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EFFICIENCY IMPROVEMENT OF BOILER THROUGH DESIGN OPTIMIZATION AT KUWAIT OIL AND GAS COMPANIES

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ABSTRACT

For a plant engineer, the boiler efficiency is one of the most crucial aspects. Therefore, different techniques are developed to improve the boiler performance. In the several studies, it is found that a boiler consumes the energy around eighty percent of the boiler operating cost.The efficiency of a boiler suffered due to the various losses occurred. These losses are mainly occurred due to the flue gas accumulation, unburned fuel, convective and radiated heat loss.To improve the efficiency of a boiler, the design optimization is studied in this research.

In this study, several parameters such as pre-heater design, economizer design, an efficient heating system design, etc., are used.In a boiler, heat loss is very high when the flue gas released almost thirty percent of the energy loses due it. Therefore, it is essential to optimize the design of a boiler so that the performance can be improved.In a boiler design, complex geometry is used because it has multiple inputs and multiple outputs. This system is of a non-linear type which has no self-balancing mechanism. The combustion process of a boiler is also complicated in terms of physical as well as chemical process. A boiler is used for various applications such as food industries, cement industries, etc. The efficiency of a boiler is required to improve due to multiple reasons such as energy savings, low maintenance cost, and environmental safety, etc. Recent days, everyone is developing a design that can help in energy conservation on the urge of pressing environmental issues such as global warming. In several industries and power plants, boilers are primarily used for generating steams or producing hot water. Several studies showed that the consumption of energy in boilers is significant (M.C. Barama et al. 2017). Therefore, improving the boiler efficiency even in small amount can lead to save a significant amount of energy. It can also help to improve the carbon emission that will be a significant step towards the environmental safety.

By definition, a boiler is a pressure vessel which is used for generating electricity or supplying the hot water to the industry for providing the heating facilities depending upon the requirements. In some commercial and residential buildings, boilers are used for providing hot water or steam facilities for various domestic and commercial purposes (L. Jaymaha, 2006). In all over the world for generating electricity, coal, gas, etc., and nuclear power is primarily used. For converting energy generated by these resources, for example, thermal energy into electricity, boilers are one of the suitable options. The fossil fuels reserves are depleted day by day and the demand for other energy resources such as oil, gas, and coals, etc., for electricity production are increasing. According to a study, these energy resources demands will reach 47.5% - 94.7% by the end of 2030 (M.C. Barma et al., 2017), (S. Som and A. Dutta, 2008). Therefore, improvement in boiler efficiency is crucial.

In a steam boiler, chemical energy obtained from the fuel is transformed into the thermal energy with the help of combusting fuels in the furnace. These days the design of a boiler are getting more complex as more number of equipment are connected such as heat exchanger, pre-heater, economizer, etc.

KEYWORDS: *Efficiency Improvement of Boiler, Kuwait*

Article History

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INTRODUCTION

In Kuwait, steam boilers are primarily used in various industries such as cement industries, chemical plants, etc. Energy efficiency is one of the key aspect of that will help in making several energy policies in future. It will also help in cost saving. A boiler consumes a huge amount of fuel. Therefore, boiler efficiency is required to be increase. A small increment in the efficiency can further cause huge fuel and operating cost saving. Efficiency of a boiler can be increased by using a good maintenance program such as preventive maintenance program or optimizing the design of a boiler.

Four factors are critical for assessing energy efficiency in the industrial powerhouse supplying energy to make products for the benefit of customers in a highly competitive international market-place (Ahamed et al., 2010). These four factors include a) Fuel type b) Combustion system limitations c) Design of equipment d) Requirements for the operation of a steam system. Boilers are used since the last century in many applications in human life. Boilers play vital roles in oil and gas industries in different applications. However, boiler efficiency is varied from one type to another and from one application to another. Also, the material used to manufacture the boiler, and the type of fuel used, effects on boiler efficiency due to the complete or incomplete combustion. Moreover, emission produced by the boiler is quite dangerous for the nature and human life. Many other problems and disadvantage can happen due to the losses occur during the combustion which may decrease the efficiency and lead to cost a lot of fuel. These problems can be solved by improving the efficiency of the working boilers.

In several literatures, different factors are studied for improving the boiler efficiency, but optimization in the boiler design is not performed so far. Different types of fuels are studied and for each type of fuel, the efficiency of a boiler is reported. Certain other factors such as flue gas temperature or stack temperature, presence of excess air also significantly affect the boiler efficiency. On the basis of the previous literature data, the design optimization of a boiler is required to perform.

An efficient boiler will help to save energy, which is one of the major concerns these days, and it will reduce in the carbon emission. Low carbon emission is required to reduce the environment harm.

