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RETROFICATION AND MODERNIZATION TECHNIQUES FOR AN IMPROVEMENT IN AIR POLLUTION CONTROL SYSTEM OF AN EXISTING BOILER

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Abstract **:** This study paper presents the findings of study carried out on evaluation of Adequacy &Efficiency of existing Boiler System and an improvement in it by modernization & retrofication techniques required to upgrade its efficiency. Due to serious concern over Air Pollution issues, statutory authorities have become more stringent and compelling the industries to run pollution control system more efficiently. Moreover, the industries are facing numerous problems of public outrage, legal proceedings and costly inefficient operations. In this study paper Boiler Efficiency as well as Adequacy & Efficiency of Air Pollution Control System is evaluated and set of recommendations are made to improve the overall efficiency of Boiler System. This retrofications & modernization will not only improve the performance of industry, but will also lead to monetary benefits.

Keywords**:** Adequacy and Efficiency of Boiler System, Air Pollution Control System, Multi Dust Collector, Water Scrubber

I. Introduction:

Ahmedabad has emerged as an important economic and industrial hub in India. Air pollution is one of the major pollution aspects due to industries. To control air pollution from industry control devices had already installed but it's today's need to work on getting better efficiency of air pollution control system to avoid legal offences.

Boilers are pressure vessels used for heating water or producing steam to provide heating facility in industries and to generate electricity through driving steam turbines [7]. Fossil fuels such as coal, gas, oil etc., and nuclear energy, are being used to generate a major portion of world's electricity and generally boilers are the best choice to convert these types of energy into electricity [5,10]. Hence, it is obvious that enhancement of the efficiency of a steam boiler by just a small fraction, will reduce a vast amount of energy consumption in electricity generation. Again, despite the depletion of fossil fuel reserves and environment protection issues, the oil, natural gas and coal demand is expected to rise up to 47.5%, 91.6%, and 94.7%, respectively between 2003 and 2030 [4]. Moreover, most of the industrial heating systems employ boilers to produce hot water or steam. Therefore, an efficient boiler has also a significant influence on heating-related energy savings [9]. A substantial amount of energy can be saved by adopting energy saving measures and by improving the overall boiler efficiency.

The efficiency of boiler is the ratio of the net amount of heat which is being absorbed by the generated steam to the net amount of heat supplied to the boiler. This can also be determined by subtracting the net amount heat lost from the boiler from the net amount of heat supplied to the boiler [9]. Hence to improve the boiler efficiency, the amount of heat being wasted from the boiler needs to be reduced by optimizing some parameters such as excess air, steam demand, fuel flow rate, etc. [6].

II. Methodology

- To evaluate boiler efficiency, indirect method as "input-output method" was used, and opportunities for improvement were identified and set of recommendations were made to increase the efficiency.
- Flue gas stack monitoring and analysis was carried out to measure air pollutants concentrations viz, O_2, CO,CO_2, SPM, SO_2 and NO_X to evaluate efficiency of Boiler & Air Pollution Control Devices.
- The drawings, specifications& performance data related to Evaluation of Adequacy & Efficiency of APCS were obtained from plant personnel and detailed adequacy of same was evaluated and retrofication & modernization measures were identified and recommended.

III. Case Study

One of the textile units of Ahmedabad, on request of the owner, a study related to evaluation of Adequacy & Efficiency of Air Pollution Control System (APCS) of existing boiler and thereby improvements in it by retrofication & modernization techniques were undertaken. The study unit is a small scale unit involved in Cotton and Polyester Dyeing and Finishing with manufacturing capacity of40,000 m/d. The unit falling under small scale sector is operating with limited resources in terms of technology and technical manpower.

Boiler is the major source of energy in the unit. The details pertaining to boiler system, fueland its APCS is presented in **Table 1** and flow train of the same is presented at **Fig.1**.

