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Improving Capacity Utilization In A Nigerian Brewery

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Abstract: *This research work considered how installed machine capacities are utilized and to reduce cost of production in a Nigerian brewery. It implies that if the installed machines are utilized optimally, production and quality will be improved which is the primary goal of every industry involved in production. Overall equipment effectiveness analysis was done using MATLAB. It is the product of the equipment availability, performance and quality. Calculation showed that the equipment availability lies between 87-92%, the equipment performance lies between 59-69%, and the quality of the equipment lies between 97-98% while the overall equipment effectiveness factor lies between 53-59%. Values got from calculation using availability analysis with the aid of MATLAB revealed the actual state of the machines in a brewing sequence that involved boilers and cooling towers. For the boiler, the boiler efficiency was 63%, evaporation loss was 6.25, boiler fuel consumption was 62 gallons per day, boiler horsepower was 645 and factor of evaporation was 1.01. However, the cooling tower effectiveness was 51%, cooling duty handled was 12480000 kcal/hr and makeup water required was at 29.7024m^3/hr. The values showed that the machines were due for servicing for maximum performance.The results from this project if properly implemented will improve machine capacity, proffer solution to the best practices of maintaining them equipment used in brewing and convince investors that it is best to utilize the locally produced sorghum for beer production to reduce production cost Nigerian breweries.*

Keyword *– Capacity Utilization, Effectiveness, Productivity, Quality*

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I. Introduction

This project covers the improvement of the installed machine Capacity in a Nigerian Brewery**.**The process of beer production involves malting, milling, mashing, extract separation, hop addition and boiling, removal of hops and precipitates, cooling and aeration, fermentation, separation of yeast from younger beer, aging, maturing and packaging. Almost all beer is made from the four essential ingredients namely: Water Fermented carbohydrate. E.g. Barley malt, starch and sugar adjuncts, Hops, Yeast.The essence of the entire process is to convert grain starches, to sugar with water extract and then ferment it with yeast to produce the alcoholic, lightly carbonated beer.

Arnold (2003).Wrote one of the first comprehensive books on brewing titled “Origin and History of Beer and Brewing” which Hornsey (2003).Later made contributions and modifications on the knowledge gotten from the previous author who titled his book “A history of Beer and Brewing”. Brewing initially was done in small scale. It wasn’t supplied in commercial quantity rather; it was supplied to parties that were interested in the commodity. But in recent time, it is now an industry growing rapidly by which few large companies compete to attain global supremacy in the production and supply of branded recreational alcoholic beverages.

The equipment responsible for these processes will be analyzed in the course of this research to see if it meets standard and requirement. The aim of this study is to improve the utilized machine capacity in a Nigerian Brewery. According to James (2002), Capacity utilization is the extent to which an organization, a country, an enterprise etc. uses its installed productive capacity. This is the ratio of output produced with the installed equipment to the potential output that could be produced with it, if capacity was fully utilized.

When there is maximum use of installed capacity, productivity and quality is improved automatically. In the case of a brewery industry, the major equipment that runs the sequence of brewing is the cooling tower and the boiler. Steingress (2001) explained the boilers serve as heaters to vessels that require heat to function such as the mash tun and wort kettle as the case may be. On the other hand,Sutherland (2017) the cooling tower cools the heated water that has been used down to a lower temperature. The work of these equipment in a brewery industry cannot be over-emphasized because the quality of product solely depends on the efficiency of these machines.Snow (2008) explained how the performance of these equipment play a major role on the productivity and quality of the end product. These machines will be discussed and analyzed in the project.

II. Methodology

2.1 Cooling Tower Capacity/Performance

There are parameters used to determine cooling tower performance. They are:

- Range
- Approach
- Cooling tower effectiveness
- Cooling Capacity
- Evaporation loss
- Cycles of concentration (COC)
- Blow down losses.
- Liquid/Gas (L/G) ratio.
- **Range:** It is the difference between the water inlet temperature and outlet in the cooling tower.
- **Approach:** The difference between the outlet (cold water) temperature and the ambient temperature (wet bulb temperature).
- **Cooling tower effectiveness (in percentage):** This is the ratio of the range to the ideal range of the cooling tower. It can also be defined as the difference between the inlet temperature and the ambient wet bulb temperature which can also be;

$$CTe = \frac{\text{Range}}{\text{Range} + \text{Approach}} \qquad (2.1)$$

- **Cooling Capacity**: This is the amount of heat neglected (in kcal/hr). This is the product of mass flow rate of water, the specific heat and also the temperature difference (ΔT).
- **Evaporation loss:** this is the amount of water evaporated during cooling. It is calculated theoretically that for every 10,00,000 Kcal of heat that is being rejected, the evaporation quantity works out to $1.8m^3$. Empirically, a relationship has been developed for evaporation loss which is.

