L.3 CAST IRON MELTING IN CUPOLA : ITS DESIGN, OPERATION AND CONTROL

by

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CAST IRON MELTING IN CUPOLA : ITS DESIGN OPERATION AND CONTROL

Cupola is a melting furnace used for melting Cast irons for the production of grey cast iron castings, malleable iron castings and ductile iron castings. The word cupola is the diminutive of the latin word "Cupa" meaning cask, due to the fact that cupola was just like a cask. The first design of the modern cupola was made by John Wilkinson and took patent in 1794. This was followed by several designs by Poumay, Moore, Piwonarsky, Griffin and MBC hot blast cupola.

Advantages

Being most popular melting equipment for cast iron, this is being used by all foundries for the following advantages :

- Low initial cost of investment
- Easily constructed with indigenously available materials
- Operation is simple
- Metal can be made available continuously which is extremely important for mechanised foundries
- Small size units can suffice due to continuous availability of hot metal
- Can compete economically with any other mode of melting

Disadvantages

However, it also suffers from some disadvantages :

- Sulphur and Phosphorous of coke is absorbed by pig iron
- Fluctuation in iron composition
- Erratic swings in hot metal temperature
- Some of the Mn of pig iron combines with S to form MnS
- Some Mn and Si are oxidized by the air blast and the loss is proportional to the amount initially present
- Carbon of the hot metal decreases or increases depending on absorption from coke or oxidation by blast

Capacity of Cupola

One of the most important decisions for a foundry is to decide the capacity of cupola. This can be decided on the basis of the saleable castings per year. To decide the capacity of the cupola, one has to take care of

- 10% rejection
- 40% used for runner and risers (generally 60% yield)
- 10% pigged
- Say for example 1000 tonnes of finished castings are to be produced per year
- Taking into consideration 10% rejection one has to produce 1100 tonnes
- Taking 60% yield, 40% is wasted in runner and risers and 10% pigged so one requires 1100 x 100/50 = 2200 tonnes per year
- Say the casting is done 300 days a year so that metal required will be 2200/300 = 7.33 tonnes per day
- If cupola operates for 5 hours then 7.33/5 = 1.46 tonne/hr
- If cupola operates for 8 hours 7.33/8 = 0.916 so a cupola of 1.5 tonne or 1 ton is enough

Alternatively if a mechanised foundry of 6000 tonnes of castings per year works 5 days a week and 50 weeks per year. Assuming a yield of 60% and 10% rejection, required total liquid metal :

6000/0.9 x 0.6	=	11, 111 tonnes per year or
11,111/5 x 50	=	44.4 tonnes a day

If pouring is done for 8 hours, the capacity of the cupola should be

44.4/8 or 5.6 tonnes/hr say 6T/Hr

However in this case the cupola has to be of continuous tapping type and the liquid metal should continously flow through a front slagging spout to the holding furnace. Also the holding furnace should be of mininimum 10 tonne capacity as also acts as balancing furnace for equalising the chemical composition of the metal.

DESIGN AND CONSTRUCTION OF CUPOLA

The cupola is a tall chimney like structure fabricated in Steel plates and lined with heat resistant bricks. Various parts are shown in Fig. 1.

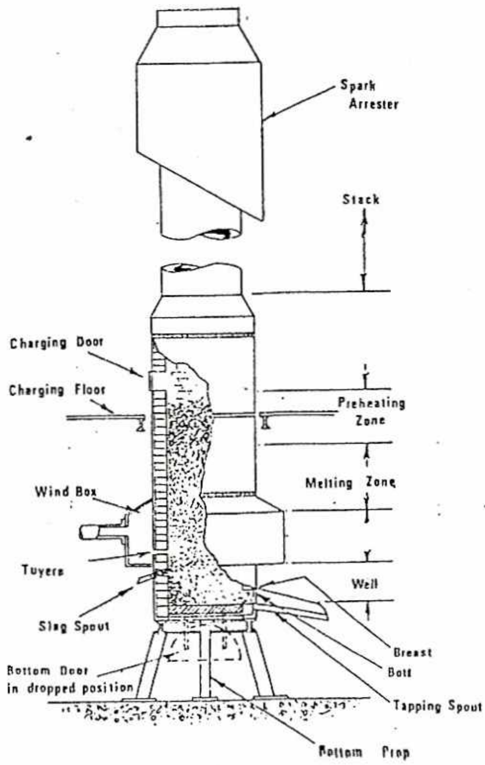


Fig. 1 : The Cupola Furnace

1. Supporting columns 2. Bottom ring or frame 3. Bottom doors 4. Shaft or stack 5. Spark arrester or hood 6. Taphole and spout 7. Slag hole and spout 8. Breast 9. Tuyeres 10. Wind belt 11. Wind pipe or blast 12. Charging door 13. Refractory Lining 14. Bottom Prop

Now let us consider the design aspects one by one.

1. Supporting Columns

Normally cupola is supported on four COLUMNS made of steel fabricated from channel or I Sections. Thickness of section about 6 mm and height approx 1.5 - 2 M.

2. Bottom Ring or Frame

This is a cast iron ring or frame fabricated in steel, on which the cupola shaft or stack is supported. This ring or frame is expected to withstand the total load of shaft, lining and charges and also of the heat from the incandescent charges.

3. Bottom door

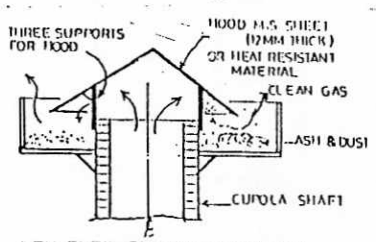
BOTTOM DOOR is used for dropping the bottom of the cupola after the day's heat is completed. Normally it is semicircular in two halves hinged to the bottom frame.