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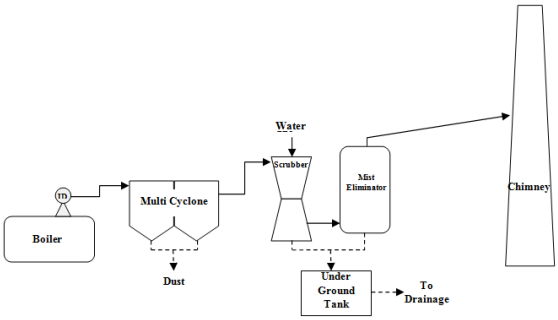

Fig 1:Flow Train of Boiler System

Table 1: Details of Boiler

Type of Boiler	:	3-Pass, Wet Back, Horizontal Fire Tube, Package Boiler
Boiler Capacity	:	3000 kg/h
Type of Fuel	:	Brown-coal(Lignite)
Fuel & Consumption	:	760kg/h
Calorific Value of Fuel	:	4000kCal/kg
Details of Air Pollution Control System :		
Stack Height (m)	**Diameter (m)**	**Air Pollution Control Devices**
30	0.5	Multi Cyclone followed by Water Scrubber.

A. Flue Gas Stack Monitoring and Analysis

The flue gas stack monitoring and analysis was carried out and results of the same are presented in**Table 2.**

Table 2:Flue Gas Stack Analysis Results

S. N.	Parameter	Pollutant Concentration	Monitoring & Analysis Method
1	CO_2, (%)	7	Volumetric method by Orsat Analyzer
2	O_2, (%)	12	Volumetric method by Orsat Analyzer
3	CO,(%)	1	Volumetric method by Orsat Analyzer
4	SPM, (mg/Nm^3)	180.1#	IS : 11255 Part I:1985
5	SO_2, (ppm)	106.0#	IS : 11255 Part II:1985
6	NO_x, (ppm)	17.0#	IS : 5182 Part VI : 1975

Note : #Standard O_2 correction @11%

Table 2 Indicates that, the concentration of SPM, SO_2 and NO_X are above the permissible limit of GPCB i.e. SPM-150 mg/Nm^3, SO_2-100 ppm and NO_X-50 ppm.

B. Evaluation of Steam Boiler Efficiency:

To evaluate the steam boiler efficiency, the indirect method as "input-output method" was used, where the energy gain of the working fluid (water and steam) is compared with the energy content of the boiler fuel.Boiler efficiency of the unitwas evaluated and reported in**Table 3.**

Table 3: Existing Boiler Efficiency

S. No.	Particulars	Value
1.	Percent of Excess Air	133.33
2.	Flue Gas Temperature(^oC)	180.00
3.	Ambient Temperature(^oC)	30.00
4.	**Percent Heat Losses**	
	H1:Heat loss due to Dry flue gas loss	15.91
	2:Heat loss due to evaporation of water formed due to H_2 in fuel	5.54
	3:Heat loss due to moisture present in the fuel	4.89
	4:Heat loss due to moisture present in the air	0.45
	5:Heat loss due to radiation and other unaccounted losses	2.00

	6:Heat loss due to partial conversion of C to CO	8.24
	H7:Heat loss due un-burnt in flyash	0.21
	H8:Heat loss due un-burnt in bottom ash	3.61
	BOILER EFFICIENCY (%)	**59.15**

The **Table 3**reveals that boiler efficiency of the study unit is 59.15%. The major efficiency losses are due to high temperature of flue gases, incomplete combustion of 'C' to 'CO and unburnt in bottom ash. The Heat losses due $H_2$and moisture in the fuel and ambient air are related to poor fuel quality and ambient atmospheric conditions and could not be averted.

C. Boiler Efficiency Findings & Measures for Improvement:

On the basis of energy audit conducted and the analysis of the heat losses and their causes, opportunities for improvement were identified to increase the efficiency of exiting boiler. The various findings and measures identified are as shown in **Table 4**.

