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"EVALUATION OF THE EFFICIENCY OF COOLING WATER SYSTEM IN 20 MW JABANA II THERMAL POWER PLANT IN RWANDA"

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ABSTRACT

Cooling water system is the one of the system which is used to maintain the temperature of the engines producing electricity, at JABANA, cooling water system is divided into two circuits: HT (High Temperature)-circuit and LT (LOW Temperature)- circuit which cool different parts of the engine. The aim of this research was to calculate the efficiency of cooling water used to cool the engines which produce electricity at JABANA and then to evaluate the efficiency by using the data recorded from radiator. Through this study, different ways in which cooling water system is circulating, and working, how it can be treated, its advantages and its disadvantages were launched. During this research more information about cooling water system at JABANA were obtained, and then it was found that the efficiency is at good level and efficiency will not cause the damages on the engines, temperatures also are almost equal, this means that the engines are working well. The method used in this research was to collect data recorded, read books relating to our project in order to get more information and make a research on the different websites where we got the information we did not find through books. All those methods helped us to use the data recorded from radiator and to analyze them. As conclusion, after analyzing data obtained, we found that the efficiency is good, even water for cooling is good, this show us a well working of the engines and cooling water system. We recommend all operators, technicians and engineers into the plant to avoid

that the efficiency become low by keeping up their temperatures and doing maintenance at time.

KEYWORDS: Cooling water system, evaluation of efficiency,20 MW JABANA Thermo power plant, Rwanda.

1. INTRODUCTION

In Rwanda we have four thermal power plants in which 20MW JABANA II thermal power plant is included, and is the first which produce more electricity. Through a contract signed between RECO and Wartsila Finland in July 5th, 2007, 20MW JABANA II Thermal power plant was supplied and installed at JABANA/KIGALI. The plant is created on an enclosed plot of approximately 120 X 240 meters comprising an engine hall, a utility block, a fuel treatment block, a fuel unloading station, a storage tank area, a day tank area and a switchyard area. The power house basically comprises three model 18V32 engines. Each engine is an eighteen cylinder medium speed type coupled to a generator nominally rated at 7139 KW making a total of 20.5 MW. The engines have been especially developed for the base-load heavy fuel fired power generation with a utility block including a modern computerized control room and 6.6 kV switchgear room.

The fuel unloading station basically comprises one Light fuel oil unloading pumping system and one HFO unloading system with a capacity of 2 tankers maximum. Each system has got a metering system. The storage capacity is 2000 KL for Heavy fuel oil with 2 storage tanks and 0.5 KL for LFO in one tank. All the tanks are steel insulated type. Heavy fuel oil tanks are equipped with electrical heaters. The plant is connected to the national grid through a 15/110 kV switchyard which has been erected and includes two 6.6/110 kV -15 MVA power transformers connected to a bus bar 110kV via two 110kV bays. A 1.2 km 110 kV power line links the plant to JABANA 110 kV substation.[1]

2. Description of Study Area

20MW JABANA II Thermal power plant was supplied and installed at JABANA/KIGAL I, GASABO District. The plant is created on an enclosed plot of approximately 120 X 240 meters comprising an engine hall, a utility block, a fuel treatment block, a fuel unloading station, a storage tank area, a day tank area and a switchyard area.[1]

3. METHODOLOGY

Research methodology is the examination of data and interactive for the particular process used in study. This chapter covers the principle methods for data collection; techniques used and describe the experimental procedures while creating cooling water system , its working principal and its efficiency in 20 MW JABANA II TPP. The next various methods were used to carry out our research used internet for documentation in order to get more information associated to this project. Consulting the websites, we related the written information with others given by 20MW JABANA II TPP operators, staffs and try to share them. Although, the information from those books was not abundant, we read them to get more about the cooling water system, how and where is used. And also to carry out the research, we used personal observations in the whole process day to day records. For this reason we passed our industrial attachment at 20MW JABANA TPP, with this we were able to collect data easily and find the really efficiency of cooling water system in 20MW JABANA II TPP.

