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Reduction of Coal Usage and Improving Boiler Efficiency in Thermal Power Stations

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***Abstract*—**India is the third largest producer of electricity in the world. The national electric grid in India has installed capacity of 399.467 GW as of 31 March 2022. Renewable power plants which also include large hydroelectric plants constitute39.2 % of total installed capacity. During the fiscal year (FY) 2019–20, the gross electricity generated by utilities in India was 1,383.5TWh and the total electricity generation (utilities and non-utilities) in the country was 1,598 TWh. India has a surplus power generation capacity but lacks adequate fuel supply, transmission and distribution infrastructure. India's electricity sector is dominated by fossil fuels, particularly coal which produced about three-quarters of the country's electricity. The government's National Electricity Plan of 2018 states that they are commissioning 50,025 MW coal-based power plants under construction. The dependable report of the International Energy Agency (IEA) shows that general coal use is on the trip again +1.84% showed up contrastingly in relationship with 2020. It was observed that more amount of coal is using to generate the electric power than reference level. This was because of presence of magnetic elements in the bed material which was used in boiler to maintain desired temperature at the bottom of the boiler. The efficiency of the boiler is decreasing due to damage caused by the magnetic elements in the bed material. These magnetic elements decrease the reference temperature in the boiler and consequently the boiler operator is allowing excess amount of coal to maintain the reference temperature in the boiler. Because of this, excess amount of coal is used to generate electric power and there by producing excess amount of ash. This can be reduced by constructing a magnetic separator near the bed material stack point and verifying the magnetic elements in the bed material thoroughly. Due to this separator, the boiler efficiency can be maintained nearer to the designed value, usage of excess amount of coal can be reduced. The investment cost for erecting the magnetic separator can be obtained in a couple of years. As a case study, the SKS Power Generation CG Ltd, Raigarh (the one considered in the present assessment), is considered. It is seen that the proposed issue is attempted with MATLAB condition and cost appraisal of thermal power plant is disengaged and existing making data. The test results exhibited that the proposed structure gives a feasible system and best experience and is proved that it is essential for solving such type of assignments.

Keywords: Electrical Energy Situation, fluidized bed, efficiently removes iron particles from material, limit, Payback time, MATALB.

I. INTRODUCTION

India is the third largest producer of electricity in the world. The national electric grid in India has an installed capacity of 399.467 GWas of 31 March 2022. Renewable Power plants, which also include large hydroelectric plants, constitute 39.2% of total installed capacity. During the fiscal year(FY) 2019–20, the gross electricity generated by utilities in India was 1,383.5TWhand the total electricity generation (utilities and non-utilities) in the country was 1,598 TWh. The gross electricity consumption in FY2019 was 1,208 kWh per capita. In FY2015, electric energy consumption in agriculture was recorded as being the highest (17.89%) worldwide. The per capita energy consumption is low compared to most other countries despite India having a low electricity tariff.

India has a surplus power generation capacity but lacks adequate fuel supply, transmission and distribution infrastructure. The average plant load factor of the thermal power plants is below 60% against the norm of 85%.India's electricity sector is dominated by fossil fuels, in particular coal, which produced about three-quarters of the country's electricity. The government is making efforts to increase investment in renewable energy. The government's National Electricity Plan of 2018 states that the country does not need more non-renewable power plants in the utility sector until 2027, with the commissioning of 50,025 MW coal-based power plants under construction and additionof275,000MW total renewable power capacity after the retirement of nearly 48,000 MW old coal-fired plants. It is expected that non-fossil fuels generation contribution is likely to be around 44.7% of the total gross electricity generation by 2029–30.