$$E_{Loss} = 0.00085 \times 1.8 \times C_r \times (T_1 - T_2) \qquad (2.2)$$

where

E_{Loss} = Evaporation loss $\left(m^{-3}/hr\right)$

C_r = Circulation rate $\left(m^{-3}/hr\right)$

$T_1 - T_2$ = the temperature difference between the inlet and outlet water.

- **Cycles of Concentration:** (COC): This is the ratio of dissolved solid in the cycling water to the dissolves solids in the makeup water.
- **Blow down losses:** This depends on the cycles of concentration and the evaporation losses. Theoretically, it is given as:

$$\textbf{Blow down} = \frac{\textbf{Evaporation Loss}}{(\textbf{COC}-\textbf{1})} \qquad (2.3)$$

- **Liquid/Gas (L/G) Ratio:** This is the ratio between water and the air mass flow rate.

Thermodynamically it shows that heat removed from the water must always be equal to heat by air in the surrounding.

$$L\,(T_1 - T_2) = G\,(h_2 - h_1) \quad = \frac{L}{G}\frac{h_2 - h_1}{T_1 - T_2}. \qquad (2.4)$$

L/G = Liquid to gas mass flow ratio (kg/kg)

T_1 = Hot water temperature (^oC)

T_2 = Cold water temperature (^oC).

h_2 = enthalpy of air water mixture at exhaust wet bulb temperature

h_1 = enthalpy of cold water vapor mixture at inlet wet bulb temperature. (Same unit).

2.2 Boiler Capacity

There are parameters used to determine cooling tower performance. They are:

- Boiler efficiency
- Boiler fuel consumption
- Boiler Horsepower
- Factor of Evaporation

- **Direct and indirect boiler efficiency**

It has been stated earlier that the overall efficiency do not only depend on combustion and thermal efficiency which are the major parameters. Other minor losses like ON/OFF losses, conversion losses, radiation losses, blowdown losses must be put into consideration.

Direct Efficiency

This method is used to calculate boiler efficiency with the aid of the basic efficiency formula below $\frac{\text{Energy Output}}{\text{Energy Imput}} \text{ x } 100$

$$\text{Boiler Efficiency} = \frac{Q(H-h)}{qxGcv} \text{ x } 100 \qquad (2.5)$$

Where
Q = Quantity of steam generated (kg/hr)
H = Enthalpy of steam (kcal/kg)
h = Enthalpy of water (kcal/kg)
q = quantity of fuel used per hour (kg/hr)
GCV = Gross Calorific Value

Cycles of Concentration: For boilers, it is the ratio of the boiler water chloride to the feed water chloride (all measured in ppm). Mathematically;

$$CYC = \frac{Bch}{Fch} \qquad (2.6)$$

Where;
CYC = Cycles of Concentration. (ppm)
Bch = Boiler Water Chloride (ppm)
Fch = Feed water chloride

Boiler Horsepower: This is defined as the boilers capacity to deliver steam to a steam engine. One boiler horsepower is equal to the thermal energy rate required to evaporate 34.5 pounds of fresh water at 212ºF in one hour mathematically,

$$BHP = \frac{\frac{IB}{Hr} \text{ x } FE}{34.5} \qquad (2.7)$$

Where;
BHP = Boiler Horsepower
Ib/hr = Pounds per Hour
FE = Factor of Evaporation (can be assumed to be 1)

- **Indirect Efficiency**

This method is archived only when all losses that take place in the bolder are calculated individually and then subtracting the sum from 100%. Blow down values is kept this procedure.

III. Results And Discussion

The tables, charts and graphs below shows the summarized data of a cooling tower and boiler capacity of a Brewery. (Calculated using MATLAB). Parameters were generated when the cooling tower and boiler was on load.

