Potential Saving For Steam Boilers Based On The Impact Of Most Affecting Factors: A Case Study

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Abstract

This paper presents valuable potential savings from fuel and financial expenses of a steam boiler being studied at Elkhmus power plant, Libya. For this research, a visual basic program was developed and being applied for analyzing the gathered data. Key findings pointed to an acceptable level of savings throughout the entire operations within the studied section of the power plant. The highest level of findings was found to be the increasing of thermal gain along with the total efficiency of the boiler as a result of using the exhaust temperature for heating-up the feed water to the boiler. It was clearly found that the increase of the total efficiency has a direct impact on saving the amount of consumed fuel, and thereby the financial expenses were saved by an average of about 11.6%.

Keywords
Boiler, Efficiency, Exhaust, Fuel, Thermal

1. Introduction
Electricity is a form of energy and it is a basic part of nature and one of the most widely used forms of energy around the globe. It can be produced from the conversion of other sources of energy, like coal, natural gas, oil, nuclear power and other natural sources, which are called primary sources (Muhaisen and Hokoma 2012). Beginning with Benjamin Franklin's experiment with a kite one stormy night in Philadelphia, the principles of electricity gradually became understood (IEA 2012). In the mid-1800s, everyone's life changed with the invention of the electric light bulb. The light bulb's invention used electricity to bring indoor lighting to our houses (Energy 2013).

According to IEA (2012), the production of energy in Libya during the period from 2004 to 2008 increased by 21.5%, whereas the energy exports increased by 27%. The domestic consumption of energy was likely driven by industry and population growth. During this period, according to the International Energy Agency (IEA 2012), the world population grew 5.3%, and the Libyan population grew 9.4%. Muhaisen and Hokoma (2012) stated that such situations compelled many organizations around the globe and in Libya in particular to effectively improve their technical and managerial operations throughout their business. Among of these organizations are those involved in the area of power production, where allot of attention should be paid on developing the production of the electrical energy more effectively and economically. That indeed plays a key role for updating and improving this area of industry and related areas of research (Bindra and Hokoma 2004).

For producing electrical energy, many methods are well known and being used within this area, among of them is steam generation stations, where boilers are being considered as the key part in any power plant as they are the places where the fuel is used for producing the needed amount of heat required to generate power (IEA 2012). The term boiler is used for a closed vessel in which water (in this case) is heated. The heated water exits the boiler for use in boiler-based power generation (Frederick *et al*. 2003). Sample of steam boilers is explored in Figure 1.

The boiler efficiency can be determined as the percentage between the used amount of heat to generate the steam and the amount of heat produced by burning the used fuel (Ahmed 2001). In the same line Ramadan & Monshat (2000) stated that the efficiency level of the boiler can be increased by decreasing humidity and heating the feed water used for generating the electrical power. If so, the efficiency level of the related boiler and as a result of this situation the overall efficiency of the whole power plant could be improved (Ramadan and Monshat 2000).

Figure 1: Sample of steam boilers

Boilers feed water is water used to supply a boiler to generate steam. At thermal power stations the feed water is usually stored, pre-heated and conditioned in a feed water tank and forwarded into the boiler by a boiler feed water pump (Frederick 2001). Figure 2 shows boiler feed water pump.

Figure 2: Boiler feed water pump

Experimental Study

The experimental study took place at Elkhmus steam power plant (Libya), focusing in particular on the changes related to boiler efficiency along with the impact of factors being considered with a direct impact on boiler's performance. The studied factors are the temperature of feed water, the temperature of exhaust gases, and the impact of these two factors on thermal efficiency. The annual fuel saving (AFS) and the financial annual saving (FAS) are also considered for this research. For this kind of study, energy absorbed by feed water (E1) and the amount of loss in energy throughout the exhaust gases (E2) both should be calculated, thereby AFS and FAS could be clearly determined. For these calculations, constants (Muhaisen and Hokoma 2012) needed for running the developed program were gathered as secondary data and represented in Table 1 (Library 2005).

