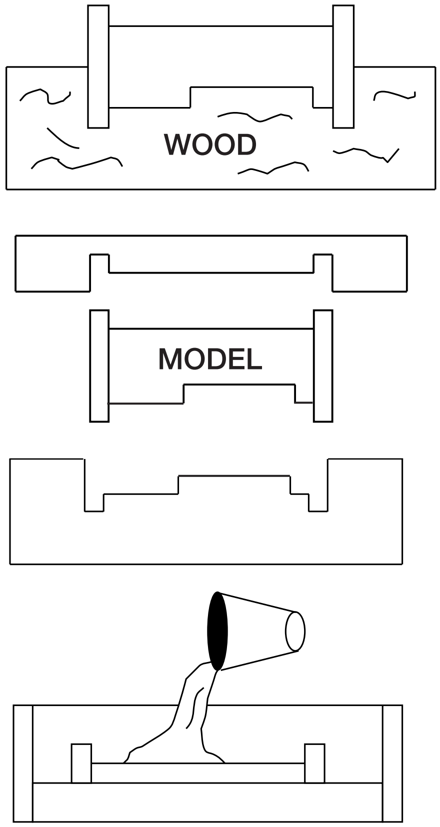
Alloys

Only non-ferrous alloys can be poured with the plaster mold process. Typical alloys are Aluminum, Zinc, Brass, and Magnesium.

Tooling

Both ridged and flexible patterns are used. Rigid patterns are usually sealed wood, metal or plastic. Flexible patterns, made from silicone rubber, are often used.

PLASTER MOLD



MAKE MODEL: Materials can be wood, metal or plastic.

PARTING BOARD OR JOINT: Pattern can be run " loose" at this stage for small quantities.

MAKE RESIN NEGATIVES: Materials can be epoxy, urethane or plaster.

MAKE COPE AND DRAG PATTERN: Materials can be resin, urethane or rubber.

MAKE PLASTER MOLD: Pour the plaster, also known as liquid slurry.

BAKE MOLDS: Bake at 5000 for 6 – 24 hours to remove moisture.

POUR CASTING: Use gravity or pressure of vacuum.

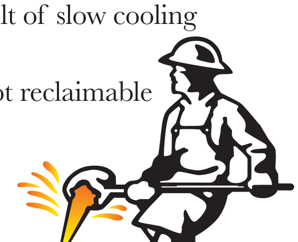
COOL CASTING: Wash off plaster, saw and grind gate.

Advantages

- The ability to produce complex shapes
- The ability to produce thin section castings
- The excellent replication of pattern detail
- The ability to produce castings, which are dimensionally accurate
- The ability to produce castings with good surface finish

Disadvantages

- Poor productivity due to lengthy processing problems
- The need for multiple patterns to improve molding productivity
- The requirement for close control of the production process
- The need for special procedures to overcome the problems of poor mold permeability
- The possibility of impaired mechanical properties arising as a result of slow cooling of the casting
- The mold materials are not reclaimable



PLASTER MOLD

General Design Data

SIZE RANGE: Up to 50 lbs.

METALS: Aluminum, zinc, magnesium, brass

TOLERANCES: +/- .005" for 2" then add +/- .002 inches/inch

PARTING LINE SHIFT: +/- .010"

TYPICAL ORDER QUANTITY: 1 – 250 pcs.

AVERAGE TOOLING COST: $5,000 to $10,000

AVERAGE TOOLING LEADTIME: 2 to 6 weeks

SURFACE FINISH: 63 to 125 RMS

MINIMUM SECTION THICKNESS: .060 “premium/.080" average

MINIMUM DRAFT REQUIRED: ½ to 3 degrees

Note: The above information is meant to be a basic guideline for comparison purposes only.

Cost Drivers

- Number of impressions per mold
- Number of molds produced per shift
- Amount and complexity of cores required
- Amount of cleaning, grinding, buffing, blasting required
- Weight of casting
- Heat treat specification
- Scrap factor

SAND CASTING

SAND CASTING

How it Works

The Sand Casting (Green Sand) molding process utilizes a cope (top half) and drag (bottom half) flask set-up. The mold consists of sand, (usually silica), clay and water. When the water is added it develops the bonding characteristics of the clay, which binds the sand grains together. When applying pressure to the mold material it can be compacted around a pattern, which is either made of metal, wood, or urethane to produce a mold having sufficient rigidity to enable metal to be poured into it to produce a casting. The process also uses coring to create cavities inside the casting. After the casting is poured and has cooled the core is removed.

The material costs for the process are low and the sand casting process is exceptionally flexible. A number of metals can be used for castings in sizes from ounces to many thousand pounds. The mold material is reclaimable, with between 70 and 75% of the sand being recycled, although new sand and additions are required to make up for the discarded loss. These features, combined with the relative ease of mold production, have ensured that the green sand molding process has remained as the principal method by which castings are produced.

The Sand

The sand used for green sand molding is critical and determines the favorable or unfavorable outcome of the casting. It controls the tolerances, surface finish and the repeatability while in production. Remembering that the tolerances on sand castings are usually wider than the other casting methods.

The sand must exhibit the following characteristics:

FLOWABILITY: The ability to pack tightly around the pattern.

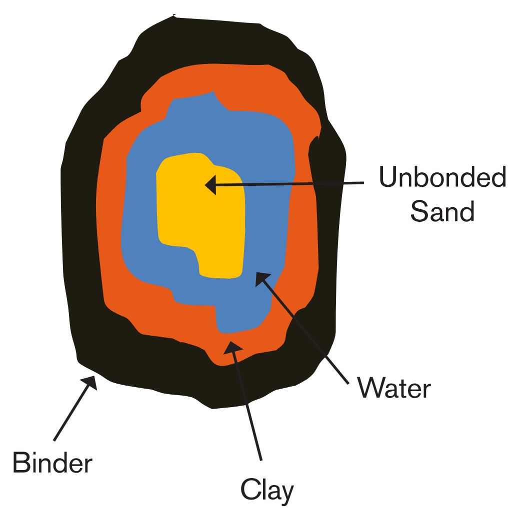
PLASTIC DEFORMATION: Have the ability to deform slightly without cracking so that the pattern can be withdrawn.

GREEN STRENGTH: Have the ability to support its own weight when stripped from the pattern, and also withstand pressure of molten metal when the mold is cast.

PERMEABILITY: This allows the gases and steam to escape from the mold during casting.

All of these requirements are dependent on the amount of active clay present and on the water content of the mixture.

Green Sand (Bonded Sand)



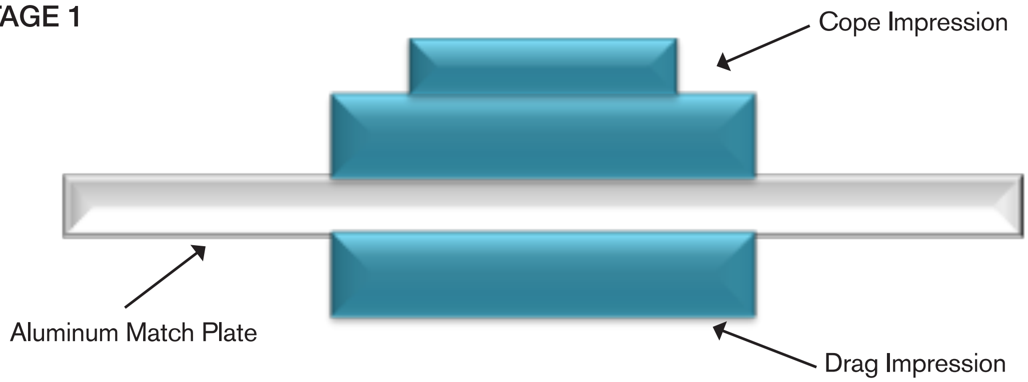
Unbonded Sand

Local Contact: Michael Cellerino • 860-614-0992 • cellcastings@comcast.net

SAND CASTING

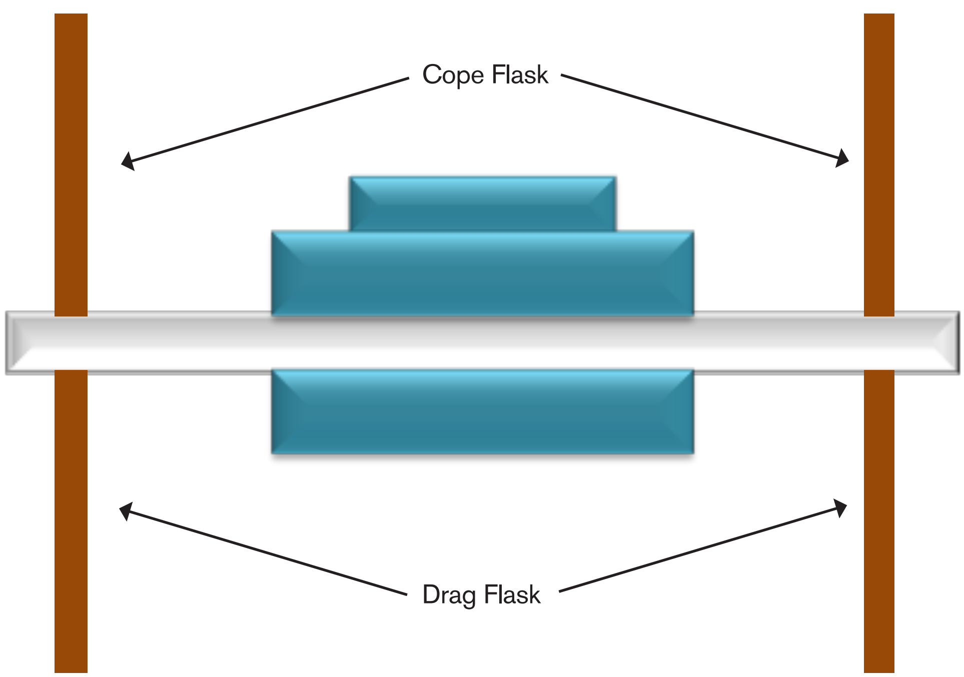
Sand Casting Process

STAGE 1



A pattern is produced of aluminum or wood which is a representation of the final product used to imprint the shape into the sand.

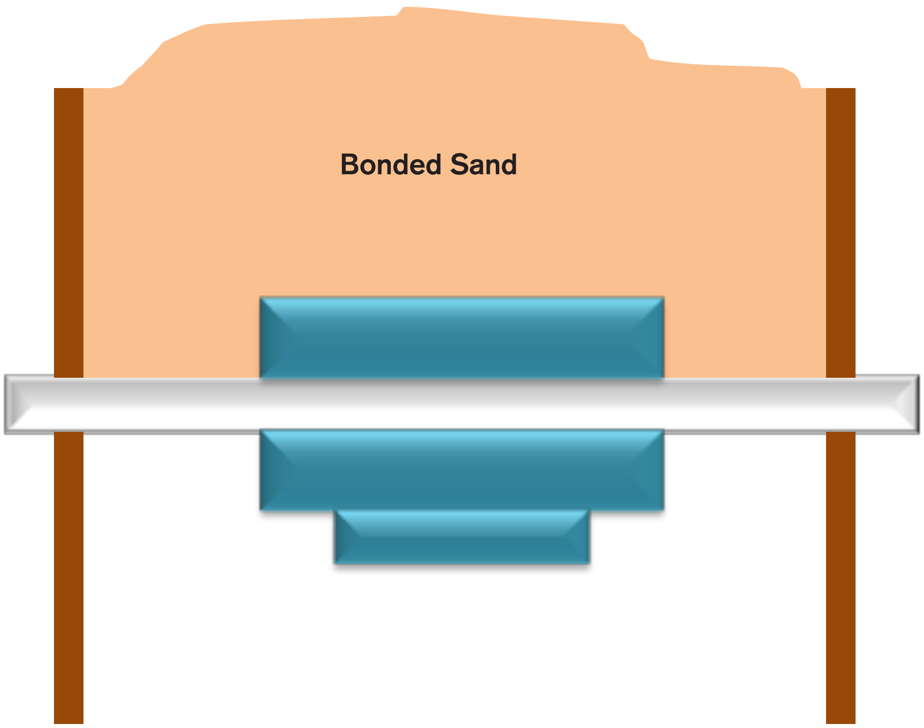
STAGE 2



A flask is assembled around the cope and drag pattern.