Table 1: Summary of the Capacity of a Cooling Tower in Use

PARAMETER	VALUE	UNIT
Range	8	°c
Cooling Tower Approach	7.5	°c
Cooling Tower Effectiveness	51.6	%
Rated Cooling Tower Effectiveness	64.516	%
Cooling Duty Handled	12480000	Kcal/hr
Evaporation Loss	19.0944	%
Blowdown Requirement for Site C.O.C of 2.8	10.608	$M^{3/}hr$
Makeup Water Requirement	29.7024	$M^{3/}hr$

Table 2: Relationship between Approach and Cooling Tower Size

Approach	2.5	39.0	3.5	4	4.5	5.5
(Inlet)Hot Water (℃)	36.5	37.5	38.7	39.4	40	42
(Outlet)Cold Water (℃)	29.5	29.5	30.0	30.5	31	32
Wet bulb temperature (℃)	26.5	26.5	26.5	26.5	26.5	26.5
Number of Cells	4	4	3	3	3	3
Length of Cells (ft)	10.95	8.52	10.95	9.75	8.54	8.55
Overall Length (ft)	43.5	34.15	32.95	2925	25.60	25.61
Number of Fans	4	4	3	3	3	3
Fan Diameter	7.32	7.32	7.32	7.32	7.31	6.70
Total Fan Capacity (kW)	270.1	254	239	202	183.5	183.5
Cooling Tower Effectiveness (%)	75	72.72	71.31	68.87	66.66	64.5

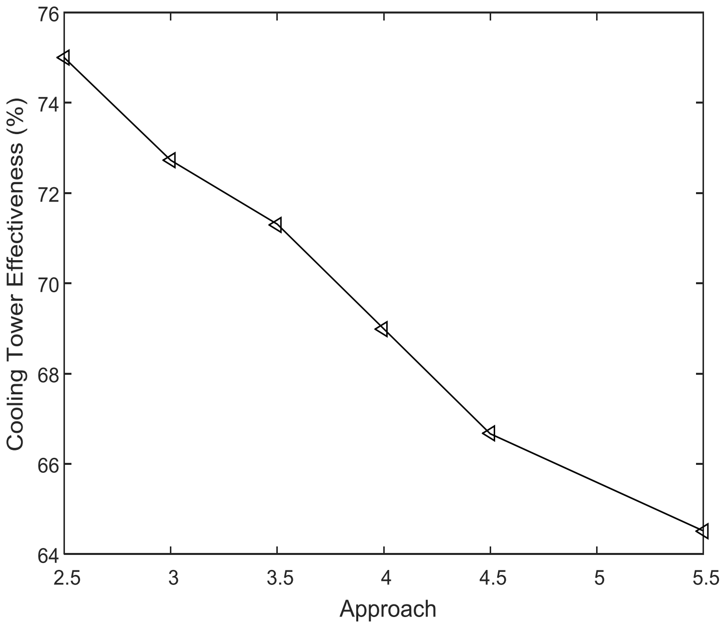

Figure 1: Relationship between Approach and the Cooling Tower Effectiveness

IV. Discussion

- Observation showed that there was flow stratification in the cooling tower cells
- From the calculated value of the makeup water requirement, it is observed that there is algae (Legionella) growth in the cooling tower cells. The presence of these algae increases the makeup water requirement.
- From observation, Glass Reinforced Plastic blades are used. This type of fan requires a high starting torque resulting in the use of high HP motors. The heavy weight of the fan can also decrease the life of the gearbox.
- From calculation, the cooling tower effectiveness had dropped from 64% to 51%. This drop could give us a hint that it is due for servicing.
- From Fig. 1, It is observed that as the Cooling tower approach is as low as reasonably practicable, the cooling tower effectiveness will be optimal. As the approach increases, the effectiveness reduces. This is responsible for the performance of the cooling tower.