E1 and E2 as well as AFS and FAS all can be expressed and calculated as follows (parameters within these equations are shown in Table 2):

- Energy absorbed by feed water. $E1=[Ms(hs-hw)+Mrh(hro-hri)]/mf$ (1)
- Loss in thermal energy throughout exhaust gases, $E2 = [Mg. Cpg (Tg- Ta)]/Mf$ (2)

- Annual fuel saving, $AFS = \frac{EE \times Mf \times 365 \times 24}{AOC}$ (3)

Table 1, constants needed for the developed program

Constant	Symbol	Value
Enthalpy of steam outlet of the boiler	hs	3445 kJ/kg
Enthalpy of steam inlet to reheat	hri	3075 kJ/kg
Enthalpy of steam outlet of reheat	hro	3555 kJ/kg
Cost of installing and operating devices	CIOD	10000 Dinars

- According to Taje (1980) the amount of financial saving could be found as a result of installing set of devices for the related boiler, and it can be found from $FAS = 1.5 \times AFS - CIOD$ (4)
- EE1, the amount of heat gain during raising the temperature of feed water, determined as 37219-E1.
- EE2 is the amount of heat gain during decreasing the exhaust temperature, determined as 2167.053-E2.
- ET means the total thermal energy used within the boiler, determined as 37219+EE.
- EF% means the thermal efficiency of the boiler, equals to ET/HHV.

Table 2, gathered data from Elkhmus steam power plant

Parameter	Symbol	Value /Unit
Temperature of feed in inlet economizer	Tw	230 C^o
Mass of used fuel	Mf	29264.75 Kg/hr
Flow ratio of steam outlet of super heater	Ms	351300 Kg/hr
Specific heat of fuel	Cp.f	2.3 KJ/Kg.K^o
Mass of combustion gases per kg of fuel	Mg	14.21 g/Kgfuel
Average temperature for exhaust gases	Tg	160 C^o
Average temperature for air surrounding the boiler	Ta	25 C^o
Specific heat for exhaust gases	Cpg	1.0893 J/Kg.K^o
Flow ratio of steam outlet of reheat	Mrh	300000 Kg/hr
Thermal value of fuel	HHV	40200 KJ/Kg

The annual operating costs (AOC), which in some cases called running costs, includes all types of costs such as maintenance, operating, employees, and materials, whereas the cost of installing and operating devices (CIOD) is found to be in the range of 10’000 Libyan Dinars, needed to install and operate devices for decreasing the exhaust temperature and using this amount of energy for raising temperature of the feed water, such instruments could be considered as heat exchanger, pressure gauge, thermo cables, pipes, vans and sensors. These instruments are allocated specially for conducting this research, and a computer program was developed to calculate the change in the efficiency levels along with AFS and FAS. The needed data being used as an input for this research program were taken during the maximum operating load of the studied boiler.

2. Results and Discussion

Key findings are shown in Table 3, values of hw/KJ/Kg, E1/KJ/Kg, EE1/KJ/Kg, ET/KJ/Kg, EF%, AFS/KJ/year and FAS/Dinars, all being calculated based on the temperature changes of feed water (Tw). Considering the value of (hw) as the enthalpy of feed water and its value changes by the change of the temperature of the feed water. The table also shows that by increasing Tw the value of E1 decreases with an average of about 1%. This means that the needed amount of energy to heat the feed water within the boiler decreases, making the amount of heat gain (EE1) goes up. The table clearly shows a valuable amount of saving of AFS and FAS within a range up to 11.6%.

Table 3: Calculated values with temperature change of feed water

Tw	hw	E1	EE1	ET	EF%	AFS	FAS
230	990.12	37218.98	0.02344	37219	0.925	00000	00000
235	1013.62	36917.84	301.156	37520	0.933	73501	100251
240	1037.32	36614.15	604.848	37824	0.940	151235	216852
245	1061.23	36307.77	911.231	38130	0.948	227842	331763
250	1085.36	35998.57	1220.434	38439	0.956	305155	447732
255	1109.73	35686.29	1532.715	38752	0.963	383237	564856
260	1134.37	35370.55	1848.453	39067	0.971	462184	683275

On the other hand, Table 4 clearly shows that any decrease of exhaust temperature makes a noticeable decrease of the thermal energy loss. That means the amount of heat gain (EE2) increases, and the similar results can be easily relished within the other values of the studied areas. Almost the same ratio of saving can be realized from decreasing the exhaust temperature and increasing the temperature of the feed water being presented in Table 3.

Table 4: Calculated values with temperature change of exhaust gases

Tg	E2	EE2	ET	EF%	AFS	FAS
160	2167	00000	37219	0.926	00000	00000
155	2090	77.77	37297	0.928	19446	19169
150	2010	155.55	37375	0.930	38893	48339
145	1935	233.32	37453	0.932	58340	77510
140	1857	311.10	37530	0.934	77787	106680
135	1780	388.88	37608	0.936	97234	135850
130	1703	466.65	37686	0.937	116681	165021

The Effect of increasing the temperature of the feed water used to produce the required steam within the boiler is explored on Figure 3. It can easily be seen that there is a smooth increase of the thermal efficiency. The key point that should be mentioned here is that the source of increasing the temperature of feed water was from using the thermal energy lost with the exhaust gases (E2).