SAND CASTING

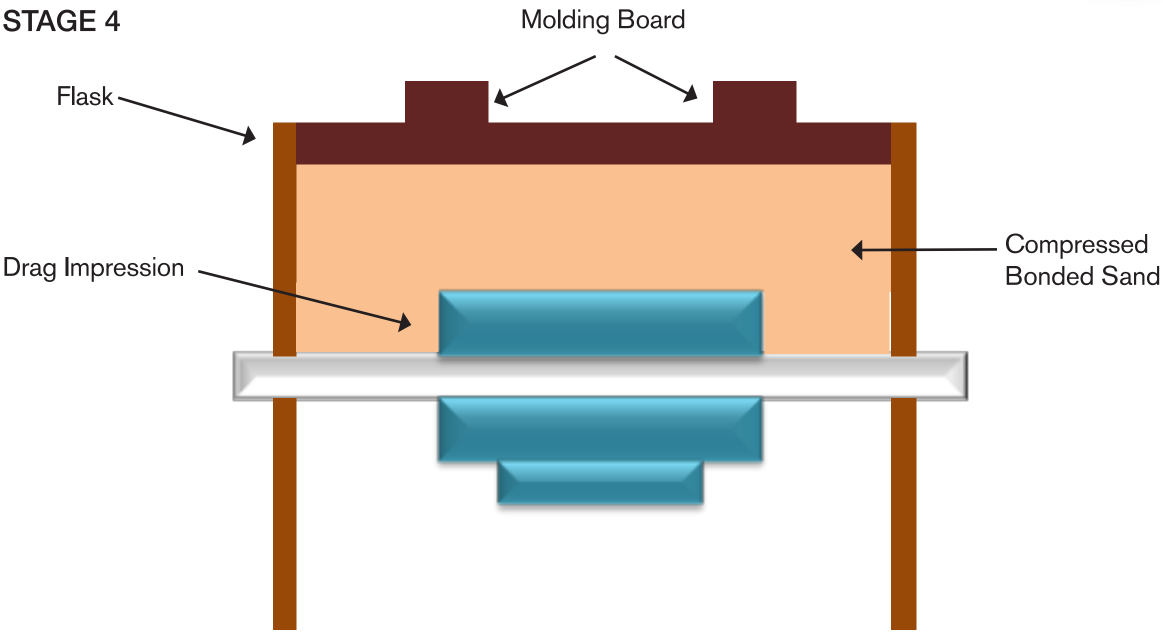
STAGE 3



The mold is rotated so the drag side of the mold is facing up.
The drag flask is then filled with a bonded sand.

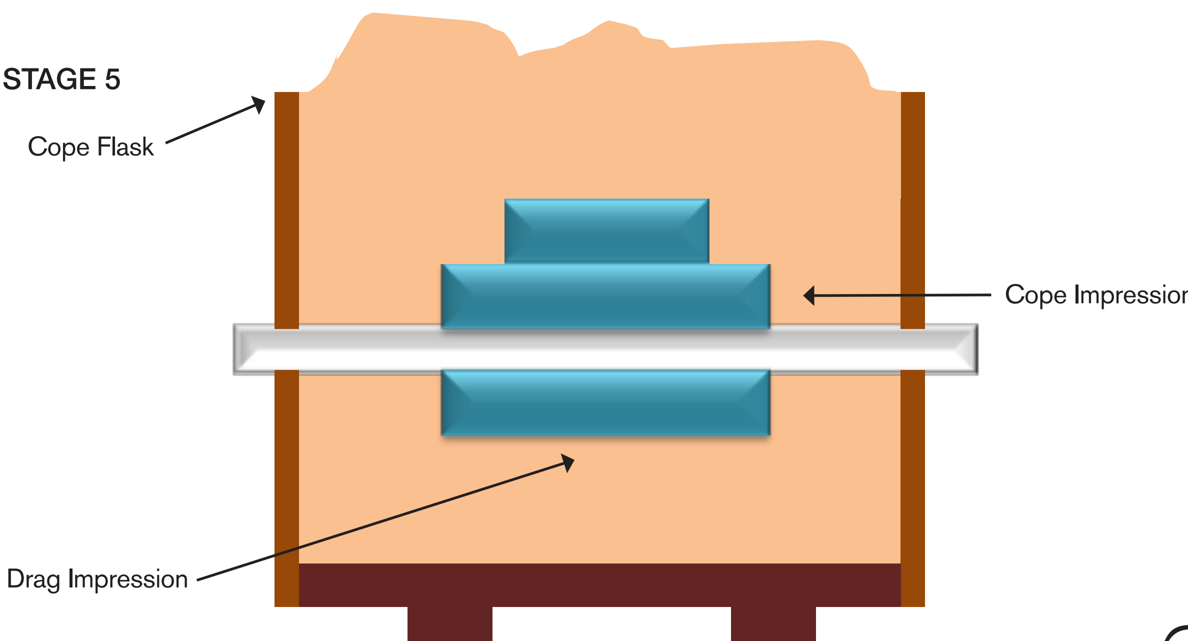
SAND CASTING

STAGE 4



A molding board is applied to the drag and then compressed hydraulically to compact the sand.

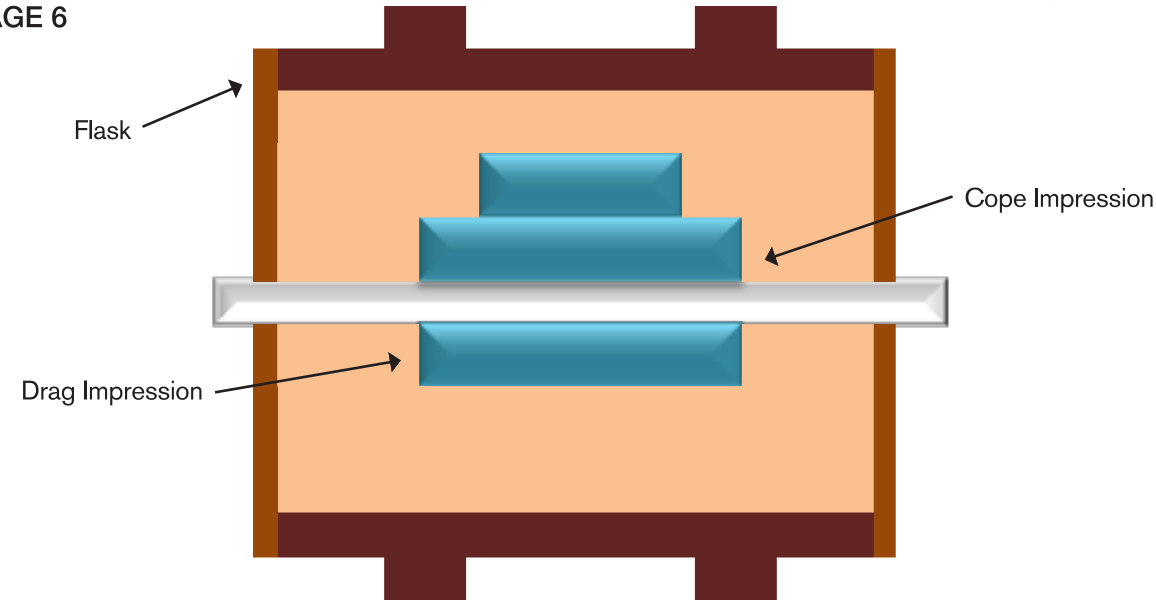
STAGE 5



The mold is rotated cope side up and is filled with bonded sand.

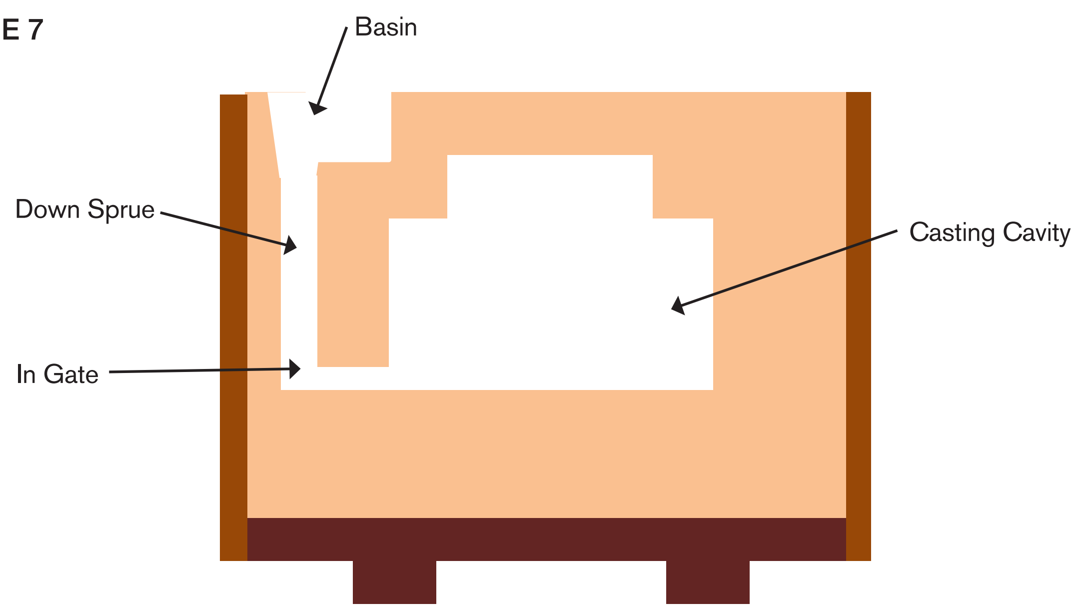
SAND CASTING

STAGE 6



The mold is rotated cope side up and is filled with bonded sand. Then the entire mold is compacted hydrologically.

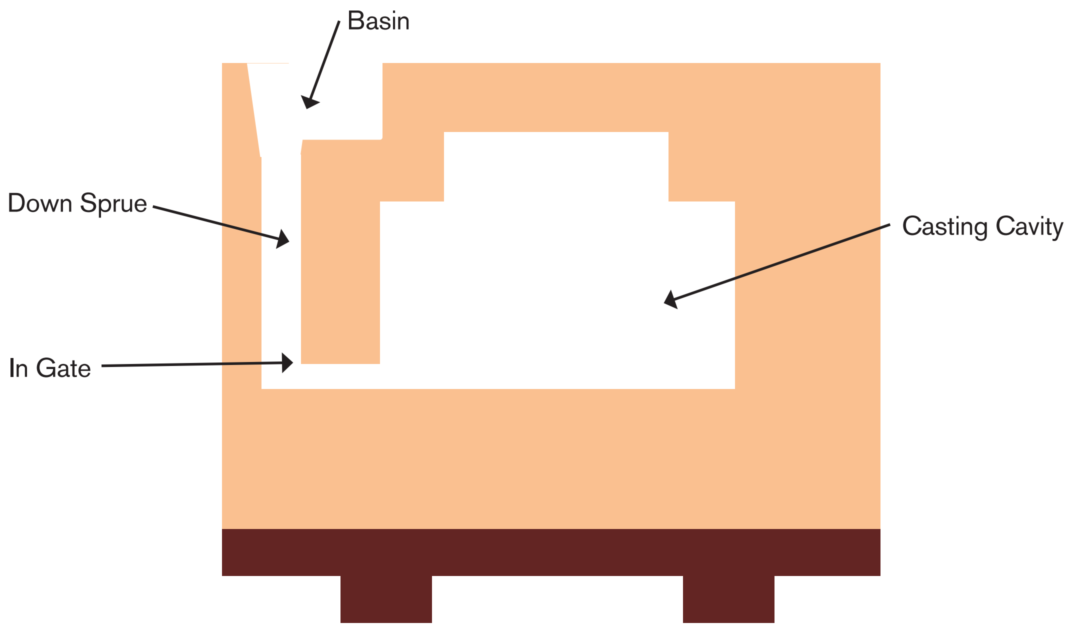
STAGE 7



The basin and down sprue are formed and connected to the gating system.

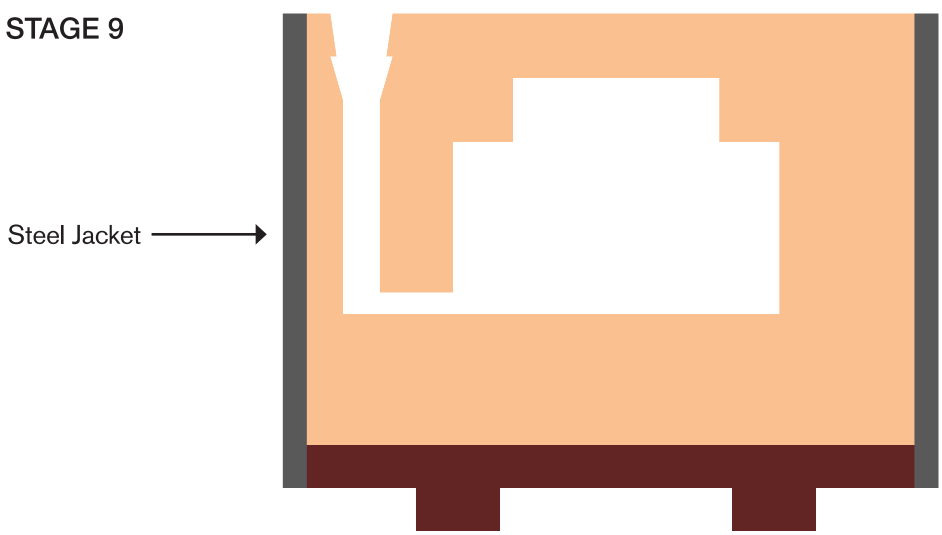
SAND CASTING

STAGE 8



The top board, cope flask and drag flask are all removed.