3.1. Operation of Cooling Water System In 20mw Jabana Tpp

3.1.1. Cooling process

The normal operating temperature of the engine must be maintained in order that the engine will be able to function efficiently. If the normal operating temperature of the engine is exceeded, the engine is said to have overheated. The clearance which will be reduced resulting to poor access of the oil and overheating will eventually cause early wearing out of the rubbing surfaces of the moving parts. In contrast if the engine operating temperature is cooler than normal, this will cause formation of the sludge in the oil because the water moisture that has impregnated the oil will have no chance to evaporate due to low operating temperature. Aside from this, the air-fuel mixture will not be completely burned and there will be formation of the carbon at the valve head, shoulder, piston surface, valve ports, and exhaust manifold, which eventually will render the failure of the engine. At any case, both abnormal operating temperatures will cause adverse effect to the performance of the engine.[6]

Since a cooling system is needed to maintain the normal operating temperature of the engine, it was found that more than 20% of the heat is wasted from the heat produced by burning the air-fuel mixture inside the cylinder.

The normal operating temperature of the engine is about 190-250 degrees Fahrenheit. If the engine continues to operate, the normal operating temperature may be exceeding if not controlled by the type of cooling system. There are two type of cooling system, namely: the air cooled and water cooled. The water cooling system is composed of the water pump, radiator, fan, and thermostat. The air cooling system, on the other hand, may be composed of the oiler cooler, cooling fins, fan, and baffle plate. But related to our topics, we will discuss water cooled system. In the water-cooled system, the engine drives the water pump. The water pump makes the circulation of the water inside the system possible. The heated water inside the jacket of the engine goes out of the upper spout at the cylinder head and then enters the upper spout of the radiator at the upper header.

The water inside the radiator is cooled by convection process. Because of conduction, the heated water transmits heat to the cooling fins. The cooling fins in return are cooled by the stream of air withdrawn by the fan from the atmosphere so that the water inside the capillary tubes of the radiator is cooled by convection process. The process involved in this type of cooling system creates the difference in temperature of water inside the water jacket of the engine. The water that has been heated inside the water jacket moves to the top or to the cylinder head and finally goes of the outlet spout and recycles back to the radiator, the warm air is again cooled in the radiator.

Water pump and fan assembly. The type of water pump usually adapted to the automotive engines is centrifugal type, which consists of the shaft, pulley adaptors, impeller, bearing, mechanical seal, and housing. The impeller, pulley, and fan blade are coupled to a shaft so that when the pulley turns, the impeller and fan blade also turn to effect simultaneously the circulation of water in the system. This cools off the cooling fins by the stream of air being directed by a fan toward the radiator.

There are water pumps today which do not operate unless the normal operating temperature of the engine is reached. The operation of this type of water pump is related to the principle of the thermostat. In fact, the thermostat and the water pump will not work if one is without the other.

After the engine has just started, the water inside the water jacket of the engine is cool enough to activate the clutch that couples the impeller and the fan blade but as the engine continues to operate.

The temperature increases so that the thermostat is activated to activate the clutch, causing it to engage. However, if the engine speed is reduced, the temperature of the water inside.

The water jacket will correspondingly reduce and the chemical content of the thermostat condenses, causing the chamber to contract. The act of contraction and expansion of the thermostat chamber causes the closing and opening of thermostat, by which the synchronous movement of the thermostat and the water pump depends upon the change in the temperature of the cooling medium.[6]

3.1.2. Thermostat

This is the unit of the water cooling system that controls the outlet of water from the engine in order that the required operating temperature can be maintained inside the water jacket.

A thermostat is a component of a control system which senses the temperature of a system so that the system's temperature is maintained near a desired set point. The thermostat does this by switching heating or cooling devices on or off, or regulating the flow of a heat transfer fluid as needed, to maintain the correct temperature.

A thermostat may be a control unit for a heating or cooling system or a component part of a heater or air conditioner. Thermostats can be constructed in many ways and may use a variety of sensors to measure the temperature. The output of the sensor then controls the heating or cooling apparatus. A Thermostat may switch on and off at temperatures either side of the set point the extent of the difference is known as hysteresis and prevents too frequent switching of the controlled equipment.

3.1.3. Discussion of main parts to be cooled

As the above paragraph shows how the electricity is produced by four stroke engine, some components become very hot than others. For instance: cylinder liners and cylinder heads. Because is where piston is found. This is why they must be cooled by HT circuit and other by LT circuit such as charge air cooler and lube oil cooler etc. All these circuits are connected to the heat exchanger which is located in the radiator.


