Metal casting is an important component of industrial production. It allows for the creation of near-net shape or near-finished products, decreasing the amount of material removed to make a finished product. Being such an important aspect of industry, many different approaches have been developed for the casting of metal. The following is intended to be a short overview of a number of processes used for the casting of both ferrous and non-ferrous metals.

Melting – To cause a phase transformation from a solid to a liquid state.

Cupola – The basic structure consists of a tower with an opening at the top. A charge that contains both the metal to be melted and the fuel is loaded into the tower. Air is blown in through passages in the side called tuyeres and the charge is refilled from the top. The metal melts in the area near the tuyeres and collects at the bottom of the cupola to be tapped.

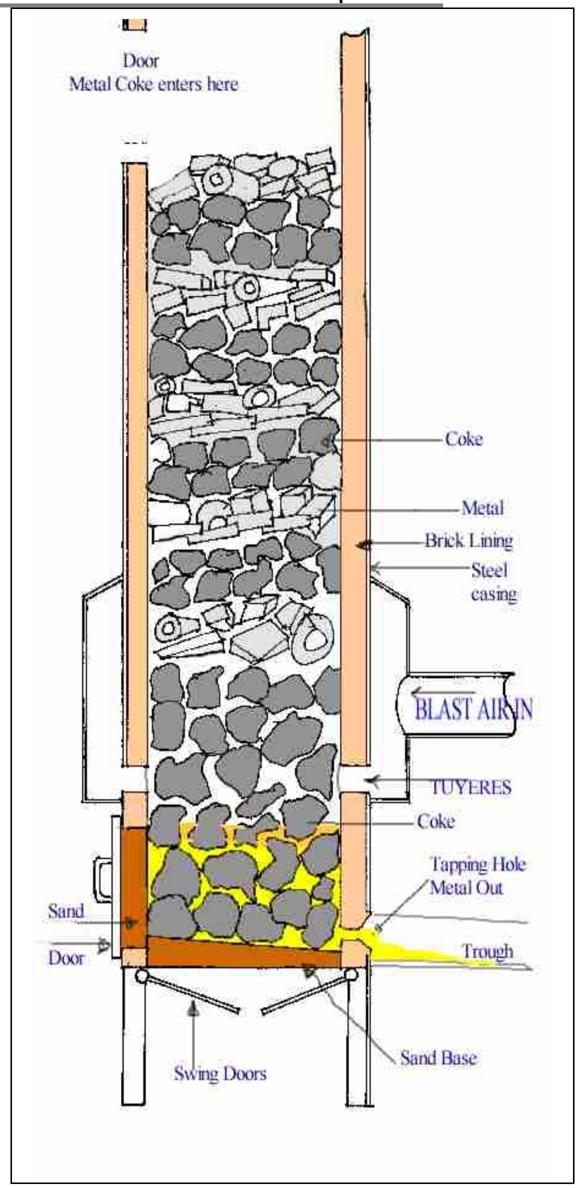

Figure 1. Cupola Furnace Illustration.

Blast furnace – This process is similar to a cupola but much larger and most often used for reducing iron ore into pig iron. Oxygen is blown in from the sides lower in the furnace; the charge is introduced from the top. As the iron ore is reduced, the liquid iron flows down to the bottom of the furnace where it is tapped. This can then be sent to a basic oxygen furnace to be made into steel.

Oxy-fuel furnace* – Any furnace that uses the burning of natural gas, acetylene, propane or a variety of other fuels provide heat for melting. Used often for small amounts of low melting point metals. An example of this

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would be the furnace used for the aluminum pours or the forge in the MTU foundry.

Reverberatory furnace – Hot gas from the combusted fuel is forced over the charge material. The furnace is also shaped in such a way that the refractory reflects some of the heat onto the charge as well. The charge material and the fuel are separate.

Electric arc furnace – Can be DC or AC. Large AC furnaces typically have three carbon electrodes that a high voltage current is passed through. A plasma arc is developed between the electrode and either the other electrodes or the charge material. The arc can reach tens of thousands of degrees at its center providing the heat for melting the charge. DC operates in similar manner but the current passes through the charge into an anode in the base of the furnace. Electric arc furnaces are typically used to melt scrap metal in mini-mills.

Induction furnace* – Current carrying coils are embedded in a refractory material. The coil is water cooled. The current in the wire is oscillated which induces a magnetic field in the charge material. The metal in the charge is heated as the electrons move in response to the changes in the magnetic field. Examples of this would be the furnaces used for iron pours and the furnace in the vacuum caster.