4. Cupola Shaft or Stack

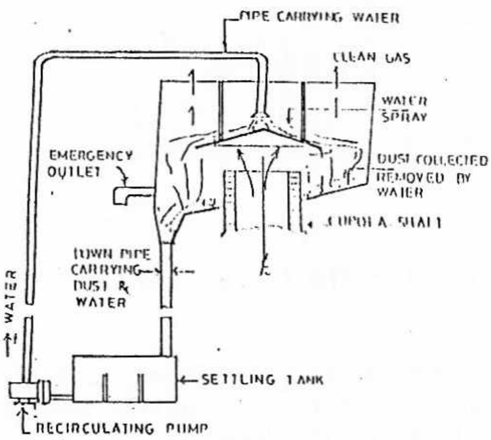
CUPOLA SHAFT is of circular shape made of mild steel plates and acts as the main body of the cupola. The diameter of the shell is the diameter of the cupola plus the refractory lining thickness + 10 mm. Number of mild steel angles are fixed around the inside periphery of the shell at about 600 mm as support to the firebrick lining.

5. Spark arrester or hood

A cover is provided on the top of the cupola to take care of large quantity of burnt material like hot ash, burning cinder, thrown off from the top of the stack. The SPARK ARESTER can be of two type - dry type or wet type as shown in Fig. 2.



DRY TYPE SPARK ARRESTER



WET TYPE SPARK ARRESTER

Fig. 2 : Spark Arresters

Tap hole & Spout

Molten metal can be taken out from cupola continuously or intermittently from tap hole and is known as TAPPING. Intermittently the metal can be tapped out every 10-20 minutes depending on the requirement of the metal and has the tap hole 15-25 mm in dia. In case of continous tapping the tap hole is 10-15 mm dia. The opening in the shell to make the tap hole is kept about 150 mm above the bottom ring or plate. This 150 mm is required to make up the sand bed at the bottom of the cupola. Figure 3 shows the correct and incorrect method of tap hole. Fig. 4 shows the metal spout which is a channel fabricated in steel and lined with firebricks to take out molten metal from tap hole to ladles. The length is generally kept between 600 mm to 1000 mm.

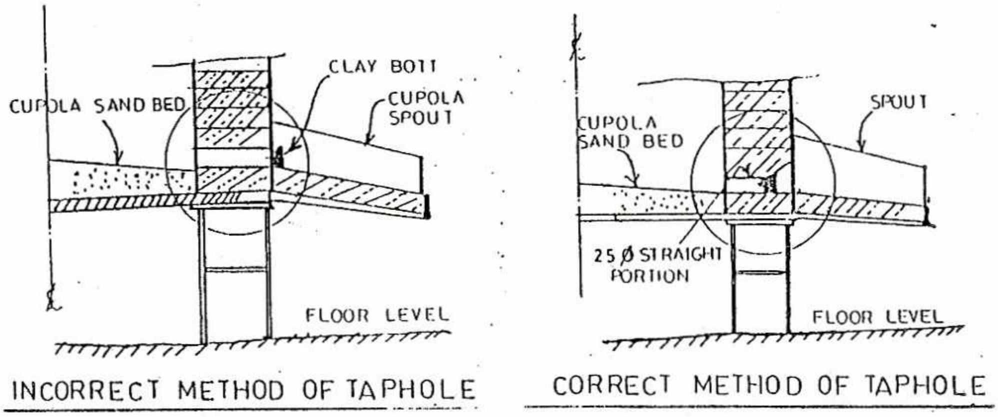


Fig. 3 : Tap Hole

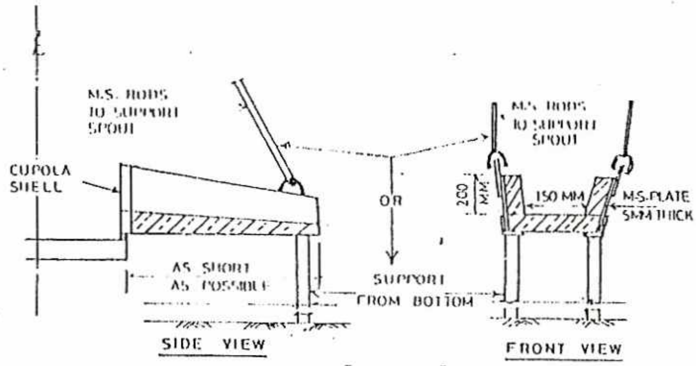


Fig. 4 : Cupola Spout

Slag Spout and Slag hole

Slag formed during melting is taken out through a slag hole which is normally located at the rear side of the cupola. The height of the slag hole from the tap hole depends on whether the cupola is intermittently or continuously tapped. Between tap hole and slag hole the space is known as HEARTH. Volume of metal accumulating in the hearth is $V = 1/2\ [\pi/4\ D^2 H]$ where D is the dia of the cupola and H is the height between tap hole and slag hole.

The height of the hearth should be kept to minimum as it influences the amount of bed coke needed to be charged every time the cupola is operated.

Front Slagging Spout

In some of the continuous tapped cupolas the slag is removed on the tapping spout. Fig. 5 shows one such design.

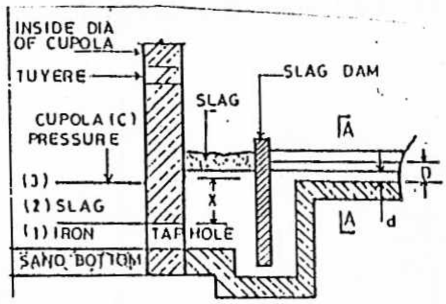


Fig. 5 : Front slagging spout

Cupola Breast

At the bottom of the cupola, an opening called BREAST is left for the purpose of lighting up the bed coke. This is rectangular and is shown in Fig. 6. Normally it is 300 x 300mm for small cupola and 450 mm x 450 mm for bigger size cupola. A plate is put up to close it after the cupola is lighted up.

