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(Research Article)

Design and modifications of boiler mounting device in Asmara brewery factory

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Abstract

Energy and environment are closely related and important issues in the present all over world. Present industrial and others organization thought the unique of energy utilization and diverse source reviles such as coal, oil, gas, nuclear, hydropower, solar, wind and biofuel. The Non-renewable energy sources are being limited in this world and energy conservation is one of growing need nowadays. The major issues in the world's energy consumption are getting used in boilers. Thus, this energy used has to be wisely consumed with great efficiency in industries. Boilers are considered as an important and an expensive property in many industries. In addition to initial cost, boilers have high operational and maintenance cost in order to secure production in safe and acceptable working conditions. In this study concerned with an energy saving, economic and environmental analysis of the fire tube boiler in ASMARA BREWERY. In this project, we concentrated on the improvement of boiler efficiency by recovering a portion of heat content of the flue gas. This is possible due to the most dominant device which is the economizer. The preexisting boiler was designed without an economizer. The present modification involved about the design of economizer in the boiler to reduce fuel consumption and thermal shock. Furthermore, in this type of boiler attain higher efficiency and little enhancement in the efficiency of the boiler will save an outsized amount of fuel and also help to reduce CO_2 emission.

Keywords: Energy consumption; Boiler efficiency; Economizer design; Brewery factory

1. Introduction

Asmara Brewery Factory is a large-scale manufacturing plant that produces beer, arrack, vodka and other different types of alcoholic drinks to be used in our country and to export to other countries. When people ask to know the key ingredients for beer production, you will get the usual answers: wheat, barley, oats …etc. But there is another key ingredient which is heat. The unsung hero of brewing industry is the steam boiler that quietly provide the necessary heat required to transform grain, hops, water, and yeast into the delectable liquid that beer enthusiasts know and love. The best breweries in the world can't produce their amazing beers without a quality boiler system in the first place [1].

1.1. Brewing excellence: The Role of Boilers in Breweries

A steam generator, also known as a boiler, is typically a closed steel vessel that generates heat and produces steam or hot water. Breweries, like many other industrial activities, rely on this powerful equipment. They perform a variety of responsibilities in the brewing process, ensuring uniformity, quality, and efficiency. Brewing is a complex operation that requires precision, and boilers give the tools to maintain the required temperatures throughout the many phases. Temperature management is critical throughout the process, from mashing, when hot water is combined with malted

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grains to extract sugars, to boiling, where hops are added. Boilers guarantee that each stage of the brewing process is carried out correctly, allowing brewers to get the appropriate tastes, smells, and character in their recipes [2].

Breweries rely heavily on steam, which is produced as a byproduct of boiler operations. Steam is essential in a variety of applications, including heating and sterilizing equipment, disinfecting bottles and kegs, and providing a continuous supply of energy for different brewing operations. Steam's adaptability makes it a great tool to brewers, increasing productivity while maintaining strict cleaning requirements. Boilers are critical to guaranteeing consistent, high-quality beer production since they provide the required heat and steam for brewing processes as well as maintain exact temperatures. They not only improve efficiency, but also help to promote sustainability by recovering and recycling heat. So, the next time you lift a glass of your favourite craft beer, remember to respect the quiet worker who powered the boiler [3].

1.2. Research Gap

The present paper focuses on improving boiler efficiency by using an economizer on the reduction of heat losses and increasing the efficiency of fire tube steam boiler. It also aims to calculate the precise amount of efficiency before and after applying an economizer in the tested fire tube boilers. The trials offer the data required to mimic the effects of critical factors that are more effective on efficiency. The primary goal of this research is to illustrate the value of utilizing an economizer to enhance fuel savings throughout the life of a fire tube steam boiler, which is the most often used boiler.

2. Literature Review

Article, [4], It focuses on an energy-saving, economic, and environmental examination of industrial boilers in Malaysia. A heat recovery system or economizer saves energy and reduces emissions. The results showed that the total annual energy savings when installing an economizer in all six factories in Malaysia is 2529779 KWH. Finally, the results were compared and concluded that there is a significant amount of energy savings when installing an economizer and a 5.4% increase in thermal efficiency of the boiler due to the heat recovery system.

