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Critical issues in controlling suspended particulate matters (SPM) from cupola exit gases

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ABSTRACT

Among the various industries in our country, the metallurgical industry is one of the most polluting. Since we produce about 18 million tonnes of steel per year, due to its huge production rate the iron and steel sector is a major polluting industry among the various metallurgical industries. The present paper deals with one of the most neglected metallurgical industries in our country namely foundries where very little work has been done to reduce pollution especially pollution caused by suspended particulate matters (SPM). The paper describes the results of the investigation carried out by the authors to understand the nature of pollution caused by foundries in West Bengal. It has also been shown that SPM level from cupola exit gases can be brought down below 150 mg/Nm^3 by proper design and operation of cupola and aided by simple and inexpensive pollution control devices. The results are based on the data collected at the demonstration plant where the pollution control system designed by the authors have been set up.

INTRODUCTION

Environment has now become one of the most important global issues. There has now been increasing pressure of society on industry to reduce and if possible eliminate pollution and waste generation. Amongst the various industries in our country, the metallurgical industry is one of the most polluting. Since we produce about 18 million tonnes of steel per year, due to its huge production rate, the iron and steel sector is a major polluting industry among the various metallurgical industries. However, the integrated steel plants generally have necessary funds and trained manpower available for pollution abatement. On the contrary, the small and medium scale metallurgical industries such as foundries have some unique problems such as limited availability of funds, extremely limited availability of technologists who can design and implement a cost effective and compatible pollution control system, very limited availability of process water, lack of availability of additional electric power as required for operating the pollution control system and often lack of necessary attitude to implement pollution control devices. It may also be noted that these industries are located in a very densely populated areas and the pollution they create are highly visible. This article discusses a few basic issues concerning pollution control in cast iron foundries.

Pollution sources in cast iron foundries

Founding activity is a substantial contributor to the environmental pollution through solid (particulate) and gaseous emissions arising from sand preparation and handling, moulding and core making, melting and pouring, fettling and cleaning etc. Dust, smoke, coal ash and fumes contaminate the air both inside and around the foundry plant. Dust from shakeout and return sand handling system is composed of burnt and fractured sand containing binders. Large amount of silicon dust is also produced/generated during shot cleaning and knock operations which makes the environment, in and around the area, both injurious and difficult to work in. Fine silicon dust may cause silicosis.

Pollutants generated during cupola melting and casting operations include emissions (particulate and vapour) from charge and occasional sparks generated during the process. Mostly these comprise metallic oxides, silicon, calcium oxide, carbon monoxide (CO), carbon dioxide (CO_2), sulphur dioxide (SO_2), nitrogen oxide (NO_x), hydrogen (H_2), hydrofluoric acid (HF), methane (CH_4) and other contaminants from the cupola emissions. The source for silicon and calcium oxide is the furnace refractory lining erosion, entrained mould and core sands from foundry returns, dirt from scrap yard which adheres to scrap, flux dust etc. Handling of materials such as fuel and flux generated enough fines and increases the amount of suspended particulate matters (SPM) in the environment. Degassing and fluxing prior to pouring also contribute to environmental pollution. The disposal of patterns, used and burnt sand and foundry slag also create unpleasant environmental conditions. The operation of various equipments and units also create noise pollution. More details about the pollution aspects of various metallurgical operations have been provided by Ambardar and Chesti[1].

Based on the survey conducted by National Metallurgical Laboratory, Jamshedpur in various cast iron foundries in the Howrah area it has been found that the average level of suspended particulate matters (SPM) in the cupola exit gases is around 1500 mg/Nm^3 whereas the average sulphur dioxide level is around 750 mg/Nm^3 (Tables 1-3). It may be noted that the permissible level for SPM is 450 mg/Nm^3 for cupolas with capacities for less than 3 tonnes and for larger cupolas the permissible limit is 150 mg/Nm^3. Thus the level of pollution is really alarming and immediate steps are needed to reduce pollution with a judicious combination of proper control in raw materials, by adopting scientific operating procedures and design changes in cupolas and also by using appropriate gas cleaning devices.