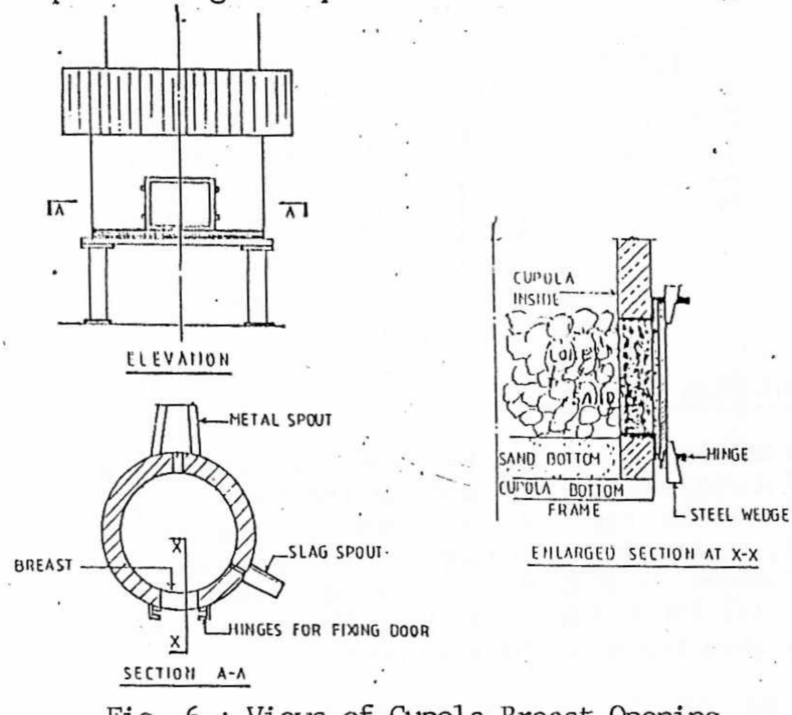


Fig. 6 : Views of Cupola Breast Opening

Tuyeres

These are openings in the cupola for blowing in the air required. for combustion. Proper design and placement of the tuyeres control the metal. Coke ratio, metal tapping temperatures and other operation parameters. As shown in Fig. 7 these tuyeres are circular or rectangular in shape and are flared or tapered.

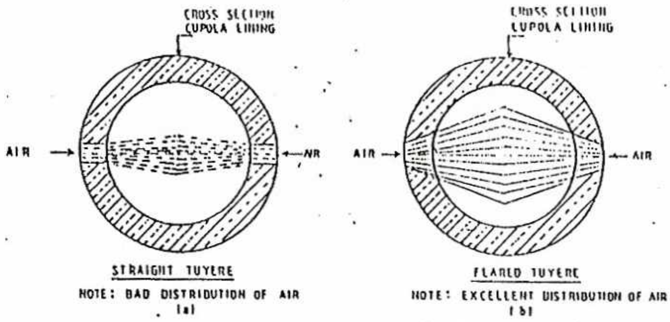


Fig. 7 : Tuyeres of the Cupola

The front part of the tuyere is in contact with slag and molten metal, even when the cupola is in operation. These are made easily replaceable.

Area of the tuyeres = $1/3 \cdot \pi/4 \; D^2$ where D is the dia of the cupola. The number of tuyeres depend on the design, generally 4 to 6 in single row or 8-12 in two rows. However one has to remember that more the number of tuyeres better is the distribution of air.

$$\text{Area of each tuyere opening} = \frac{\text{Total area of tuyeres}}{\text{No. of tuyeres}}$$

Normally the height of the tuyere opening is 100 mm

$$\text{Width of the tuyere opening} = \frac{\text{Area of tuyere}}{100}$$

All tuyeres should have sight holes to watch the cupola condition.

Wind Belt

The wind belt surrounds the cupola at the tuyere level and functions as a reservoir of air, capable of distributing of air at all

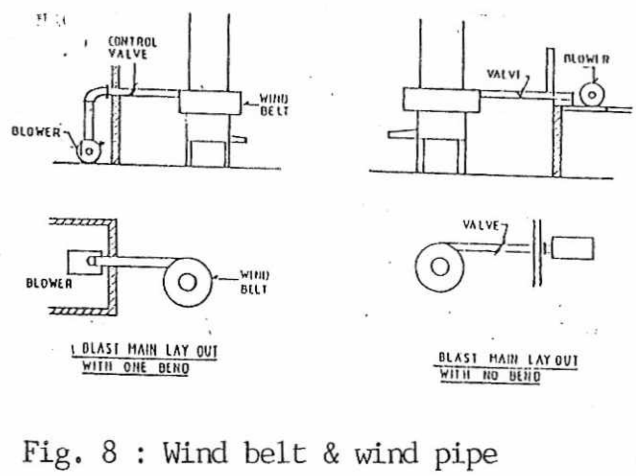


Fig. 8 : Wind belt & wind pipe

the tuyere openings at a constant pressure. Distribution of air at constant pressure will give a constant velocity of air at all the tuyeres and this is essential for good cupola operation. Cupolas of good design have wind belt of height varying 1000 to 1500 mm, whilst the dia is 450 - 600 mm larger than the dia of the shell of the cupola.

Wind pipe

WIND PIPE connects the wind belt of the cupola to the blower which supplies air to the cupola. The dia of this pipe should be as large as possible so that friction loss of pressure is minimum. It normally varies 150 mm to 450 mm according to the dia of the cupola. The bends of this pipe should as few as possible, otherwise there will be heavy loss of pressure at the bends.

Charging door

The CHARGING DOOR is the opening usually rectangular in shape placed at the level of the charging plat form for making cupola charges. The height is fixed on the number of charges inside the cupola at any time. This can be calculated from the formula :

$H = 2\ D + 5'$ (for cold blast) in feet   OR $H = 2D + 1{\cdot}524$ (For cold blast in meters.)

$H = 2.5 \times D + 5'$ (for hot blast) in feet $H = 2.5D + 1{\cdot}524$ (For hot blast in meters)

Where H is the height of the charging door from the tuyere and D is the diameter of the cupola. The dimensions in the charging door opening depend upon, whether the cupola is skip charged or hand charged. If hand charged the opening is kept 450 mm x 600 mm, but if the charging is done by mechanical means, then dimensions should be suitably designed.

Height of the cupola

The height of the cupola to the topmost part from the charging door, depends on the height of the roof above the charging platform. If the cupola is hand charged, a height of 3-4 metre is good enough. But with mechanical charging, it has to be suitably designed. However, the cupola must extend atleast 0.5-1 meter above the roof to avoid the roof getting spoiled by the hot flames and gases.

Cupola lining

Most of the cupolas are lined with fire bricks. The thickness of the lining depends on the diameter of the cupola. The lining thickness below charging door varies from 115 x 230 mm and above, depending on the diameter of the cupola. The lining thickness above the charging door can be kept between 60 mm to 115 mm. It is also possible to have monolithic lining from mixture of fireclay and grog rammed against the shell. Fig. 9 shows the linings of cupola of different dimensions.

