

# Cupola furnace

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A **Cupola** or **Cupola furnace** is a melting device used in foundries that can be used to melt cast iron, ni-resist iron and some bronzes. The cupola can be made almost any practical size. The size of a cupola is expressed in diameters and can range from 18 inches to 13 feet<sup>[1]</sup>. The overall shape is cylindrical and the equipment is arranged vertically, usually supported by four legs. The overall look is similar to a large smokestack.

The bottom of the cylinder is fitted with doors which swing down and out to 'drop bottom'. The top where gases escape can be open or fitted with a cap to prevent rain from entering the cupola. To control emissions a cupola may be fitted with a cap that is designed to pull the gases into a device to cool the gasses and remove particulate matter.

The shell of the cupola, being usually made of steel, has refractory brick and refractory patching material lining it. The bottom is lined in a similar manner but often a clay and sand mixture ("bod") may be used, as this lining is temporary. Finely divided coal ("sea coal") can be mixed with the clay lining so when heated the coal decomposes and the bod becomes slightly friable, easing the opening up of the tap holes.<sup>[2]</sup> The bottom lining is compressed or 'rammed' against the bottom doors. Some cupolas are fitted with cooling jackets to keep the sides cool and with oxygen injection to make the coke fire burn hotter.

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A cupola furnace in operation at Wayne State University, in Detroit, Michigan

## History

The first known cupola furnace was made by René-Antoine Ferchault de Réaumur around 1720,<sup>[3]</sup> though evidence suggests that this technique was in use in China as far back as the 3rd and 2nd centuries BC.<sup>[4]</sup>

<http://www.staff.hum.ku.dk/dbwagner/cice/cice.html>

## Operation

To begin a production run, called a 'cupola campaign', the furnace is filled with layers of coke and ignited with torches. Some smaller cupolas may be ignited with wood to start the coke burning. When the coke is ignited, air is introduced to the coke bed through ports in the sides called tuyeres.

When the coke is very hot, solid pieces of metal are charged into the furnace through an opening in the top. The metal is alternated with additional layers of fresh coke. Limestone is added to act as a flux. As the heat rises within the stack the metal is melted. It drips down through the coke bed to collect in a pool at the bottom, just above the bottom doors. A thermodynamic reaction takes place. The carbon in the coke combines with the oxygen in the air to form carbon monoxide. The carbon monoxide further burns to form carbon dioxide. Some of the carbon is picked up by the falling droplets of molten steel and iron which raises the carbon content of the iron. Silicon carbide and ferromanganese briquets may also be added to the charge materials. The silicon carbide dissociates and carbon and silicon enters into the molten metal. Likewise the ferromanganese melts and is combined into the pool of liquid iron in the 'well' at the bottom of the cupola.

The operator of the cupola, the 'cupola tender', observes the amount of iron rising in the well of the cupola. When the metal level is sufficiently high, the cupola tender opens the taphole to let the metal flow into a ladle or other container to hold the molten metal. When enough metal is drawn off the taphole is plugged with a refractory plug made of clay<sup>[5]</sup>.

The cupola tender observes the iron through the sight glass for signs of slag formation, which is normal. Most slags will rise to the top of the pool of iron being formed. A slag tap hole, located higher up on the cylinder, and usually to the rear or side of the iron taphole, is opened to let the slag flow out. The viscosity is low (with proper fluxing) and the red hot molten slag will flow easily. Sometimes the slag which runs out the slaghole is collected in a small cup shaped tool, allowed to cool and harden. It is fractured and visually examined. With acid refractory lined cupolas a greenish colored slag means the fluxing is proper and adequate.

After the cupola has produced enough metal to supply the foundry with its needs, the bottom is opened, or 'dropped' and the remaining materials fall to the floor between the legs. This material is allowed to cool and subsequently removed. The cupola can be used over and over. A 'campaign' may last a few hours, a day, weeks or even months.

When the operation is over, the blast is shut off and the prop under the bottom door is knocked down so that the bottom plates swing open. This enables the cupola remains to drop on to the floor or into a bucket. They are then quenched and removed from underneath the cupola.

#### Cupola and Cupolet operation. small furnaces for short runs CUPOLA VRS CUPOLET

Both are the same in most respects from the tuyeres down. The cupolet is short and has a lid to maintain pressure and heat inside the furnace. The cupola has a tall stack and no lid. The operation varies only in how the furnace is charged. The cupolet is a batch melter. The iron charge is bashed very small and the full amount of metal to tap can be charged at one time. When charging be sure not to let the coke bed get too low. If the tap is 100lbs you can often charge the full amount all at one time or as much as will fit in the furnace. Watch the tuyeres as the iron rains and when it stops its time to tap. The cupola is charged in smaller amounts in sequence. If the tap is 100lbs then charge 25lbs iron then 5lbs coke then iron then coke etc. To know when to tap keep time with the charges. Usually 7-10minuts to melt a charge. Mark the time of the first iron charge and watch the tuyeres for the first drops iron. This will give you an idea of how fast you are melting. The slag hole is often used to determine when to tap. As the well fills with iron the slag will run. When iron runs from the slag hole the well is full and the furnace is taped. Conversely cupolets don't always have a slag hole. After a tap the tap hole is left open to run off the slag. Be sure not to over fill a furnace with no slag hole or iron and slag will pour into the wind box.