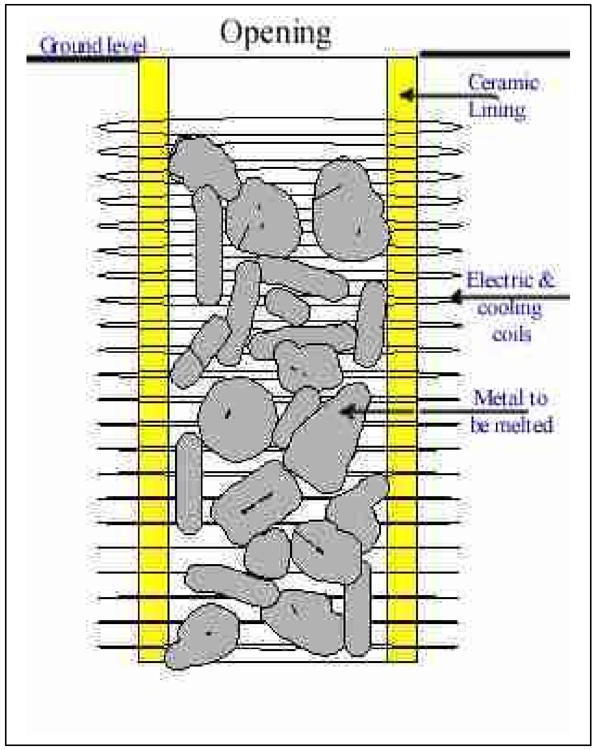

Figure 2. Coreless Induction furnace with charge.

Resistance furnace* – A current is passed through a wire or ribbon, made of Nichrome for example, increasing the temperature of the wire through ohmic heating. The heat produced by this is used to melt the charge. Commonly used for table furnaces or ovens. An example of this would be the furnaces in the heat treat lab or common space heaters.

Electro-slag re-melting – Process where an already cast ingot is slowly introduced into a

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molten slag pool. As the ingot is melted by the slag small droplets of metal separate and fall through the slag layer and recombine and solidify at the bottom of the furnace. Falling through the slag layer allows for any inclusions to move out of the droplet. This process is used to produce very clean ingots of material.

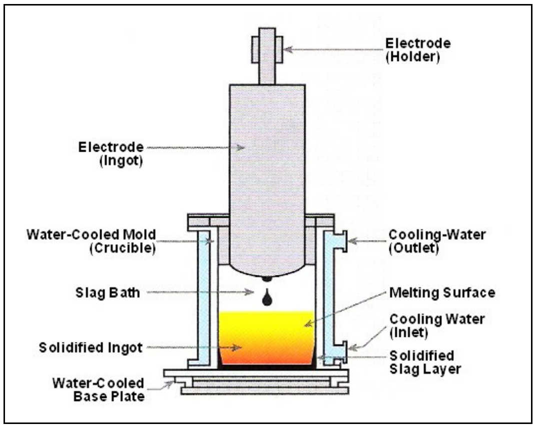

Figure 3. Electro-slag re-melt furnace.

Electric Glo-bar Furnace – A silicon carbide rod heats as a current is passed through it. This type is not normally used for melting but for use in holding furnaces.

Any number of these processes can usually be combined, often to aid in efficiency. For instance, oxy-fuel burners can be used to preheat metal in an electric arc furnace. Though the use of the burners would be impractical to completely melt the charge, the combination of the two helps to decrease melt times and save money.

Casting – The process of solidifying a liquid into a solid in a desired shape.

Permanent mold* – A permanent mold is able to be used multiple times. Typically they are made from steel and used with metals with lower melting temperatures. A permanent mold also allows for shorter solidification times due to the higher thermal conductivity of the mold material.

Die casting* – A permanent mold is filled with a “shot” or measured amount of metal. The metal is kept in a reservoir and loaded into an area where a plunger can then push the metal into the

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die. The die consists of a permanent mold that may be cooled.

Semi-permanent – Mold is made with sections made of green or chemically bonded sand and sections of permanent mold material.

Spin casting – Pattern is spun as metal is introduced into the mold. This helps to fill thin or intricate sections of the casting by increasing the force driving the metal into the mold.

Squeeze casting – Pressure is applied to a permanent mold as the liquid solidifies, to help prevent porosity. Often used for parts requiring little to no porosity, strict dimensional tolerances and a good surface finish.

Low Pressure/Vacuum/Inert atmosphere casting* – metal is heated and poured while under low pressures to avoid oxide formation or the surrounding atmosphere is displaced by an inert gas.

