EXPERIMENTAL INVESTIGATIONS, OF EFFECT OF OXYGEN ENRICHMENT OF PREHEATED AIR ON PERFORMANCE, SPECIFIC FUEL AND ENERGY CONSUMPTION OF LDO FIRED ROTARY FURNACE,

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Abstract-

This paper deals with Experimental Investigations of oxygen enrichment of preheated air in LDO-fired rotary furnace, for optimal specific fuel and energy consumption. Energy consumption is major problem being faced by the Indian ferrous foundries. "Bureau of Energy Efficiency, "The Energy Research Institute," Govt. of India New Delhi & other International agencies has reported that energy consumption in Indian ferrous foundries is much more above the required limits and has to be drastically reduced.

The author conducted experimental investigation on oxygen enrichment of preheated air in a self designed and developed 200 kg rotary furnace in an industry The specific fuel and energy consumption of furnace, (when operated under existing conditions, without oxygen enrichment of preheated air,) in melting only was 0.460liter/kg or 4110.45 kwh/tone and total 4172.00 kwh/tone. When operated with oxygen enrichment of preheated air, the specific fuel and energy consumption in melting only reduced to 0.260 liter/kg or 2667.00 kwh/tone and in total to2711.00 kwh/tone. The energy consumption in melting only is reduced by 35.12% and in total by 35.01%

Keywords - Rotary furnace, Specific fuel, Oxygen enrichment, Energy consumption**.**

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1. INTRODUCTION:

A number of investigations had been conducted in the past on a rotary furnace. Baker EHW [1] explained the working of Rotary furnace. Jain R.K, Singh R,[2].applied regression modeling and excel solver technique for mathematical modeling and optimization of critical parameters of rotary furnace viz. rpm, melting rate, specific fuel consumption etc. Jain RK, Singh R, Gupta B.D. [3] presented an overview of energy consumption in ferrous foundry and stressed upon the need of an energy efficient furnace for foundries. Baijayanath, Pal Prosanto Panigrahy K.C. [4] explained that most of the units are crippled with usage of rudimentary techniques. The Indian foundry industry needs optimization of energy consumption. Singh Kamlesh Kumar [5] advocates the use of newer and cleaner technology for energy conservation. Arjunwadkar S.H, Pal Prosanto [6] stressed upon to use energy efficient melting techniques. Pandey G.N., Singh Rajesh, Sinha A.K[7] emphasized upon to supply oxygen at 8kg/cm^2 pressure as it reduces melting time and emission levels.

The present exercise is yet another attempt in energy conservation of the rotary furnace through oxygen enrichment of preheated air. In rotary furnace for melting of cast iron, the input parameters are (1) charge weight, (2) fuel (LDO), (3) flame temperature, (4) Preheated air volume, (5) Preheated air temperature, (6) Duration of a particular heat.(7)oxygen consumption. These parameters need to be controlled for optimal specific fuel and energy consumption. Figure-1 shows the layout and accessories of a rotary furnace.

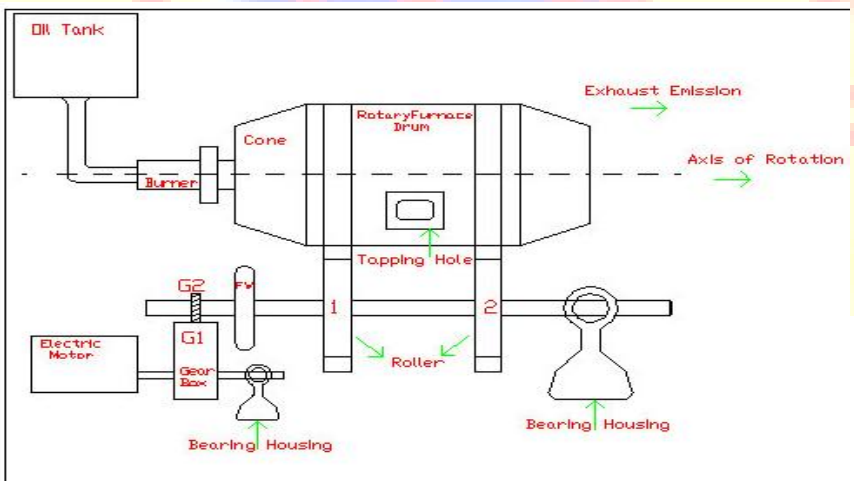

Fig 1 -Layout and accessories of a rotary furnace.

