Re-Engineering Concept on Enhancing the Thermal Efficiency of Thermal Power Station Boiler

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Abstract— This paper deals with the Re-engineering concept on enhancing the Thermal efficiency of Thermal power station boiler. The Thermal power plants generate 80% of the total electricity produced in the world. For producing power in power station, boiler is the main unit. After a continuous usage period, the original boiler efficiency will decrease considerably after a period of 20 years. Then re-engineering works will help to increase its life and efficiency to the original status by the expense of small amount ($1/6^{th}$ of new boiler cost) of the huge investment for purchase of new boiler. The existing boiler status was studied for failure rate, operational history, performance, remnant life determination, evaluation of re-engineering, pollution control and C & I updates. Replica structure details, hardness, case history, investigation, dimensional measurement, micro examinations, R&D of water chemistry laboratory, NDT of Boiler pressure parts were studied in detail. After the study's conclusion was taken to change SH tubes, W.W.tubes, ECO coils and main steam lines.

Index Terms - downcomer and upriser tubes, NDT of Boiler, Re-engineering, Thermal efficiency, Thermal power station boiler, SH tubes, W.W.tubes

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1 INTRODUCTION

Energy is the blood of all developmental activities either in industrial or agricultural or any other associated sectors. The progress of any country happens along with the demand of more power.

Thermal power plants generate more than 80% of the electricity produced in the world. Steam is also required in many industries for processing heat. To meet dual need of power and to process heat, power plants are installed. While considering the generating unit i.e. boiler, boiler efficiency is the main criteria to be taken into account.

There has been always a search for various new techniques for producing more power. In our country power generation capacity of various power plants installed are hydro-electric, nuclear, thermal, etc.

It is obvious that thermal power plant meet the large demand of energy compared to other plants. But at the same time the cost of construction for thermal power station now ranges from 5.5 to 6 crores per MW, showing the increased cost of energy every day. Hence the installation of new power plant is both cost and time consuming job.

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Power generation is the backbone of any nation and there is a need for ensuring a reliable power generation. To ensure this, the need and benefits of condition assessment, life extension, capacity regain and efficient operation through modernization of steam generators have been well recognized. More and more steam plant managers across the world are opting to take of these works for achieving improved plant availability and plant load factors.

2 EXISTING TECHNOLOGY

The thermal power stations in the country are mostly based on the following technologies

i. Steam power plants
ii. Gas turbine power plants

I. Steam power plants

The steam power plants are mostly coal-based power plants having maximum unit size of 500 MW. All the steam power plants in the country have sub-critical steam parameters. Indigenous manufacturers are capable of offering steam power plants up to 500 MW unit size and are quite competitive compared to the world leading manufacturers. Considering these points in mind, the title for this research study is chosen.

The major areas of concentration are:

1. Thermal performance assessment.
2. Modernization of controls and instrumentation.
3. Load regains for old units by appropriate replacements and up gradation.

4. Residual Life Assessment (RLA) of pressure parts and life extension measures.
5. Milling capacity up gradation.
6. Milling system replacement.

3 Review Of Literature

As per the recommendation of Thermal Energy Research Institute (TERI) on R&M and life extension of thermal power stations 31.3.2000, the expected benefits are illustrated. From the above recommendations provided by Thermal Energy Research Institute, the project has been done [1]. V. V. Bogomolov and N. V. Artem'eva, (2005) "Characteristics of non design fuels needed for analyzing their efficiency when used in thermal power plants. With reference to V.Bogomolov, suggest that all thermal power plants are enhancing the reliability and efficiency can be improved by the process of Re-engineering [2]. K. Roth and V. Scherer Department of Energy Plant Technology (LEAT), University of Bochum, 44801 Bochum, Germany. Roth suggest that enhancing the dynamic performance of electricity production in steam power plant by the integration of transient waste heat sources into the feed water Re-engineering system [3]. Farber, P., S. Katzberger, W. Siegfriedt, *Results of FGD Upgrade Projects on Low-Rank Coals*, Electric Power 2007 Conference and Exhibition. As per the research work of Farber, they suggest that the thermal power plant can be improved by the application of Re-engineering [6]. Kitto, Jr., J. B., S. A. Bryk, J. M. Piepho, "Upgrades and Enhancements for Competitive Coal-Fired Boiler Systems," Babcock & Wilcox, Technical Paper. As suggested by Kitto, upgrades and enhancement of competitive coal system boilers, some of the water walls can be changed and the efficiency may be improved [7].

In recent study reveals that the Researchers explored theoretically upon the Re-engineering, but in the thesis, Re-engineering is practically implemented to increase the thermal efficiency.

4 Need For The Study

The power demand is steadily increasing day by day in India. Since our country is economically in downward position, we could not invest more amounts to procure new boilers. The above draw backs are to be rectified by the Re-engineering works.