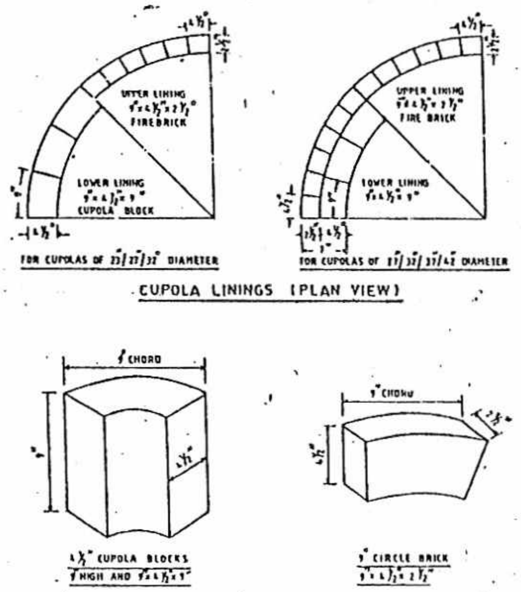


Fig 9 : Cupola refractory blocks and lining

In setting the refractory bricks, about 10 mm space has to be left between the brick and the cupola shell. This space is filled with sand so that it can absorb the expansion stresses produced when the lining is heated, thus preventing the distortion of the lining. The bricks must be laid very close to each other and a thickness of the fireclay mortar must be absolutely minimum. As already indicated, the angles of the steel are provided at intervals inside the shell so that the lining bricks may be supported on these angles. The erection of the cupola lining is normally started at the bottom ring proceeding to taphole and slaghole height then to tuyere level, then charging door and then it is completed. After the lining is completed it should be left for air drying before any heat is provided inside the cupola.

Bottom PROP

The bottom prop is extremely important as it closes the bottom door and is capable of dropping the bottom after the cupola operation. Therefore, the prop has to be so designed and erected that it can withstand the total load on the bottom door during operation of the cupola.

OPERATION OF THE CUPOLA

Theimportant aspects of the operation of a cupola are:

1. Preparation of sand bed
2. Making of the fuel bed and lighting up
3. Preparation of bed coke
4. Preparation of charges and charging methods
5. Blowing of the cupola - tapping and slagging
6. Adjustment in bed coke level during operation
7. Final stages of melting and dropping the bottom
8. Quenching of the drop and cooling of the cupola
9. Cupola lining repair
10. taphole and slaghole preparation.

PREPARATION OF SAND BED

The bed of the cupola is made with moulding sand after proper sieving and tampering with water. The bottom door is first lifted, then supported by a prop under it. Clay water is sprinkled over the door and any clearence between the door and bottom ring of the cupola is packed with clay. Then the tampered moulding sand is placed over the door and rammed properly. The bed should be made to flow gently towards tap hole to facilitate the liquid metal to flow towards the tap hole as shown in Fig. 10.

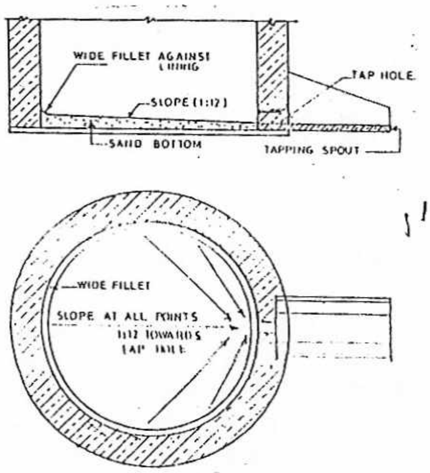


Fig. 10 : Preparation of sand bed

MAKING OF FUEL BED AND LIGHTING UP

Wood chips and sieving are spread over the sand bed and wood fuel in the range of 600 mm height kept vertically inside the cupola in the form of an inverted cone. The central space being left in the centre so that the fuel is lighted up easily. The fire wood is lighted up by cotton waste and when the wood is fully lighted up, 1/3 of the bed coke is dropped from the charging door then rest of the bed coke is charged. The central trough is sufficient for lighting up the bed coke and blower should not be used for lighting up. The tuyere, the tap hole and slag hole should be kept open. It is to be ensured at this stage that the coke is lighted up uniformly throughout the cross section and no cold spots should be visible. The bed coke height is always maintained constant throughout the operation of the cupola, as it plays an important part in the melting of cast iron. The bed coke height should be checked through out the operation as shown in Fig. 11.

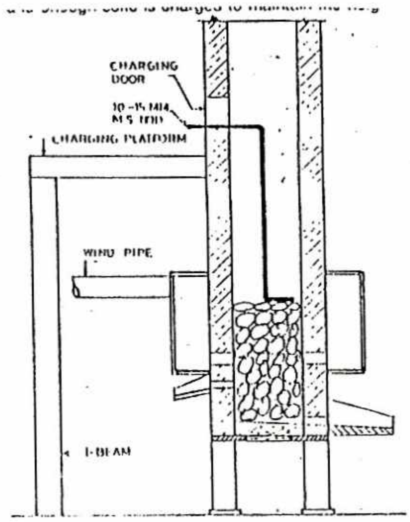


Fig. 11 : Checking the height of bed coke

Normally this is calculated with the formula

$$H = 10.5 \sqrt{P} + 6$$

where H is the height of the bed coke in inch above the top of the door and P is the wind belt pressure in ounces/sq.in. The bed coke height falls below the minimum level the temperature will increase and later decrease and metal may show signs of oxidation. The slag colour changing from normal glaze green to dull black indicates falling of the bed coke level below optimum. It should be maintained immediately.

CHARGING OF THE CUPOLA

The charges for the cupola consists mainly of metal, coke and flux. These must be weighed properly. Over the bed coke, the charge of flux i.e. limestone is placed before the first metal is charged. After this, the continuous sequence of metal, then cike, then flux is maintained through out the operation. The charging may be done by hand or by skip in the mechanically charged cupola.