2. MATERIALS AND METHODS

2.1Melting Operation-The process of melting the charge in rotary furnace is carried out in the following steps:

(I) Preheating of oil and furnace-

The oil is preheated up to 70ºC and forced at 1.5 kg/cm^2 to preheat the furnace and starting the combustion. A small volume of oil in the form of stream jet, and primary air is forced inside the furnace. The droplets of oil come in contact with small volumes of primary air. At exit end of burner, initially drenched jute or warm cloth pieces are placed which are immediately ignited. As combustion proceeds, the volume of primary air is increased. When full ignition takes place, the secondary air at the same pressure is started. The volumes of primary and secondary air are controlled by valves to avoid the danger of backfire.

(II) Charging– After pre heating, the furnace is charged.

(III)Rotation-After sufficient pre heating and charging, the furnace is rotated at desired speed.

(IV) Melting- The flame starts coming out of the exit end, which is initially yellowish in color. After approximately 1 hour, the colour of flame changes to white indicating that metal has been thoroughly melted. The temperature of the molten metal is measured using pyrometer. If it is approximately 1250 to 1300ºC, the rotation of furnace is stopped.

(V) Tapping-The tape hole is slightly lowered and opened and metal is transferred into ladles, which are pre heated prior to the transfer of molten metal to avoid heat losses.

(VI) Inoculation-The Ferro silicon and Ferro manganese approx. 600 grams per heat are added in molten metal contained in the ladles.

(VII)Pouring –The ladles are then carried to moulds and pouring is completed. The furnace is shown in fig 1

3. EXPERIMENTAL INVESTIGATIONS-

3.1 Operating furnace under existing conditions of operation without oxygen enrichment—Specific fuel and energy consumption -

The furnace was operated under existing conditions of operation without oxygen enrichment. The charge per heat is 200.0 kg. In first heat, as furnace was started from room temperature, the melting time, fuel and energy consumption were more. In subsequent heats, the melting time,

fuel and energy consumption were reduced. 1liter of LDO is equivalent to 9.9047kwh/kg of energy. Observations are given in table 1.

S N	Heat no	Rpm	Time min	Fuel liters	Specific Fuel (lit/kg)	Melting Rate (kg/hr)	Flame temp.^{0}C	Preheated air cons. m^3	Energy consumption kwh/kg
1	1	2.0	50.0	92.0	0.460	240.0	1310.0	1320.0	4.556
2	2	2.0	47.0	90.0	0.450	255.3	1314.0	1290.0	4.457
3	3	2.0	46.0	87.0	0.435	260.8	1325.0	1240.0	4.308
4	4	2.0	46.0	86.0	0.430	266.0	1334.0	1220.0	4.259
5	5	2.0	45.0	83.0	0.415	266.0	1350.0	1175.0	4.110

Table1- Performance and specific fuel consumption of furnace under existing conditions of operations without oxygen enrichment

The total energy consumption (kwh/tone) of furnace under existing conditions of operations without oxygen enrichment is given in table 2

Sn	Particulars	Energy consumed/MT	Total Energy consumed
1	Plant& equipments (a)Plant & Equipment Blower7.5hp= 5.595 kwh Motor2,0hp=1.492kwh. =7.087kwh,for266.0kg/hr For 1 tone=26.648 kwh	26.648kwh	26.648kwh
2	Fuel combustion unit(SPT burner) (1)Oil filtering pump1hp. (2)heating element	0.746 kwh 2.00kwh=2.746kwh/266kg	10.323 kwh
3	Pollution control equipments 1.IDFan5hp=3.73kwh 2.Motor1hp=0.746kwh		