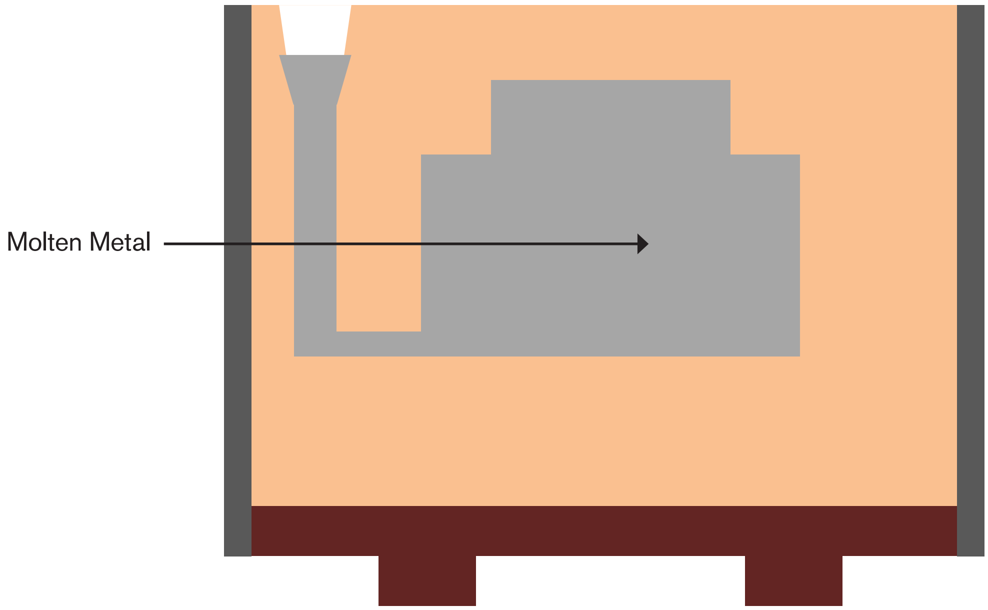
STAGE 9



A steel jacket is placed over the mold. The mold is now ready to receive the molten metal.

SAND CASTING

STAGE 10

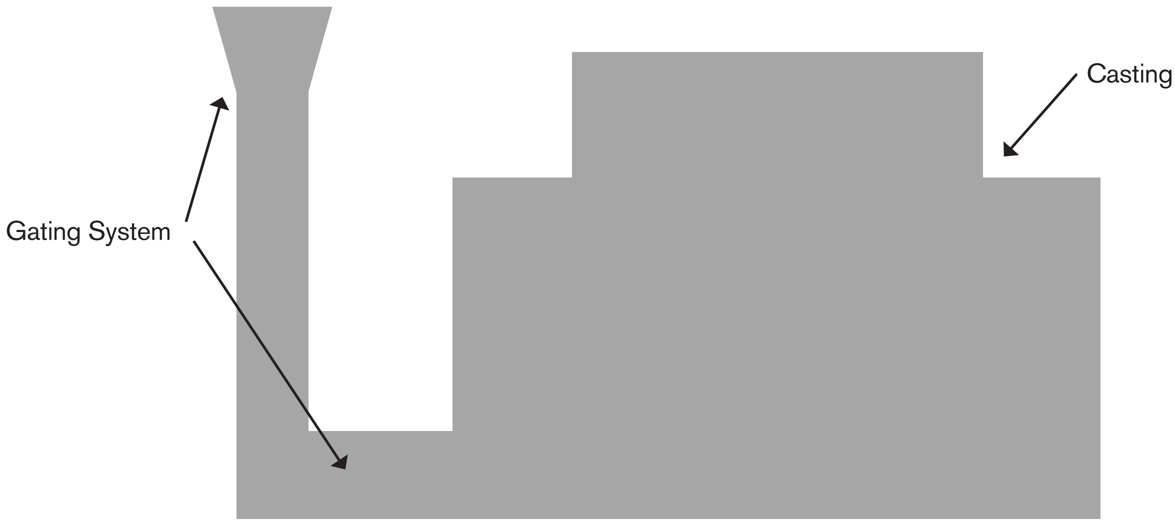


Molten metal is poured into the mold cavity.

STAGE 10

SAND CASTING

STAGE 11



The steel jacket is removed before the casting with the gating and risers are sent through the shakeout.

STAGE 11

Casting after being removed from shakeout.

SAND CASTING

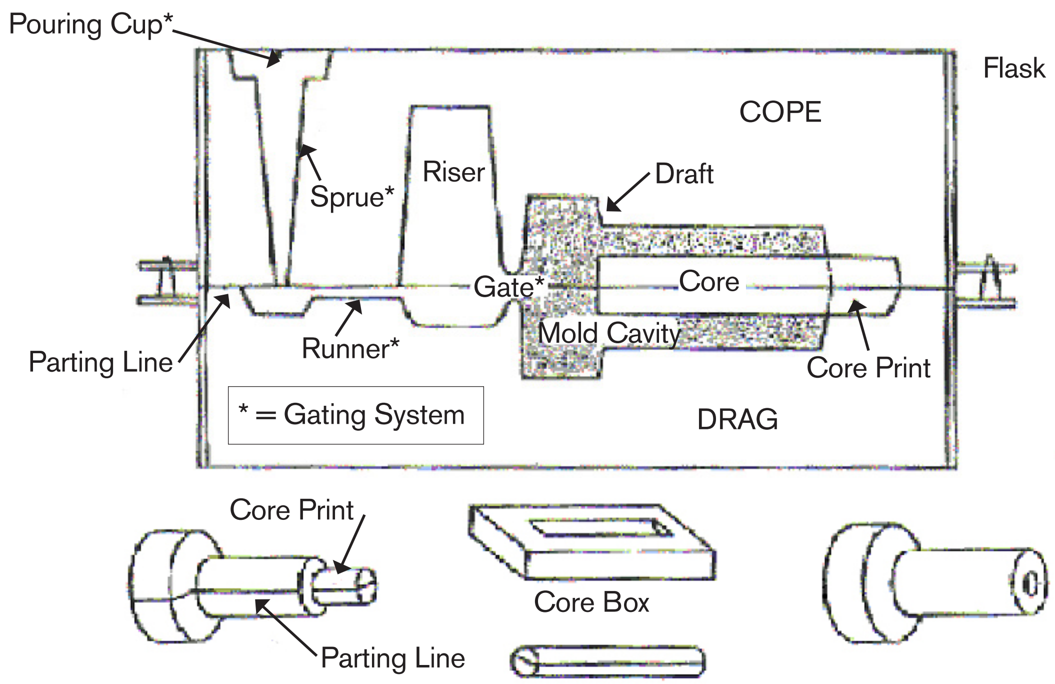
STAGE 12

The gating and risers and removed and you are left with the raw casting.

The gating is removed and you are left with the casting.

SAND CASTING

Anatomy of a Sand Casting Mold



Pattern + Core = Completed Casting

Definitions

CORE: A sand shaped insert placed in the mold cavity to produce internal features on the part.

COPE: The upper half of the sand mold.

DRAG: The lower half of the sand mold.

FLASK: A box made of wood or metal to contain the sand.

GATES: Multiple openings in the mold to allow the molten metal to flow into the mold cavity.

GATING SYSTEM: A passage where the molten metal flows into the mold. The gating system is made up of the pouring cup, sprue, runner and gates.

MOLD: A cavity or matrix by which molten brass is shaped into a desired product.

PARTING LINE: The line where the top and bottom halves of the sand mold meet.

PATTERN: A representation of the final product used to imprint the shape into the sand.

RISERS: Reservoirs called risers inside the mold, which is filled with the molten metal to compensate for shrinkage or"feed" the mold cavity during the solidification process.

RUNNER: The horizontal part of the gating system, which supplies molten metal to the gates.

SPRUE: The vertical part of the gating system, which is connected to the pouring cup at the top and feeds the runner with molten metal at the bottom.

SAND CASTING

Sand Casting Benefits

- Least Expensive Casting Process
- Castings can be up to Several Tons
- Less Expensive than Machining Shapes from Bar Stock
- Can Cast Intricate Shapes
- Can be used with Most Pourable Metals and Alloys

Shrinkage allowance for metals commonly used in Sand Casting

Gray Iron	.83 – 1.3
Ductile Iron	.83 – 1.3
Malleable Iron	.78 – 1.3
White Iron	2.1
Aluminum Alloys	1.3
Magnesium Alloys	1.3

Multiply the dimension by the factor to determine how much the metal will shrink over that dimension.

General Design Data

SIZE RANGE: Ounces to tons

METALS: Most all Castable Alloys

LINEAR TOLERANCES: +/- .030" to 6" then add +/- .003"

PARTING LINE SHIFT: +/- .020"

FLATNESS: +/- .030" to 6' then add +/- .002"

ANGULARITY: +/- 1 degree

CONENTRICITY: +/- .050" TO 6" then add +/- .005"

CORE TOLERANCE: +/- .040'

STANDARD DRAFT: 3 Degrees

AVERAGE TOOLING COST: $3,000 to $6,000

TYPICAL ORDER QUANTITY: All

AVERAGE TOOLING LEADTIME: 2 to 6 weeks

SURFACE FINISH: 250 to 500 RMS

MINIMUM SECTION THICKNESS: .150 " to .185'

MINIMUM DRAFT REQUIRED: 2 to 5 degrees

Note: The above information is meant to be a basic guideline for comparison purposes only.

Pattern Tooling Cost Comparison

MATERIAL	LIFE OF PATTERN	ABILITY TO MODIFY PATTERN	COST
Wood	2,000	YES	$1,000 to $3,000
Urethane	10,000	LIMITED	$3,000 to $6,000
Aluminum	20,000	YES	$6,000 to $10,000

These are just basis guidelines to follow tooling cost will vary according to geometry and size of part.

SAND CASTING

Advantages

- Least Expensive Casting Process
- Castings can be produced up to Several Tons
- Less Expensive than Machining Shapes from Bar Stock
- Can Cast Intricate Shapes
- Can be used with Most Pourable Alloys

Disadvantages

- Rougher Surface Finish
- Can not cast thin walls
- Least Dimensionally Accurate

Cost Drivers

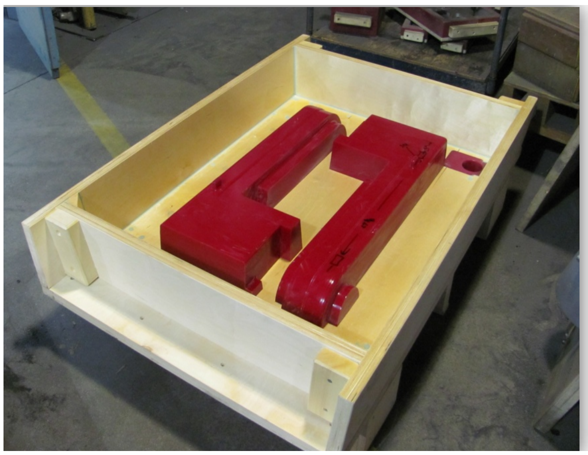
- Number of impressions per mold
- Number of molds produced per shift
- Amount and complexity of cores required
- Amount of cleaning, grinding, buffing, blasting required
- Weight of casting
- Heat treat specification
- Scrap factor

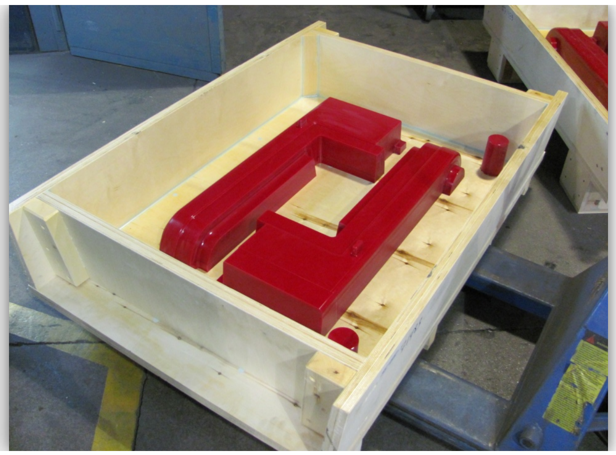
AIR-SET (NO BAKE) CASTING PROCESS

AIR-SET (NO BAKE) CASTING PROCESS

Dry sand is combined with liquid resin, making it wet and sticky. A chemical hardener is then added and the resulting mixture compacted around a pattern and left to set. When the sand mold halves are pulled apart, the pattern removed, and the mold brought together again, molten metal is poured into the mold cavity.

The air-set (no bake) process can handle larger and more complex parts than with the green sand molding process.

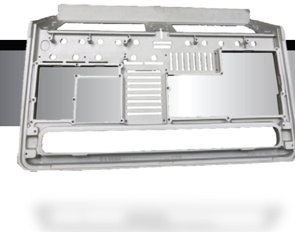




Advantages

- More precise than conventional sand casting
- Able to cast oversized parts
- Better surface finish than conventional sand
- Part to part repeatability
- Minimum draft required 1.5 degrees

V-PROCESS



V-PROCESS

Where it Started

The V-PROCESS (technically vacuum molding) was developed and patented in Japan in the late 1970's. Bill Wilmont, President of the Herman Molding Machine Company in Zelienople, Pennsylvania, was instrumental in bringing the process to the United States.