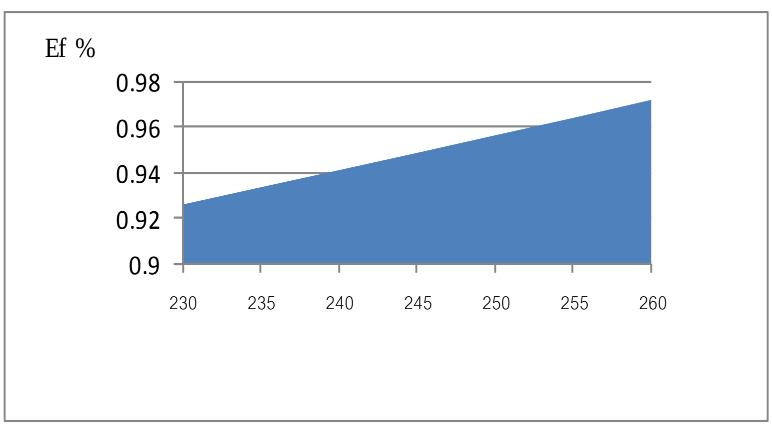

Figure 3: Effect of temperature of feed water (Tw C°) on EF%

Whereas in Figure 4, decreasing in E2 values results a noticeable decrease in the exhaust temperature (Tg) from 160 C° to 130 C°. This change of Tg values makes another positive change of EF%.

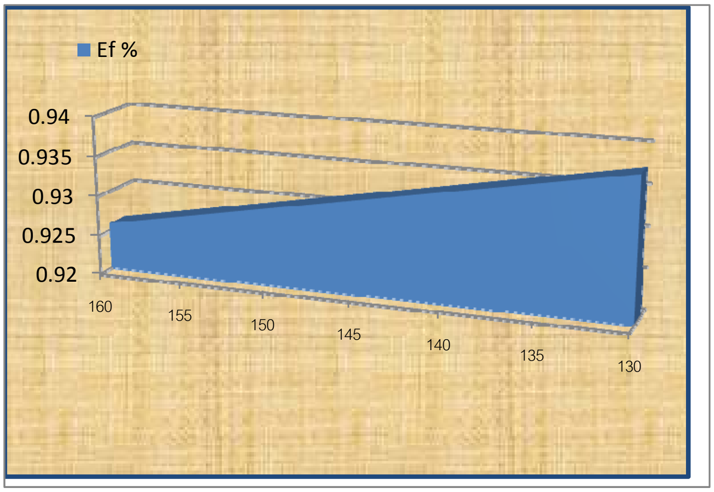

Figure 4: The effect of exhaust gases temperature (Tg C°) on EF%

Figure 5 and Figure 6 both represent key savings based on a positive change of EF% that results from increasing the temperature of the feed water as well as decreasing the thermal energy lost with the exhaust gases and exhaust temperature.

Both figures highlight the valuable savings from all studied areas, making an overall percentage of annual saving from the used fuel (Diesel/Natural Gas) up to 11.6% from the total amounts of the annual operating costs (AOC), which includes all types of costs such as maintenance, operating, employees, and materials. Making the average of the expecting savings from the fuel stands at a range of 11600 Libyan Dinars every year. This valuable result could be very encouraging to the decision makers within the management system at the power station to implement such systems and conduct more research in order to improve the performance and the quality of their operations throughout the entire workplace.