Spray Casting – A stream of liquid metal is atomized by a fast flowing gas, which also propels the metal toward the mold surface. This is done in a protective atmosphere to prevent oxidation of the droplets.

Continuous casting – Metal is poured into a liquid cooled permanent mold, as the liquid in contact with the mold walls solidifies it is moved out of the mold. More liquid metal is introduced as the solidified metal exits the mold.

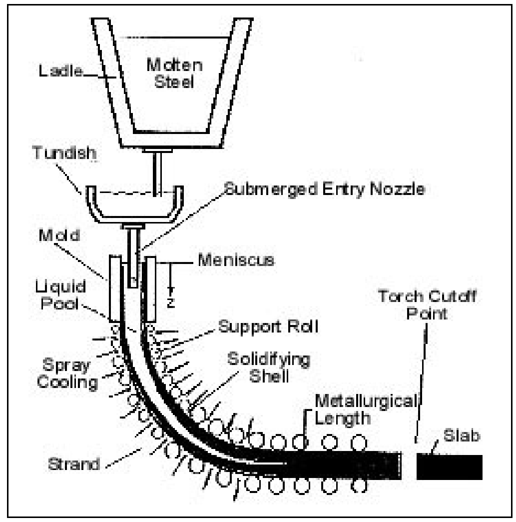

Figure 4. Continuous casting illustration.

Semi-continuous casting – Similar to continuous casting but after a certain length is reached, casting is halted and the equipment is reset for the next cast.

Slip casting – Liquid metal is introduced into a mold. Using the estimated solidification time of the material, a shell of a certain thickness can be predicted and the remaining liquid metal is removed when the proper thickness has been achieved.

Thixocasting/Rheocasting/Slurry casting – These processes uses alloys with a large solidification temperature range. As the metal begins to

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solidify, it is introduced into the mold where the remaining liquid is allowed to solidify. Thixocasting differs slightly, instead of heating the metal into a fully liquid state; it is heated midway into the temperature range for solidification. The result is still a mixture of solid and liquid metal, but heating costs are reduced.

Investment casting/Lost pattern* – Casting process where a pattern is made from a wax or other material that can be melted and is then covered with an investment of ceramic, sand or other suitable material. The wax is then melted and/or burned out of the pattern, which may also serve to cure the mold. The melt is then poured into the cavity created. Depending on the thickness and strength of the investment the pattern may be supported by sand in a flask. Investment casting can usually be divided into shell molding or solid molding. In shell molding, the investment is built up from successive layers of ceramic and a ceramic slurry binder. While in solid molding, a ceramic mixture is poured around the pattern in a container and left to harden.

Lost foam* – A variant of investment casting, a pattern is made in a permanent mold using polystyrene beads that are expanded with heat. These patterns have gating glued on and a ceramic coating applied. The pattern is packed in sand and the metal poured in. As the metal fills the mold the foam is vaporized and escapes out through the sand, while the ceramic helps to keep the surrounding sand in place. Differs from investment casting by the pattern remaining until metal is poured in.

Counter-gravity Casting – An open mold is inverted over the metal source and pressure is used to force the metal up into the mold. This allows for more control while filling the mold than typical gravity cast processes. The mold itself can be made using a variety of methods.

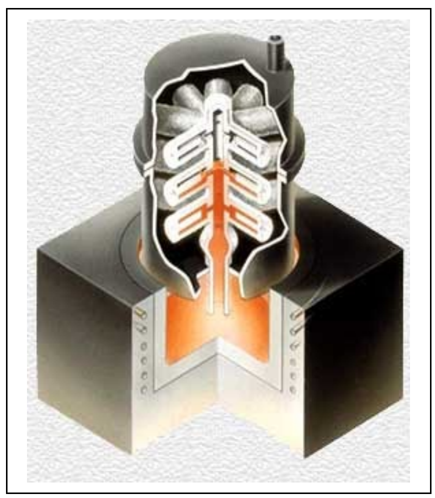

Figure 5. Diagram of a countergravity casting cell.

Resin Shell Molding – This process uses sand that has been coated with a thermosetting resin. A metal pattern is heated, coated with a

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releasing agent and the sand is poured over the pattern. The pattern heats the sand which first softens the thermoset, then cures it. The excess sand is then removed and the shell that is formed is prepared for casting.

Ribbon casting – This method of casting is used to produce a continuous strip of the cast material. A stream of metal is poured onto a cooled drum that rapidly cools the metal resulting in a very fine grain structure or amorphous structure.