Research Motivation

The performance of a boiler is significantly affected due to the several factors including the type of fuel, excess air, stack temperature, incomplete combustion, etc. Due to poor performance of a boiler, the consumption of fuel increases a lot and start emitting the carbon dioxide and carbon monoxide in the environment. Irrespective of the type and size of boiler, there are several other factors, which are required to identify and analyzed to control the impact of each factor on the boiler efficiency. These analyses will help in studying the heat losses, such as radiation heat loss, conduction heat loss, convective heat loss, due to several factors. A proper analysis of boiler efficiency will help to reduce the main cause that affect the performance of a boiler such as generation of dry flue gas, presence of excess air, accumulation of carbon dioxide, accumulation of bottom ash due to unburnt fuel, etc.

Due to lack of proper boiler design optimization, low performance and abnormal behavior will be occurred in the boiler. It can be all time threat while working in such industries where efficiency of a boiler is poor, and there is a lack of maintenances and care for the operating condition of a boiler. There is still lack in adopting various dynamic control techniques because of the problem of identifying the primary root cause, due to which the performance of boiler is suffering

In a literature, it is reported that the efficiency of overall plant is decreased mainly due to heat loss. The only solution to overcome this problem is good practice of maintenance and optimizing the various boiler designs along with its components design optimizations. In most of the available literature, it is found the researcher have used only certain specific parameters. No one has so far performed a complete study that includes most of the major factors and its impact on the boiler performance.

This research work is based on a detailed study on the boiler efficiency improvement, and it includes optimization of all the operating parameters of a boiler. The approach used in this research work is based on a survey. Several participants including working engineers, students have given their overview regarding what are the designing aspects of a boiler that can be optimized and how. On the basis of their review, a complete analysis will be made.

Research Scope

This project was focused on improving the boilers efficiency used in oil and gas companies in Kuwait. The study was focused on studying the boilers types and their efficiencies, in order to select the suitable types of boilers to be established in oil and gas industries in Kuwait. The project underwent the following processes:

- Studying and investigating the working conditions, temperature, pressure, etc. in Kuwait oil and gas industry.
- Studying the different types of boilers and identify the losses occur which affect negatively on the boiler efficiency.
- The selection of the suitable boiler to be improved further in its efficiency with less fuel used and less emission produced so that can be used in the oil and gas industry.

Significance of the Research

Conservation of energy and reducing the carbon emission are two major factors in which, several researches are going, and these days, the two parameters are primarily used in different studies. A boiler requires a significant amount of energy for the steam production that further can be used for the power production, etc. Generating power on the cost of high resources consumption is a severe issue. All the natural resources are depleted these days. Therefore, it is essential to focus on energy consumption reduction by improving the efficiency of a boiler.

The running cost of a boiler is also very high, and it can be improve with the help of optimization technique. A small improvement in the boiler performance can significantly reduce its operating cost, and that will lead to improve the efficiency of overall power plant that runs on boilers. In various industries, steam is substantially used as a fluid with which, heat transfer process can be easily achieved. Steam has various advantage such as low boiling point comparing oil, high latent heat compared to hot water. Steam has capability of storing a very high amount of heat and can supply a constant temperature during the time of condensation. Therefore, industries prefer to use steam rather than hot water or oil for heat transfer mechanism.

In any industry, the heat loss takes place due to the steam wastage by several reasons. There are several studies, which suggested that approximately 35% of energy wastage is due to the steam loss. For literature, only a few papers are present that deals with the design optimization of a boiler for efficiency improvement. This research gap makes this research essential towards the energy efficiency direction.

Types of Boilers

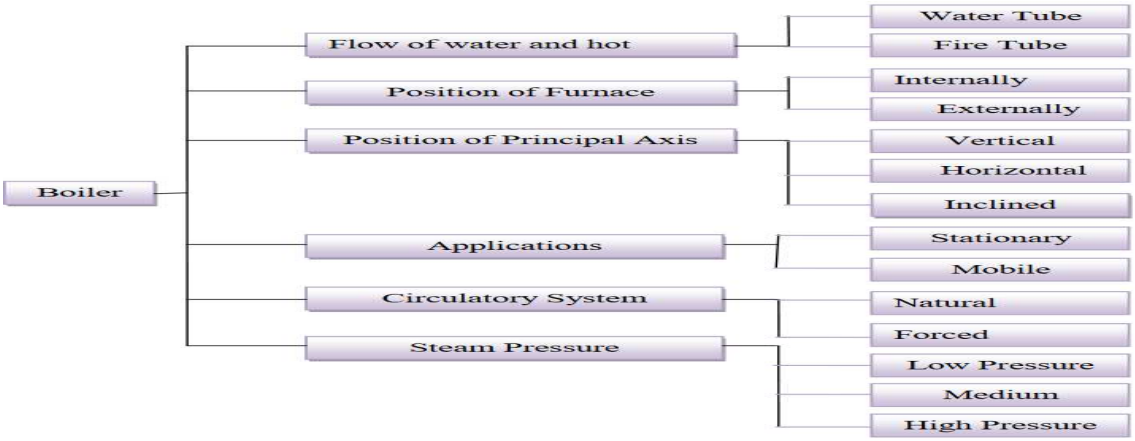

Figure 1: Different Types of Boilers.