	=4.476kwh for 266kg/hr =16.827kwh/Tone	16.827kwh	16.827kwh
4	Shot Blasting equipment 30H.P.=22.38kwh,For 3 tones for one tone/hr =7.46 kwh	7.46 kwh	7.46 kwh
5	Fuel consumption- LDO 0.415liter/kg=415liter/tone	415x9.9047=4110.45	4110.45kwh
		Grand total	4171.703=(4172.00Kwh /Tone

Table2. The Energy Consumption of Rotary Furnace: under existing conditions of operation without oxygen enrichment

3.2 Operating furnace with oxygen enrichment of preheated air- Specific fuel and energy consumption

It is thought to optimize the energy consumption by reducing the amount of air and supplying oxygen externally, required for combustion. Several experiments were conducted, gradually reducing air to its theoretical requirement and even lesser in steps of 5.0 to 10.0% and supplying oxygen externally in steps of 1.0 to 2.0 %, and its effect on flame temperature, time, fuel, melting rate, and fuel consumption was studied. The effect was significant only when air was reduced to 75.0% of its theoretical requirement and approx 7.0% oxygen was supplied externally. The experimental investigations conducted are given in following sections.

(I)Effect of 6.9%oxygen enrichment of 75.3-75.4 % of theoretically required air on flame temperature, time, fuel, melting rate, specific fuel and energy consumption-Numbers of experiments are conducted, rotating furnace at optimal rotational speed 1.0 rpm, with 6.9% oxygen enrichment of 75.3-75.4% of theoretically required air, preheating LDO to 70^0C. The effect of above on flame temperature, time, fuel, melting rate, and specific fuel consumption are given in table 3

Heat no	Rpm	Preheated air temp ^{0}C	Flame temp^0 C	Time min	Fuel liter	Melting rate kg/hr	Specific fuel cons lit/kg	Oxygen cons m^3	Oxygen cons %	Preheated air cons. m^3	Preheated air cons %
1	1.0	410.0	1710.0	33.0	56.0	363.0	0.280	39.0	6.9	459.0	75.3
2	1.0	418.0	1722.0	32.0	56.0	375.0	0.280	39.0	6.9	459.0	75.3
3	1.0	428.0	1730.0	32.0	55.0	375.0	0.280	38.5	6.9	451.0	75.4
4	1.0	449.0	1746.0	31.5	54.0	385.0	0.270	38.0	6.9	443.0	75.4
5	1.0	454.0	1752.0	31.0	53.0	387.0	0.265	37.0	6.9	434.5	75.3
6	1.0	458.0	1754.0	30.5	52.0	393.0	0.260	36.6	6.9	426.7	75.4
7	1.0	460.0	1755.0	30.5	52.0	393.4	0.260	36.5	6.9	426.5	75.4

Table 3- Effect of 6.9% oxygen enrichment of 75.3-75.4% of theoretically required air on performance (flame temperature, time, fuel, melting rate), and specific fuel consumption.

The above experimental investigations reveal that by 6.9% oxygen enrichment of 75.3-75.4% of theoretically required preheated air, the specific fuel and energy consumption are significantly reduced.