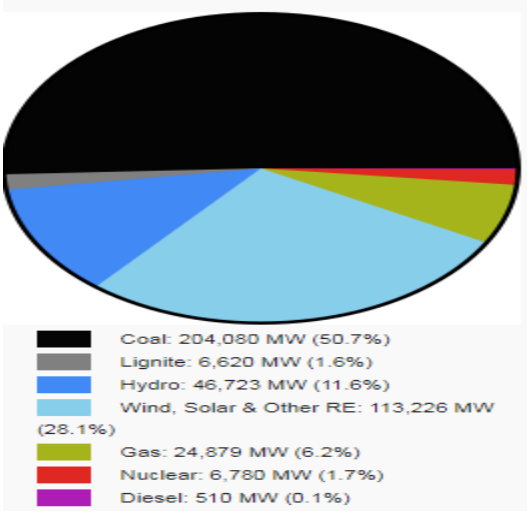

Fig1: InstalledCapacityinIndiaasonJune2022

The propelling report of the International Energy

Agency(IEA) shows that general coal use is on the outing again(+1%showed up contrastingly in association with 2021).

There are two types of boilers are used in sub critical, super critical and ultra-super critical coal fired thermal power plant: Pulverized coal-fired Boiler and Fluidized Bed combustion (FBC) boiler. The Circulating Fluidized Bed Combustion (CFBC) boiler is the most advanced steam generator technology. Among many distinguishable advantages of CFBC boilers, it achieves very low NOx and Sox emission by capturing sulfur contents of the fuel during the burning process. The bubbling type AFBC boiler offers efficient, cost-effective, reliable and viable alternative to conventional solid fuel-fired boilers for industrial applications. CFBC boilers are said to achieve better calcium to sulphur utilization – 1.5 to 1 vs.3.2 to 1 for the AFBC boilers, although the furnace temperatures are almost the same. CFBC boilers are generally claimed to be more economical than AFBC boilers for industrial application requiring more than 75 - 100 T/hr of steam. We get the higher temperature from CFBC boiler because of high gas velocity through the system. Lower combustion temperature can be achieving constantly, which result in minimum NOx formation. In CFBC boiler the combustion air is supplied at lower pressure as compared.

Table1: Growth of Installed Capacity of Thermal Power Stations

Installed Capacity as on	Installed Capacity (MW)
31.12.1947	854
31.12.1950	1153
31.03.1956	1825
31.03.1961	2736
31.03.1966	4903
31.03.1974	9058
31.03.1979	15207
31.03.1985	27030
31.03.1990	43764
31.03.1997	61010
31.03.2002	74429
31.03.2007	86015
31.03.2012	131603
31.03.2014	168255
31.03.2017	218330
31.03.2018	222906
31.03.2019	226279
31.03.2020	230600
31.03.2021	234728
31.03.2022	236109

This is an upsetting model, considering the course that despite expanding no matter how you look at it perception of the perils of an unnatural natural change in context on ozone draining substance outpourings, some enormous economies can't substitute their coal based power with less carbon-concentrated energies. Absolutely, coal is pervasively used for control creation, with 66% of world's use going to control age; this degree moves to seventy five percent if China and India, which generally have Progressively sweeping uses, are denied; the rest of utilization goes to industry (in a general sense steel).Coal remains the most dirtying wellspring of centrality: it everything considered transmits twice as a tremendous measure of CO2 as burnable gas it's fundamental competitor [2]. Coal remains the standard vitality source to pass on control. Around the globe, coal use for control age is in each functional sense making at a comparative rate as the power use (2.8% dependably versus 3% dependably some spot in the degree of 2000 and2017). Accordingly, the bit of coal in the power mix has about remained determined as far