BLOWING OF THE CUPOLA - TAPPING AND SLAGGING

It is a normal practice to give a soaking time of one hour before the blast is started. This ensures obtaining metal at high temperature right from the first tap. Although it looses small amount of coke but for uniformity of the metal temperature and flow, ultimately it pays back. Before the tap hole is closed after the start of blowing of air, tuyere should remain open. This will ensure the tapping region to be hot and also heats the spout. The tap hole is then closed and slag hole is also closed. When enough metal is accumulated in the hearth, it may take 30 to 40 minutes, the tuyere can be opened by scooping out the sand from tuyere and punching the hole with a sharp pointed bar called tap bar. After enough metal is run out of the tap hole, it is closed by packing with clay and bott. It is shown in Fig. 12. The second tap is made at quick interval,

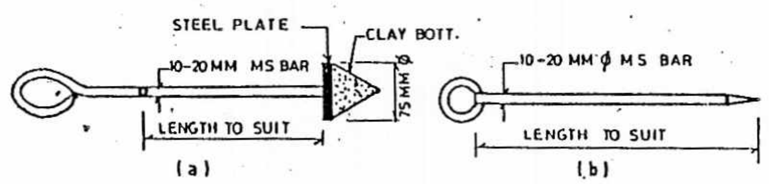


Fig. 12 : Clay Bott for closing cupola tap hole

if the tap hole is closed. Thus, a sequence is maintained. In a continuous tapping this problem does not arise.

FINAL STAGES OF MELTING AND DROPPING THE CUPOLA BOTTOM

When enough charges are completed and the required metal charging is fulfilled, the charging is discontinued. However, it is good practice at least to have one charge of extra metal than is necessary. This will ensure cleaned cupola after the operation is completed. The quentity of air blown is decreased and then the blow is stopped. All metal from the cupola is drained and tuyeres are opened. Then the bottom support of the cupola tuyere is pulled out by a chain or striking the prop. The burning coke and metal charged should be quenched by water. The lining is thoroughly checked.

CUPOLA LINING REPAIRS

The lining of the cupola is repaired as soon as possible to avoid further damage. After the lining has been repaired, temperature of the combustion zone should be kept more than that of the hearth.

TAP HOLE AND SLAG HOLE PREPARATION

Great care should be taken in the preparation of slag and tap hole. As improperly prepared tap hole may give rise to a lot of troubles during melting. Fig. 13 shows the refractory block for tap holes of large cupolas and the outside of the tap hole for small cupolas. The length of the straight operation of the tuyere is very critical and should not be longer than 40 to 50 mm.

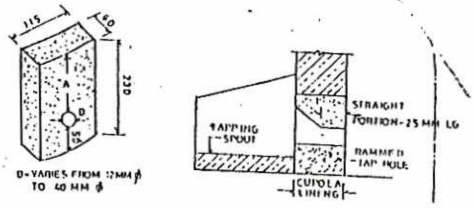


Fig. 13 : Tap hole and slag hole preparation

CUPOLA CHARGES

Cupola charges comprise Metal charge (including pig iron, cast iron and steel scrap), coke charge and flux charge including limestone and other chemical fluxes. The performance of the cupola depends on the proper proportioning, mixing and charging of the above materials.

Determination of coke charge weight

A good practice in cupola operation is to have atleast 150 mm of coke between each metal charge. If cupola is assumed to be of 600 mm dia. Then volume of coke $= \frac{\pi}{4} \times D^2 \times 0.15 = \frac{\pi}{4} \times (0.6)^2 \times 0.15 = 0.042\ m^3$. This is equivalent to 21 Kg coke (assume 500 kg/m^3). Hence 21 kg of coke is to be charged in each layer.

Calculation of Metal Charge weight

The proportion of metal to coke depends on

a) quality of coke, particularly ash percent
b) type of metal charged
c) Desired tapping temperature

Depending on the metal charged, it should be 6-12 times with low ash coke. However, under Indian conditions where ash percent is more than 35%, it becomes 3 to 5 times only. Each foundry has to find its most economical melting ratio in accordance to its requirements.

Calculation of flux charge

Fluxes like limestone are added in the cupola for obtaining proper slagging conditions. It is said that a good slag formation and removal is the secret of succesful operation. Normally this is 20% of the coke charge.

Calculation of metal mixtures

The metallic charge in the cupola usually consists of pig iron, cast iron scrap, steel scrap, foundry return scrap and ferro alloys. The proportion of each of these depends on :

- Chemical composition of the charge
- Chemical composition of molten metal
- Quality of coke - ash percent
- Availability of each of the material
- Oxidation losses of elements

While considering the composition of hot metal, it has to borne in mind that loss of Si percentage is 10%, loss of Mn is 20%. FeSi and FeMn are used to make up losses.

CUPOLA OPERATION CONTROL

It is important to have control on the operation of the cupola as it will ensure :

i) the molten metal of right chemical composition at the right temperature with most economical cost

ii) a smooth operation of the cupola throughout the day

This can be done by judicious adjustment and

i) Control of various operations at the start of cupola e.g. preparation of beg, preparation of tap hole and slag hole, lighting up, bed coke preparation and charging etc.

ii) Control of the height of bed coke

iii) Control of weighing of charges and proper charging

iv) Control of the volume and weight of air blower

v) Control of slag

vi) Control of metal tapped

(i) and (ii) have already been discussed earlier.

Weighing of charges and proper charging

Weighing of charges is extremely important as proper proportioning of metal and coke can give optimum efficiency. This can be done by use of platform type weighing balance. Charging should be done in a uniform way and not in a haphazard way to avoid unnecessary bridging and to obtain optimum metal coke ratio. A thumb rule is not to exceed the size of scrap larger than 1/3 dia of the cupola.

Control of air weight and pressure

The weight and volume and pressure of air should be so controlled that complete combustion of coke take place.

$$\text{Quantity of air flow} = 5.648 \times E \times d^2 + \sqrt{hxp}$$

where Q = vol. of air flow in cuft/mt
E = efficiency of orifice as given below
d = dia of orifice (in inch)
h = pressure differential (in water column)
p = pressure (psi absolute)

d/D	0.10	0.20	0.25	0.5	0.75
E	0.5990	0.6004	0.6016	0.6271	0.7505

Slag and slag control

Slag control is extremely important and this is mainly generated from the ash of the coke. Higher the ash, higher will be the amount of limestone and higher will be the amount of coke to make it in slag form. Another source of slag is the melting away of the lining of the cupola at high temperatures. The third source is the loss of silicon or oxidation of Si to SiO_2. Similarly Mn and Fe also combines with oxygen to form MnO and FeO. The fourth source of slag is the unintentional addition of dirt and sand which gets charged during charging. The last source with proper care can be atleast partially avoided.