(II) The graphical presentations-Effect of 6.9% oxygen enrichment of 75.3-75.4% of theoretically required air on flame temperature, time, fuel, melting rate, and specific fuel consumption- are presented graphically in figs 2(a) to(d) --

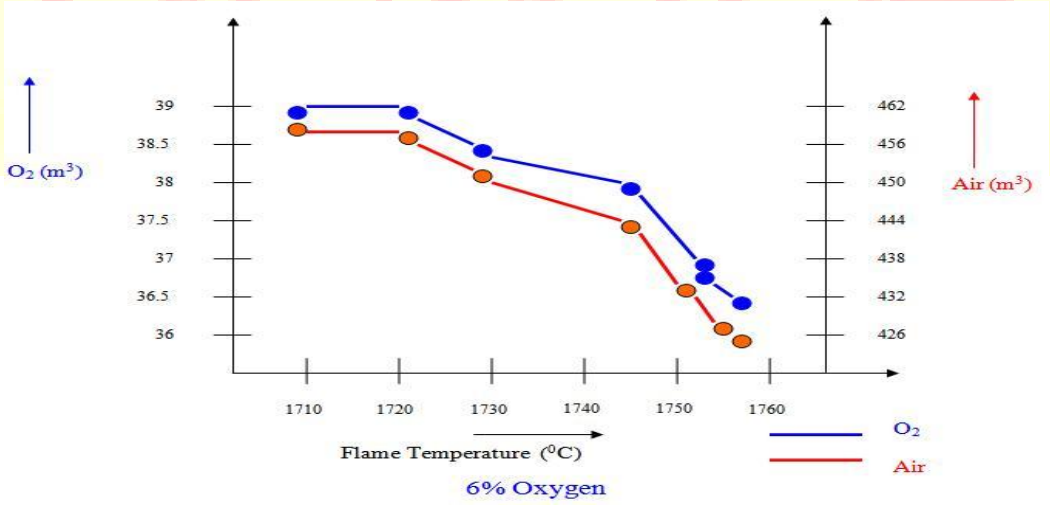

Fig 2(a)-Effect of 6.9%oxygen enrichment of 75.3 -75.4 % of theoretically required preheated air on flame temperature

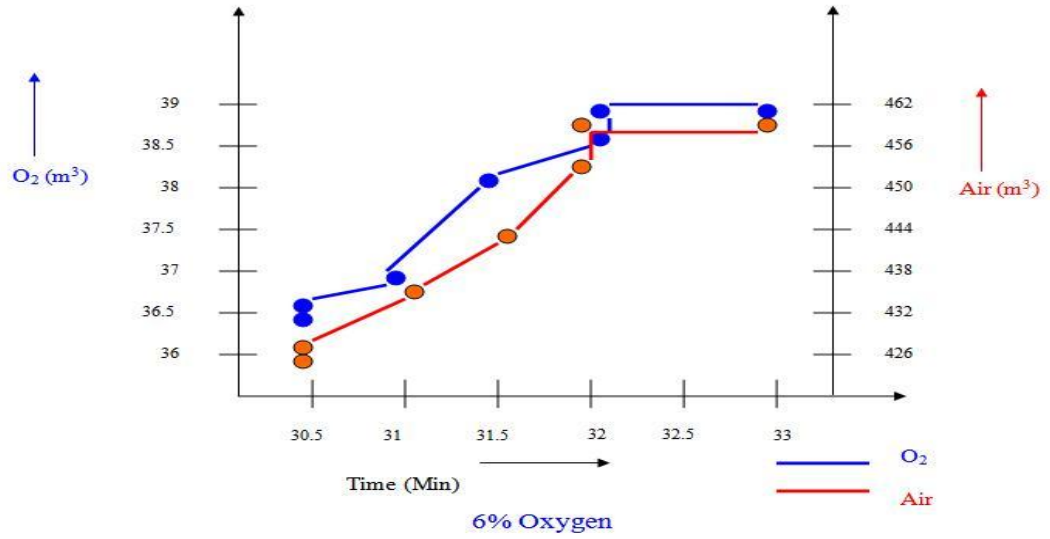

Fig 2(b) - Effect of 6.9% oxygen enrichment of 75.3-75.4%of theoretically required preheated air on time (minutes).