Table-1 : Concentration of suspended particulate matters (SPM) in cupola emissions

Location of sampling : 0.45 m inside and 0.15 m above the top of the door level of the cupola; Probe Position : Through the charging door

Foundry Code	Melting Rate(MT/hr)	Conc. of SPM (mg/Nm³)
1	4 - 5	2646
2	3.5 - 4	791
3	3.5 - 4	2541
4	2.5	2517
5	3.5	1012
6	5.5	1660
7	3.5	407
8	4.5	1074
9	4.5	747
10	8.5	1655
11	8.5	417
12	4.0	2044

Table-2 : Concentration of sulphur dioxide in cupola emissions

Location of sampling : 0.45 m inside and 0.15 m above the top of the door level of the cupola; Probe Position : Through the charging door

Foundry Code	Melting Rate(MT/hr)	Conc. of SO_2 (mg/Nm³)
1	3.5 - 4	1442
2	2.5	2608
3	5.5	173
4	3.5	402
5	5.5	198
6	3.5	480
7	4.5	455
8	4.5	168
9	8.5	704
10	8.5	334
11	4.0	1376

Table-3 : Concentration of CO and CO_2 in cupola emissions

Sampling location : 0.45 m inside the cupola and 0.15m above the top of charging door

Foundry Code	Conc. of carbon monoxide		Conc. of carbon dioxide (%)
	(g/Nm^3)	(%)	
1	50.43	(4.03)	5.7
2	42.33	(3.39)	10.3
3	124.93	(9.995)	10.6
4	50.41	(4.03)	5.8
5	61.21	(4.90)	8.5
6	30.50	(2.44)	9.6
7	28.96	(2.32)	5.3
8	57.08	(4.57)	6.7

Control of foundry pollution

Pollution levels as above can be brought down to the desired levels by a combination of design and operational changes and installation of gas cleaning devices. Table-4 presents the various gas cleaning devices used in foundries[2].

For heavily dust laden gases we recommended a high presence venturi type wet scrubber along with a dual alkali circuit for scrubbing sulphur dioxide gases[3].

Table-4 : Typical gas cleaning devices used to control SPM from cupolas

Melting capacity (MT/hr)	Possible collector required to meet SPM limit
1-4	Simple Dry/Wet Arrester
5-10	Simple/Multi cyclones or Medium Intensity Scrubbers
11-14	High Intensity Scrubbers/Fabric Filters/Electrostatic precipitators

The venturi scrubber has been chosen as they have a typical operating efficiency of 99% and can be put up with moderate capital expenditure. One of the greatest advantage of this type of scrubber is that change in particle size has very little effect on its operational efficiency. Thus the SPM concentration in the exit gas is not likely to change with changes in the input material characteristics which are very common in such foundries. However, where water supply is a problem, an appropriate dry gas cleaning system has to be employed. The recommended process flow sheet for the dry gas cleaning system is presented in Fig.1.

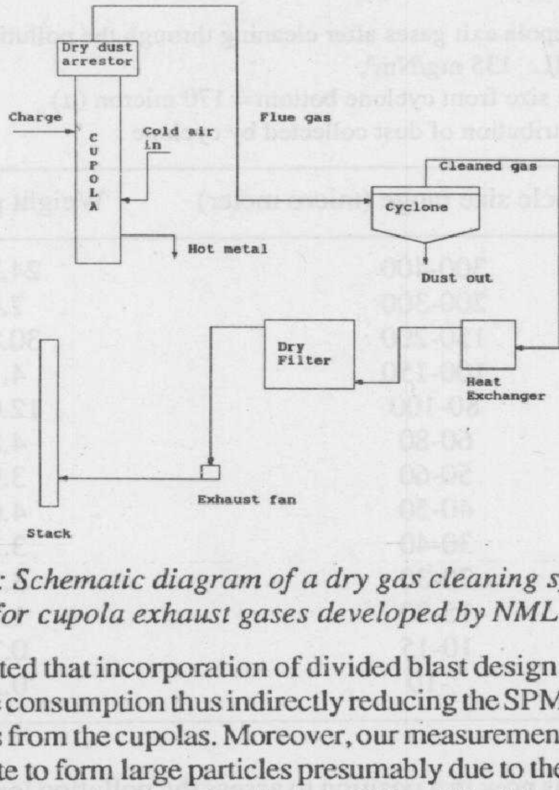

Fig.1 : Schematic diagram of a dry gas cleaning system for cupola exhaust gases developed by NML

It may be noted that incorporation of divided blast design in existing cupolas will reduce the coke consumption thus indirectly reducing the SPM and other pollutant load in the exit gases from the cupolas. Moreover, our measurements indicate that finer particles agglomerate to form large particles presumably due to the presence of higher temperatures due to the combustion of majority of CO to CO_2. It has also been observed that the average particle size is around 400 micron whereas in other cupolas in most cases the -10 micron fraction amounts to 50%. In view of the presence of particles of larger size in such cupolas it is even possible to clean the gases to the desired limits just by employing dry arresters and cyclones thereby avoiding expensive bag filters. In cases where the nature of dust is fairly fine, employment of specially designed cyclones such as Stairmand Cyclones or multi-cyclones may be needed.

