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Air pollution problems from cupola furnaces in iron foundries

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ABSTRACT

Emissions from cupola furnaces for melting iron predominantly consist, heavy metal fumes, particulate matters, sulphur dioxide (SO_2) and carbon monoxide (CO). Emission from a single cupola furnace may not be significant except when number of units are located in same air basin. Presently in India there exists only a very few air pollution control systems installed on cupola furnace. A comprehensive approach on the problem of emission is necessary before designing any control system. In-situ investigations were carried under different operational variations of cupola energised by conventional and chemical (NML) coke. Emission parameters studied include particulates, SO_x and CO. Observations reflected that high dust emission continued till the process ended whereas high SO_x emission occured only in the first hour of firing. High CO emission projected the possibility of energy recovery and its use employing after burners. Sulphur balancing for Indian cupola is also performed. Based on these field tests a few considerations for air pollution control devices to be adopted are discussed.

INTRODUCTION

The cupola furnace is most economical and basic melting unit for producing iron castings. Most of the foundries, in India, are classified as small to medium scale industry, producing variety of items ranging from simple manhole covers to sophisticated railway spare parts and are located in only few cities. The average melting rate of cupolas is less than 4 MT/hr. Though the emission from an individual unit is relatively small, the impact from a group of units in a particular locality could be significant to deteriorate the ambient air quality. Cupola furnace flue gases contain CO, SO_x, NO_x besides wide range of particles of iron and other metal oxides, lime dust, coke breeze and fly ash[1-3]. In India almost all the cupola furnaces deploy minimal control technology for emissions to air. There is a scope of designing control system to mitigate air pollutants from cupola. The design of an appropriate control systems and to quantify its impact on surrounded air basin, a systematic characterization of flue gas is essential. Studies were carried out on cupolas

Table-1 : Stack Gas Characteristics for Gaseous Emissions with Conventional Coke (Average values)

Temperature °C	=	650
Velocity m/sec.	=	7.8
Vol.flow rate Nm^3/hr	=	10580
<u>Average of 1st hour Emission :</u>		
SO_2 (mg/Nm^3)	=	2024
<u>Average Emission of rest of the period</u>		
SO_2 (mg/Nm^3)	=	335

Table-2 : Stack Gas Characteristics for Gaseous Emissions with NML Coke (Average values)

Temperature (°C)	=	475
Velocity (m/sec.)	=	5.6
Vol.flow rate Nm^3/hr	=	8519
<u>Average of 1st hour Emission :</u>		
SO_2 (mg/Nm^3)	=	2048
<u>Average Emission of rest of the period</u>		
SO_2 (mg/Nm^3)	=	499

* *National Metallurgical Laboratory (NML) has specially manufactured chemically impregnated coke*

*Table-3 : Sulphur balance of coke during combustion**

Sulphur present in Coke	=	0.5%
95% of sulphur converted to SO_2 and 5% to SO_3		
During first hour approximately 2200 kg of coke is combusted		
21 kg. of SO_2 is being emitted theoretically		
We obtained Avg. SO_2 concn.	=	2036 mg/Nm^3
Avg. flue gas volume	=	9550 Nm^3/hr
SO_2 emitted 19.5 kg		
During rest of the priod of operation of 6 hrs.		
Avg. SO_2 concn. obtained	=	417 mg/Nm^3
SO_2 emitted	=	4 kg/hr
Approximately 2940 kg of coke is combusted in 6 hrs.		
i.e. 490 kg/hr		
SO_2 emitted	=	4.7 kg/hr

**The calculations are based on the average values of Tables-1 and 2.*

energised by conventional and chemically treated coke. The results of these studies are presented in this communiction.

MATERIALS AND METHODS

Cupola furnace is a simple vertical cylinder made of steel and lined with refractory bricks. Initially a bed of cȯke is laid in the cupola up to a height of about 2-3 meters above the base and ignited. Raw materials like iron scrap, pig iron, coke and limestone are charged through the opening at the top of the cupola and the hot metal and slag are drawn from the bottom. Air for proper combustion is supplied through the tuyeres provided at the base. Average size and melting rate of the cupola was as follows :

Cupola height (m)	-	9.00
Cupola diameter (m)	-	1.22
Melting rate (MT/hr)	-	4-5
Average working hours	-	6-8

EMISSION IN FOUNDRIES

The potential emissions from iron foundry operations are mainly associated with : (a) melting facility, (b) the casting yards, and (c) core making. The products of emissions from the cupola include[2] : (i) Smoke from oil, grease etc. present in steel scrap, (ii) grit and dust particles arising from charged materials and their impurities, and (iii) metallurgical fume which consists of metallic oxides, ash, etc. and apart from these the main emissions are sulphur oxides, particulate matters and carbon monoxide.

The particulate matter emission depends on the manner of charging. Engles[4] broadly classified the particle size distribution as: (1) particles of 100 to 500 microns due to mechanical abrasion of refractory, coke breeze and limestone dust, (2) particles of 20 to 50 microns due to coke ash emanating from the upper portions of the charge column at low temperatures, and (3) particles of 2 to 5 microns due to oxides of metal.

Andonyev et al[5] have stated that content of CO in the gas varied from 150 to 200 kg/MT of metal. They further said that the problem of CO could be reduced by using afterburners. Sulfur dioxide is considered to be a major pollutant of concern for foundries and enforcing agencies[2]. Sulphur is introduced into the cupola mainly through coke and partly through scrap. This sulphur after combustion is released as SO_2 through the cupola exit.