Boilers are used in many applications with different efficiencies based on their manufacturers. In fact, types of materials effect on the percentage of efficiencies due to the losses occur, such as radiation losses. The fuel incomplete combustion as well has a vital role in decreasing the efficiencies and it depends on the portion that had been burned as complete combustion; the less fuel consumed the more efficiency will get (Loo & Koppejan, 2012). The basic purpose of a boiler is to convert chemical energy into thermal energy, which is achieved in two fundamental processes in the boiler. First, the fuel is mixed with an appropriate amount of oxygen to allow for a sustained combustion. The heated gases from the combustion process are then used to transfer the thermal energy to a fluid or steam (Oland, 2002). There are two types of boiler, generally; fire-tube and water tube boilers. The classification of boiler is differentiated under “high-pressure” or “low pressure” and “steam boiler” or “hot water boiler”. For boilers that operate larger than 15 psig are called “high-pressure” boilers (Thielsch & Cone, 1994). A hot water boiler, usually called a fuel-fired hot water heater, strictly speaking, is not a boiler. Due to its similarities to a steam boiler in many ways to a steam boiler, the term “hot water boiler” is used.

- ‘High temperature hot water boiler’ – temperature > 250° Fahrenheit or pressures >160 psig
- ‘Low temperature hot water boiler’ - temperature < 250° Fahrenheit or pressures
- < 160 psig

Fire Tube Boiler

Fire Tube, which contains long steel tubes through which the hot gasses from a furnace pass, and around which the water to be converted to steam circulates. (Refer Figure 2). Fire tube boilers, typically have a lower initial cost, are more fuel efficient and easier to operate, but they are limited generally to capacities of 25 tons/hr and pressures of 17.5 kg/cm2. Fire tube boiler consists of a vertical, cylindrical shell, equipped with a fire box in the bottom, water space in the middle portion and steam space in the upper portion. The fire grate is placed at the bottom of the fire box and coal is fired at the fire box.

An ash pit is located at the bottom of the grate to collect the ash of burnt coal, which is periodically removed.

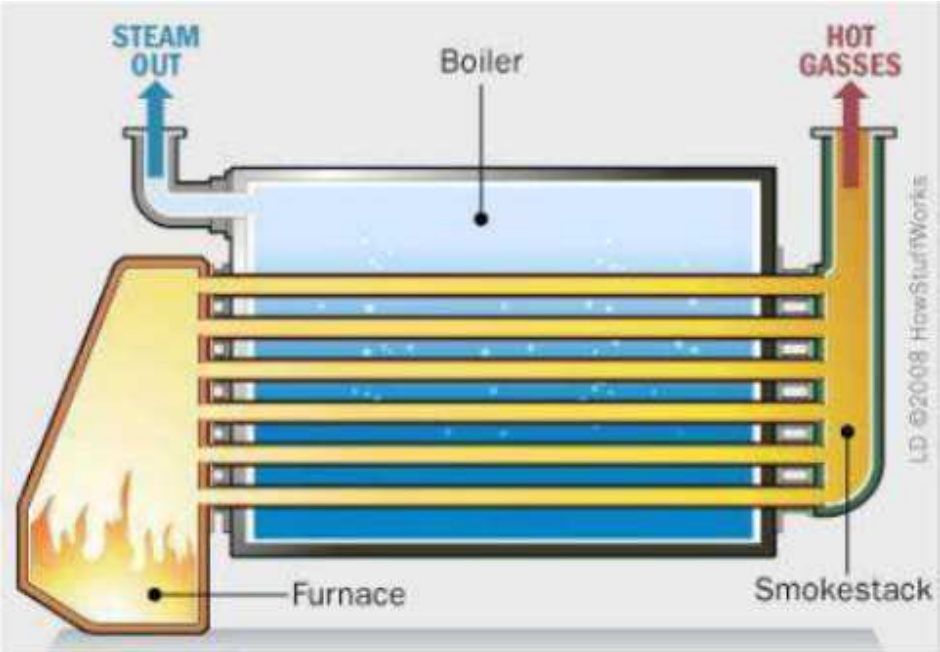

Figure 2: Schematic of a Fire Tube Boiler (M. Faizal et al. 2009).