Effect of slag fluidity

Control of slag fluidity affects to a great extent the operation of the cupola. Highly viscous slag due to high SiO_2 content will give

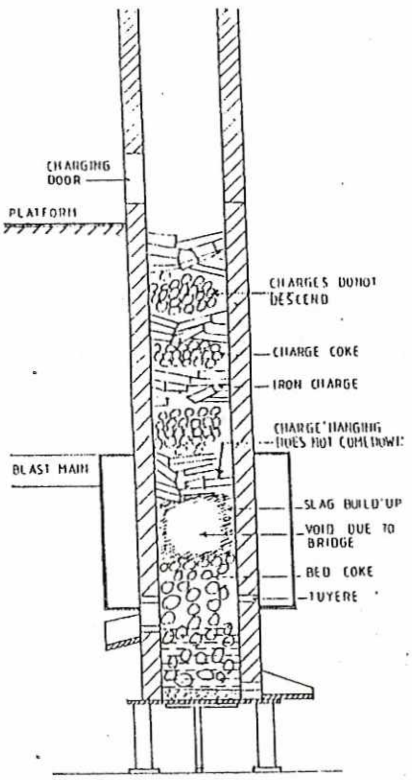


Fig. 14 : Bridging in the Cupola

rise to bridging as shown in Fig. 14. Viscous slag chills and sticks to the lining while low fluidity slag slowly builds up just above the tuyeres and in front of the tuyeres, slowly restricting the effective dia. of the cupola. This causes brding. By addition of proper limestone, soda ash one can avoid viscous slag and in turn briding.

Metal Control

Cast irons are generally classified as those alloys of iron and carbon where carbon ranges between 2-4.5%. The industrial cast irons are basically an alloy of iron, carbon and silicon and their metallurgical structures on solidification can be understood by the study of iron-carbon equlibrium diagram given in Fig.15(a), (b) and (c).

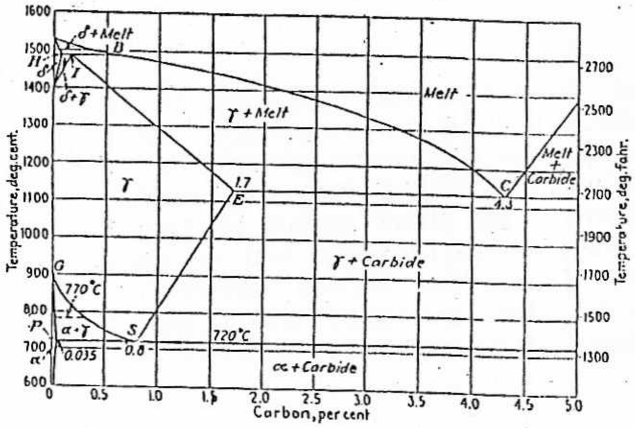


Fig. 15 (a)
Iron Carbon Diagram

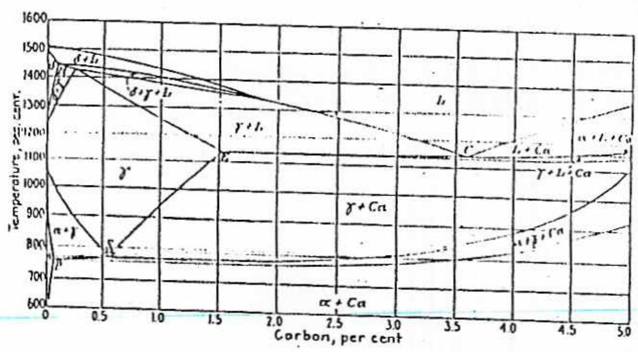


Fig. 15 (b)
Iron-Carbon-Silicon Diagram
(at 2% Silicon level)

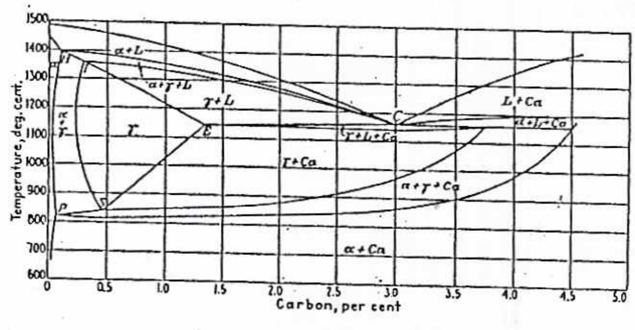


Fig. 15 (c)
Iron-Carbon-Silicon Diagram
(at 3.5% Silicon level)

Fig. 15 : Iron-Carbon diagram as useful for Cupola Operation

Effect of Silicon

The structure and property of cast iron is influenced by the amount of carbon and silicon in the metal. Low silicon favours formation of cementite. While higher silicon favours formation of graphite. It is a product of eutectic reaction when austenite and graphite separated out. The amount of graphite present in cast iron makes the metal softer and weaker in mechanical properties but imparts good machinability, resistance to warping on heating and cooling resistance to wear and resistance to corrosion. It has lower shrinkages value and imparts good for number of taping quality to the cast iron.

Graphite

The size, shape and distribution of graphite greatly influences the property of the metal. In fact state of cast iron is a study of graphite, its size, shape and distribution. Graphite exists in cast iron in various forms like flake, tempered, under cool and nodular etc. The most important form is in the graphite in the flake form. The nodular form of graphite can be achieved by interaction of magnesium or cerium. In some cast iron, the carbon mostly occurs as cementite and are called white cast iron because the graphite is non-existent in the structure. As already indicated, the structure depends on the cooling rate. Faster cooling rate induces formation of cementite and inhibits formation of graphite. While slow cooling gives the flaky graphite structure.