Plaster/Ceramic Molding – Similar to solid investment casting, but instead of a solid mold different faces of the pattern are made and the molds placed together to make the complete mold cavity.

Directional/single crystal – Direction solidification results in a structure with grain boundaries parallel to the direction of solidification. Single crystal castings have no internal grain boundaries. Both directional and single crystal castings can be produced by having a surface for heat extraction contacting the molten metal. For directional solidification this can be a simple plate, whereas a single crystal would have a grain selector or seed crystal to produce the desired orientation.

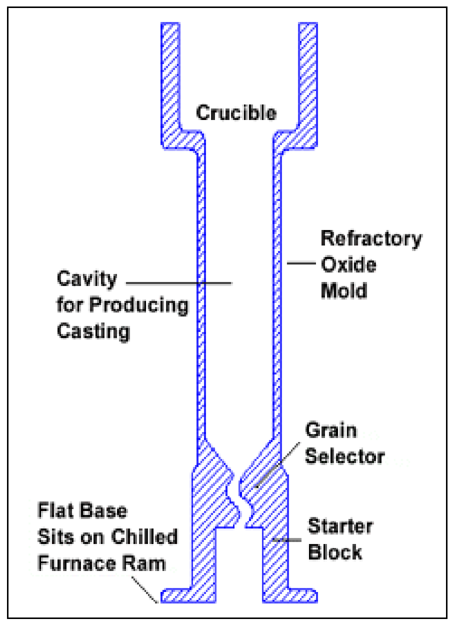

Figure 6. Diagram of a single crystal casting mold.

Sand casting* – The melt is poured into a mold made of packed sand. The sand can be made of a wide range of materials such as silicon dioxide,

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zirconium dioxide or chromium oxide. The binding addition can also vary widely. Binders typically consist of clay and either water or oil. The mold sand can also be mixed with different chemical binders.

Skin Dried Molding
Uses a heat source, such as a propane torch, to remove moisture from the surface of a green sand mold, usually for large ferrous castings.

Dried Sand Molding
Mold moisture is evaporated out of the sand after it has been molded, often used with a petroleum binder.

Cold Box Molding
Sand that has been covered in a chemical binder is blown into a mold. The mold then has a gas catalyst passed through it which activates and cures the binder.

No-bake Chemically bonded
A liquid binder and catalyst are mixed with the sand and packed into the mold. The binder sets and a solid sand pattern results.

Squeeze Molding
A hydraulic or pneumatic ram with the mold pattern on the face, is used to pack the mold sand into a flask.

Sand Slinger - Throws the mold sand into a flask. This fills and packs the mold sand against the pattern in the flask at the same time.

Impact/Impulse Molding
Impact or impulse molding is used to pack the mold sand in a flask by jarring or vibration.

Flask-less Molding
Mold sand is placed in a removable flask then compacted on the pattern. Then the flask is removed. A version of this would be the Disa molding process, where mold sand is compacted between a ram and a swing arm in a stationary flask. Then the mold is pushed out of the flask by the ram, and contacts the previously created mold.

High Density Green Sand
Green sand that is molded with pressures over 100psi is considered high density green sand.

Glossary

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Refractory: Materials used to line the inside of furnaces, composed of a wide range of ceramics. The refractories can either be in direct contact with the charge material and liquid metal or surrounding a crucible to prevent heat loss. These are typically chosen for their relatively low reactivity with the metal being contained, insulation properties, and high melting temperature.

Charge: any combination of materials that will be melted in the furnace.

Thermal Conductivity: Materials property describing the rate at which heat is transferred within a material or from one material to another.

Ferrous: Related to iron and other various alloys with a major constituency of iron.

Non-Ferrous: Materials without iron as a major constituent.

Porosity: The appearance of voids or cavities either in the bulk of a casting or on the surface.

Gravity casting: Any casting process that uses gravity as the driving force to fill the mold with liquid. Most commonly associated with sand casting.

Mold: The cavity that metal will be poured into to achieve the desired shape.

Pattern: An example of the desired final shape, used to produce the mold cavity for casting.

Tundish: Holding vessel for liquid metal that is to be poured into the mold, which is filled from either a ladle or directly from the furnace.

Ladle: Container used for transporting liquid metal.

Crucible: Used to contain metal as it is melted. A crucible is in the furnace with the charge material as the metal is heated.

Holding Furnace: Furnace used to maintain the temperature of material that has already been melting by another process.

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