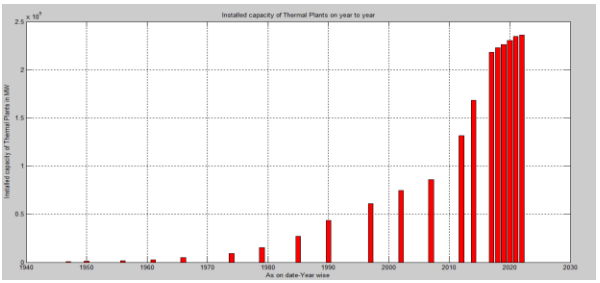

Fig2: Growth of installed capacity of Thermal Plants from year to year

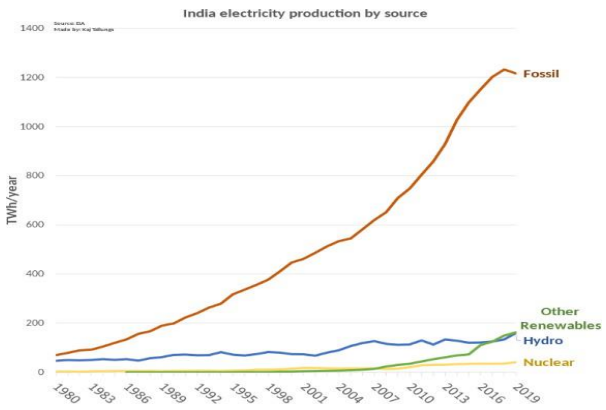

Fig 3: Electricity Production in India As on June 2026

UnequivocalcoaluseistheQuantityrequiredformaking1 unit of criticalness. It is depicted as the degree of Plant Heat Rate by GCV of Coal. Warmth Rate is a term normally utilized in control stations to show the power plant ability [3]. The sparkle rate is something contrary to the productivity: a heat rate is better. While ampleness is dimension less measure (now and again referred to in %) heat rate is ordinarily conferred as Btu/kWh. This is considering the way that watt hours are much more typically utilized when hinting electrical vitality and BTU is considerably more normally utilized when recommending warm criticalness. Warmth rate as for control plants can be thought of as the information expected to passion one unit of yield. It everything considered shows the extent of fuel required to make one unit of force. Execution parameters sought after for any warm power plant like ability, fuel costs, plant load factor, floods level, and so forth are a piece of the station heat rate and can be related direct.

India is the second most critical coal producer on earth after China with basic coal holds. The improvement of renewable and the supporting of continuously equipped coal-completed

power plants in India are not pleasing to ingest the progress in charge demand, which has discovered the center estimationof7%dependablysince2007.Othercountriesare trying to build up their essentialness mix and are genuinely using coal to make their capacity: Malaysia (45%, +10), Chile(37%,+9),South Korea(46%,+2) and Japan(33%, +6). These countries rely on coal for a few reasons: despite routinely being an inexorably moderate well spring of power, coal limits their dependence on oil-and gas-creation countries, and in that capacity obliges the effect of hydro carbon respect unconventionalities on their economies. By prudence of a non attendance of private non-reasonable power source resources, Japan is extraordinary compared to other oil-, ignitable gas and coal-getting countries. Some spot in the degree of 2011 and 2015, the bit of coal in Japanese power creation loosened up inside and out to change as per the fruition of nuclear power plants following the Fukushima disaster. Finally, a couple of countries with national coal spares, for instance, the Philippines (half, +15) and Vietnam (34%, +14), are developing this advantage for give control and to improve their essentialness self-organization and parity of payment.

During the glow balance time for testing imported coal (Indonesian) was used. For all glow balance checks the above gross calorific worth is used.

Table2: Unit & Cost of Energy

Particulars	Unit	Value
Electricity	Rs/KWh	4.00
Coal	Rs/MT	3900

Table3: Theoretical and Practical values of a Boiler

Description	Theoretical Values	Practical Values
Unit-1,BoilerEfficiency	86.26%	83.50%
Unit-2,BoilerEfficiency	86.26%	83.01%
Unit-1,UnitRate	2585.64	3109
Unit-2,UnitRate	2588.77	3207

In the event that an engaging fragment in the bed material structures, at that point acceptable warmth can't be kept up in the radiator, developing the stoppages, and utilization of coal and particularly influencing the evaporator life. An applicable assessment facilitated on the first and second generator's pot uncovered that the ability of the evaporator was diminished to 83.50% and 83.01% from arranged efficiency of 86.26% respectively.