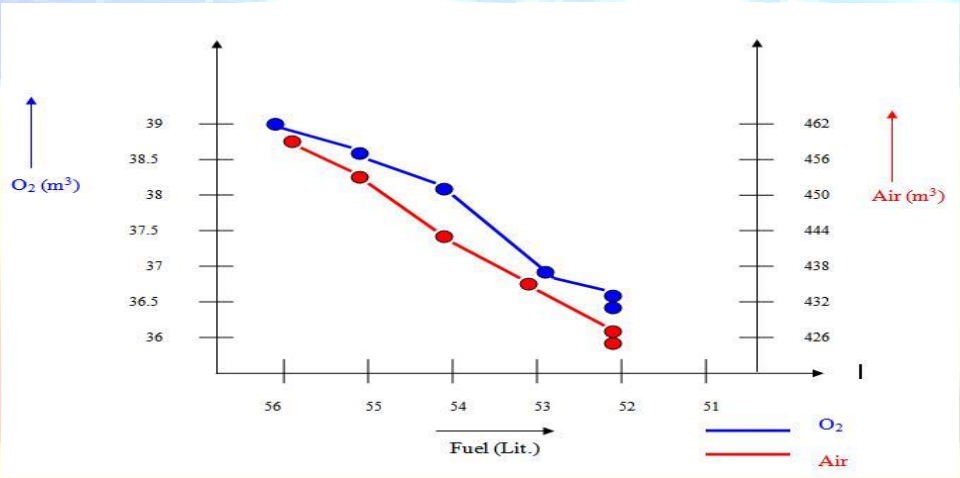

Fig2(c)-Effect of 6.9 % oxygen enrichment of 75.3-75.4 % of theoretically required preheated air on fuel consumption (liters).

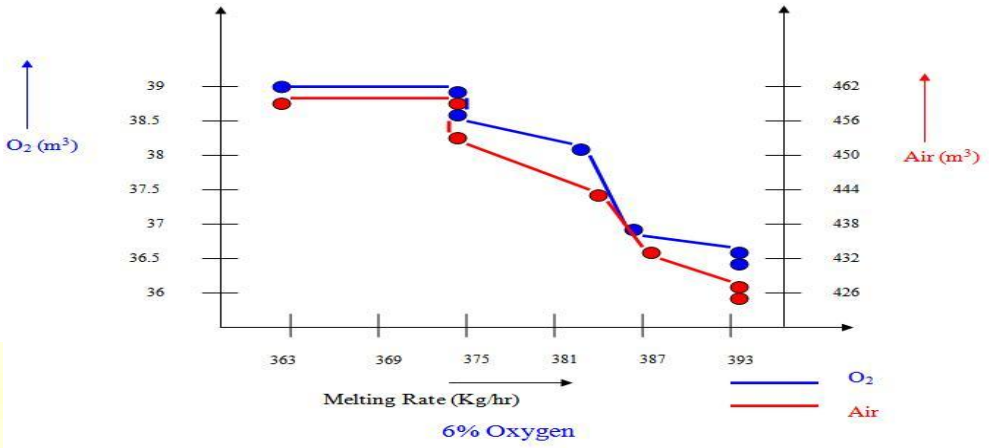

Fig 2 (d)-Effect of 6.9% oxygen enrichment of 75.3-75.4 % of theoretically required preheated air on melting rate.