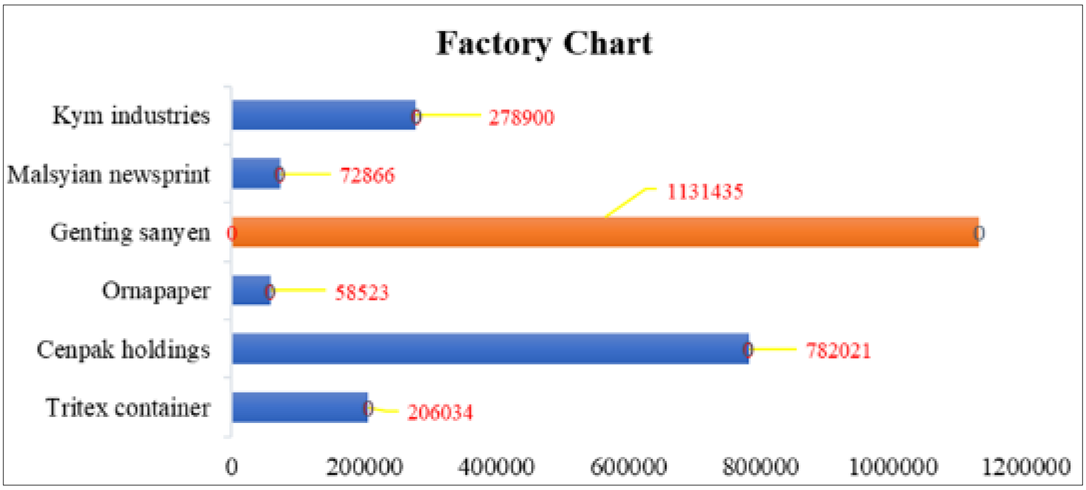

Figure 1 Factory charts [4]

Article, [5], Based on the performance indices of two fire tube three passes wet back steam boilers with a capacity of 3000kg/hr, assess the influence of an economizer on the efficiency of a fired tube boiler. This sort of loss was observed for both boilers with the same capacity and fuel (diesel). Dry flue gas losses were decreased from 11.71% in boiler 1 to 5.25% in boiler 2 (economizer included). The losses due to hydrogen and moisture in fuel did not differ significantly between the two tested boilers. Using an economizer in boiler 2 reduced flue gas temperature from 226°C to 123°C, significantly boosting boiler 2's efficiency by 7% compared to boiler 1. The final findings, when compared to boilers 1 and 2, showed that the boiler efficiency increased from 77.22% to 84.54%.

Article, [6], examined the velocity of flue gases in the tube banks of the economizer of the Kosava B coal power station. The velocity of flue gas was analysed using CFD algorithms [7]. After creating the geometry in SolidWorks, it was loaded into the design modeller, ANSYS workbench. Figure 2 shows the study results, which include a meshing diagram in 2D mode, a velocity profile by contour and vector chart, and a velocity flue gas analysis for the economizer. Finally, they assessed the effectiveness of heat transport [8-9].