IIPROBLEMFORMULATION

For the SKS Power Generation CG Ltd, Raigarh (the one considered in the present assessment). The maximum generating capacity of the generator is 300 MW and minimum Capacity of each generator is 150 MW. Generally speaking, the bed material should not to contain greater than 2.5%. Evaporator efficiency test was driven on 19/10/2019 and20/10/2019forUnit-1andUnit-2independently.During the estimation time period, load ontheUnit-1andUnit-2was around144.96MWand146.18MWindependently.The display evaluation of evaporator of the two units was done by testing the pot profitability by under handed procedure. In the quick methodology the essentialness increment of the water to change over into steam is differentiated and the imperativeness commitment through coal, while if there ought to emerge an event of indirect system, the capability is assessed by deducting various disasters from the data imperativeness through coal. During the testing time allotment screen diverse parameter of the radiator and differentiate and the arrangement regard [5]. The nuances of boilers parameter and their deviation from the arrangement regard are given in table 2.6.It can be seen from the above table, 3% to 5% deviation is found for Unit-1 and Unir-2 as complexity and structure parameters. In like manner, assessed the funnel gas temperature and O2, CO2 at various territories, for instance, economizer delta, outlet, and Air pre hotter sound and outlet. Nuances of the conscious parameters are given in the table 3.

Details of Boilers

The power plant involves two amounts of 300 MW coal based generators. The Boilers is of circulating fluidized bed First generator and second generator independently. Regardless, the use of coal is to be diminished as low as would be reasonable. Express coal use are showed up in table 2.

Coal Analysis

Plant workforce on steady calendar screen the coal tests and use structure. To check the glow regard for tallies, coal tests are assembled during study period and Ultimate examination has been finished at plant inquire about focus

In the event that an engaging fragment in the bed material structures, at that point acceptable warmth can't be kept up in the radiator, developing the stoppages, and utilization of coal and particularly influencing the evaporator life. An applicable assessment facilitated on the first and second generator's
potuncoveredthattheabilityoftheevaporatorwasdiminishedto83 .50% and 83.01% from arranged efficiency of 86.26% respectively. Table.2 underneath shows the sorted out qualities and ensured estimations of the glow pace of a unit, and sufficiency of radiator. The evaporator under handed adequacyofUnit-1andUnit-2isaround83.50%and83.01 % independently which is hardly less as stand out from plan capability (86.26%). It is essentially a result of the glow set back on account of radiation. A radiation adversity for unit-1 and unit-2 is 1.54% and 1.46% independently. The standard radiation adversity for 100MW to 500MW evaporator is under 1.0% (0.3% to1.0%). In the event that an engaging fragment in the bed material structures, at that point acceptable warmth can't be kept up in the radiator, developing the stoppages, and utilization of coal and particularly influencing the evaporator life. An applicable assessment facilitated on the first and second generator's pot uncovered that the ability of the evaporator was diminished to 83.50% and 83.01% from arranged efficiency of 86.26% respectively. Table.2 underneath shows the sorted out qualities and ensured estimations of the glow pace of a unit, and sufficiency of radiator.

Table3: Load on the plant, Generated Units, Usage of coal and its blending ratio

Month &Year	Unit#1							
	Load (MW)	Gen. M.U	Coal Feeding MTS		Blending Ratio		Overall GCV	Total coal Consumption MTS
			Aus	Indo	Aus	Indo		
01.10.2016	143.96	3.455	1000	729	57.84	42.16	**5084**	1729
02.10.2016	130.38	3.129	980	599	62.06	37.94	**5075**	1579
03.10.2016	145.42	3.490	1100	660	62.50	37.50	**5099**	1760
04.10.2016	139.42	3.346	850	831	50.57	49.43	**5110**	1681
05.10.2016	136.25	3.270	900	748	54.61	45.39	**5088**	1648
06.10.2016	129.63	3.111	800	779	50.66	49.34	**5055**	1579
07.10.2016	124.58	2.990	750	764	49.54	50.46	**5048**	1514
08.10.2016	127.96	3.071	800	751	51.58	48.42	**5042**	1551
09.10.2016	106.54	2.557	650	649	50.04	49.96	**5024**	1299
10.10.2016	137.42	3.298	817	850	49.01	50.99	**5038**	1667
11.10.2016	102.38	2.457	650	603	51.88	48.12	**5049**	1253
12.10.2016	100.33	2.408	606	630	49.03	50.97	**5056**	1236
13.10.2016	131.21	3.149	800	810	49.69	50.31	**5043**	1610
14.10.2016	145.17	3.484	950	818	53.73	46.27	**5032**	1768
15.10.2016	147.67	3.544	950	851	52.75	47.25	**5039**	1801
16.10.2016	16.04	0.385	150	50	75.00	25.00	**5027**	200
17.10.2016	0.00	0.000	0	0	0.00	0.00	0	0
18.10.2016	114.92	2.758	750	700	51.72	48.28	**5026**	1450
19.10.2016	134.46	3.227	850	802	51.45	48.55	**5032**	1652
20.10.2016	7.71	0.185	50	48	51.02	48.98	**5014**	98
21.10.2016	0.00	0.000	0	0	0.00	0.00	0	0
22.10.2016	0.00	0.000	0	0	0.00	0.00	0	0
23.10.2016	0.00	0.000	0	0	0.00	0.00	0	0
24.10.2016	0.00	0.000	0	0	0.00	0.00	0	0
25.10.2016	0.00	0.000	0	0	0.00	0.00	0	0
26.10.2016	0.00	0.000	0	0	0.00	0.00	0	0
27.10.2016	0.00	0.000	0	0	0.00	0.00	0	0
28.10.2016	0.00	0.000	0	0	0.00	0.00	0	0
29.10.2016	0.00	0.000	0	0	0.00	0.00	0	0
30.10.2016	0.00	0.000	0	0	0.00	0.00	0	0
31.10.2016	0.00	0.000	0	0	0.00	0.00	0	0
TOTAL	**2221.42**	**53.31**	**14403.00**	**12672.00**	**1024.68**	**875.32**	**95979.85**	**27074.82**