One or more cross tubes are either flanged or riveted to the water space, located in the fire box to increase the heating surface area to improve the water circulation. A short chimney is connected at the top of the fire box to discharge the waste and flue exhaust gases at some greater height. Manhole and hand holes are provided for cleaning the interior of the boiler shell and cross tubes. The boiler consists of a pressure gauge, water level indicator, safety valve, steam stop valve and a manhole as mountings to provide safety and ease of working. Fuel burns on the grate in the fire box. The resulting hot flue gases are allowed to pass around the cross tubes. The water surrounding the cylindrical fire box also receives heat by convection and radiation. Thus, steam is produced. The water circulation in the boiler depends on the density difference in water, created by the temperature difference in water (Sarkar, 2015).

Table 1: Experimental Results for the Boiler Efficiency Test (R.D. Gupta, et al. 2011)

Major heat loss factors	Heat loss in (kJ/kg) coal	Percentage heat loss
Dry flue gas	1328.53	5.93
Moisture present in boiler fuel	256.03	1.14
Moisture present due to the hydrogen burning	843.47	3.77
Combustion in refuse	1347.03	6.03
Formation of carbon monoxide	17.62	0.0785
Moisture present in combustion air	56.65	0.255
In the bottom ash presence of sensible heat	92.11	0.41
Heat loss due to the radiation and convection	-	0.7
Heat loss due to blow down	-	0.7
Total loss		19.015%

A general boiler efficiency ranges from 20%-92%, and it completely depends upon the application of the boiler as well as the used boiler type. For different boiler, this efficiency range varies for example, boiler efficiency of coal fired is in the range of 81% - 85%, oil fueled boiler efficiency is in the range of 78% - 81%, and gas fueled boiler efficiency is in

the range of 76%-81%. The efficiency of boiler reduces in case of poor maintenance. Sometimes, the efficiency reduced more than 30% from the practical boiler efficiency when the maintenance of the boiler is not properly performed or wrong maintenance program is selected.

In this study, researcher has used various energy efficiency programs and certain boiler design optimization to improve the efficiency of a boiler(R.D. Gupta, et al. 2011).

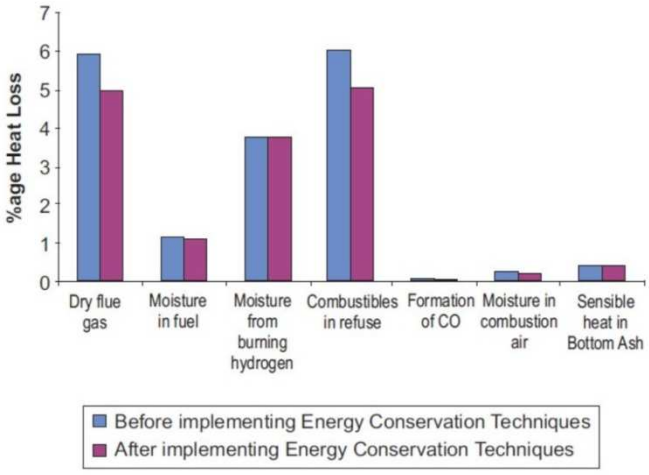

Figure 3: Outcome of an Experimental Results for Minimizing the Heat Loss by using Various Energy Efficiency Technique Implementation (R.D. Gupta, et al. 2011).

The energy efficiency approach to improve the boiler efficiency is found to be suitable for few cases only including dry flue heat loss, combustible in refuse heat loss. In other cases, the applied energy efficiency techniques are not showing significant improvement, as shown in figure 3

RESEARCH METHODOLOGY

A total sample of (100) filled questionnaires were collected. All incomplete responses were deleted. The collected data were analyzed using (SPSS v.25) program: "Statistical Package for Social Sciences", as follow: Exploratory Factor Analysis (EFA) according to principle component method used to identify the main factors affecting the boiler efficiency and confirmatory factor analysis (CFA) in AMOS v.25 used to confirm this factor, Cronbach's alpha used to determine the reliability for the factors out from factor analysis. Descriptive statistics used to describe the basic features of the total in the study (100), such as frequencies, Percentages, Mean and Stander Deviation. With large enough sample sizes (> 30 or 40), the violation of the normality assumption should not cause major problems (Pallant J; 2007); this implies that we can use parametric procedures even when the data are not normally distributed (Elliott AC, Woodward W; 2007). If we have samples consisting of hundreds of observations, we can ignore the distribution of the data according to the central limit theorem (Altman DG, Bland JM; 1995); therefore T independent sample test were used to find the difference in the five factors according to job.

RESEARCH OBJECTIVES

The purpose of this research is to study the factors affecting the boiler efficiency, and by optimizing the boiler design; how it can be improved? A proper survey approach is used to fulfil the requirements of this research.