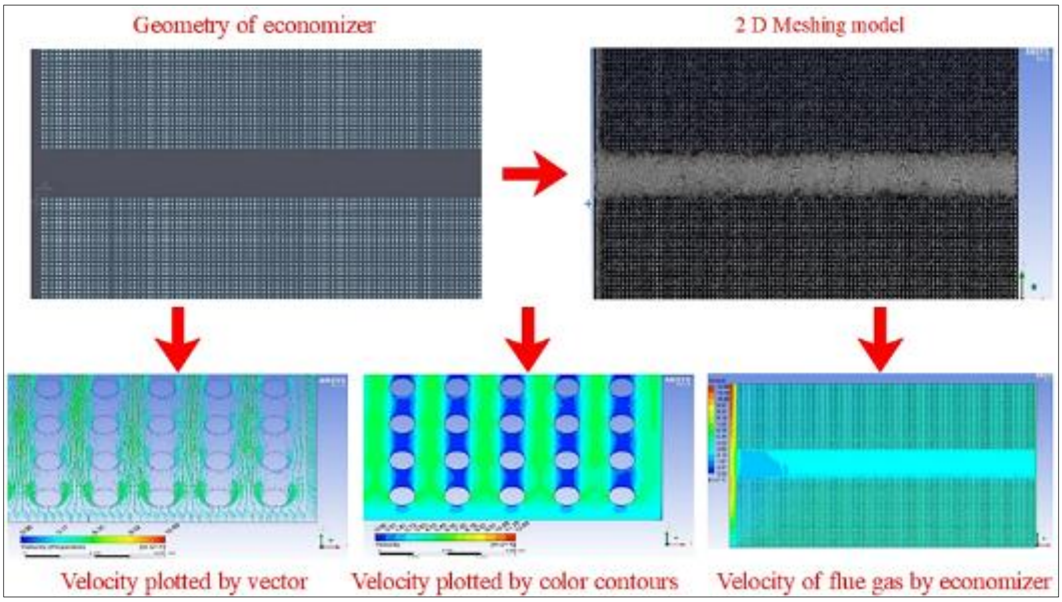

Figure 2 Analysis of flue gas in the designed economizer [6]

Article, [10], This study described a method for improving the thermal efficiency of an economizer by increasing the number of tubes. The primary goal of the research was to construct an economic analysis that discovered that optimizing economizer design and increasing heat savings reduced the volume of combustion product, resulting in less environmental pollution. The findings showed that the boiler efficiency increased by 1% over the previous planned economizer, and the heat loss due to exhaust gas was reduced as compared to the current design. The new design demonstrated an eight-month payback time as well as a reduction in fuel (natural gas) use of 192096 m^3 per year.

Article [11], The major goal of the heat transfer improvement was to improve the design of a STHE by installing sealers on the shell side. The sealers filled the gaps between the baffle plates and the shell, substantially reducing short-circuit flow on the shell side. The heat transfer experiment findings reveal that the upgraded heat exchanger's shell-side heat transfer coefficient rose by 18.2-25.5%, the overall coefficient of heat transfer increased by 15.6-19.7%, and the exergy efficiency increased by 12.9-14.1%. Pressure losses rose by 44.6-48.8% after installing the sealer, however the increases in necessary pump power may be ignored when compared to the increase in heat flux. The heat transfer performance of the revised heat exchanger was enhanced, which was a clear advantage of improving heat exchanger design for energy saving [12].

3. Experimental work

Figure. 3 It is observed that the functioning of a fire tube boiler is as basic as its design. In firetube boilers, the fuel-air combination is burned in the burner, resulting in flame formation. The hot flames are then transported spirally through the corrugated furnace. The apparent benefit of a corrugated furnace is that it reduces the barrier to flame circulation, allowing the flames to travel spirally through the furnace, as seen in the image. After this, the hot gas bounces back and enters the fire tube. The gases' heat energy is then transmitted to the surrounding water. As a consequence, steam is produced in the water, which naturally rises and is kept in the water in the same vessel as the fire tube boiler.

Figure 3 Real corrugated Furnace of fire tube boiler in Asmara Brewery Factory

Figure 4 a) Fire tubes with scaling b) Scaling removed from the tubes

When the fluid temperature is heated, it increases in volume and becomes lighter. This heated water, which is now lighter, rises, while cooler water lowers to replace it. Steam bubbles ultimately develop, breaking through the water's surface and entering the steam region. The inclusion of tubes within the water-filled drum improves the heating surface. The heating surface is the section of the boiler that contains water on one side and combustion gasses on the other. By expanding the heating surface, more heat is collected from combustion gasses and transferred to the surrounding water. This causes more rapid water circulation and the creation of steam bubbles. When more steam is discharged, the boiler's thermal efficiency improves. Thermal efficiency is defined as the ratio of heat absorbed by water to heat provided by the fuel. Placing an internal furnace inside the boiler shell significantly improves the heating surface, allowing for optimum heat absorption and thereby minimizing the time required to generate steam.

The above figure. 4 a) and b) show the soot particles and scales that has been formed within the boiler in Asmara Brewery Factory. That is why it’s very important criteria to consider these common boiler problems in the operation of the boiler.