The process has been used and accepted by companies ranging from Fortune 100 to start-ups and is proving to be a very cost effective process for producing tight tolerance, esthetically pleasing, thin wall aluminum castings. The value of the process has enabled many companies to minimize the cost of new designs and to reduce the cost of current programs.

Major markets are in the medical, instrumentation, electronics, computer and telecommunication. We excel at long term projects requiring accurate, high quality castings.

Zero Draft

The V-PROCESS is unique in that it **does not require any draft angle**. This is due to the lubricity of the plastic film that allows for the mold to be stripped from the pattern without the friction of the sand against the pattern. The vacuum that is applied during the film forming operation is released and the vacuum is then applied to the mold. This causes a slight, controlled expansion or contraction of the mold features. The advantages of the zero draft capabilities are:

- Constant Wall Thickness for weight reductions and aesthetic appeal
- Elimination of Machining off the draft for clearances for mating parts.
- Total Tolerance range remains for the actual feature, not the feature plus draft. Draft does not use up the tolerance.
- Pattern Construction is more accurate and efficient.

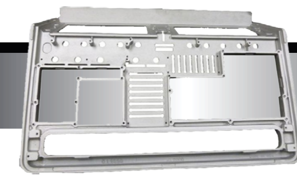
How it Works

First, we heat a thin plastic film and place it over a pattern. A vacuum tightly draws the film over the pattern. Which is then surrounded by a flask. Next, we fill the flask with dry, unbonded, extremely fine sand and vibrate the sand so that it tightly packs the pattern. After a second sheet of film is placed on the flask, a vacuum draws out the air, and the completed mold is then stripped from the pattern.

Each half of the mold is made in a similar fashion and then aluminum is poured directly from the furnace into the closed halves. The mold is held under a vacuum to retain its shape. After the mold cools, the vacuum is released and the sand and completed casting fall free.

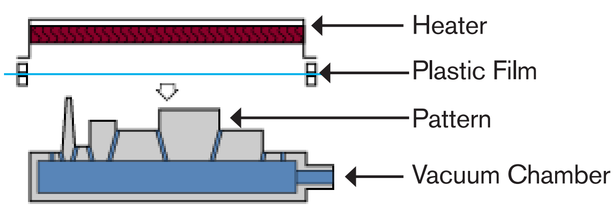
Simple in concept and far reaching in impact, V-PROCESS produces quick turn-around, high-value castings.

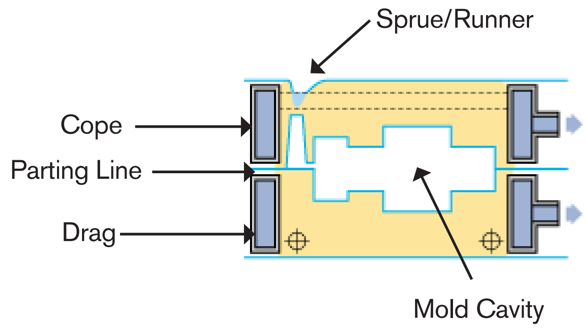
It is no accident that major companies in the medical, instrumentation, electronics, computer and telecommunication industries rely on the V-PROCESS for their casting needs.



V-PROCESS

V-Process Casting





Coring

The V-PROCESS uses cores that are similar to a sand core with the exception that we coat the core with a ceramic wash. The purpose of this is to seal the corer core sand so when a vacuum is pulled on the core the aluminum is not sucked into the core resulting in a "burn in" condition.

Definitions

SPRUE: The vertical channel from the top of the mold to the gating and riser system. Also, a generic term used to cover all gates, runners and risers.

RUNNER: The portion of the gate assembly that connects the sprue to the casting in gate or riser.

MOLD CAVITY: The impression in a mold produced by the removal of the pattern. When filled with molten metal it forms a casting.

COPE: Upper or top most section of a flask, mold or pattern.

DRAG: Lower or bottom section of a flask, mold or pattern.

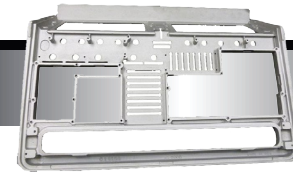
PARTING LINE: A line on a pattern or casting corresponding to the separation between the parts of a mold.

PATTERN: A pattern made from wood, metal, epoxy or machined plastics around which molding material is placed to make a mold for casting metals.

HEATER: Used to soften the plastic film before it is drawn around the pattern.

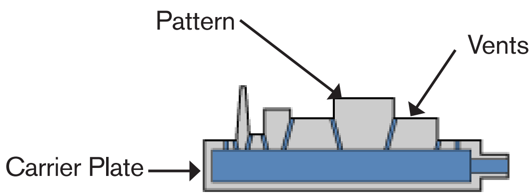
PLASTIC FILM: Ranging from .003" to .008" it is used to stretch to form over and into features of the pattern.

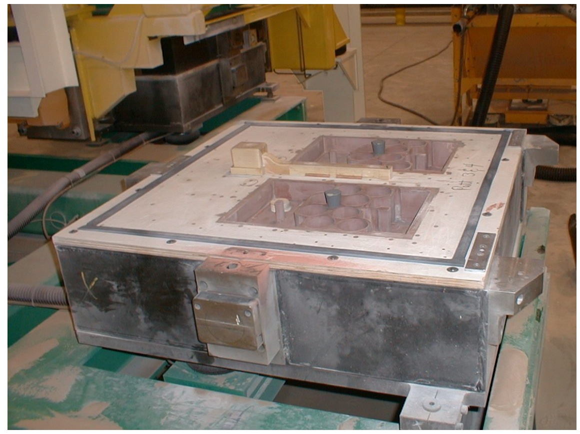
VACUUM CHAMBER: When a vacuum is applied to it, it draws the plastic film over the pattern.



V-PROCESS

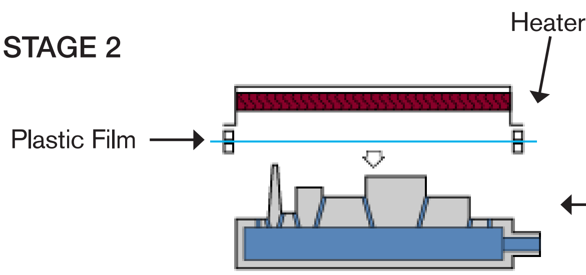
STAGE 1

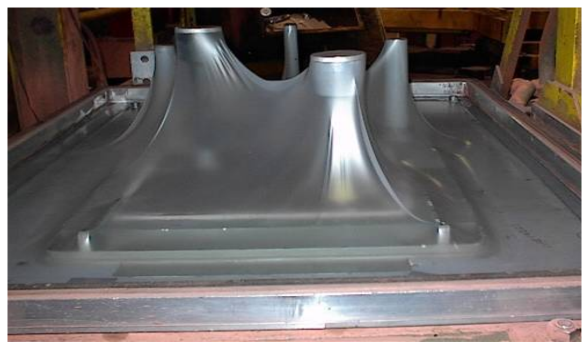




The pattern (with vents) is placed on a hollow carrier plate.

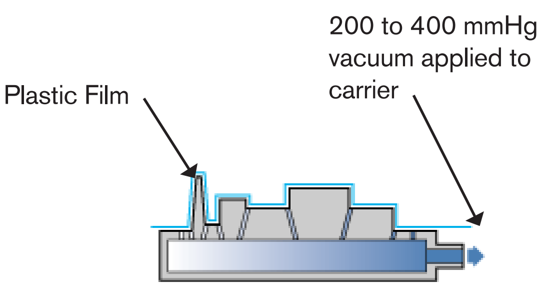
STAGE 2



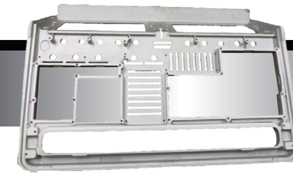


A heater softens the .003" to .008" plastic film. The plastic film has good elasticity and a high deformation ratio.

STAGE 3

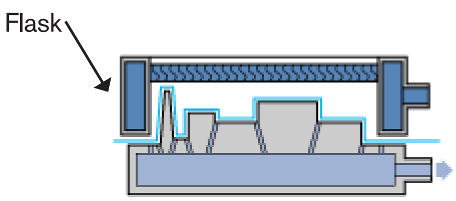


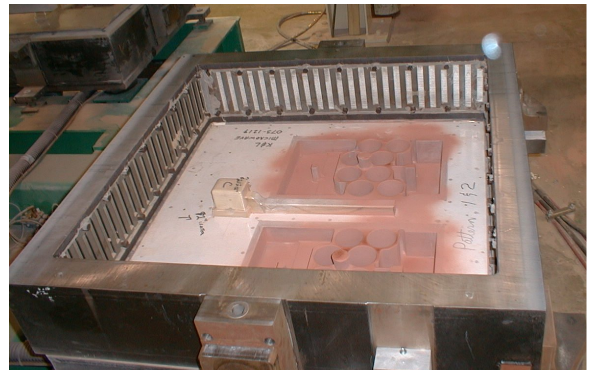
Softened film drapes over the pattern with 200 to 400 mm Hg vacuum acting through the pattern vents to draw it tightly around the pattern



V-PROCESS

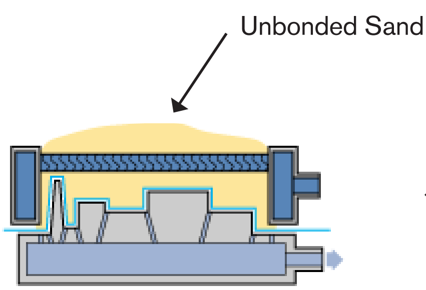
STAGE 4





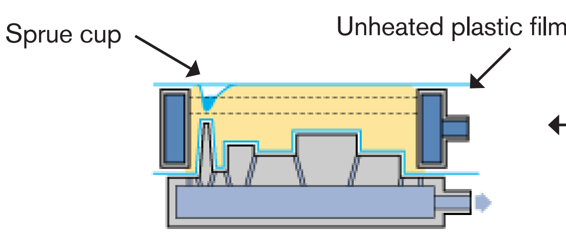
The flask is placed on the film-coated pattern. Flask walls are also a vacuum chamber with the outlet shown at right.

STAGE 5

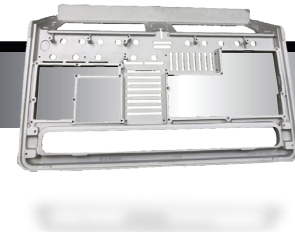


The flask is filled with dry, unbonded sand. A slight vibration compacts sand to maximum bulk density.

STAGE 6



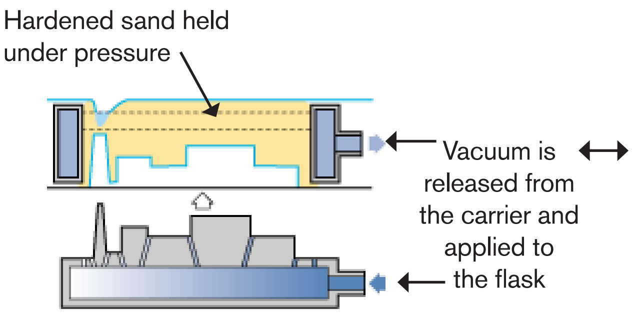
A sprue cup is formed and the mold surface leveled. The back of the mold is covered with unheated plastic film.

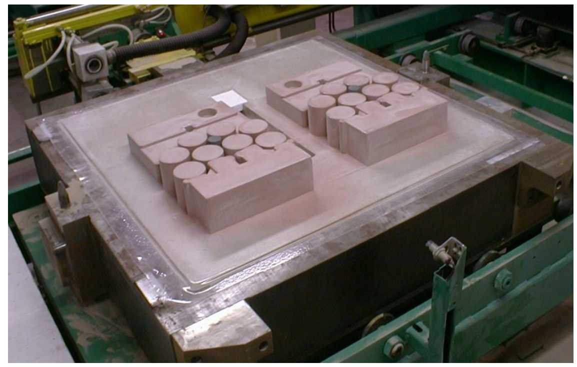


V-PROCESS

V-Process Sequence

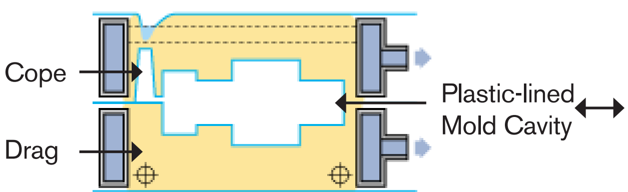
STAGE 7





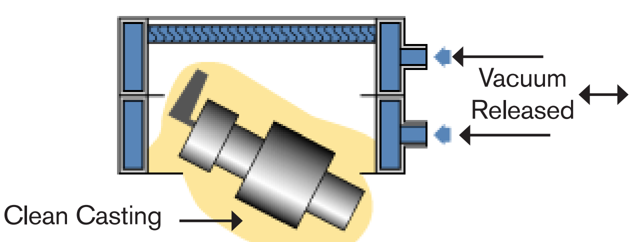
Vacuum is applied to the flask. Atmospheric pressure then hardens the sand. The vacuum is released, pressurized air is introduced into the carrier and the mold is stripped.