By incorporating measures shown in **Table 4**, there will be increase in Boiler efficiency by 25-30% in the study unit based on the existing efficiency level. This will result in fuel savings of approx. 1200 t/a. The Monetary benefits due to this will be approximately Rs. 40-50 Lakhs with payback period of less than 3Months.

Table 4: Boiler Efficiency Findings and Measures

Sr. No.	Observations	Remark/ Recommendations
	The percentage O_2 in flue gas was found to be 12%, CO_2 - 7% and CO-1%. Based on above analysis results and fuel consumption @ 760 kg/h the percent of excess air worked out to be 133.33 %. . The flue gas exit temperature was 180^oC	The unit should improve on the air to fuel ratio. The Excess Air Supplied should be in the range of 20-50 %. For every 1% reduction in excess air there is approximately 0.6% rise in efficiency[4]. The unit has not provided heat recovery system. The excess temperature of the flue gases must be controlled and it should be between 140-160^oC [4]. Approximately 1 % efficiency is gained per 4.44^oC (40^oF) decrease in flue gas temperature [4] The unit is suggested to provide Air Pre-heater and Excess Air Monitor and Control System.
	Based on aboveall, Boiler Efficiency worked out to be 59.5%.	
	The size of the fuel feed was varying from powder to lumps of 4-5 inch. Fuel feeding was manual forthe Boiler.	The fuel should be uniform in the size approx. 1 to 2 inch size/dia. Large pieces should be broken whenever required. By applying automatic fuel feeding system the efficiency of boiler can be improved up to 4-5 %. The unit is suggested to provide Auto Fuel Feeding System.
	The Cooling Jet water was used as a boiler feed water.	Good quality feed water shall be used for boiler feed water. Also appropriate chemical treatment shall be given. Feed water quality should be analyzed for Silica & TDS which leads to scaling, chocking & low heat transfer.

D. Adequacy of Air Pollution Control System:

For the steam boiler, the unit has provided 2 nos. of Multi Cyclone followed by a Water Scrubber. The detailed design adequacy of the same is presented in**Table 5**and design drawing at **Fig. 2**.

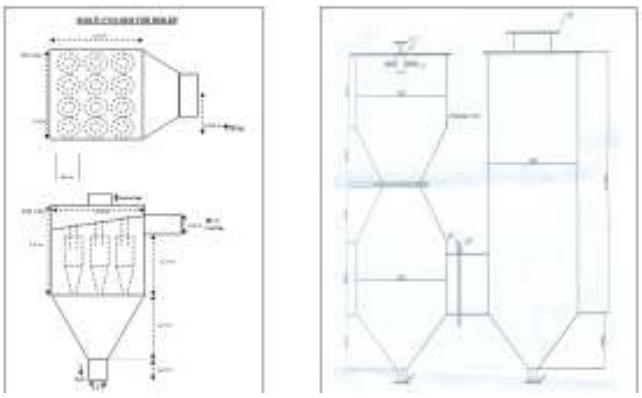

Fig.2:Design Drawings of APCS

Table 5:Adequacy of Air Pollution Contol Devices (Steam Boiler)

SN	Design Provided			Design Criteria (1,8)	Remark
Multi Dust Collector					
1	No. of Units	:	2	--	Adequate
	Flue Gas Volumetric Flow (m^3/h) each	:	5000	--	
	Flue Gas Inlet Temperature,(°C)	:	250	--	
	Inlet Duct (mm), each	:	600 x 300		
	Outlet Duct (mm) , each		600 x 300	--	
	MDC Casing dimensions (mm) , each	:	1200 x 1200 x 700	--	
	MDC Hopper ,each			--	
	Top dimensions, (mm)	:	1200 x 1200	--	
	Bottom dimensions,(mm)	:	350 x 350	--	
	Height, (mm)	:	700	--	
	No. of Tubes	:	12	--	
	Array of Tubes	:	4 x 3	--	
	Cyclone Configuration, each			--	
	Cell Diameter,(mm)	:	150	Proportions as per Stairmandhigh efficiency cyclone	Adequate
	Cylinder Length,(mm)	:	225		
	Cone Length,(mm)	:	375		
	Outlet Length,(mm)	:	75		
	Outlet Diameter,(mm)	:	90		
	Bottom Diameter, (mm)	:	40		
	Design Verifications:				
	Inlet Velocity, in each MDC	:	10 m/s	12-27 m/s	Adequate
	Pressure Drop in each MDC	:	100 mm wc	5-15 cm of water (for each tube)	Adequate
	Power Requirement, in each MDC	:	2 HP	--	Adequate