- A survey on different boiler design parameters such as exhaust temperature, steam flow rate, FAD fans etc., is performed to identify which parameters are critical for improving efficiency

- To identify what are the factors, which are not focused on boiler design so far in the previous literature work.
- To study the environmental conditions where the boilers are used; Kuwait oil and gas industry as a case.
- To study heat lost from boilers by flue gas losses
- To propose a new type of boiler to obtain high efficiency with cost saving by studying material properties and type of fuel used or any other alternative such as electrical boiler and condensing boiler.
- To optimize the operation of a boiler plant in Kuwait oil and gas industry

Research Questions

- What is the main factors affecting the boiler efficiency?
- Which component of the boiler design is required to optimize to achieve maximum efficiency of the boiler?

Research Hypotheses

- There is no significant difference in the reuse of heat as a factor, affecting the boiler efficiency among participants according to job.
- There is no significant difference in optimization of combustion as a factor, affecting the boiler efficiency among participants according to job.

Analysis and Findings

Demographics data for participants (N=100), shows that 51% of the participants were technical while 49% were engineers, the highest group 52% were 45 to 55 years old, 49% had master degree, 42% had six to ten years as experience and 30% working in steel industry. Table 2

Table 2: Demographic Characteristics (N=100)

Demographics Characteristics		N	%
Job	Engineer	49	49%
	Technical	51	51%
Age	24- 44 years	22	22%
	45- 55 years	52	52%
	Over 55 years	26	26%
Education Level	Bachelor	32	32%
	Master	49	49%
	PhD	19	19%
How much professional experience do you have?	1 – 5 years	18	18%
	6- 10 years	42	42%
	> 10 years	40	40%
In which type of industry you are working?	Oil and gas industry	16	16%
	Chemical industry	19	19%
	Food industry	15	15%
	Steel industry	30	30%
	Cement industry	20	20%

Table shows that 64% of the participants use Multitube horizontal/ vertical boiler as a fire tube boiler, while 57% use single tube horizontal/ vertical boiler as a water tube boiler. Table 3

Table 3:Types of Fire/Water Tube Boiler used in Industry

		Frequency	Percent
What type of fire tube boiler you have used in your industry?	Single tube horizontal/ vertical boiler	36	36.0
	Multitube horizontal/ vertical boiler	64	64.0
	Total	100	100.0
What type of water tube boiler you have used in your industry?	Single tube horizontal/ vertical boiler	57	57.0
	Multitube horizontal/ vertical boiler	43	43.0
	Total	100	100.0

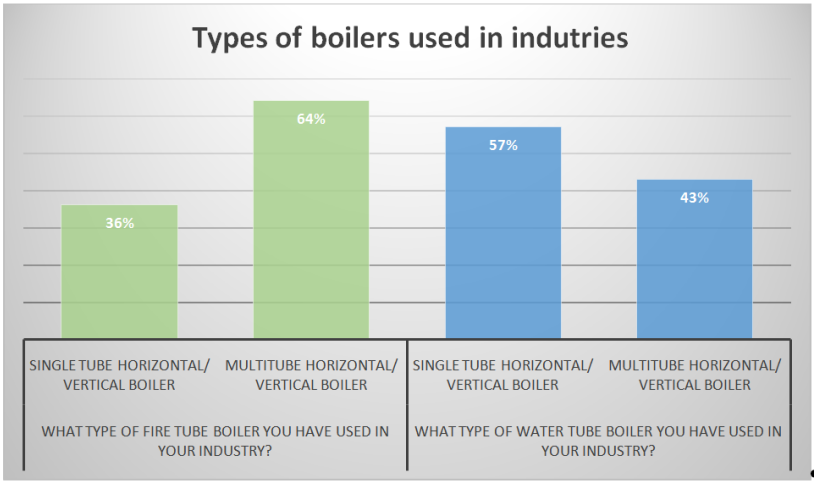

Figure 4: Ranking Results for the Types of Boilers used in Industries.

When participants asked about the rank of component of the boiler design which required to optimize to achieve maximum efficiency of the boiler, on scale 1 to 5 results are found as shown in figure 4 In this scale, rank 5 was given to the most required and rank 1 is given for least required. Among the various parameters, pre-heater had the highest mean score 3.06 with stander deviation 1.45. Second highest rating was given to the boiler feed with mean 3.05 and stander deviation 1.38. Third highest rating was given to the variable frequency drive (VFD) with mean 2.88 and stander deviation 1.42, then the economizer with mean 2.83 and stander deviation 1.43, followed by the least rank flue gas fan/ combustion fan with mean 2.80 and stander deviation 1.50 as shown in figure Table 4 given below.

Table 4: Ranking given to Various Factors for Boiler Efficiency Improvement

Boiler Components					
Rank	**Economizer**	**Pre-heater**	**Variable Frequency Drive**	**Boiler Feed**	**Flue Gas Fan/ Combustion Fan**
1	25	19	25	18	29
2	20	23	16	19	17
3	18	13	20	22	19
4	21	23	24	22	15
5	16	22	15	19	20
Mean	2.83	3.06	2.88	3.05	2.80
St. D	1.43	1.45	1.42	1.38	1.50

The results mentioned in the above Table 4, the efficiency of a boiler design can be improved by optimizing the design of a pre-heater, economizer, and variable frequency drive boiler. Flue gas and fan combustion are the least affecting factor. Therefore, the main focus should be towards the design optimization of pre-heater and economizer and variable frequency driver.