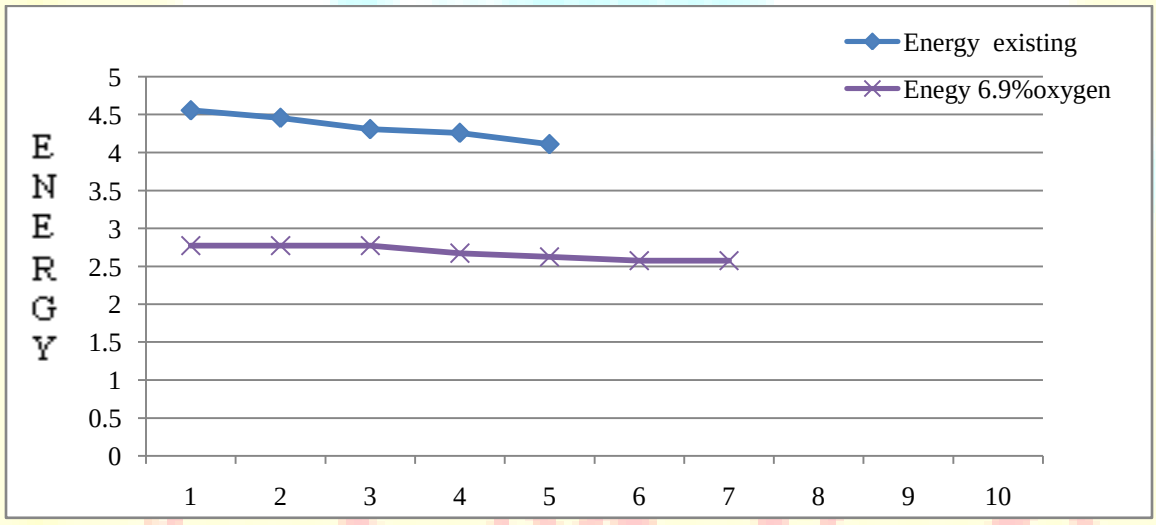

Fig 2(e) - comparison of energy consumption under existing conditions of operation and experimental investigations (6.9% oxygen enrichment of 75.3-75.4 % of theoretically required preheated air

(III)The three dimensional graphical representations using Mat Lab-Mat lab is software**,** which can also be used for three-dimensional graphical representations of three variables. The graphical representation of (i) Fuel consumption is shown in figure 3

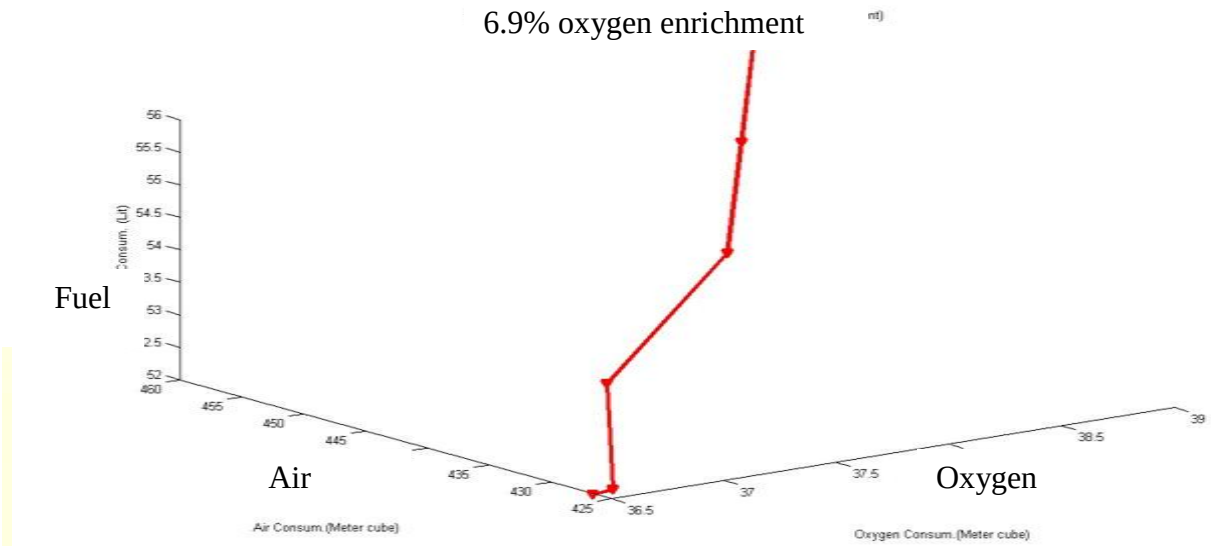

Fig 3- Three dimensional representation of Effect of 6.9%oxygen enrichment of 75.3-75.4 % of theoretically required air on fuel consumption (liters) using mat lab. X -axis–oxygen. Y- axis-air. Z - Axis fuel. On (ii) time/heat is shown in fig 4