1) The components of power plants are designated to withstand a predetermined number of load cycles and the normal safe operating life of a high-pressure boiler is 1.8 to 2 lakhs hours. Scaling, corrosion, thermal creep and fatigue in the high pressure and temperature zones of the units, render them unusable thereby reducing the service life of the plant.
2) At this stage, instead of scrapping the entire unit, Re-engineering works have to be done to extend the life of the boiler for another 20 years
3) Critical components of the boiler like water wall tubes, economizer coils, super heater tubes and main stream lines are to be replaced.
4) Damaged coils of low pressure & high pressure heaters are to be replaced.
5) Air ingress through the duct plates, shield plates and mill casings are to be arrested.

The purpose of Re-engineering is to enhance the boiler efficiency after a continuous usage period of 15-20 years. Then Re-engineering works of the boiler will help to increase its life and efficiency to the original status by the expense of little money compared to the huge investment for the purchase of new boiler. Re- engineering can be carried out and the original efficiency can be achieved.

5 Objectives

The following is the objective of the study,

To increase the efficiency of Thermal Power Station- I Boiler of Neyveli Lignite Corporation Ltd., Neyveli.

6 Methodology Adopted

The objective of the study is achieved through,

1. Heat Rate for the power generation is reduced.
2. The steam flow rate from the existing condition is increased.
3. The live steam temperature to the norms is increased.
4. Leakage of flue gas and air are reduced.
5. The combustion is improved.
6. The heat absorption in the pressure parts is improved by external soot cleaning and internal acid cleaning.
7. Mixing up of the flue gas with the combustion air in the system is avoided

6.1. Operational history

1. Capacity: steam flow :- 220 T / H, Pressure – 90 Kg / cm^2 & Temperature – 540 $^{\circ}$C
2. Type of service: continuous.
3. Operating hours: 1, 80,853.

6.2.No. of Tube failures:

Economizer	Water Wall	Screen Super Heater	Convection Super Heater 1	Convection Super Heater 2
33	7	4	2	10

No of chemical cleaning: Nil

Non-Destructive testing was conducted before Re-engineering. Economizer header butt welds and nipple joints, condenser joints and down comer joints were conducted for full testing. The tube thickness measurement in economizer coil, super heater coils, down comer tubes, water walls and main steam lines were analyzed. The economizer bottom middle and top bank tubes' thickness were analyzed.

To achieve all the items listed above, the following procedures are to be adopted:-

6.3. Evaluated the present performance of the unit.

1. Collected all relevant boiler performance data from the past and present log data.
2. Identified the critical areas of boiler performance causing the deterioration in boiler output and availability.
3. Listed out specific areas requiring major attention to ensure significant improvements in boiler output and availability.
4. Analyzed boiler performance data after major Re-engineering.
5. Implementation of replacement, repairs and modifications.
6. The present condition of water wall tubes, super heater tubes and economizer coils were studied. From the performance study the Residual Life Assessment (R L A) was taken.
7. Boiler water wall tube deposit was analyzed for chemical analysis and physical properties. Super heater tubes' thickness was measured. Drum circumferential weld joints; steam cross over pipe joints, super heater coils, main steam line near boiler outlet and main stream line to turbine were checked for hardness and the structural details before Re-engineering.
8. Dimension was measured in economizer headers and coils, water wall tubes and super heater tubes. As per the measurement, most of the tubes' thickness was found less. The Re-engineering was applied to replace the existing tubes of the pressure parts.
9. Air ingress study before Re-engineering was done at 42 MW load condition and the steam flow was 180 Tons / Hour.

Details	% of Oxygen	% of excess air
After Super Heater	8.1	63
In sloping duct	9.35	80
At Induced draught fan suction	11.15	113

Norms: 17% in convective shaft and 25% in the Induced draught fan suction can be permitted.

The leaky boiler shield plates located at different locations were changed and air that enters through the leaky shield plates was arrested.
The above works were carried out with Re-engineering concept, so as to minimize the expenditure and also to get the maximum benefit from the study.

7 Results and Discussion

After the implementation of Re-engineering assessment, the boiler was subjected to the following performance tests:

i. The boiler was loaded with rated capacity for several hours. After that readings were taken.
ii. Unit operation ran at full load and the data was collected at steady and stable conditions of the boiler.
iii. The unit ran at 60% or 70% load and the data were collected at steady and stable conditions of boiler.

7.1. Evaluation of Re-engineering

The thermal performance and pressure part life extension were carried out after Re-engineering.

The works were carried out in Re-engineering and the boiler was commissioned.