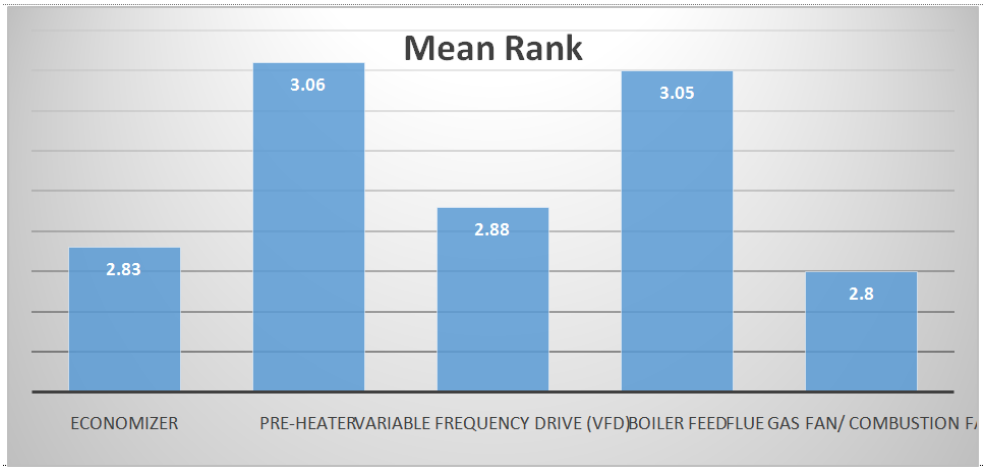

Figure 5: Mean Rank of Various Boiler Components.

When participants asked about the rank of main factors of the boiler efficiency, on scale 1-5, such as rank 5 is the highest factor and rank 1 will represent least factor. **Reuse of heat** was found with the highest mean score 3.10 with stander deviation 1.35 that suggested that the boiler efficiency would affect more significantly by reuse of heat. Another parameter that had high mean was the **treatment of the water** with mean 3.07 and stander deviation 1.29. It suggested after the reuse of heat, water treatment was second significant factor that control the boiler efficiency. After these two mentioned parameter, **improving control methods** was found with third highest mean 3.05 and stander deviation 1.41. The fourth highest mean parameter was **optimization of combustion** with mean 3 and stander deviation 1.40, followed by the least rank **regular boiler maintenance and retrofits** with mean 2.97 and stander deviation 1.39 as given in the Table 5

Table 5: Ranking Results for the Boiler Efficiency Affecting Parameters

Boiler Efficiency Affecting Parameters					
Rank	**Reuse of Heat**	**Optimization of Combustion**	**Treatment of the Water**	**Improving Control Methods**	**Regular Boiler Maintenance and Retrofits**
1	14	17	15	21	21
2	23	26	17	14	17
3	24	18	32	23	24
4	17	18	18	23	20
5	22	21	18	19	18
Mean	3.10	3.00	3.07	3.05	2.97
St. D	1.35	1.40	1.29	1.41	1.39

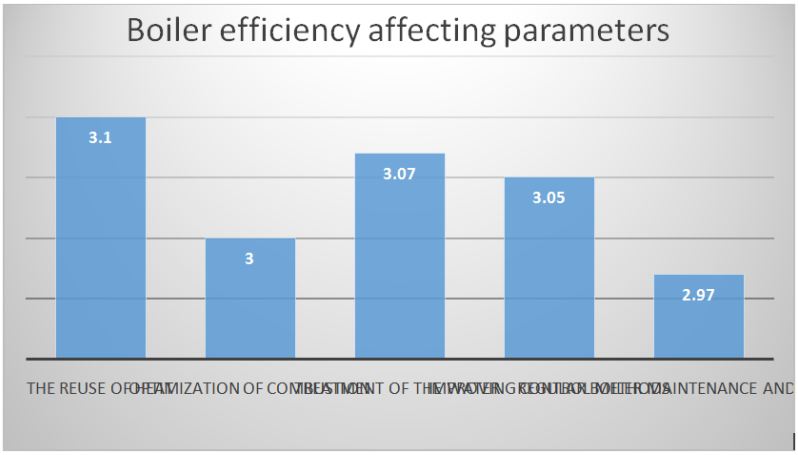

Figure 6: Results for the Reuse of Heat Factor.