Fig4: Images of Erection of Magnetic Separator

Fig5: Location of Magnetic Separator in the thermal power plant

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III RESULTS AND DISCUSSIONS

The cost of the bed material per ton is Rs. 5,000/-. First boiler uses 8000 Tons per its operation. The cost of the bed material is 400 Lakh rupees. Because of the construction of Magnetic separator, one can reduce the usage of coal to maintain the temperature in the boiler. The payback time because of construction of magnetic separator is 5.4 years if the magnetic elements available in the bed material are 1%. The following fig 1 shows the payback times for different amounts of magnetic elements in the bed material i.e. for1% to 10% of magnetic elements in the bed material.

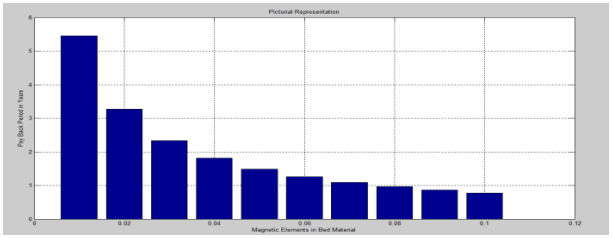

Fig4: PercentageofMagneticelementsVs.PaybackTime

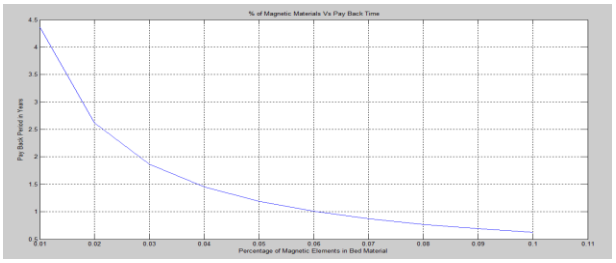

Fig 5: payback times for different amounts of magnetic elements in the bed material i.e. for 1% to 10% of magnetic elements in the bed material

S. No	Cost of Bed Material per Ton (Rs)	Number of Tons of Bed Material required (Tons)	Total Cost of the Bed Material (Lakhs)	Magnetic Elements in the Bed Material	Pay Back Period (Years)
1.	5,000	8000	400	1%	5.4
2.				2%	3.2
3.				3%	2.3
4.				4%	1.8
5.				5%	1.4
6.				6%	1.25
7.				7%	1.1
8.				8%	0.9
9.				9%	0.8
10.				10%	0.7

Table 4: payback times for different amounts of magnetic elements in the bed material i.e. for 1%to 10%of magnetic elements in the bed material for the 8000 Tons of bed material.