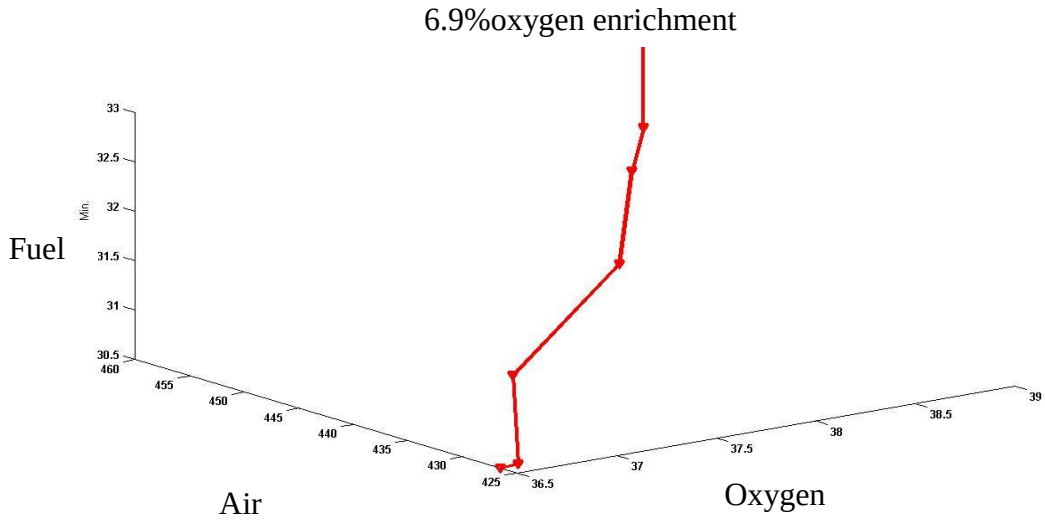

Fig 4-Three dimensional representation of Effect of 6.9% oxygen enrichment of 75.3-75.4% of theoretically required air on, time, using mat lab axis–oxygen, Y-axis-air-axis -time.

4.RESULT-The effect of oxygen enrichment of preheated air based on experimental investigations is given below

4.1 - Energy consumption -

(I) Energy consumption with 6.9-% oxygen enrichment of 75.3%-75.4% of theoretically required air is given table 4

SN	Particulars	Energy Consumed	Total Energy consumption kwh/tone
1	Fuel consumed in melting- (6.90-6.96% oxygen enrichment of 75.38%-75.43% of theoretical air, LDO=260Litre/tone Oxygen=36.50/200m^3/ kg=182.5 m3/tone	260x9.9047=2575.22kwh 182.5x0.5kwh=91.25kwh	2666.47kwh
2	Fuel combustion unit 2.5 hp=1.865 kwh for 393.44kg/hr.=4.740 kwh/tone	1.865 kwh for 393.44kg/hr 4.740 kwh/tone	4.740 kwh
3	Plant & equipments 1. Blower 7.5 HP 2. Geared motor 2 HP 3. Fan heat exchanger 1.0HP atmosphere side and 0.5HP furnace side	5.595 kwh 1.492kwh 1.119 kwh= 8.206 kwh for 393.44kg/hr =20.857kwh/tone	20.857kwh
4	Pollution Control Equipment: 1. ID Fan 5 HP 2. Motor 1 HP For 393.44 Kg melt/hr For 1 tone	3.73 kwh 0.746 kwh=4.476kwhfor 393.44 kg/hr =11.376 kwh/tone	11.376kwh
5	Shot Blasting M/c Capacity 1 T/Hr. Motor 30 H.P. = 22.38kwh	22.38/3 = 7.46 kwh/ tone	7.46 kwh
		Grand Total	2710.90=**2711.00**kwh