Table 3: Summary of the Capacity of a Boiler in Use

Parameters	Values	Unit
Energy output/Boiler Efficiency	70	%
Evaporation Ratio	6.25	-
Boiler Fuel Consumption	62	Gallons (gal)
Boiler Horsepower	645	
Factor of Evaporation	1.01	-

Table 4: The Relationship Between Chloride Water and Cycles of Concentration

Chloride Content of Boiler Water (ppm)	Feed Water Chloride Content (ppm)	Cycles of Concentration
189	38	4.89
189	38	4.97
192	38	5.05
196	38	5.16
201	38	5.29
206	38	5.42
211	38	5.55
215	38	5.66
220	38	5.79
224	38	5.89
228	38	6
231	38	6.08
235	38	6.18
239	38	6.29
246	38	6.48
251	38	6.61
256	38	6.74
261	38	6.87
267	38	7.03
271	38	7.13
275	38	7.24
281	38	7.39
287	38	7.55
292	38	7.68

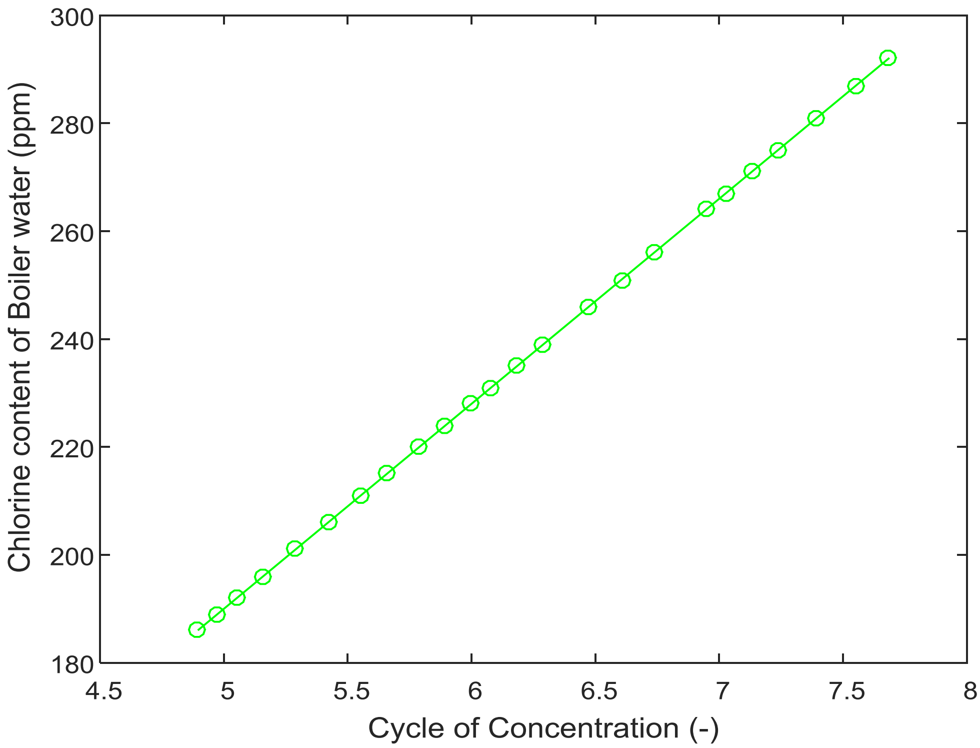

Figure 2: Relationship between the Cycles of Concentration and Chlorine content of the Boiler Water

V. Discussion

A careful inspection was carried out on the boiler for two months to analyze the rate at which the cycles of concentration increased. It was monitored 3 times a week for two months making it 24 and was observed that as time went by, the chloride content in the boiler increased due to evaporation thereby increasing the cycles of concentration where the feed water entering the boiler remained constant shown in Table 4. See Fig 2 for graphical representation

VI. Concusions And Recommendation

- If the circulating water is contaminated by algae (legionella), and finds its way into the product, it causes cancer of the lungs therefore, periodic flushing is required,
- From the value gotten from the makeup water requirement (about 30%), it means that more water will be required to maintain and sustain the process after some amount are lost due to evaporation therefore, Cooling water treatment is recommended for the cooling tower for controlling suspended solids and algae growth.
- From calculation, it is observed that there is a drop in the effectiveness of the cooling tower because the rated effectiveness was given to be 64% but after calculating, the effectiveness was seen to be at 51% hence, the first objective has been achieved.
- Table 4.3 and figure 4.5 showed that the size of a cooling tower plays a major role in the approach. A four (4) fan cooling tower is more effective than a three (3) fan cooling tower hence, it is recommended that a 3 three fan cooling tower be replaced with a four (4) fan cooling tower. This swap will increase effectiveness and also improve cooling.

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