The cost of the bed material per ton is Rs. 5,000/-. First boiler uses 6000 Tons per its operation. The cost of the bed material is 300 Lakh rupees. Because of the construction of Magnetic separator, one can reduce the usage of coal to maintain the temperature in the boiler. The payback time because of construction of magnetic separator is 0.7 years if themagneticelementsavailableinthebedmaterialare10%. The following fig 2 shows the payback times for different amounts of magnetic elements in the bed material i.e. for1% to 10% of magnetic elements in the bed material.

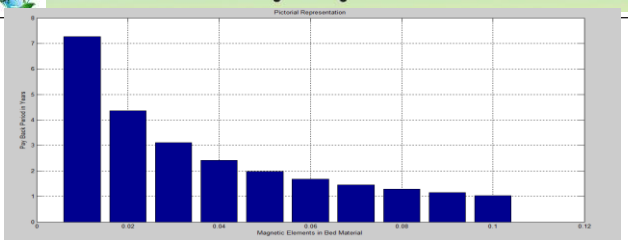

Fig6: Percentage of Magnetic elements Vs. Payback Time

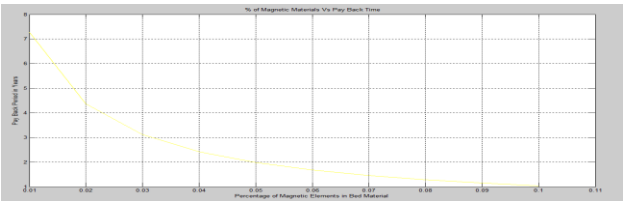

Fig 7: payback times for different amounts of magnetic elements in the bed material i.e. for 1% to 10% of magnetic elements in the bed material

S. No	Cost of Bed Material per Ton (Rs)	Number of Tons of Bed Material required (Tons)	Total Cost of the Bed Material (Lakhs)	Magnetic Elements in the Bed Material	Pay Back Period (Years)
1.	5,000	6000	300	1	7.2
2.				2	4.4
3.				3	3.1
4.				4	2.4
5.				5	2.0
6.				6	1.7
7.				7	1.5
8.				8	1.3
9.				9	1.1
10.				10	1.0

Table 5: payback times for different amounts of magnetic elements in the bed material i.e. for 1% to 10% of magnetic elementsinthebedmaterialforthe6000Tonsofbed material.

The cost of the bed material per ton is Rs. 5,000/-. First boiler uses 9000 Tons per its operation. The cost of the bed material is 450 Lakh rupees. Because of the construction of Magnetic separator, one can reduce the usage of coal to maintain the temperature in the boiler. The payback time because of construction of magnetic separator is 0.7 years if the magnetic elements available in the bed material are 10%. The following fig 2 shows the payback times for different amounts of magnetic elements in the bed material i.e. for 1% to 10% of magnetic elements in the bed material.

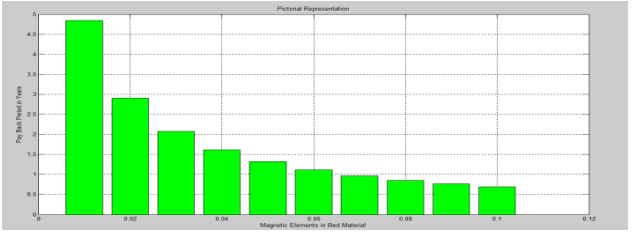

Fig8: Percentage of Magnetic elements Vs. Payback Time

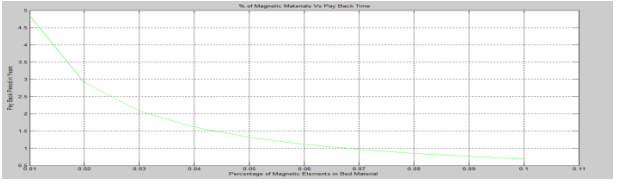

Fig9: Payback times for different amounts of magnetic

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elements in the bed material i.e. for 1% to 10% of magnetic elements in the bed material

S. No	Cost of Bed Material per Ton (Rs)	Number of Tons of Bed Material required (Tons)	Total Cost of the Bed Material (Lakhs)	Magnetic Elements in the Bed Material	Pay Back Period (Years)
1.	5,000	9000	450	1%	4.8
2.				2%	2.9
3.				3%	2.0
4.				4%	1.6
5.				5%	1.3
6.				6%	1.1
7.				7%	0.9
8.				8%	0.8
9.				9%	0.7
10.				10%	0.6

Table6: payback times for different amounts of magnetic elements in the bed material i.e. for 1% to 10% of magnetic elements in the bed material for the 6000 Tons of bed material.