These results are plotted as shown in Figure 6 on the basis of mean value ranking for various parameters that affect the efficiency of a boiler. Highest mean value is obtained for ruse of heat in the boiler. It indicates that, to improve the efficiency of a boiler is to use the released heat, somehow. Another important factor is related to the combustion process. It is required to improve the combustion process so that the combustion efficiency can be improved. This process can be improved with the help of supplying sufficient air to the combustion chamber. Dirty water affect the boiler efficiency by developing some soot on the boiler surface. It can also play an important factor while boiler design optimization. There are various controlling method exists with the help of them combustion fan speed, etc., can be improved. Therefore, while optimizing the efficiency of a boiler it must be considered. There is no doubt, boiler maintenance is always required for improving the boiler efficiency.

Factor Affecting Efficiency of a Boiler

With the help of the collected data on response of the questionnaires answer, a pattern matrix is developed. Factor analysis was performed with (1) as the Eigen value to improve the strength of the factors. Using principal component analysis as extraction method, then, five factors were extracted when the rotation converged in 5 iterations.

Out of the 20 items in the questionnaire, 5 items were categorized as the first factor, 4 items under factor 2, 3 items under factor 3, 5 items under factor4 and the last 3 items under factor 5 as given in the table 6

Table 6: Pattern Matrix for the Factor Analysis

	Component				
	1	2	3	4	5
Minimization of fuel consumption can help in improving the boiler efficiency.				.727	
Reduction of exhaust temperature can improve the boiler efficiency.				.822	
Re-designing approach of pre-heater will be helpful in boiler efficiency.				.488	
A properly designed economizer will be useful in improving the boiler efficiency by recovering heat and reusing it later.				.789	
Improving the design of blowdown valve of the boiler will be useful in heat recovering for improving the boiler efficiency				.812	
Reduction slag carbon content can improve the boiler efficiency.	.739				
Operational improvement of boiler design can be achieved by reducing the emission of carbon dioxide and nitrogen oxide	.829				
Flow rate of steam affect the boiler exhaust temperature and efficiency of boiler varies with flow rate.	.778				
Single burner and FD fans should be designed for low loads and for this design specific air/fuel ratio can help to achieve maximum boiler efficiency	.840				
Using punching tubes and cleaning heat transfer surfaces will be useful in improving the boiler efficiency	.707				
To study the boiler efficiency, temperature gradient between the feed water and water heat source can be an essential parameter.		.775			
Treating the water by filtration to prevent impurities or particulates in the water is an important step in ensuring boiler efficiency.		.814			
Exchangers can be used to preheat feed water, ensuring that the boiler has less work to do.		.910			
New control method for water feed system such as installing VFD’s and apply different valve control positions can help to improve the boiler efficiency and reduce the power consumption.		.926			

Table 6 Contd.,

Improving the direct digital control method, can help in effective range of firing in burner will help in boilers efficiency improvement.			.988		
Boiler efficiency can improved by putting variable speed drive controls on the feed pumps, so that the motor will not run above the required speed at any given moment.			.946		
In operations requiring multiple boilers, the machines should be optimized to work in tandem without using energy redundantly.			.983		
Regular Boiler Maintenance accordance with manufacturer guidelines, keeps boiler running smoothly and efficiently.					.917
The best kind of boiler depends on factors such as fuel type, boiler model, and operating conditions.					.876
Replacing or retrofitting an old boiler might be the best way to reach efficiency targets.					.870
Extraction Method: Principal Component Analysis. Rotation Method: Promax with Kaiser Normalization.a					
a. Rotation converged in 5 iterations.					

The analysis extracted a five–factor solution, each with Eigen values above one, which explains 71.57% of the total variance. The KMO was 0.76 indicating a meritorious level based on Kaiser and Rice (1974) and the Barlett's test for sphericity was significant ($\chi 2 = 1381.575$, $p = 0.00$).The Measure of Sampling Adequacy (MSA) was found to be above 0.7 for all 20 items.

CONCLUSIONS

Among (100) participants, 49% were engineer and 51% were technical, 52% were (45 to 55) years old, 49% had Master degree and 42% had (6 to 10) years working in this industry, 64% of the participants use Multitube horizontal/ vertical boiler as a fire tube boiler, while 57% use single tube horizontal/ vertical boiler as a water tube boiler.Pre-heater had the highest mean rank as a component of the boiler design, which required optimizing to achieve maximum efficiency of the boiler, and reuse of heat had the highest mean rank as a main factor of the boiler efficiency.

Suggested Future Work

In this research work, the design optimization approach for the boiler performance was studied with the help of a questionnaire based quantitative approach, but a qualitative study is still required to perform. This study is for the steam boiler design; the other boiler design can be done for the future.