Table 5 ContdN	Design Provided			Design Criteria (1,8)	Remark
Water Scrubber					
2	Flue Gas Volumetric Flow,	:	10000	--	--

	(m^3/h)				
	Flue Gas Inlet Temperature,(^oC)	:	200-220	--	--
	Diameter, (mm)	:	1200	--	The Water Scrubber design is more resembling to Spray Towers.
	Velocity of Gas, (m/s)	:	2.23	0.06 – 1.2	
	Height (mm)	:	2580	--	
	Circulating Water Flow, (L/m)	:	500	--	Adequate
	Liquid to Gas Ratio, (L/m^3)	:	3.0	Liquid to gas ratio suggested for Spray Tower is 3.0-4.0	
	No. of Pumps	:	1	--	--
	Pump details			--	Adequate
	HP	:	1	--	
	Head(ft)	:	30	--	
	No. of Nozzles	:	20	--	Adequate
	Nozzle Dia., (mm)	:	10	--	

	Treatment of scrub bed water	:	The scrub bed liquid after settling is let off to Municipal Drainage.	--	The scrub bed water, after settling shall be treated in the ETP and then disposed off or reused.
	MOC	:	MS 304	As the unit is using Lignite as a fuel, having Sulphur content of 2-5 % the MS 304 gets corroded over a period of time. The MOC of scrubber was eroded and corroded, leading to raindrop out around scrubber.	
	Thickness ,(mm)	:	2.5	--	--
	Mist Eliminator	:	Provided	--	--

E. APCS Adequacy Findings & Measures for Improvement:

On the basis of evaluation of adequacy of APCS attached to a boiler, opportunities for improvement & retrofications were identified to increase the overall efficiency of existing boiler system. The various findings and measures identified are here under:

Table 6: Adequacy of APCS- MDC (Boiler)

Observations	Remark/ Recommendations
The unit has provided 2 nos. of MDC at Boiler	The design was verified and found adequate. There was some leakage in MDC. The unit needs to get it repaired. The Unit needs to provide dust hopper of appropriate size at the bottom of MDC and collected dust shall be hauled out from time to time (Once per shift) and appropriately disposed.

Table 7: Adequacy of APCS- Water Scrubber (Boiler)

Observations	Remark/ Recommendations
The unit has provided Water Scrubber at Boiler.	• The Water Scrubber is neither Venturi Scrubber nor Spray Tower. The design of it resembles more to Spray Tower.
The MOC of Water Scrubber was, MS 304 L. The unit is using Lignite as a fuel with Sulphur Content ranging from 2-5%. Due to SO_2 in the flue gases the MOC of Water Scrubber attached to boiler was corroded, leading to raindrop out around the Water Scrubber.	• Due to SO_2 in the flue gases the MOC of Water Scrubber attached to boiler shall be replaced with SS 316 L.
The scrubbed water after scrubbing was disposed to Municipal Drainage	• Proper system of water pumping, treatment and recycling shall be maintained. • Due to high SO_2 level in Flue gases from Boiler, it is suggested to add Caustic in scrubbingwater. • The effluent from Water Scrubber shall be treated in the ETP and disposed off along with the ETPeffluent.

F. Overall Adequacy & Efficiency of APCS:

Table 8: Quality and Extent of Deviation for Flue Gas Stack:

Parameters	Permissible Limits	Pollutant Concentration	
		Stack attached to Boiler	%Deviation
SPM (mg/Nm^3)	150	180.1	20.06
SO_2 (ppm)	100	106.0	6
NO_x(ppm)	50	17.0	*

Note :(*) Indicates that concentration is within permissible limit.