The cost of the bed material per ton is Rs. 5,000/-. First boiler uses10000 Tons per its operation. The cost of the bed material is 550 Lakh rupees. Because of the construction of Magnetic separator, one can reduce the usage of coal to maintain the temperature in the boiler. The payback time because of construction of magnetic separator is 1.1 years if the magnetic elements available in the bed material are 5%. The following fig 2 shows the payback times for different amounts of magnetic elements in the bed material i.e. for1% to 10% of magnetic elements in the bed material.

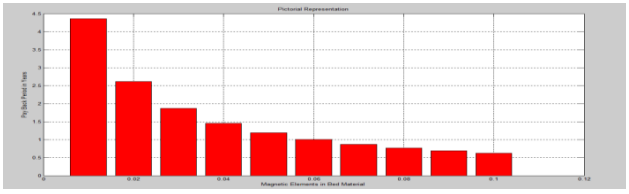

Fig10: Percentage of Magnetic elements Vs. Payback Time

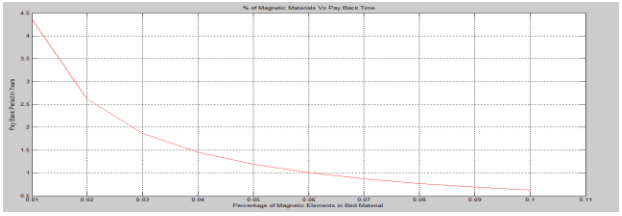

Fig 11: payback times for different amounts of magnetic elements in the bed material i.e. for 1% to 10% of magnetic elements in the bed material

S. No	Cost of Bed Material per Ton (Rs)	Number of Tons of Bed Material required (Tons)	Total Cost of the Bed Material (Lakhs)	Magnetic Elements in the Bed Material	Pay Back Period (Years)
1.	5,000	10000	500	1%	4.3
2.				2%	2.6
3.				3%	1.8
4.				4%	1.4
5.				5%	1.1
6.				6%	1.0
7.				7%	0.8
8.				8%	0.7
9.				9%	0.6
10.				10%	0.5

Table 7: payback times for different amounts of magnetic elements in the bed material i.e. for 1% to 10% of magnetic elements in the bed material for the 10000 Tons of bed material.

S. No	Cost of Bed Material per Ton (Rs)	Number of Tons of Bed Material required (Tons)	Total Cost of the Bed Material (Lakhs)	Designed boiler (%ή)	Actual boiler (%ή)	Cost of the Magnetic Separator (Lakhs)	Pay Back Period (Years)
1.	5,000	8000	400	85.60	83.50	23.8110	5.4
2.	5,000	6000	300	85.60	83.50	23.8110	7.2
3.	5,000	9000	450	85.60	83.50	23.8110	4.9
4.	5,000	10000	500	85.60	83.50	23.8110	4.4

Table 8: payback times for different amounts of magnetic elements in the bed material i.e. for 1% to 10% of magnetic elements in the bed material for the various Tons of bed material.

With this foundation of enchanting separator gear, all the additionally sizzling practical insight can be loose up to 2.1% i.e., from 83.50% to 85.60% more for first generator and from 83.01% to 85.21% more for second generator, to keep up the customary temperature to keep up a principal unremarkable ways from pot stoppages. An evaluation was shaped to the various parameters to be viewed pulling back for the foundation of a drawing in separator.

IVCONCLUSIONS

With the construction of magnetic separator, the temperature in the boiler maintained as per the reference temperature without using excess amount of coal. The cost spent for the construction of magnetic separator can be obtained in a couple of years. As the percentage of magnetic elements is more and more, the payback period is smaller and smaller. Payback times for different amounts of magnetic elements in the bed material i.e. for 1% to 10% of magnetic elements in the bed material are from 4.3 years to 0.5 years if the bed material is 10000 Tons.

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