Before and after Re-engineering works the following readings were taken and the student's't' test was conducted for the following parameters as

1. Power generation vs. Steam flow.
2. Power generation vs. Induced draught fan current.
3. Power generation vs. Percentage of oxygen content in the flue gas.
4. Power generation vs. Exit gas temperature.
5. Power generation vs. Thermal efficiency
6. Power generation vs. Live steam temperature.
7. Power generation vs. Forced draught fan current.
8. Power generation vs. Percentage air ingress to the boiler.

1. Power Generation Vs Steam Flow

In the process of Re-engineering the impact of Re-engineering on power generation was studied. After Re-engineering the impact of the same on several factors were considered and for this purpose the steam flow before and after Re-engineering was taken as variables (x) and (y). To examine whether the steam flow differs significantly before and after Re-engineering student's't' test for independent values were used. The results were given in table I (c) & I (d).

T-Test Table: - 1(c) Group Statistics

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ANOVA	N	Mean	SD	Std. Error Mean
1.00	20	84.4000	6.80093	1.52073
2.00	20	219.9500	4.00625	0.89582

Table: 1 [d] : Independent Samples Test

Shows that 'T' Statistics value t=20.12 with a corresponding value of p=0. Hence there is a significant difference between before and after steam flow.

Table	Levene's Test for Equality of Variances		T-Test for Equality of Means				
	F	Sig	T	Df	Mean-Difference	95% Confidence Interval of the difference Lower	Upper
Equal Variancesassumed	3.41	0.07	-20.142	38.000	-35.550	-39.12300	-31.97700
Equal Variancenot assumed			-20.142	30.769	-35.550	-39.15078	-31.94922

From this table, it could be seen that't' statistics value t=20.142 with a corresponding p value p=0. Hence there is a significant difference between the steam flow levels on the average before and after Re-engineering. It is also statistically proved.

2. Power Generation vs. Induced draught fan current:

The above power generation vs. Induced draught fan current shows difference between before and after Re-engineering. The student's 't' test't'=47.15 is showed in the left hand side and 19.909 in the right hand side. This shows a significant improvement in Re-engineering impact.

3. Power generation vs. Percentage of oxygen content in the exit flue gas:

This shows the difference between before and after Re-engineering of Percentage of oxygen content in flue gas. The student`s't' test't' value is 20.337. This shows significant difference after Re-engineering compared to before.

4. Power generation vs. Exit gas temperature:

The exit flue gas temperature is considered with power generation. 't'=26.96 in the left hand side and 17.304 in the right hand side. This shows an impact of Re-engineering.

5. Power generation vs. Thermal efficiency:

Thermal efficiency before and after Re-engineering was considered. 't'=57.635. This shows a significant improvement.

6. Power generation vs. Live steam temperature

This deals with live steam temperature with power generation. 't'=2.055 and this shows significant difference between before and after values.

7. Power generation vs. Forced draught fan current:

Similarly Forced draught fan current is considered for't' test. The 't' values are 31.30 in the right hand side and 10.337 in the left hand side. This shows a significant improvement in Re-engineering.

8. Power generation vs. Percentage of air ingress to the boiler:

Student's "t" test value for percentage of air ingress t =96.294.The mean level of air ingress differs before and after Re-engineering and it significantly improves the thermal efficiency.

7.2. Cost Saving Details:

Cost saving attained after Re-engineering

DESCRIPTION	COST IN CRORES
Cost of installation of a 50 MW boiler	Rs.300
For the same capacity 50 MW old boiler Re-engineering cost	Rs.50
Cost saving per boiler due to Re-engineering	Rs.250

After Re-engineering, we gained the cost benefits of Rs.250 crores for the same new boiler life (20 years) with the investment of 1/6 cost of new boiler ie.50 crores

C.BEFORE RE-ENGINEERING

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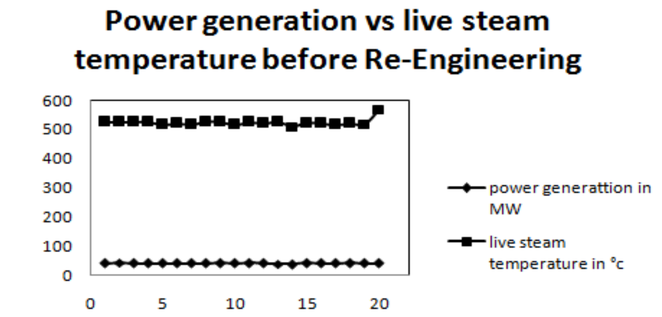