It may also be noted that National Metallurgical Laboratory, Jamshedpur has designed a cost effective pollution control system for foundries and has set up a demonstration pollution control unit at one of the foundries in Howrah (M/s Crawley and Ray, Foreshore Road, Howrah). The plant has been commissioned in middle of

November this year and the cleaned gas has an average SPM content of 135 mg/Nm³ as against the permissible norm of 150 mg/Nm³. Detailed characteristics of dust collected from cyclone bottom are provided in Table-5.

Table-5 : Summary of results for evaluation of performance of pollution control system at M/s Crawley & Ray, Howrah

(1) SPM level in cupola exit gases after cleaning through the pollution control system designed by NML: 135 mg/Nm³,
(2) Average particle size from cyclone bottom = 170 micron (μ)
(3) Particle size distribution of dust collected by cyclone :

Particle size range (micro meter)	Weight percent
300-400	24.3
200-300	7.4
150-200	30.8
100-150	4.1
80-100	12.0
60-80	4.8
50-60	3.9
40-50	4.0
30-40	3.3
20-30	3.3
15-20	1.1
10-15	0.7
-10	0.3

Thus NML is now in a position to assess the pollution level of foundries and other metallurgical units and provide these industries with a cost effective pollution control system suiting to individual requirements. It has also been shown by us that SPM level from cupola exit gases can be brought down below 150 mg/Nm³ by proper design and operation of cupola and aided by simple and inexpensive pollution control devices.

SUMMARY AND RECOMMENDATIONS

1. Out investigation reveals that for most of the foundries the emission levels are much higher than the permissible limits. It is essential that we reduce the pollution levels through judicious use of appropriate raw materials and

process optimization, improving cupola design to make them more energy efficient and lastly by putting up gas cleaning units which are capable of reducing both suspended particulate matters as well as sulphur dioxide.

2. In regard to the design changes, major attention need to be paid to increasing the shaft height such that shaft height : cupola internal diameter ratio is around 5.5 - 6. This helps in proper pre-heat of the charge materials and in improving the thermal efficiency of the cupola. Also the height of cupola above the change door should have a similar ratio i.e. 6 with the internal diameter for complete combustion of carbon monoxide to carbon dioxide. This help in reducing the CO emission level and also reduce the SPM as larger particles have a tendency to settle down.

3. It is very much necessary to install the divided blast system in the existing cupolas for improving energy efficiency and reduce pollution.

4. For heavily dust laden gases we recommended a high pressure venturi type wet scrubber along with a dual alkali circuit for scrubbing sulphur dioxide gases. The venturi scrubber has been chosen as they have a typical operating efficiency of 99% and can be put up with moderate capital expenditure. One of the greatest advantage of this type of scrubber is that change in particle size has very little effect on its operational efficiency. Thus the SPM concentration in the exit gas is not likely to change with changes in the input material characteristics which are very common in such foundries. However, where water supply is a problem, an appropriate dry gas cleaning system has to be employed.

5. Even for small cupolas which contribute much less towards the total pollutant load emitted to the atmosphere, at least a simple natural drought dry/wet arrester should be employed. However, for most of the large size cupolas, a suitable air pollution control device such as scrubber, cyclone or bag filter have to be employed to bring down the SPM level below the permissible limit i.e. 150 mg/Nm^3. The choice of a specific device will depend on a number of factors which includes both design and operational parameters.

6. It has often been found that immediately after the charging, the concentration of CO in the exit gases are fairly high. Since the gas temperature during this time is around 200°C - 300°C, spontaneous combustion of CO may not take place with the air entering the charge hole. In such cases the CO may be burned by employing an afterburner.

7. The stack discharge height should be kept at least 20 meters.

8. All the cupolas should be provided with some basic instrumentation for operating them in a scientific and optimized way especially an air flow measurement device to measure the air input rate.

9. It has also been shown by us through our demonstration unit at M/s Crawley and Ray, Howrah that SPM level from cupola exit gases can be brought down below 150 mg/Nm^3 by proper design and operation of cupola and aided by simple and inexpensive pollution control devices.

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