REFERENCES

1. *Anon. (2010). Boiler efficiency guide [Online] available at: http://cleaverbrooks.com/referencecenter/insights/Boiler%20Efficiency%20Guide.pdf [Accessed 8th Feb 2020].*
2. *A. Behbahaninia, S. Ramezani, L. Hejraandoost, (2017). A Loss method for energy auditing of a steam boiler. Energy. Vol. 140 pp: 253-260.*
3. *A. M. Lahijani, E.E. Supini (2018). Evaluating the effect of economizer on efficiency of a fire tube steam boiler. Innovative Energy and Research. Vol 7(1) pp: 193-198.*

4. *A. Naeimi, M. Bidi, M.H. Ahmedi, R. Kumar, M. Sadeghzadeh, N.Alhuyi (2019). Design and energy analysis of waste heat recovery system and gas engine for power generation system on Tehran cement factory. Thermal Science Engineering. Vol 9 pp: 299-307.*

5. *Ltd LEP. Best practice guide for improving energy efficiency of food manufacturing plants in SINGAPORE. 2016 [Cited] at: Availablefrom: ‧http://www.e2singapore.gov.sg/DATA/0/docs/Resources/Industry/FMBS%20Best%20Practice%20Guide.pdf‧; 2020.*

6. *Churchill Jr, G. A. (1979). A paradigm for developing better measures of marketing constructs. Journal of marketing research, 64-73.*

7. *C. Luo, K. Luo, Y. Wang, M. Zhitong. G. yulie (2017). The effect analysis of thermal efficiency and optimal design for boiler system. Energy Procedia. Vol 105 pp: 3045-3050.*

8. *C. Li, C. Gallium, K. Toupin, B. Donaldson, (2015). Biomass boiler energy conservation system analysis with the aid of energy-based method. Energy Conversation Management. Vol 103 pp: 665-673.*

9. *C.L. Lee and C.J G. Jou, (2011). Saving fuel consumption and reducing pollution emissions for industrial furnace. Fuel Processing Technology. Vol 92(12) pp: 2335-2340.*

10. *DeVellis, R. F. (1991). Scale Development: Theory and Applications. Newbury Park, CA: Sage Publications*

11. *D. Kaya, and M. Eyidogya, (2011). Energy conservation opportunity in an industrial boiler system. Journal of Energy Engineering. Vol 136(1) pp: 18-25*

12. *E. B. Hafeni, D. Bouskela (2019). Boiler (steam generator) modelling. In modelling and simulation of thermal power plants with thermos system pro: A theoretical introduction and a practical guide. Springer International Publishing, Switzerland; pp: 153-164. ISBN-978-3-030-05105-1.*

13. *E.L. Glaeser, M.E. Khan (2010). The greenness of cities: Carbon dioxide emission and urban development. Journal of Urban Economics. Vol 6(3) pp: 404-418.*

14. *F. Gacenga, A. Carter-Steel, M. Tolemen, W.G. Tan (2012). A proposed and evaluation of a designed method in design science approach. Electronics Journal of Business research Method. Vol 10(2) pp: 89-100.*

15. *G. Sankar, D.S. Kuamar, K.R. Balasubhramanya (2019). Computational modelling of pulverized coal fired boilers- A review on the current position. Fuel Vol 236 pp: 643-665.*

16. *H. Hajebzadeh, A.N.M. Ansari, S. Niazi (2019). Mathematical modelling and validation of a 320 MW tangentially fired boiler: A case study. Applied thermal engineering. Vol 146 pp: 232-242.*

17. *Elsholkami, M., et al. "Development of Optimal Energy Infrastructures for the Oil Sands Industry with Effective Steam Management."*

18. *Kaliappan, Mr S., et al. "Analysing The Losses Affecting The Bolier Efficiency." International Journal of Applied Engineering Research 10.33 (2015): 2015.*

19. *Cl, Chayalakshmi, Ds Jangamshetti, And Savita Sonoli. "Time Series Analysis and Forecasting of Boiler Efficiency." International Journal Of Electronics, Communication & Instrumentation Engineering Research And Development(2016): 1-8*
20. *Prakash R Kolhe et al., "Computer Programming Tool ('C' Program) to Determine Boiler Efficiency" International Journal of Mathematics and Computer Applications Research (2016): 33-42*
21. *Mahto, Vikas, and Harveer Singh. "Effect of Temperature and Pour Point Depressant on the Rheology of Indian Waxy Crude Oil." International Journal of General Engineering and Technology (2013).*
22. *Selvan, R. Tamil, Na Siddqui, And Kanchan Bahukhandi. "Study Of Hazard Identification Techniques Adopted By Oil And Gas Industries For Risk Assessment." Best: International Journal Of Management, Information Technology And Engineering (Best: Ijmite) 3.10 (2015): 117-126.*
23. *Rajesh, S., B. M. Kulkarni, and S. Shanmukhappa. "Investigations on fuel properties of ternary mixture of ethanol, bio diesel from acid oil and petroleum diesel to evaluate alternate fuel for diesel engine." International Journal of Research in Engineering and Technology, 2 (6), 181 188 (2014).*