Figure 5 Firetube boiler in Asmara Brewery Factory

The figure.5 that can be seen above is the fire tube boiler in Asmara Brewery Factory; which has the same working operation as described as above for fire tube boilers. It is this boiler that feed steam to the whole factory if any failures occur, the whole factory will stop manufacturing the beer we normally drink to enjoy out ourselves, it is now the objective of our research to improve the efficiency of the fire tube boiler shown in the above figure. Here the feedwater that is feed to boiler directly is pumped from the well with its average temperature of 20 °C and after reaching 180°C ; this high pressurized steam leaves the boiler and distributed to the whole factory to accomplish different tasks.

4. Simulation of the designed heat exchanger

simulation	SHELL SIDE		TUBE SIDE	
Total mass flow rate Kg/s	15		6.4	
Vapor mass flow rate Kg/s	15	15	0	0
Liquid mass flow rate Kg/s	0	0	6.4	6.4
Vapor mass fraction	1	1	0	0
Temperature °C	310	181.51	20	98.22
Bubble/dew point °C	/	/	/	/
Operating pressure bar	/	6.81426	25	24.95699
Film coefficient W/(m^2-k)	567.1		1886.3	
Fouling resistance m^2-k/W	0.0003		0.00023	
Velocity(highest) m/s	36.49		0.29	
Pressure drop(allow/calc) bar	0.25855 / 0.18574		0.49987 / 0.04301	
Total heat exchanged	2272.3	Unit	AEU 4 PASS 1 SER 2 PAR	
Overall clean coefficient(plain/finned)W/(m^2-k)	415.3 /	Shell size	533 1800 mm Hor	
Overall dirty coeff.(plain/finned) W/(m^2-k)	340.4 /	Tubes	plain	
Effective area.(plain/finned) m^2	38.1 /	Insert	None	
Effective MTD °C	175.27	No.	124 OD 1 Tks 0.065 in	
Actual/required area ratio.(plain/finned)	1 / 1.22	Pattern	45 pitch 1.25 in	
Vibration problem(HTFS)	No	Baffles	single segmental cut(%d) 41.68	
RhoV2problem	No	Total cost	48796 Dollar(US)	

Figure 6 Overall performance of thermal design through ASPEN software built in tabulation form which is indicated shell side and tube side data

To now see whether the thermal design can perform the specified duty, and also to know what the designed exchanger can achieve, simulation through ASPEN software is done and it got us the below results (figure. 6).

With the help of this ASPEN software, we were able to make sure that the thermal design that has been done meets with the final output showing that the heat exchanger can do the required specified duty. The table shows the overall performance of the designed heat exchanger. After making sure the required performance is reached the Heat exchanger specification can be Tabulated in the sheet, which later based on the heat exchanger specification sheet using the ASPEN software the mechanical design can be acquired. Heat exchanger specification sheet can be seen in the next tabulation mode (figure. 7).