THE EQUIVALENT CARBON AND ITS INFLUENCE ON THE PROPERTY OF THE METAL

The equivalent carbon is the sum of total carbon in the metal and 1/3 the sum of silica and phosphorus.

$$FC = C + (Si + P)/3$$

This is shown in Fig. 16. The equivalent carbon in cast iron influences the structure and mechanical properties of the metal.

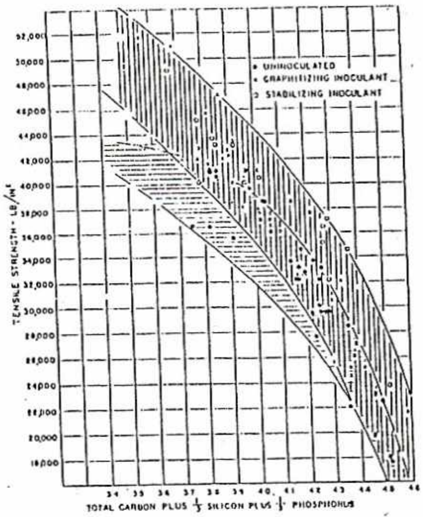


Fig. 16 : Effect of Carbon Equivalent on the tensile strength cast irons

Carbon control in cupola melting

In cupola melting carbon control becomes extremely difficult as the metal is in contact with the burning coke and carbon absorption is possible. There is also a possibility of carbon being lost due to the oxidising atmosphere in the cupola. The loss or gain of carbon in the cupola depends on

1. The initial carbon in the charges
2. Atmosphere in the furnace
3. Slag volume and fluidity in the cupola
4. Presence of other elements like silicon
5. Rapidity of, melting
6. Depth of bed coke
7. Reactivity of coke
8. Fluxes added
9. Size of coke
10. Method of tapping i.e. continuous or intermittent.

Cupola Refractories

Cupola is lined inside the steel shelf with heat resistant bricks. These are normally fireclay bricks of relatively high alumina content and shaped to make the circularity of the tuyere. In some portions ramming of refractory mixtures can also be adopted. These refractories have to undergo considerable attacks during the operation by

i) high temperature
ii) mechanical reactions
iii) mechanical abrasion

With proper care and design the correct type of refractories one can achieve high refractory life.

REFRACTORY LINING ZONES

The hearth or curcible zone

The super heated molten matters stays in this zone before tapping. Except for small attack by slag, this is relatively safe area. Only precaution is to be taken that no cracks in the joints take place and in every heat a thin coating of refractory clay should be given to protect the lining.

Zone above tuyeres

The zone extending from top of the tuyeres to 1200 mm from the tuyeres is under severe attack due to high temperature and slag reactions. The combustion of the carbon in the coke takes place in this area and the volume temperatures can range within 2000°C and above. Therefore, the attack on the lining is very severe and this part of the lining needs to be carefully watched, repaired after every heat with fresh bricks.

Zone below the charging

This zone is also very severely attacked by the hearth charges being dropped carelessly. The attack is mostly mechanical. The temperatures are not severe.

Zone above the charging

There is no attack due to abrasion or slag formation. The temperature in the zone is about 450°C. Therefore, the lining may be made of relatively purer quality bricks and the thickness may also be kept lesser than the other zones. The cupola bricks of various size and cast iron cupola bricks are shown in Fig. 17. Any bigger cupolas giving higher molten metal temperature one may have to adopt use of gun in lining repair as shown in Fig.18. The diagram of the repaired lining of curved contour is shown in Fig. 19.

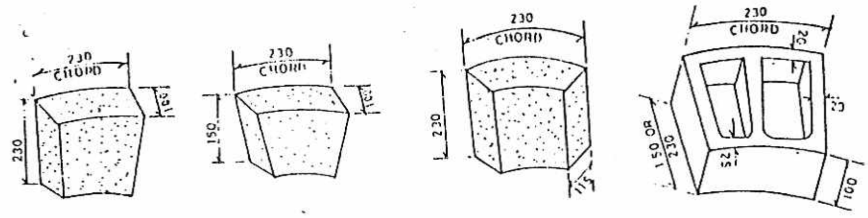


Fig. 17: Shapes of Cupola bricks

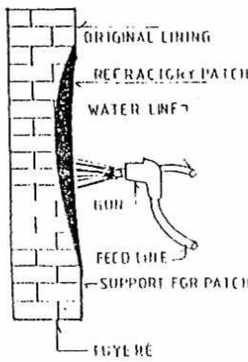


Fig. 18: Use of gun in Lining repair

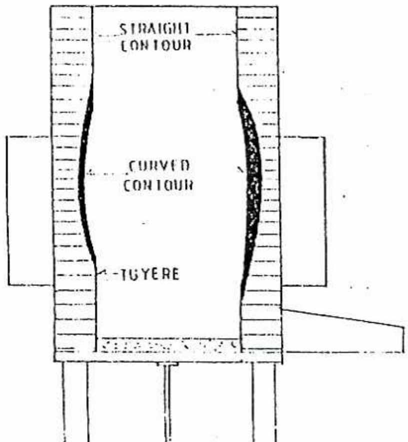


Fig. 19 : Curved contour of repaired lining

RECENT TRENDS

Melting of Steel scrap

It is common practice to melt some percentage of steel scrap to adjust the composition. By using hot blast in the cupola, it has been made possible to melt almost 80% of the steel scrap. Some of the foundries have adopted the practice of melting of the steel scrap and use acid blown converter to produce steel by using a combination of cupola and converter.

Melting of sponge iron

Due to the shortage of good quality cast iron scrap, attempts were made to melt sponge iron in cupola, thereby decreasing the sulphur and phosphorus of the metal and also avoid the tramp elements in the molten metal. This may be necessary for high quality castings necessary for certain specific purposes. Attempts have been made at National Metallurgical Laboratory, Jamshedpur and other places to melt upto 50% sponge iron in the charge without much difficulty. Although it did gave rise to the problem of excess slag compared to the normal cast iron melting. Attempts are also made to increase the sponge iron percentage to about 75% but it did create some problem because the temperature of the blast was 100°C only while it may require a temp. of 450°C.