**AIR** As a general rule of thumb, more is better. If there is any doubt you probably need more. 2 or 3 electric or gas leaf blowers (gas is not recommended due to the fact that you have GAS at an iron pour) would be ok to use on a 16inch furnace. Squirrel cage blowers are no good. Pressure is critical not just volume. In general, for a 16inch bore furnace, 600-900 CFM and 2+ inches of water. (as read on a manometer). Default to more air.

**BOTTOM SAND** Use sand with a little clay mixed in to pack the bottom. Ram the sand so that it slopes to the tap. In some cupolas the sand slopes from the height of the slag hole to the tap hole. However! A steep slope greatly increases the hydraulic pressure at the tap hole and bots have been known to break out. This can happen at any moment. Use anything you want just be sure the sand cannot run out the bottom like an hourglass.

**COKE** When loading the furnace before burn in use softball size coke (bed coke) and fill to the tuyere level. Then use coke about half that size to fill the rest. Be sure to make room at the tap for burn in and taping. Build a cave at the bottom and also at the tuyeres. Always avoid blocking holes.

**BURNING IN** The burn in is the most critical time of the iron pour other than the tap. Almost all the problems that might arise are often linked with a poor burn in. burning in with a gas burner (propane or other) is the easiest way. It allows you to make the coke bed just right and if dun well will not burn away a lot of coke as the furnace reaches temperature. Start every burn in with the burner in the tap hole. Be patient as it

can take a long time. The burn-in is not just to light the coke, its also to soak the furnace with heat. Watch the tuyeres and note the color of the coke. When the coke is bright orange or yellow you may turn on the blast and remove the burner. NEVER EVER put iron in the furnace until the coke is too bright to look at with the naked eye. Even then the furnace may need time to soak with heat. If iron is charged to soon it will melt and freeze in the well. The furnace needs to be hot enough to melt iron and hotter to keep it liquid until the tap. During the initial burn-in the center of the coke may be yellow and the coke near one or more tuyeres may be cold. The blast can be turned on with the tuyeres open and the burner can be held in the cool tuyere. Do this until all the tuyeres are evenly hot and then close the tuyeres. Start with lower blast volume as to not blow out the fire. In a pinch a furnace can be started with wood or charcoal. Brickets make a lot of ash and it can cause clogging. Hard wood charcoal is preferred, its hotter and isn't so ashy. Burring in with wood or charcoal prevents you from packing the bed so watch out for obstructions in the well and tuyeres.

**TUYERES** Keep them clear and free of slag and coke. If there is glass in them be sure to open them the moment there is no blast air this is less critical with non glass. Also the tuyeres stay open whenever the blast air is off, except for short times during charging and taping etc. Opening the tuyeres prevents the build up of explosive gases. It also prevents the furnace heat from breaking the glass.

**FLUX** About a 1/2 lb to every 100lbs of iron. Bash it small and charge it before the iron. It cleans the iron and helps to remove silica. Flux makes the slag flow and helps later when cleaning out the furnace by making the slag easier to brake out.

**CHARGE** In general the furnace should be charged as soon as there is room to do so, iron then coke. If time is needed between taps just replenish the coke that burns. Often the blast is turned off for charging. Bash the iron small. The largest chunk of iron should be no bigger than the size of a serving spoon. Never try to melt sprew cups or thick things. Cupolas can melt bigger chunks than cupolets.

**TAP** The furnace should be taped as fast as is safe. A well-run furnace should be able to be taped with a hand-spike and a hammer. Also a pointy length of rod is good. When taping, hold the ladle on its side to avoid getting crumbly bot in it as the tap is cleared. Always tap in an upward or level direction to avoid breaching the bottom sand. Never ever tap down ward. Quite often the tap needs to be poked a bit after the iron starts flowing to clear slag and obstructions.

**BOTOM DROP** Lookout it's hot!

<http://picasaweb.google.com/ironguild/CupolaCatalog#>

## Quality Control

During the production, samples may be taken from the metal and poured into small molds. A chill wedge is often poured to monitor the iron quality. These small, approx 18 mm (3/4") wide x 38 mm (1-12") tall triangular shaped pieces are allowed to cool until the metal has solidified. They are then extracted from the sand mold and quenched in water, wide end first. After cooling in the manned the wedges are fractured and the metal coloration is assessed. A typical fracture will have a whitish color towards the thin area of the wedge and grayish color towards the wide end. The width of the wedge at the point of demarcation between the white and gray areas is measured and compared to normal results for particular iron tensile strengths. This visual method serves as a control measurement.

## References

- <sup>^</sup> Intelligent Control of Cupola Melting, E.D. Larsen, Et. All, Lockheed Martin Idaho Technologies Company, June 1997[1]
- <sup>^</sup> Kirk, Edward (1899). "Cupola management". *Cupola Furnace - A Practical Treatise on the Construction and Management of Foundry Cupolas*. Philadelphia, PA: Baird. p. 95. OCLC 2884198.
- <sup>^</sup> Encyclopedia Britannica
- <sup>^</sup> Wagner, Donald B. (2001). *The State and the Iron Industry in Han China*. Copenhagen: Nordic Institute of Asian Studies Publishing. ISBN 8787062836.
- <sup>^</sup> [http://www.hdowns.co.uk/hdweb\\_melting\\_page.htm](http://www.hdowns.co.uk/hdweb_melting_page.htm)

## External links

- [Building a Cupola](#)

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