1	Customer ASMARA BREWERY FACTORY		job NO - Reference No. -			
2	Address Asmara, Eritrea		proposal No. -			
3	Plant location - ASMARA BREWERY FACTORY		date -		Rev. -	
4	Service unit -		Item No. -			
5	Size: 533-1800 mm Type: AEU Horizontal		connected in: 2 parallel 1 series			
6	Surf/unit (eff.) 38.1 m^2 shells/unit 2		Surf/unit (eff.) 19 m^2			
7	**Performance of one unit**					
8	Fluid allocation		Shell side		Tube side	
9	Fluid name		Flue gas		Water	
10	Fluid quantity, Total	Kg/s	15		6.4	
11	Vapor (in/out)	Kg/s	15	15	0	0
14	Liquid	Kg/s	0	0	6.4	6.4
15	Non condensable		0	0	0	0
16	Temperature (in/out)	°C	310	181.51	20	98.22
17	Density Vapor/liquid	kg/m^3	3.95/	4.94/	/998.86	/920.25
18	Viscosity	mPa-s	0.0289/	0.0289/	/1.0214	/0.2852
19	Molecular weight, vapor		27.34	27.34		
21	Specific heat	KJ/(Kg-K)	1.196/	1.164/	/4.524	/4.591
22	Thermal conductivity	W/(m-K)	0.0442/	0.0348/	/0.5991	/0.6754
23	Pressure (abs)	bar	7	6.81426	25	24.95699
24	Velocity (Mean/max)	m/s	21.7/36.49		0.28/0.29	
25	Pressure drop, allow. /calc.	bar	0.25855	0.18574	0.49987	0.04301
26	Fouling resistance (min.)	m^2-K/W	0.0003		0.0002 0.00023 A_0 based	
27	Heat exchanged 2272.3 kW		MTD (corrected) 175.27 °C			
28	Transfer rate, service 340.4	Dirty	340.4	clean 415.3	W/ (m^2-K)	
29	**Construction of one shell**				**Sketch**	
30			Shell side	tube side		
31	Design/ Vacuum/test pressure	bar	8.27371/ /	27.57904/ /		
32	Design temp/MDMT	°C	348.89 /	132.22 /		
33	Number passes per shell		1	4		
34	Corrosion allowance	mm	3.18	0s		
35	Connections	in	1 336.55 / -	1 40.89 / -		
36	Size and rating	out	1 304.8 / -	1 52.5 / -		
37	ID	intermediate	/ -	/ -		
38	Tube no. 62 U's OD: 25.4 Ths. Average: 1.65 mm Length: 1800 mm pitch: 31.75 mm Tube pattern					
39	Tube type: Plain Insert: None Fin no: no/m Material: SS 304					
40	Shell: Carbon Steel ID 539.75 OD 558.8 mm				Shell cover Carbon Steel	
41	Channel or bonnet Carbon Steel -				Channel cover Carbon Steel	
42	Tube sheet -stationary Carbon Steel -				Tube sheet floating -	
43	Floating head cover -				Impingement protection None	
44	Baffle-cross Carbon Steel Type Single segmental cut(%d) 41.68 H spacing: c/c 400 mm					
45	Baffle long - Seal Type				Inlet 10 mm	
46	Supports-tube U-bend 0 Type					
47	Bypass seal Tube to tube sheet joint Expanded only (2 grooves)(App.A 'i')					
48	Expansion joint Type None					
49	ρv^2-Inlet nozzle bundle entrance bundle exit					
50	RhoV2-Inlet nozzle 1801 Bundle entrance 7344 Bundle exit 1615 kg/(m s^2)					
51	Gaskets -shell side Flat Metal Jacket Fibe Tube side Flat Metal Jacket Fibe					
52	Floating head -					
53	Code requirements ASME Code Sec VIll Div 1 TEMA class R – refinery service					
54	Weight /shell 1258.1 Filled with water 1777.3 Bundle 410.1 kg					
55	remarks					

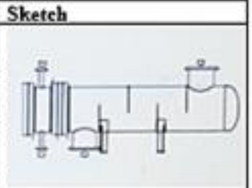

Figure 7 Asmara Brewery factory heat exchanger specifications in tabulation mode

5. Conclusion

While generating ideas for the research project, we need to work on a project that can be able to reduce the energy usage because nowadays utilizing energy is one of the significant challenges in the globe. Due to the high energy consumption in industries, we decided that to visit one of the highly energy consuming industries of our country which is Asmara Brewery Factory. After industrial visit, we planned to reduce the amount of fuel consumed by increasing the efficiency of the boiler. The project involved numerous engineering disciplines such as, heat and mass transfer, thermal engineering, metallurgical and material science, engineering economics and cost analysis, applied thermodynamics and analysis software's etc. The following procedures were followed accordingly. The initial requirement of the project learning of the boilers mounting, accessories and utilization of the available resources. Afterwards regular observation of the Asmara brewery station collected huge amount of data with respect to the working field/domain. Further development and designing of the economizer to the increase the efficiency of the boiler and fuel consumption and reduced pollutants in Asmara Brewery Factory. Finally, it concluded that the design of economizer attains attractive result than the existing design, therefore the boiler efficiency and consumptions are increased by the modification of the boiler mounting in the Asmara Brewery factory.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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