Table 4– Total energy consumption with 6.9% oxygen enrichment of 75.3%-75.4percentage of theoretically required air

5. CONCLUSIONS-Based on above experimental investigations following conclusions are drawn

5.1 Performance of furnace- The performance of furnace is compared in table 5

Parameters	Operating furnace without oxygen enrichment of preheated air	Operating furnace with 6.9% oxygen enrichment of 75.3%-75.4% of theoretically required preheated air
Time minutes	45.0	30.5
Flame temperature0C	1350.0	1755.0
Melting rate kg/hr	266.0	393.4
Fuel liters	83.0	52.0
Specific fuel cons.lit/kg	0.415	0.260
Preheated Air consumption m^3	1175.0	426.5
Oxygen consumption	-------	182.5 m^3/tone

Table 5- Comparison of performance of furnace

5.2 Energy consumption- Total energy consumption (kwh/tone) is compared in table 6

Parameters	Operating furnace at 2.0rpm without oxygen enrichment of preheated air	Operating furnace with 6.9% oxygen enrichment of 75.3%-75.4% of theoretically required preheated air
Fuel LDO liter/tone (in Melting) oxygen m^3	415.00	260 182.5m^3
(1)Energy consumption(kwh/tone) in melting	4110.45	2575.2+91.25=2666.47
(2) Plant & Equip.	26.648	20.857
(3)fuel combustion equipment	10.323	4.740
(3)pollution equip.	16.827	11.376

(4)shot blasting kwh	7.46	7.46
Total energy consumption	4171.70=4172.00	2710.90=2711.00

Table 6- Comparison of energy consumption (kwh/tone) based on experimental investigations

6. DISCUSSIONS

(I) Initially furnace was operated under existing conditions of operation without oxygen enrichment of preheated air. The energy consumption in melting only is 4110.45 kwh/tone and total is 4172.00 kwh/tone.

(II) In view of reducing the energy consumption, furnace was operated with 6.9% oxygen enrichment of 75.3%-75.4% of theoretically required air. The energy consumption in melting only reduced to 2667.00 kwh/tone and in total to2711.00 kwh/tone. The energy consumption in melting only is reduced by 35.12% and in total by 35.01%

Several castings have been produced using the rotary furnace with oxygen enrichment of preheated air. Based upon experimental investigations, it is concluded that specific fuel/energy consumption in rotary furnace is optimum when it is operated with 6.9% oxygen enrichment of 75.3-75.4% theoretically required air.

7. REFERENCE LIST:

1Baker EHW 1976 – "Rotary furnace" Modern Workshop Technology, part -1, Clever Hummer Press Ltd., London- 2nd Edition.Chap4

2 Jain R.K., Singh R, 2008- "Modeling and optimization of rotary furnace parameters using Regression & Numerical Techniques" proc. 68th world Foundry Congress, Feb7-10, 2008, Chennai. Pp 178-185

3. Jain R.K., Singh R. Gupta B.D2008.- "Energy considerations in Indian ferrous foundries'" J. Indian foundry journal, 54(8), p.p. 32-34

4.Baijya Nath, Pal Prosanto, Panigrahi K. C. 2007 "Energy conservation options among Indian foundries-a broad overview" .J. Indian foundry Journal 53(8) pp. 27-30

5. Singh Kamlesh Kumar, 2007 - "Energy efficiency in foundry process and casting rejection control" Indian foundry Journal 53(11) pp. 43-48

6. Arjunwadkar S.H. Pal Prosanto, et al 2008 -"Energy savings and carbon credits- opportunities' and challenges for Indian foundries" J. Indian foundry Journal, 54(10) p.p.33-37

7. Pandey G.N., Singh Rajesh & SinhaA.K,2007. "Efficient energy measures in steel foundry" Indian foundry Journal, 53(10) pp.49-54