Use of non-coking coal

Coke supply is always a perenial problem to the foundries in India. The type of coke used in the foundries is unbelievably poor compared to any foundries abroad. In view of this difficulty, attempts were made to use non-coking coal in the cupola. It may not be possible to charge coal along with coke lest it may give rise to number of problems. An attempt has therefore been made to inject through tuyeres non-coking coal to achieve combustion of the same in the zone just above tuyeres. Thus the entire heat required for melting of cast iron is obtained from non-coking coal and the permeability of the burden is achieved by addition of normal coke. It is possible to reduce almost 80% of the coke by powdered non-coking coal injected through tuyeres.

Cokeless cupola

Several attempts abroad particularly in Japan have been made to adopt the practice of using other heating sources other than coke. Attempts have been made using oil and natural gas as is shown in Fig. 20. It can be seen that these cokeless cupola can be safely used provided it matches economically the use of natural gas or producer gas or oil gas compared to coke. Although it is advantageous to have cokeless cupola to avoid several problems particularly the ash of the coke. The capacity of the cupola of cokeless type can produce nearly $1\frac{1}{2}$ times more compared to normal cupola.

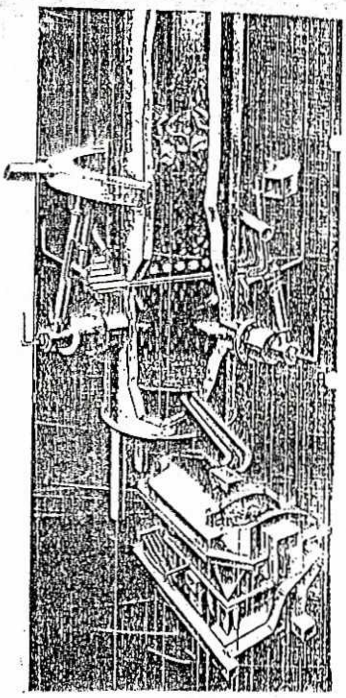


Fig. 20 : Cokeless Cupola

Mini Cupola

National Metallurgical Laboratory has developed a mini-cupola of 250 kg per hour as shown in Fig. 21. The idea of this mini cupola is to use it in rural areas where it may be useful to produce small castings which may be useful for the villagers and other persons. The cupola designed, fabricated and worked out at NML is portable that it can be carried in a truck to any place, work out products castings and it may be shifted to next location. This technology has been transferred to 7 countries and 20 organisations in India.

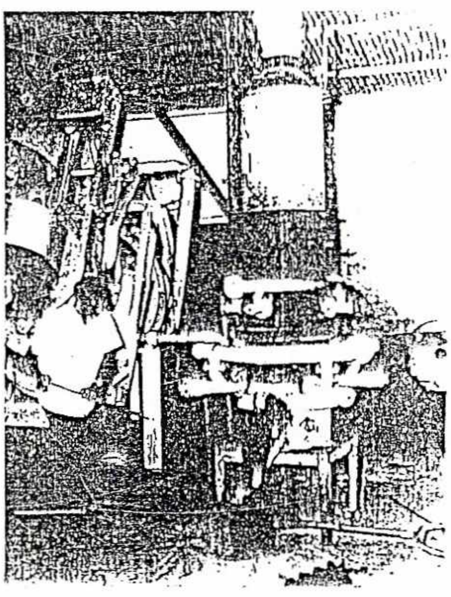


Fig. 21 : NML Mini-cupola

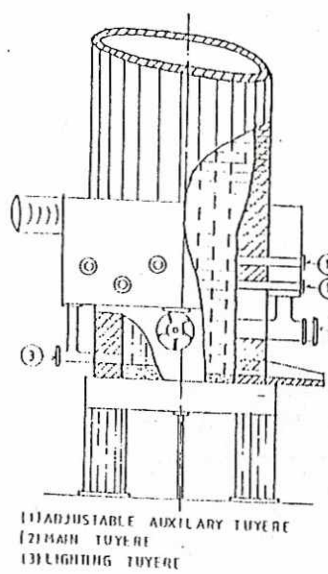


Fig. 22 : Balanced Blast Cupola

Howrah Foundries - Problems and solutions

NML as a team has had the experience of visiting large number of foundries in Howrah and experienced in the following :

Coke - The coke used in the foundries is of poor grade but since good quality coke is not available, they have to satisfy themselves with whatever coke is available. It may be mentioned here that the poor quality coke is partly responsible for lower metal coke ratio. While abroad, one can easily get 6 to 12:1 metal coke, whilst in India we get only 3 to 4. Good quality coke should be made available for this industry.

Type of pig iron

Normally the pig iron meant for foundries is not available i.e. foundry grade iron. This is always in short supply as most integrated steel plants do not prefer to produce it in the plant. The foundry owners therefore have to satisfy themselves with whatever type of scrap available to them in the market. They use therefore any type of scrap big or small, rusted or good quality, angular or bulky and charge directly in the cupola. The Foundry Association should mutually work on this and get some solution.

Weighment of cupola charges

As already indicated earlier, it is important for the foundries to be using exact weight of metal and coke to achieve the optimum efficiency. It has been experienced that hardly one or two percent of the foundries have got the balance to weigh the charge of castings and rest are charging just by visual experience that cause the poor efficiency.

Design of the cupola

While it is important to have proper design of the cupola, most of the cupola are poorly designed both from the view point of air blown in the cupola, no controlling equipment or instrument for measuring the air flow and pressure, improper height to diameter of the cupola ratio, lower height of charging door, lower height of cupola Stack above the charging door and improper design of the tuyeres. All these factors have already been dealt earlier in the text and with proper care, the cupola of the foundry can produce more metal with better metal coke ratio.

Problem of emission

It has been found that none of the foundries have got any emission control. As per the Pollution Control Board, the SPM level should be less than 150 mg/cubic metre. The values are as high as 1200 to 1500. Similarly the sulphur level should be less than 20 while it is more than 200 to 300. It is impressed therefore to use the pollution control means to avoid this and make the foundries safer for human beings. This will also avoid a dark greyish black smoke in the Howrah foundry area.

CONCLUDING REMARKS

In the end, I would like to mention that cupola operation though appears very simple, highly profitable with no hazard but it is not true. Cupola operation needs proper raw material, correctly graded scrap, nicely designed cupola with its accessories, important instrumentation, right type of tapping the metal and slag are important areas and need very careful consideration to achieve the maximum profitability and the quality.