Looking to the deviations in the **Table 8** and the existing adequacy of air pollution control device, the unit needs to improve the overall removal efficiency of Particulate Matter and Sulphur Dioxide. The unit has provided Multi Dust Collector followed by Water Scrubber as Air Pollution Control Devices. The design adequacy of Multi Dust Collection System was verified and found adequate. Some leakage in the MDC needs to be repaired. The Water Scrubber design was not as per standard design practices. Moreover, the scrubber was corroded. The unit is suggested to replace the existing Water Scrubber with standard design to improve the overall efficiency of scrubbing system.

IV. Conclusion

Most of the Small & Medium Scale units in India, lack adequate knowledge of utility operations particularly of Boiler Operations, which leads to inefficient boiler operations & ultimately pollution load on APCS. Hence, there exist potential for improvement in the existing Boiler Efficiency by retrofication&modernization of existing system by providing Auto fuel feeding system, Air Pre-heater and Excess air monitoring & Control System. By adopting these measures there will be increase in the Boiler efficiency up to 25-30% based on the existing efficiency level, and thereby fuel savings up to Rs 40-50Lakhs with payback period of less than 3Months.

As far as, APCS adequacy and efficiency is evaluated, the SPM and SO_2removal efficiencies are low and stack monitoring results are above permissible limits. This could be due to the poor design of Water Scrubber attached to the Boiler. The Water Scrubber provided by the unit is neither Ventury Scrubber nor Spray Tower. It is fabricated without using standard design criteria and design practices. Moreover, the MOC used by the unit is SS304 grade. The unit is using Lignite as a Fuel. Due to high Sulphur levels in the fuel i.e.2-5% the scrubber was corroded and leading to raindrops around the scrubber. To improve the overall Adequacy and Efficiency of APCS attached to the Boiler, the unit needs to replace the existing Water Scrubber with appropriate Scrubber of standard design practice and of MOCSS 316 L.

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References

1. Crawford, M. (1976). Air Pollution Control Theory. McGraw-Hill Inc.,US (1 January 1976).
2. Efficiency, B. o. (n.d.). Retrieved from www.beeindia.gov.in:https://beeindia.gov.in/sites/default/files/2Ch1.pdf
3. Efficiency, B. o. (n.d.). Retrieved from www.beeindia.gov.in: https://beeindia.gov.in/sites/default/files/2Ch2.pdf
4. Efficiency, B. o. (n.d.). Retrieved from www.beeindia.gov.in: https://beeindia.gov.in/sites/default/files/4Ch1.pdf
5. (EIA), International energy annual. online, retrieved [cited 2009 3rd January 2009]; 2007.
6. Ganapathy V. Industrial boilers and heat recovery steam generators: design, applications, and calculations. CRC Press; 2002.
7. Jayamaha L. Energy-efficient building systems: green strategies for operation and maintenance. McGraw Hill Professional; 2006.
8. Ray, T. (2004). Air pollution control in industries. Tech Books International, 2004.
9. Kenneth Wark, C. F. (1998). Air Pollution : Its Origin and Control. Addison-Wesley, 1998.
10. Som S, Datta A. Thermodynamic irreversibilities and exergy balance in combustion processes. Progress Energy Combust Sci 2008;34(3):351–76.
11. Statistics UEH. Breakdown of Electricity Generation by Energy Source [cited 2015 21.09.2015]; Available from: ⟨http://www.tsp-data-portal.org/Breakdown-ofElectricity-Generation-by-Energy-Source#tspQvChart⟩; 2015.

Abbreviations:

APCS	:	Air Pollution Control System
GPCB	:	Gujarat Pollution Control Board
MDC	:	Multi Dust Collector
MOC	:	Material of Construction
TDS	:	Total Dissolved Solid