STAGE 8

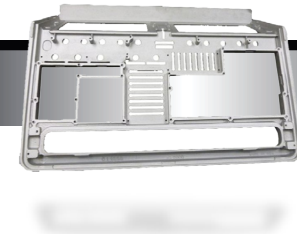


The cope and drag assembly form a plastic-lined cavity. During pouring, molds are kept under vacuum.

STAGE 9



After cooling, the vacuum is released and free-flowing sand drops away leaving a clean casting, with no sand lumps. The sand is cooled for re-use.



V-PROCESS

Benefits

- ZERO DRAFT: The advantages of the zero draft capabilities are:
  – Constant wall thickness
  – Elimination of Machining
- DOES NOT REQUIRE ANY DRAFT ANGLE
- UNLIMITED PATTERN LIFE
- SUPERIOR SURFACE FINISHES: 125 – 150 Rms
- THIN WALLS: As thin ss .125"
- TIGHT TOLERANCES: +/- .020" To 6"
- FAST TURNAROUND: Sample casting in 2 -3 weeks
- EASY COST EFFECTIVE PATTERN CHANGES

General Design Data

SIZE RANGE: Up to 150 lbs.

METALS: Aluminum Alloys A356, 319

LINEAR TOLERANCES: +/- .010" for 1" then add +/- .002 inches/inch

PARTING LINE SHIFT: +/- .010" to .020"

AVERAGE TOOLING COST: $7,000 to $14,000

TYPICAL ORDER QUANTITY: All

AVERAGE TOOLING LEADTIME: 2 to 4 weeks

SURFACE FINISH: 125 to 150 RMS

MINIMUM SECTION THICKNESS: .125" average

MINIMUM DRAFT REQUIRED: Zero

FLATNESS: .003 inch per inch

HOLES: Minimum castable hole size is .375"

ANGLES: The standard tolerance is +/- ½ (one half degree)

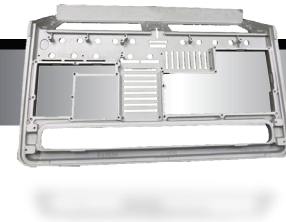
RADII: The minimum needed is .030"

FILMING: The film's physical limitation is that it can only stretch as far vertically as it is spaced horizontally. (one to one ratio)

LIMITATIONS: Height: 15" / Internal Pocket Depth: 10.5"

CORED AREAS: Additional tolerances required are based on projected area of core. Up to 10 square inches, add +/- .020, 10 to 50 square inches, add +/- .030", 50 to 100 square inches, add +/- .045.

The above information is meant to be a basic guideline for comparison purposes only.



V-PROCESS

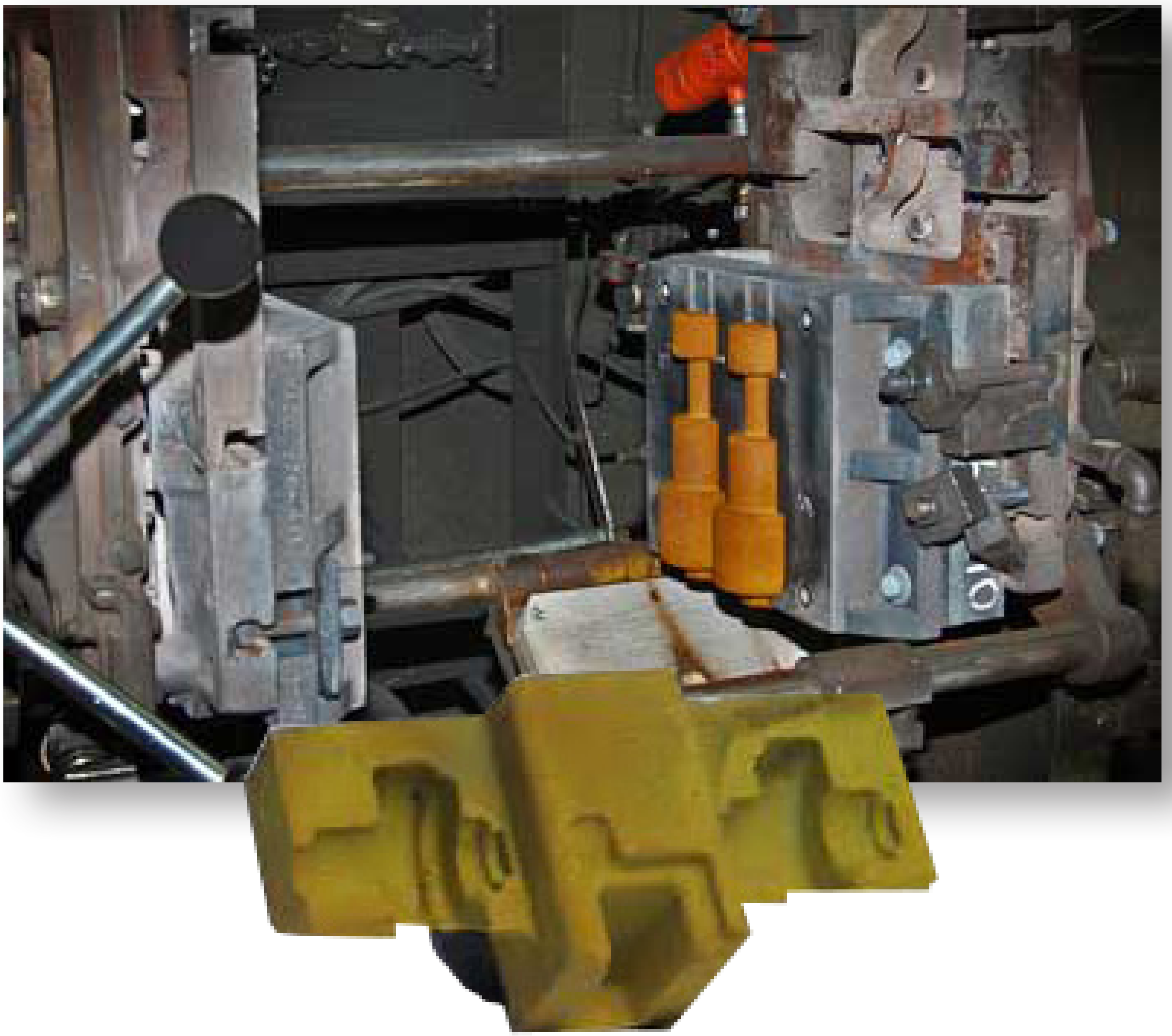
Mechanical Property Limits for Commonly Used Sand Casting Alloys

Alloy	Temper	Ultimate (ksi) 1000 PSI	Yield (ksi) .2% offset	% Elongation	Hardness Brinell
356	F	19	—	2	40-70
356	T5	23	16	—	45-75
356	T6	30	20	3	55-90
A356	T6	34	24	3.5	70-105

Cost Drivers

- Number of impressions per mold
- Number of molds produced per shift
- Amount and complexity of cores required
- Amount of cleaning, grinding, buffing, blasting required
- Weight of casting
- Heat treat specification
- Scrap factor

CORING



CORING

Cores and Core Making

Cores are pieces that are placed into casting molds to form internal cavities of the casting, or to form extra sections of the mold for castings that have external projections or negative draft, which, if included in the pattern, would prevent the pattern from being removed from the mold. Multiple cores may be used in complex castings.

Cores can be made from metal (in shapes that are easily removed from the casting, and used in permanent mold processes) or chemically bonded sand (complex shapes, and used in all mold types). Metal cores need to be configured such that they are parallel to the mold parting line, or can be removed before the casting is removed from the mold, and shaped so that is readily freed from the casting.

Used to produce

- Internal Cavities
- Undercuts

Core Selection

- Production Quantity
- Required Precision
- Required Surface Finish
- Size
- Geometry

Main Types of Cores

- Shell
- Resin

Advantages

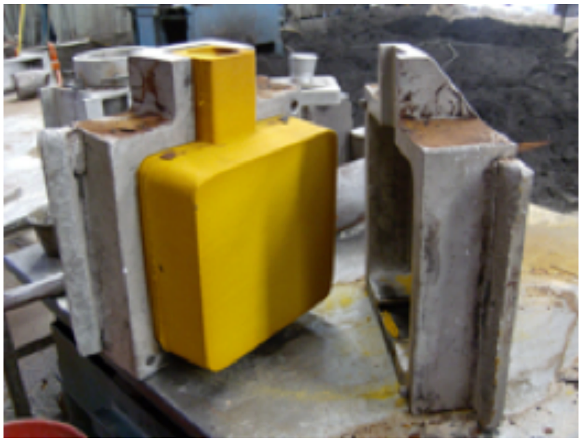
- Provide detail that cannot otherwise be integrated into a core-less casting or mold.

Disadvantages

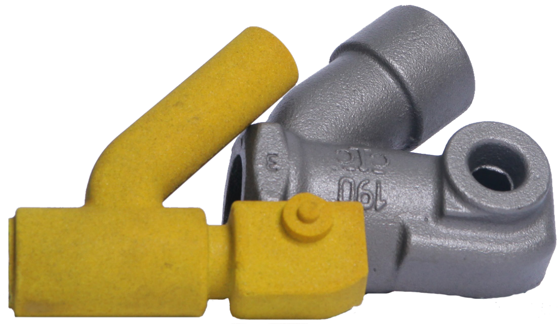
- Adds Cost

Different casting processes use different coring types depending on alloy volume and configuration needed.

SHELL CORING



Metal Core Box

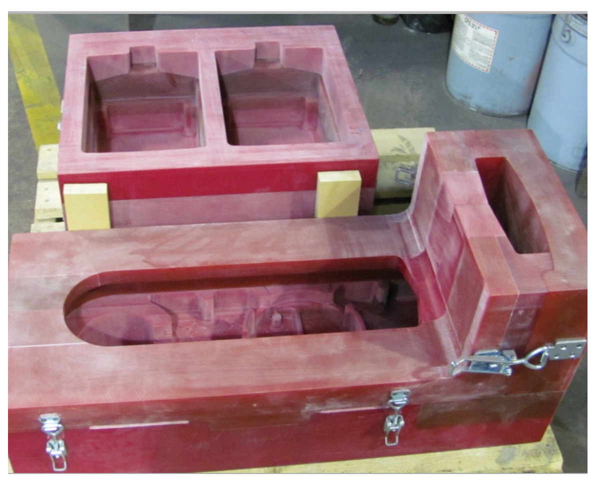


Shell Core

The Shell Process uses a blend of dry sand, with resin coating applied, blown into a metal "corebox" to form a sand core. Core boxes are typically made of some type of metal, usually iron or aluminum. The core box is heated by natural gas to temperatures of 450 to 600 degrees depending on how the box was constructed. Temperature control and uniform heating of the core box are very important to making a good core.

Shell sand has very good flowability and produces cores of high dimensional accuracy. The cores have excellent surface finish high density and good hot strength which then produces castings with a good surface finish. Shell cores can be made solid or hollow depending on their application.

RESIN SAND CORING



Cores are bonded with resin binders producing cores that are sound, gas defect-free, with an excellent surface finish. The resin process is used to produce larger cores but it offers the flexibility to make any size core. The tooling used in the resin process is usually more cost effective than tooling in other core processes. This process enables a foundry to produce core weights from .5 to 2000 pounds. Such resin-bonded sand cores take somewhat longer to manufacture than shell core coring because a curing reaction must take place for the binder to become effective and allow formation of the core. As in clay-bonded cores, the sand can often be recycled, although with some treatment to remove the resin.

DESIGN CONSIDERATIONS

DESIGN CONSIDERATIONS

General Design Data Sheet

	Sand Casting	V-Process Casting	Investment Casting Process	Graphite Permanent Mold Process	Steel Die Permanent Mold Process	Die Casting Process	Plaster Mold Process
Size Range	Ounces to Tons	Up to 150 lbs	Up to 75 lbs	Up to 6 lbs	Up to 100#	Ounces to 50 lbs	Ounces to 50 lbs
Tolerances	+/- 1/32 to 6"	+/- .010" to 1"	+/- .005" to 3"	+/- .005" to 1"	+/- .015" to 1"	+/- .002" to 1"	+/- .005" to 2"
Tolerance inches/inch thereafter	+/- .003"	+/- .002"	+/- .003"	+/- .002"	+/- .002"	+/- .002"	+/- .002"
Parting Line Shift	+/- .020"	+/-.010" to .020"	N/A	+/- .005" to .010"	+/- .010" to .030"	+/- .005"	+/- .010"
Minimum Section Thickness	.150"-.185"	.125" average	.060" premium .080" average	.120" average	.125" premium .187" average	.060" premium .080" average	.060" premium .080" average
Minimum Draft Required	2 to 5 degrees	Zero	Zero	1 to 3 degrees	2 to 4 degrees	1 to 3 degrees	1 to 3 degrees
Surface Finish	250 to 500 RMS	125 to 150 RMS	90 to 125 RMS	63 to 120 RMS	150 to 300 RMS	32 to 63 RMS	63 to 125 RMS
Average Tooling Cost	$3K to $4K	$7K to $140K	$4K to $12K	$6K to $14K	$10K to $25K	$15K to $100K	$5K to $10K
Average Tooling Lead-time	2 to 6 weeks	2 to 4 weeks	6 to 8 weeks	2 to 4 weeks	8 to 16 weeks	12 to 16 weeks	2 to 6 weeks
Typical Order Quantity	All	All	All	All	500 +	5,000 +	1 to 250 pcs.
Metals	All Castable Alloys	Aluminum 319 356	All Castable Alloys	Aluminum 356 319 ZA-12 ZA-27	Aluminum Bronze Iron Lead	Aluminum 360 380 413 Zinc Zamac 3 Zamac 5 ZA-8 ZA-12 ZA-27 Magnesium	Aluminum Zinc Magnesium Brass

The above information is meant to be a basic guideline for comparison purposes only.