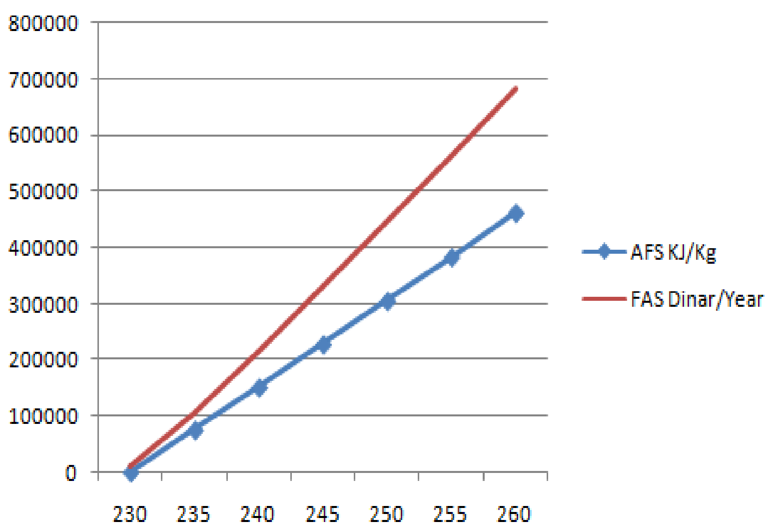

Figure 5: The effect of temperature of feed water (Tw C°) on AFS and FAS

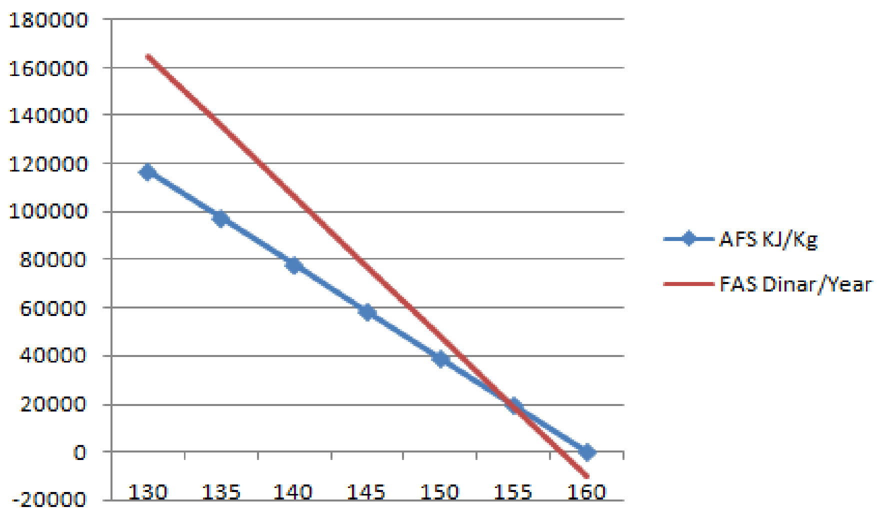

Figure 6: The effect of temperature of exhaust gases (Tg C°) on AFS and FAS

3. Concluding Remarks

This paper has presented clear calculations, showing valuable savings for steam boilers in order to improve effeminacy and performance of Elkhmus power plant (Libya). For conclusion the following points could be demonstrated:

- The thermal energy emerged with exhaust gases is considered to be as a missing energy, making any increase of its amount leads to a decrease of the thermal efficiency of the boiler and for the whole power plant. So, to reduce this missing energy it should be used for heating the feed water that required for producing the steam within the boilers.

- Using this energy makes the feed water heated up by 30C°, and similarly, the exhaust temperature was decreased down to the level of 130 C°, making the total efficiency of the studied boiler increases by about 5%.

- Finally, the findings from this research pointed to an important and valuable saving within the used fuel, which found to be at a level of 11.6% from the total amount of used fuel within the power plant during the studied period, making a valuable financial saving from the total expenses being used throughout the same period.

Future Research

The authors are strongly suggesting some points for future research, summarized as follows:

- Detailed feasibility study could be conducted to arise the potential benefits of increasing the efficiency of boilers, and thereby for the power plant.
- Conducting an investigation for other steam power plants in order to make comparisons to be aware of the working conditions and environments within other power plants.
- Future studies may include more effective factors such as boiler pressure and input air to the fuel room
- Another study should also include quality aspects of fuel within this power plants in order to improve the overall efficiency of the power plant.

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Biography

Dr. Rajab Abdullah HOKOMA began his career in Industrial Engineering in 1990, after his graduation from Industrial Engineering, University of Benghazi, Libya, he received his MSc in Enterprise Management at Warsaw University of Technology, Poland. In 2007 Mr. Hokoma was awarded his PhD in the area of Manufacturing and Quality Planning and Control from The University of Bradford, England (UK). Presently, Dr. HOKO MA is an Assistant Professor at Tripoli University *(the main university in Libya).*His duties & research interests include Manufacturing and Quality Planning & Control, JIT, MRPII, TQM, SCM, Maintenance Planning, Operations/Production Management, Pollution Control, Risk Management and Strategy. His non-lecturing duties include among others, (acting as) the consultant and advisor for manufacturing and quality planning and control and liaison with Industry and Education. Dr. HOKOMA published over 40 reviewed papers in National & International Conferences and Journals within the scope of his interested area.

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