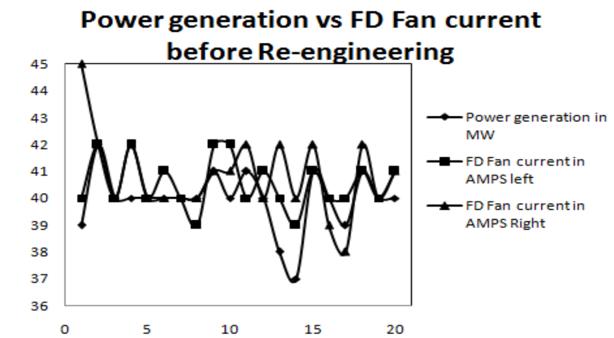

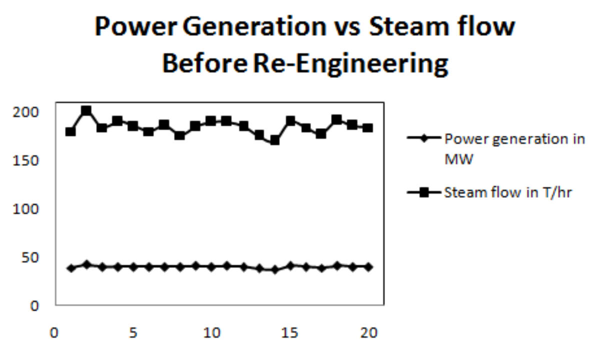

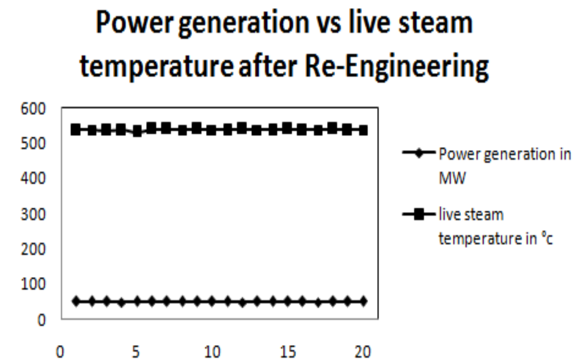

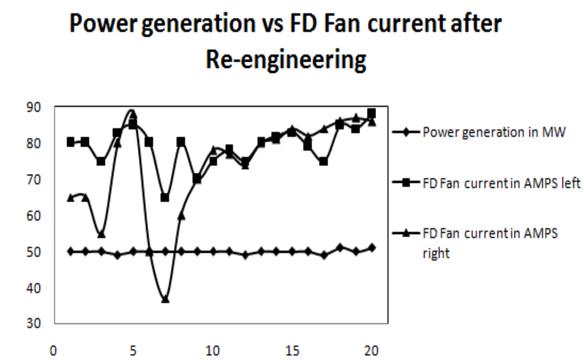

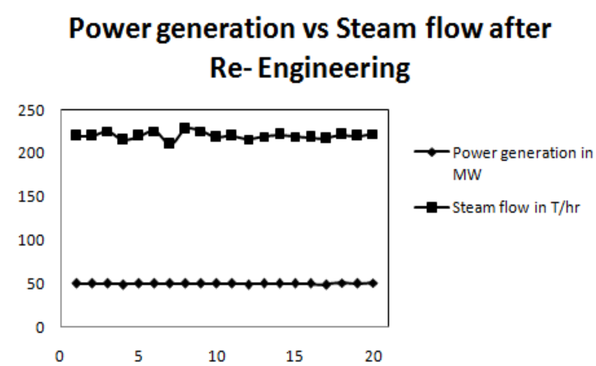

D.AFTER RE-ENGINEERING

8 Conclusions

After Re-engineering the thermal efficiency was increased from 78.15% to 88.19 %. Heat Rate was reduced from 2866 Kcals / KWH to 2629 Kcals / KWH after Re-engineering. After Re-engineering main stream flow was increased from 170 - 200 T / H to 210 - 228 T / H. Induced draught fan current was reduced from 98 - 102 Amps to 65 - 75 Amps. In the left hand side and from 97-103 Amps to 48 - 74 Amps. In the right hand side after Re-engineering. The Percentage of oxygen content was reduced from 7 - 8.9 % to 5.4 to 6.4 % after Re-engineering. After Re-engineering the exit flue gas temperature on left side was reduced from 190-218 ° C to 155-168 ° C and in the right side from 180-196 ° C to 155-167 ° C. The air ingress in the boiler was reduced from 31.82 % - 41.31 % to 10.3 % - 21.34 % after Re-engineering in the sloping duct and Induced draught fan suction after Re- engineering. The live steam temperature was increased from 510 – 526 ° C to 531 – 540 ° C after Re-engineering. The Forced draught fan current was increased in the left hand side from 39-42 Amps to 65-88 Amps. And in the right side from 38 - 44 Amps to 60-88 Amps. After Re-engineering. Due to the Re-engineering works of the steam generating unit, the cost saved was 5/6th of the new boiler investment.

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