DESIGN CONSIDERATIONS

Draft Requirements

All walls on castings that are perpendicular to the parting line require draft or taper. This draft is not consistent. It will vary with the length of draw (1).

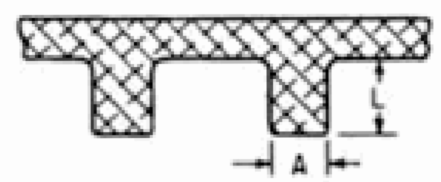


Fig. 1

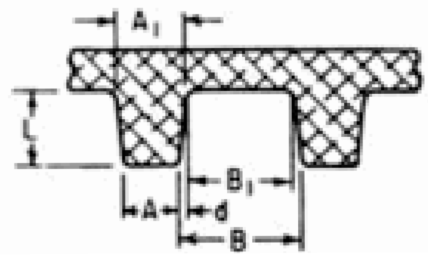


Fig. 2

Normally the drawing does not show the draft (**Fig. 1**) standard foundry practice is to add draft to the part. To avoid misunderstanding, this is synonymous with saying it will add metal to the casting, thereby adding mass.

Draft D will be added to A increasing its size to A1. Note that added draft effects dimensions by decreasing its size to B1. This is shown in **Fig. 2**.

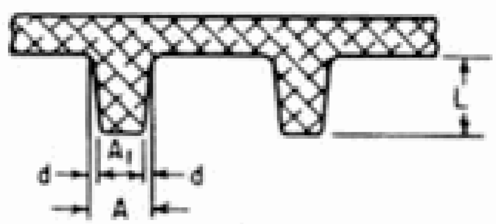


Fig. 3

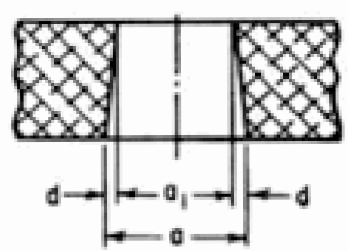


Fig. 4

Draft may be removed if desired but must be specified on drawing, as shown in **Fig. 3**. In holes draft will be added to A decreasing its size to A1, (see **Fig. 4**). When the designer desires a hole dimension to become larger for reasons such as clearance, he should specify.

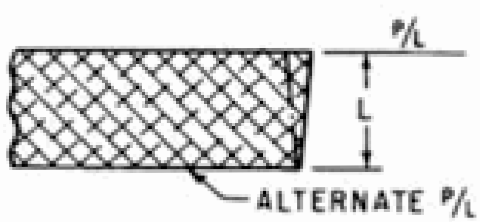


Fig. 5

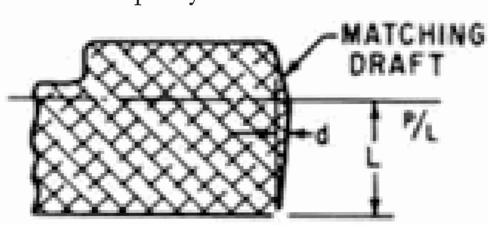


Fig. 6

The direction in which draft is applied is governed by location of parting line (**Fig. 5** and **Fig. 6**).

DESIGN CONSIDERATIONS

Walls and Ribs

NOTE: The following is not to be considered Engineering Standard but rather a guide to good casting design.

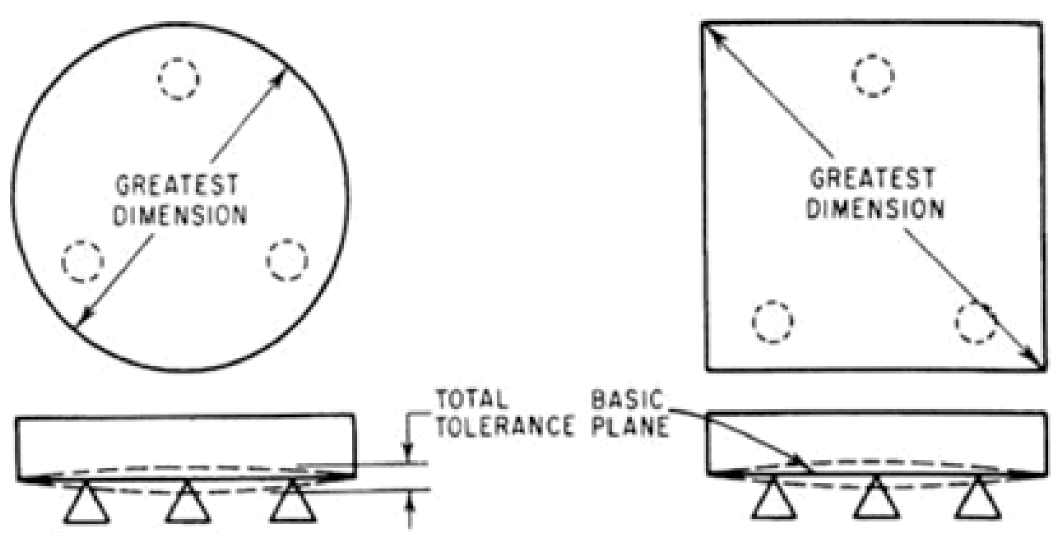
A Production problem of fundamental importance to foundries is establishing a sequence of progressive solidification that will compensate for the change in unit volume as the cast shape solidifies. The designer should, wherever possible, use sections that are tapers to increase in thickness toward points accessible to feed metal. If it is necessary to join light and heavy sections, a gradual increase in thickness is most desirable. If tapered sections are not practical or the increased expense of building the pattern or mold is not warranted, a uniform section should be maintained. Intersection surfaces forming junctions of metal thickness should be joined with fillets in order to obtain improved foundry characteristics and more uniform distribution of stress in service.

Flatness & Straightness

FLATNESS:
Flatness is the condition which exists when all points on a surface lie in the same plane. The surface of castings can be measured for flatness by supporting the surface in question by three widely separated points to establish the basic plane. The flatness variation is the deviation from the plane as measured by coordinate measuring machine dial or indicator.

FLATNESS TOLERANCE:
A Flatness tolerance is the total deviation permitted from a plane and consists of the distance between two parallel planes within which the entire surface must lie.

STRAIGHTNESS:
Straightness is that condition which, when matched with a straight edge of a true flat surface, will permit full contact along the full length.



CONSIDERATION FOR MACHINING CASTING

CONSIDERATION FOR MACHINING CASTING

Many designers/engineers utilize “Geometric Dimensioning and Tolerancing" (GDT) practices. Below are some considerations related to the application of these practices to the machining of aluminum castings (terms that are underlined are defined in the following page).

It is our experience that some explanation of the impact of the use of GDT on parts to be cast and subsequently machined is useful.

A datum feature must be an actual feature of a part. Center lines and center planes are theoretical. They do not exist as features on an actual part and, therefore, may not be used as datum features.

A datum is selected on the basis of its geometric relationship to other features and the functional requirements of the design. For mating parts, it is usually desirable to select corresponding features on each part as datum features to ensure proper interface in assembly.

Datum features must be readily discernible on an actual part, be accessible and be of sufficient size or extent to permit their use for manufacturing and inspection activities.

A casting is typically a framework to hold together places to fasten other components. The cast surfaces are generally secondary in accuracy requirements to the areas machined (threaded holes, reamed holes, milled slots, grooves, surfaces). This leads to the need for two datum reference frames. Selected datum features of castings may be used temporarily for the establishment of machined surfaces to serve as permanent datum features. Such temporary datum features may or may not be subsequently removed by machining. Permanent datum features should be physical elements not appreciably changed by subsequent machining operations.

Datum targets, as applicable on cast or machine surfaces, should be chosen with the following points in mind whenever possible:

- Be a feature on the part
- Be accessible
- Be capable of being clamped properly
- Not be cored surfaces
- Datum targets in any one datum plane should not cross the mold parting line

CONSIDERATION FOR MACHINING CASTING

There are many good reasons, as outlined in ANSI Y14.5-1982, for proceeding in the above manner. Additionally, good machining practices dictate the need for part rigidity during machining which, in turn, requires good fixturing and clamping. Clamping should be done on the ABC datum reference frame targets and in such a manner as to machine as many of the required surfaces as possible. This reduces the number of setups required to complete the part and helps to reduce the amount of variation from casting to casting. Clamping must be sufficient to hold the part in place while resisting machining forces, but not so tightly or on a surface that will cause deflection.

This leads to another major area of concern – true position callouts. Designers understandably want the highest quality possible in the parts they create. This sometimes leads to unrealistically small true position callouts on a drawing.

Experience and observation have shown that a number of factors impact on the ability to hold true position.

- Deflection caused by poor clamping circumstances, flimsy casting structure, machining forces and thermal effects (both the heat treatment of the casting and the ambient temperature conditions during machining versus those in which the casting is used).
- Machine tool capability; a manufacturer may claim repeatability of ±.0002 inch. This may well be true at the time the machine tool was built and under "lab" (non-machining) conditions. Actual manufacturing conditions and age of the equipment can erode this capability considerably.
- Post-machining operations such as plating, anodizing and painting if not properly controlled or anticipated will affect true position (among other things).

Consequently, a true position callout of .002 inch or smaller is typically difficult to achieve. With all of the above in mind, a callout of .005 inch for true position will generally be a far more practical and economical value to use.

CONSIDERATION FOR MACHINING CASTING

Definitions: *(Taken from ANSI Y14.5M-1982)*

DATUM – A theoretically exact point, axis or plane derived from the true geometric counterpart of a specified datum feature. A datum is the origin from which the location or geometric characteristics of features of a part are established.

DATUM REFERENCE FRAME – A system of three mutually perpendicular datum planes or axes established from datum features as a basis for dimensions for design, manufacture and verification. It provides complete orientation for the feature involved.

DATUM PLANE – Theoretically exact plane established by the extremities or contacting points of the datum feature (surface) with a simulated datum plane (surface plate or other checking device).

DATUM FEATURE – An actual feature of a part that is used to establish a datum.

DATUM TARGET – A point, line or small area specified on the part to establish a datum.

TRUE POSITION – A term used to describe the perfect (exact) location of a point, line or size feature in relationship with a datum reference or other feature.

The suggested hierarchy and identification of datum reference frames and their constituents are as follows:

“A” DATUM PLANE – The primary datum plane consisting of datum targets A1, A2 and A3.

“B” DATUM PLANE – The secondary datum plane consisting of datum targets B1 and B2.

“C” DATUM PLANE – The tertiary datum plane consisting of datum target C1.

“A”, “B”, “C” (ABC) datum planes are mutually perpendicular, are assigned to or utilized with cast features only on an unmachined or machined casting and may be temporary.

“D” DATUM PLANE – The primary datum plane consisting of datum target D1, D2 and D3.

“E” DATUM PLANE – The secondary datum plane consisting of datum targets E1 and E2.

“F” DATUM PLANE – The tertiary datum plane consisting of datum target F1.

DEF datum planes are also mutually perpendicular, are assigned to or utilized with machined features on a machined casting only, are permanent and are typically assigned a “start" dimension corresponding to cast datum features.

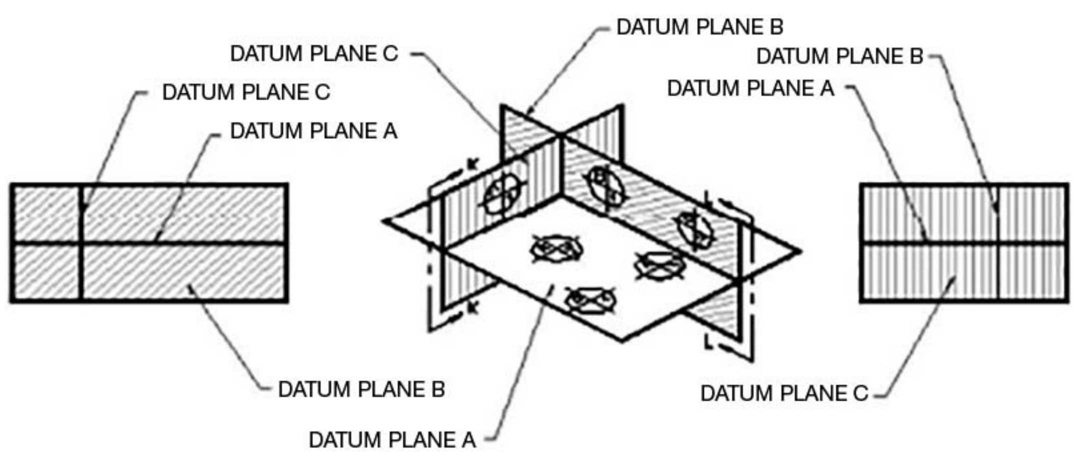
CONSIDERATION FOR MACHINING CASTING

Please be advised that McCann Sales is ready to help any customer in understanding how the above concepts affect the design, manufacture and cost effectiveness of their parts. If there are questions to be answered or issues to be resolved, contact your Project Manager for further information.