In addition there are many fugitive sources which discharge considerable quantity of pollutants. This includes the fumes while drawing the hot metal and slag during moulding operation. In general the emissions of foundries depend on (i) Iron coke ratio, (ii) temperature, (iii) specific blast rate, (iv) diameter of cupola, (v) height of burden, (vi) coke characteristics, (vii) condition of return scrap and (viii) method of charging.

RESULTS AND DISCUSSION

The data collected during the study period are summarized in Tables 1 and 2 and it showed that SO_2 emission in the initial period of cupola operation was higher with maxima varying between 2024 and 2058 mg/Nm^3 whereas, it was dropped to minimum level in the remaining period of melting. During this period it ranged between 335 and 449 mg/Nm^3. Generally 95% of sulphur emitted is converted into SO_2 and remaining 5% to SO_3[6]. Table-3 summarizes the sulphur balance calculations depicting that 21 kg of SO_2 should be theoretically generated. During this study period, it was recorded that the actual SO_2 emission was 19.5 kg and was comparable with the theoretical values. It was also observed that chemically treated coke did not show either significant improvement in cupola operation or reduction in SO_2[7]. It is documented that metal to coke ratio vary from 5:1 to 12:1 depending upon the fuel or metal charged whereas limestone feed as fluxing agent is about 25% of the coke charged[3]. Tables 4 and 5 show that the metal to coke ratio was varying between 5:1 and 6.7:1 but the limestone charging was between 20 to 22% of coke. Such variations are within acceptable range. In some cases metal to coke ratio was as low as 4:1. Table-6 reveals that average particulate emission concentration was 1.7 gm/Nm^3 (16.2 kg/hr) and 30% of the particulates were less than 20 micron size and remaining 70% were higher than 20 microns. Larger particles settled in the vicinity of cupola furnace. The larger particulates are primarily broken coke breeze whereas, fine particles are metallic oxides and combustion products. It is reported that typically grey iron cupola emits the particulate in the range of 0.1-10 micron, 10-15% CO, 10-15% CO_2 and low quantity of SO_x and NO_x[8]. In the present study it was found that CO_2 was only 5.6% whereas CO was 4.4% (Table-6). In Indian cupola, air also enters through charging door thereby disturbing the CO:CO_2 balance and diluting the overall constituents. In the present study cupola flue gas contained 12.4% oxygen which confirmed the presence of excess air (Table-6).

Mitigation Approach

The trend in may developed countries on control of emissions from cupolas has been to regulate the emissions by providing control equipment like after burners, ESPs, bag filters and wet scrubbers etc. But considering the status and capacities

Table-4 : Raw material input for conventional coke (kg)

Time(hrs.)	Coke	Pig Iron	Broken Iron	Scrap	Limestone
8.20	1400	900	-	- -	
8.25	240	450	600	1000	75
9.25	240	450	720	1000	75
9.52	240	420	1020	--	75
10.35	240	450	840	1000	75
11.15	280	480	1080	1000	75
11.50	280	480	1200	1120	75
12.30	320	600	1260	1200	100
13.07	280	540	1320	1200	100
13.50	280	540	720	1200	100
14.30	160	480	600	200	50
14.45	160	420	900	200	50
14.58	160	420	600	320	50
15.14	160	420	900	320	50
15.36	160	420	900	320	50
	4600	7470	12660	10080	1000

Lime stone usage 22% of coke. Metal to coke ratio 6.78

Table-5 : Raw material input NML coke (kg)

Time(hrs.)	Coke	Pig Iron	Broken Iron	Scrap	Limestone
8.50	1800	900	60	-	100
9.20	240	450	480	600	75
9.40	240	450	600	720	75
9.45	240	540	600	720	75
10.07	280	420	480	800	75
11.15	280	540	480	1000	75
11.45	280	450	480	1000	75
12.30	280	450	600	1000	75
13.00	280	600	840	1000	75
13.05	280	600	840	1000	75
13.32	280	600	600	1000	75
13.40	280	600	600	1000	75
14.30	280	600	600	1000	75
14.40	320	600	-	1200	75
15.15	320	600	-	1200	75
	5680	8400	7260	13240	1150

Lime stone usage 20% of coke. Metal to coke ratio = 5:1

Table-6 : Stack gas characteristics for particulate emission (Average values)

Flue gas volume, (Nm^3/hr)	..	9950
Particulate Emission Concentration, (gm/Nm^3)	..	1.7
Particulate Emission Rate, (kg/hr)	..	16.2
Size Distribution of Particulate Emitted	micron (μ)	wt.(%)
	0-5	7
	5-20	23
	More than 20	70
Flue Gas Analysis (%) CO_2= 5.6, O_2 = 12.4, CO = 4.0		
Emission Factor For		
Particulate : 3.2 kg/MT of Metal charged.		
Carbon Monoxide 96 kg/MT of Metal charged		

foundries in India, the approach should be different. Provision of conventional control equipment may not be economically viable and technically feasible because of high capital cost and intermittent operations respectively. In view of these some studies are to be conducted to reduce the emission before implementing any enforcement. These studies include : (i) process and design modifications, (ii) improvement in charging methods, (iii) to determine accurately the sulfur balance, (iv) to determine the optimum stack height (presently no chimney is provided), and (v) change in fuel. Cost benefit analysis should also be worked out on the basis of the comprehensive studies. In addition, the workers should be trained properly as most of the foundries employ local craftsman for operations without formal training.

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