A "DATUM" is a feature or group of features of a part, selected for use as a base from which other features or points are located within specified limits.

To achieve consistency in the manner in which measurements are made in all stages of production; i.e., pattern making, casting layout, tooling layout, etc., a system known as target points or datum lines, or datum planes has been devised. For the purposes of this standard, "target point" and "tooling point" are synonymous. This system relates all significant dimensions to a common reference (datum plane). It is strongly recommended that those points or planes from which inspection and/or machining layouts are started, be indicated on the drawing by symbol or other means. Where datum planes or target points are not indicated they shall be selected by the foundry, which will choose surfaces formed by the most stable portion of the mold. Such designations tend to control the accumulation of tolerances in addition to their prime purpose of establishing a common location from which to work. It is preferred that they be surfaces not affected by mold parting. Also, the surfaces at which gates and risers are to be placed are unsuitable as target points as a result of trimming and rough grinding operations. Target points should be avoided if possible on cored or tapered surfaces. They should be located close to the extremities of the casting whenever possible to eliminate variations in alignment due to projecting small surface irregularities.

The designer of a casting, the tooling engineer and the foundry should work together in establishing target points or datum planes because they directly influence casting cost not only from the tooling standpoint but also from the foundry standpoint.



Schematic illustration showing the perpendicular relations among the three planes in a system.

HEAT TREATMENT

HEAT TREATMENT

Heat Treatment of Aluminum Sand & Permanent Mold Castings

Heat Treatment: is the controlled heating and cooling of metals to alter their physical and mechanical properties without changing the product shape.

Heat Treatment is often associated with increasing the strength of material, but it can also be used to alter certain manufacturability objectives such as improve machining, improve formability, restore ductility after a cold working operation. Thus it is a very enabling manufacturing process that can not only help other manufacturing process, but can also improve product performance by increasing strength or other desirable characteristics.

Following are thermal treatment designations (tempers) and what they specify. For aluminum castings, "–T" designates thermal treatment and is always followed by one or more digits that indicate specific sequences of basic treatments. A second digit indicates a modification of the heat treatment to obtain specific properties.

F – As-cast.

O – Stress relieve or anneal.

T4 – Solution heat treat and quench.

This is an unstable treatment. While it improves mechanical properties (such properties increase through aging at room temperature over a period of weeks), it is a usual practice to artificially age to attain maximum mechanical values.

T5 OR T51 – Artificially age.

This type of heat treatment is done at a comparatively low temperature and serves to eliminate growth of thermal cycle. It also is used to stabilize castings dimensionally (improving mechanical properties somewhat) to improve machinability and to relieve stress.

T6 OR T61 – Solution heat treat, quench and artificially age.

Such heat treatment results in maximum tensile and yield strengths with adequate elongation. Aging stabilizes the properties.

T7 OR T71 – Solution heat treat, quench and artificially overage.

This heat treatment improves mechanical properties to a large degree, stabilizes the castings, and usually results in a slightly lower tensile and yield strength but an increased elongation value compared to the – T6 series of heat treatments.

HEAT TREATMENT

Quench Process

Cold water is the most common quenching medium. The time interval between removal of material from the furnace and total immersion in the cold water is critical and should be kept to an absolute minimum. Any delay in the transfer will cause a drop in alloy temperature and partial precipitation of alloy elements from solution will occur. The consequence of a slow transfer and partial precipitation is an alloy that is highly susceptible to Intergranular and Stress Corrosion. Similar effects are caused if the temperature of the water is too high. The Quench bath should begin at a temperature not greater than 30°C and should contain sufficient volume of water so as not to raise above 38°C while Quenching. During the Quench, parts should be agitated to ensure an even transfer of heat into the water.

Mechanical Property Limits for Commonly Used Casting Alloys

ALLOY	TEMPER	ULTIMATE (ksi) 1000 PSI	YIELD (ksi) .2% offset	% ELONGATION	HARDNESS BRINELL
Zamac 3	F	41	32	10	82
Zamac 5	F	48	39	7	91
ZA-12	F	59	48	7	105
ZA-27	F	62	55	3.5	122
360	F	46	23	3.5	75
360	F	46	23	3.5	80
413	F	42	19	9	80
Magnesium	F	32-34	20-23	3	50-75
356	F	19	—	2	40-70
356	T5	23	16	—	45-75
356	T6	30	20	3	55-90
A356	T6	34	24	3.5	70-105
319	F	23	13	1.5	55-85
319	T5	25	—	—	65-95
85-5-5-5	F	37	17	30	60
Cast Iron	F	31	—	—	201
304 S.S.	F	65	30	30	—

ULTIMATE STRENGTH AND YIELD STRENGTH

ULTIMATE STRENGTH AND YIELD STRENGTH

Ultimate Tensile Strength

Ultimate tensile strength (UTS), often shortened to tensile strength (TS) or ultimate strength, is the maximum stress that a material can withstand while being stretched or pulled before failing or breaking. Tensile strength is the opposite of compressive strength and the values can be quite different.

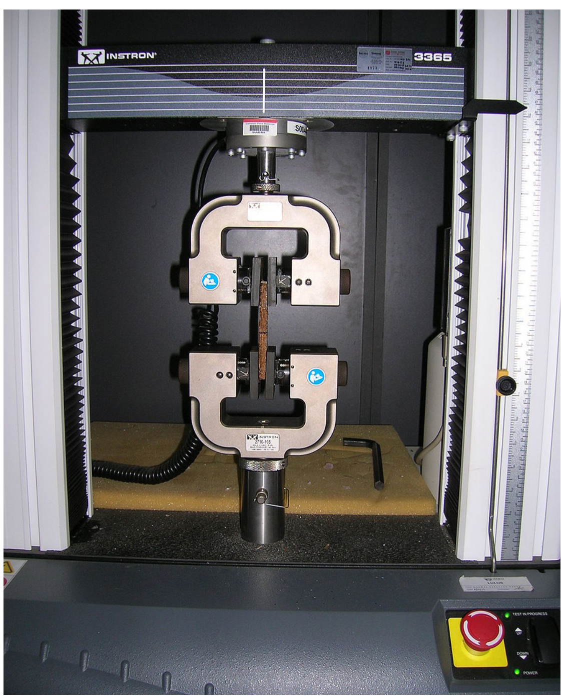
Some materials will break sharply, without deforming, in what is called a brittle failure. Others, which are more ductile, including most metals, will stretch some – and for rods or bars, shrink or neck at the point of maximum stress as that area is stretched out.

The UTS is usually found by performing a tensile test and recording the stress versus strain; the highest point of the stress-strain curve is the UTS.

Yield Strength

The yield strength or yield point of a material is defined in engineering and materials science as the stress at which a material begins to deform plastically. Prior to the yield point the material will deform elastically and will return to its original shape when the applied stress is removed. Once the yield point is passed, some fraction of the deformation will be permanent and non-reversible.

In engineering, the transition from elastic behavior to plastic behavior is called yield.



← Two vices apply tension to a specimen by pulling and stretching the specimen until it fails. The maximum stress it withstands before failing is its Ultimate Tensil Strength.

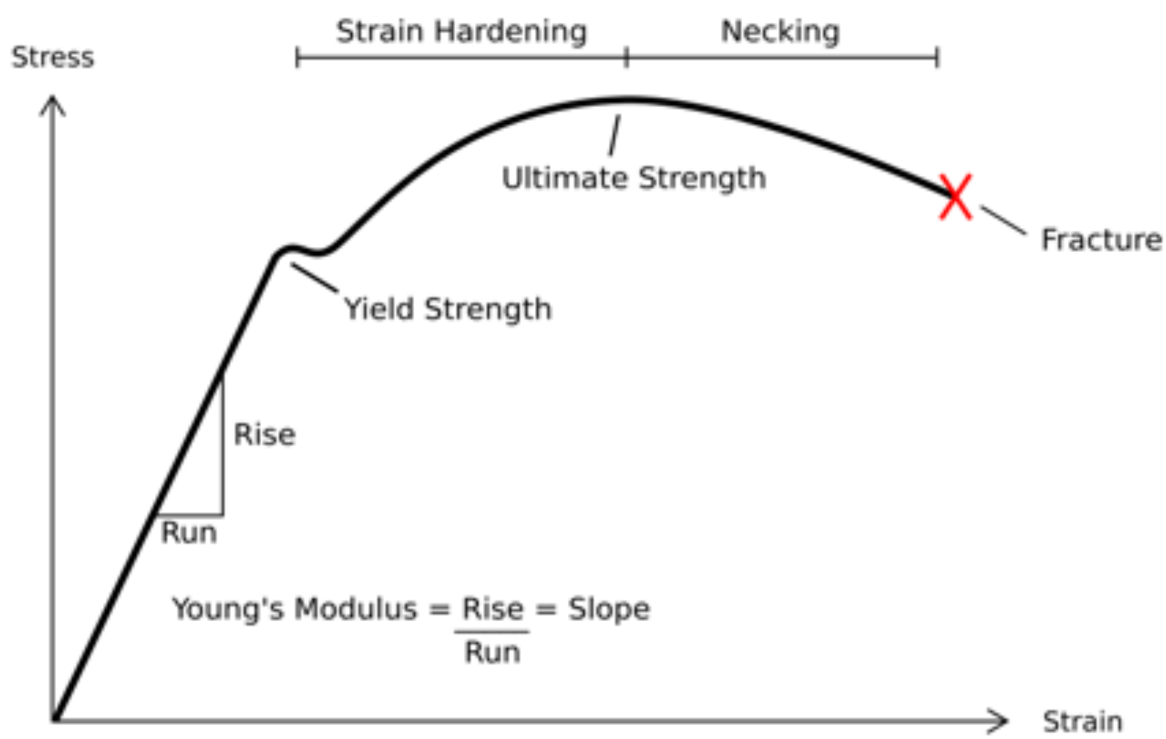
Round bar test specimen after tensil test.

↓

ULTIMATE STRENGTH AND YIELD STRENGTH

The initial slope is where stress is directly proportional to strain (like a spring) and the material behaves like this up to its elastic limit where it reaches its yield strength.

Beyond this the material deforms permanently (like an overstretched spring that won't return to its original shape). The material then becomes strain hardened until you reach the ultimate strength and necking starts to occur and the material becomes weaker again until it breaks apart.



GLOSSARY OF TERMS

GLOSSARY OF TERMS

AIR SETTING – the characteristic of some materials, such as refactory cements, core pastes, binders, and plastics to take permanent set at normal air temperatures: as opposed to thermal setting.

ALLOY – A substance having metallic properties and composed of two or more chemical elements of which at least one is a metal.

ANNEALING – Generally a heat treatment to soften metals; for iron and steel, consists of heating above the critical temperature followed by slow cooling usually in the furnace.

ANODIZING – To subject a metal to electrolytic action as the anode of a cell in order to coat with a protective or decorative film.

"AS CAST" CONDITION – Casting without subsequent heat treatment.

BACK DRAFT – Reverse taper which would prevent removal of a pattern from a mold.

BENTONITE – The clay used as a binder in compound sands for the foundry for increasing both green and hot strength.

BINDER – A material, other than water, added to sand to bind particles together, sometimes with the aid of heat.

BLASTING – A cleaning process for metal parts by the use of tumbling or high pressure air blasting, which throws abrasive particles against the surface of the part. There are different types of blasting each using their own medium. Grit blasting utilizes irregular particles of metal. Sand blasting utilizes sand. Shot blasting utilizes steel balls.

BLIND RISER – A riser that is not open to the exterior of the mold.

BLISTER – A surface defect or eruption caused by expansion of gas, usually as a result of heating trapped gas within the casting, or under metal, which has been plated on the casting.

BLOW HOLES – Voids or holes in a casting that may occur due to entrapped air or shrinkage during solidification of heavy sections.

BLOWHOLE – The presence of gas trapped in a mold during solidification causing smooth irregularly shaped cavities in the casting.

BOSS – A heavy piece of metal projecting from the casting.

GLOSSARY OF TERMS

BRINELL HARDNESS – The relative hardness of metals and alloys, determined by forcing a steel ball into a test piece under standard conditions and measuring the surface area of the resulting indentation. Bhn or HB The numerical value assigned to the Brinell hardness of metals and alloys. Also called Brinell number.

BRITISH THERMAL UNIT (BTU) – The quantity of heat required to raise the temperature of one pound of water from 60° to 61°F at a constant pressure of one atmosphere.

BURN–OUT – Firing a mold at a high temperature to remove pattern material residue.

BURNISHING – The smoothing and polishing of a metal surface by rubbing or tumbling in the presence of metallic or ceramic balls, and in the absence of abrasives.

CASTABILITY – The relative ease that a molten metal flows through a die or mold. More generally, the relative ease that a casting can be made with a particular alloy.

CASTING YIELD – The weight of casting or castings divided by the total weight of metal poured into the mold, (expressed as a percent).

CAVITY – The recess in the die in which the casting is formed.

CAVITY BLOCK – The portion of the die–casting die into which most, if not all, the cavity is formed. There are usually at least two cavity blocks in each die set.

CAVITY FILL TIME – That period of time required to fill the cavity with metal after the metal begins to enter the cavity.

CENTER LINE SHRINKAGE – Shrinkage or porosity occurring along the central plane or axis of a cast part.

CHECKING – Heat–crazing of a die surface, especially when subjected to repeated heating by molten alloys at high casting temperatures. The resulting fine cracks produce corresponding raised veins on die–castings.

CHILLS – Metal inserts in molds or cores at the surface of a casting or within the mold, which serve to accelerate solidification of heavy sections and cause the casting to cool at a uniform rate.

CLUSTER – A group of expendable patterns on sprue and runners for casting purposes.

CO^2 PROCESS – Molds and cores made with sand containing sodium silicate are instantly hardened by permeating the sand with carbon dioxide gas.

GLOSSARY OF TERMS

COINING – A press metal working operation, which establishes accurate dimensions of flat surfaces or depressions under predominantly compressive loading.

COLD-CHAMBER MACHINE – A die–casting machine designed so that the metal chamber and plunger are not continually immersed in molten metal.

COLD SHOT – Small globule of metal embedded in, but not entirely fused with the casting.

COLLAPSIBLE CORE – A metal insert made in two or more pieces to permit withdrawal from an undercut mold surface.

COMBINATION DIE – A die with two or more different cavities each producing a different part.

CONTINUOUS CASTING – A process for forming a bar of constant cross–section directly from molten metal by gradually withdrawing the bar from a die as the metal flowing into the die solidifies.

COPE – Upper most or top section of a flask, mold or pattern.

CORE BLOW – A gas pocket in a casting adjacent to a cored cavity and caused by entrapped gases from the core.

CORE BOX – Wood, metal or plastic structure containing a shaped cavity into which sand is packed to make a core.

CORE CAVITY – the cavity produced in a casting by use of a core.

CORE PIN – A core, usually of circular section. Core pins are hot work tool steel pins, usually H–13, used for a core hole in a die–casting die and may be fixed or movable. A core is made from a core pin.

CORE PLATE – The plate to which the cores are attached and which actuates them. Also heat resistant plates used to support cores while being baked.

CORE PRINT – Projections attached to a pattern in order to form recesses in the mold at points where cores are to be supported.

CORE SLIDE – Any moving core.

CREEP – The flow or plastic deformation of metals held for long periods of time at stresses lower than the normal yield strength.

CREEP STRENGTH – The constant nominal stress that will cause a specified amount of creep in a given time at a constant temperature.

GLOSSARY OF TERMS

CRUCIBLE – A pot or receptacle made of refractory materials such as high temperature resisting alloys, graphite, alundum, magnesia, or silicon carbide, bonded with clay or carbon and used in melting metal.

CUT OFF – Removing casting from sprue by band saw, refactory wheel or torch.

DAMPING – Ability of material to dampen vibration in components and thus lower noise levels.

DEBURRING – The removal of burrs, sharp edges or fins by mechanical, chemical, electrochemical or electrical discharge means.

DEGASSING – A fluxing procedure used for aluminum alloys in which nitrogen, chlorine, chlorine and nitrogen, and chlorine and argon are bubbled up through the metal to remove dissolved hydrogen gases and oxides for the alloy.

DENSITY – The mass per unit volume of a substance, usually expressed in grams per cubic centimeter or in pounds per cubic foot.

DIE CAST SKIN – The metal on the surface of a die casting, to a depth of approximately .020in.
(0.8 mm), characterized by fine grain structure and freedom from porosity.

DIE CAVITY – The impression in a die into which pattern material is forced.

DIE LIFE – The number of usable castings that can be made from a die before it must be replaced or extensively repaired.

DIE RELEASE – Die coating to improve casting surface quality and facilitate removal from die.

DRAFT – The taper given to cores and other parts of the die or mold cavity to permit easy ejection of the casting.

DRAG – Lower or bottom section of a mold, flask, or pattern.

DROSS – Metal oxides in or on the surface of molten metal.

DUCTILITY – The property permitting permanent deformation without rupture in a material by stress in tension.

ELONGATION – Amount of permanent extension in the vicinity of the fracture in a tensile test, usually expressed as a percentage of original gage length. (e.g. – 25% in two inches)

FERROUS – Metallic materials in which the principal components is iron.

GLOSSARY OF TERMS

FILLET – Curved juncture of two surfaces; e.g., walls that would otherwise meet at a sharp corner. May be of wax, plastic, leather or wood.

FIXTURE – Any apparatus that holds a part, such as a die casting, firmly in a predetermined position while secondary operations are being performed on the part.

FLASK – Metal or wood frame, without a top and without a fixed bottom, used to hold the sand of which a mold is formed, usually consists of two parts, the cope and drag.

FLASH – The thin web or fin of metal on a casting occurring at die partings, air vents, and around movable cores. The excess metal is due to the working pressure and operating clearances in the die.

FLOW LINES – Marks appearing on the surface of a casting that indicates the manner of metal flow.

FLUIDITY – Having fluid–like properties. In die–casting: the distance the molten metal will travel through a channel before it freezes, at a given temperature.

FLUX – A substance such as Halide salts used to protect and minimize oxide formation on the surface of molten metal. Also used to re–fine scrap metals.

GATING SYSTEM – The complete assembly of sprues, runners and gates in a mold through which metal flows to enter the casting cavity. Term also applied to equivalent portions of the pattern.

GOOSENECK – In hot–chamber die casting, a spout connecting a metal pot or chamber with a nozzle or sprue hole in the die and containing a passage through which molten metal is forced on its way to the die.

GRAIN – A region within a solidified metal where the crystalline structure of the atoms is relatively perfect. The entire structure of the metal is made up of such grains. During cooling the grains are formed by growing larger from chance joining of atom pairs or from an impurity. As the grains grow they meet each other and the crystalline structure ends at these boundaries.

GRAIN REFINEMENT – The manipulation of the solidification process to cause more (and therefore smaller) grains to be formed and/or to cause the grains to form in specific shapes. The term "refinement" is usually used to mean a chemical addition to the metal, but can refer to control of the cooling rate.

GRAIN STRUCTURE – The size and shape of the grains in a metal.

GRIT BLASTING – Abrasive blasting with small irregular pieces of ferrous or ceramic material.

GLOSSARY OF TERMS

HARD ANODIZING – A variation of the sulfuric acid anodizing process using lower temperatures and higher voltages.

HEAT – The entire period of operation of a continuous melting furnace such as a cupola from light–up to finish of melting. One cycle of operation in a batch–melting furnace.

HEAT TREATMENT – A combination of heating, holding, and cooling operations applied to a metal or alloy in the solid state in a manner, which will produce desired properties.

HOT–CHAMBER MACHINE – A die casting machine designed with the metal chamber and plunger continually immersed in molten metal, to achieve higher cycling rates.

HOT CRACKING – A rupture occurring in a casting at or just below the solidifying temperature by a pulling apart of the soft metal, caused by thermal contraction stress.

IMPREGNATION – The treatment of defective castings with a sealing medium to stop pressure leaks in porous areas.

IMPRESSION – A cavity in a die.

INCLUSIONS – Particles of foreign material in a metallic matrix. The particles are usually com–pounds (such as oxides, sulfides, or silicates), but may be of any substance that is foreign to (and essentially insoluble in) the matrix.

INDUCTION FURNACE – An alternating current electric furnace in which the primary conductor is coiled and generates a secondary current by electromagnetic induction which heats the metal charge.

INGATE – The passage or aperture connecting a runner with a die cavity.

INGOT – A pig or slab of metal or alloy.

LADLE – Metal receptacle frequently lined with refectories used for transporting and pouring molten metal.

MICROPOROSITY – Extremely fine porosity caused in castings by solidification shrinkage or gas evolution.

MISRUN – A casting not fully formed.

MOLD CAVITY – The impression in a mold produced by removal of the pattern. It is filled with molten metal to form the casting. Gates and risers are not considered part of the mold cavity.

GLOSSARY OF TERMS

MOLD WASH – A slurry of refractory material, such as graphite and silica flour, used in coating the surface of the mold cavity to provide an improved casting surface.

MULLING – The mixing and kneading of molding sand with moisture and clay to develop suitable properties for molding.

OXIDATION – The combination of a reactant with oxygen or an oxidizing agent.

PARTING LINE – A line on a pattern or casting corresponding to the separation between the parts of a mold.

PATTERN – A form of wood, metal or other materials, around which molding material is placed to make a mold for casting metals.

PICKLING – Removing surface oxides by chemical or electrochemical reaction.

PITTING – The appearance of small depressions or cavities produced during solidification or corrosion.

PLATEN – Portion of a casting machine against which die sections are fastened, or of trim presses against which trim dies are fastened.

POROSITY – Voids or pores, commonly resulting from solidification shrinkage, air (primarily the nitrogen component of air) trapped in a casting, or hydrogen exuded during electro–plating.

PRESSURE TIGHTNESS – A measure of the integrity of a die–casting in which a fluid under pressure will not pass through the casting. The method of testing and the pressure used must be specified.

RADIUS – A convex arc blending two surfaces of a casting or on a model from which a casting is to be made.

RAPID PROTOTYPING – Production of a full–scale model of a proposed design more quickly and inexpensively than by traditional methods like single–cavity prototype die casting, gravity casting, or machining.

RAT-TAIL – A casting surface defect; an irregular line on the casting, which results from the thermal deformation of a sand mold when it is filled with molten metal.

RELEASE AGENT – A material that is applied to the surface of the die cavity to keep the casting from sticking to the die. Such materials are usually applied frequently, sometimes every shot, and are usually applied by spraying. To facilitate the spraying, the material is mixed with water or a mineral solvent, which evaporates from the cavity surface.

GLOSSARY OF TERMS

RISER – A reservoir of molten metal provided to compensate for the contraction of metal in a casting as it solidifies.

ROCKWELL HARDNESS – the relative hardness value of a metal determined by measuring the depth of penetration of a steel ball (1/16 in. dia. for B scale) or a diamond point (C Scale) with controlled loading, the Rockwell number being the difference between the depth obtained with a minor and a major loading.

SHAKE OUT – the operation of removing castings from the mold. A mechanical unit for separating the molding materials from the solidified metal casting.

SHRINK MARK – A surface depression, often called a shadow mark that sometimes occurs at a thick section that cools more slowly than adjacent sections.

SHRINKAGE – Condition during the solidification of a casting where volumetric shrinkage results in the formation of a void inside the casting.

SLURRY – A flowable mixture of refractory particles suspended in a liquid.

SOLDERING – The sticking of molten metal to portions of the die following casting.

SPRUE – The vertical channel from the top of the mold to the parting line.

STAKING – A cold forming operation to a die–casting. Staking is usually performed in a power press to bend tabs or swage heads onto studs.

STEREOLITHOGRAPHY – A method of rapid prototyping which converts 3–D CAD data into a series of very thin slices and uses a laser–generated ultraviolet light beam to trace each layer onto the surface of a vat of liquid polymer, forming and hardening each layer until the complete, full–size prototype is formed.

STRENGTH, ULTIMATE TENSILE – The maximum tensile (pulling) stress a metal can stand, before rupturing.

STRESS RELIEVING – A process of reducing residual stresses in a casting by heating the casting to a suitable temperature and holding for a sufficient time. This treatment may be applied to relieve stresses induced by casting, machining, welding, or other processing.

SURFACE FINISH – Generally refers to the roughness of a machined surface, numerically stated as the root–mean–square height of irregularities in micro inches.

TENSILE YIELD STRENGTH – The stress at which a material exhibits a specified deviation from proportionality of stress and strain. An offset of 0.2% is used for die casting alloys.

GLOSSARY OF TERMS

TRIM DIE – Die for shearing or shaving flash from a part after die–casting. Either the trim die is forced over the casting, or the casting is forced through the die.

TUMBLING – A surface finishing process for die–castings in which a batch of castings is placed in a rotating horizontal barrel or a vibratory hopper containing polishing media.

UNDERCUT – A recess in the sidewall or core hole of a casting so disposed that a slide or special form of core, such as a knockout, is required to permit ejection of the casting from the die.

UNIT DIE – A die interchangeable with others in a common holder having two or more recesses for individual dies.

VENT – A small opening or passage in a mold or core to facilitate escape of gases when the mold is poured.

VOID – A large pore or hole within the wall of a casting usually caused by solidification shrinkage or gas trapped in the casting. Also, a blow hole.

ZA – A designation followed by a number, which is used to designate a group of three zinc based casting alloys. The number indicates the approximate nominal aluminum content.

ZAMAK – An acronym for zinc, aluminum, magnesium and copper, used to designate the zinc alloys 2, 3, 5 and 7.