Fig. 3.1.(a) Cylinder liner **Fig. 3.1.(b)Cylinder head**

3.1.4. Efficiency of a counter flow Heat Exchanger

Suppose we know only the two inlet temperatures : T_{a1}, T_{b2}, and we need to find the outlet temperatures.

$$e^{-a} = (T_{a2} - T_{b1})/(T_{a1} - T_{b2}) \quad \text{(i)}$$

Where

$$a = h_0 \pi D L\left(\frac{1}{W_a} - \frac{1}{W_b}\right) \quad \text{(ii)}$$

We know that

$$T_{a1} - T_{a2} = \frac{\dot{Q}}{W_a}; \qquad T_{b2} - T_{b1} = \frac{\dot{Q}}{W_b} \quad \text{(iii)}$$

Rearranging, Thus

$$(T_{a1} - T_{b2}) - (T_{a2} - T_{b1}) = \dot{Q}\left(\frac{1}{W_a} - \frac{1}{W_b}\right) \quad \text{(iV)}$$

Solving for the total heat transfer

$$\dot{Q} = h_o \pi D L \frac{[(T_{a1} - T_{a2}) - (T_{a2} - T_{b1})]}{In \frac{(T_{a1} - T_{b2})}{T_{a2} - T_{b1}}} \quad \text{(V)}$$

or

$$\dot{Q} = \frac{[(T_{a1} - T_{a2}) - (T_{a2} - T_{b1})]}{\left(\frac{1}{W_a} - \frac{1}{W_b}\right)} \quad \text{(Vi)}$$

$$\dot{Q} = h_o \pi \Delta L \, \Delta \, T_{TM} \quad \text{(Vii)}$$

This is the generalization (for non-uniform wall temperature) of our result

Eliminate $\dot{Q}$ from (iii)

$$T_{a2} - T_{a1} = T_{b1} - T_{a1} + \left(T_{a_1} - T_{b2}\right)e^{-a} \quad \text{(Viii)}$$

$$T_{b2} = T_{b1} + \frac{W_a}{W_b}(T_{a1} - T_{a2}) \quad \text{(iX)}$$

We now have two equations, (viii) and (ix), and two unknowns, Ta2 and Tb2. Solving first for Ta2,

$$(T_{a1} - T_{a2})\left(1 - \frac{W_a}{W_b}e^{-a}\right) = (T_{a1} - T_{b1})(1 - e^{-a}). \quad \text{(X)}$$

$$\boldsymbol{T_{a2} - T_{a1} = T_{b1} - T_{a1} + (T_{a1} - T_{b1})e^{-a} - \frac{W_a}{W_b}(T_{a1} - T_{a2})e^{-a}} \quad \text{(Xi)}$$

Or

$$\boldsymbol{(T_{a1} - T_{a2}) = \eta(T_{a1} - T_{b1})} \quad \text{(Xii)}$$

Where $\boldsymbol{\eta}$ is the efficiency of a counter flow heat exchanger?

$$\boldsymbol{\eta = \frac{1-e^{-a}}{1-\frac{W_a}{W_b}e^{-a}} = \frac{1-e^{-a}}{1-\frac{\dot{m}C_{pa}}{\dot{m}C_{pb}}e^{-a}}} \quad \text{(Xiii)}$$

Moreover, heat exchanger used like component which transfer heat from one fluid to another have the main part called tube with small diameter which distribute fluid to other pipes connected to the radiator and these pipes have the thermometers and barometers to measure temperature(inlet and outlet) and pressure(inlet and outlet). And data showed by radiator either inlet or output will help us in the next chapter to analyze them.

3.2. Data discussion

In production of electricity, data obtained for cooling are not the same. Engines in different industries are cooled according to their type. So, at 20 MW JABANA II TPP which is our case of study, they use the engine of 18v32 type which is an internal combustion engine which works in four strokes. A four stroke engine is an internal combustion engine in which the piston completes four separate strokes: to intake, compression, combustion (power) and exhaust strokes that occur during two crankshaft rotations per power cycle. The cycle begins at Top Dead Centre (TDC), when the piston is farthest away from the axis of the crankshaft. A stroke refers to the full travel of the piston from Top Dead Centre (TDC) to Bottom Dead Centre.

3.2.1. Data presentation

Table 1: Radiator Temperature for Geneset #1 (DATE: 03-23/O9/2012).

PARAMETERS	Mon	Tues	Wed	Thurs	Fri	Sat	Sun
LT INLET	50	50	50	50	50	50	50
LT OUTLET	31.5	32.5	32	32	37.5	37.5	37.5
HT INLET	96	96	96	96	96	96	96
HT OUTLET	72	72	72	72	72	72	72
EFFICIENCY	0.293	0.292	0.293	0.293	0.287	0.287	0.287

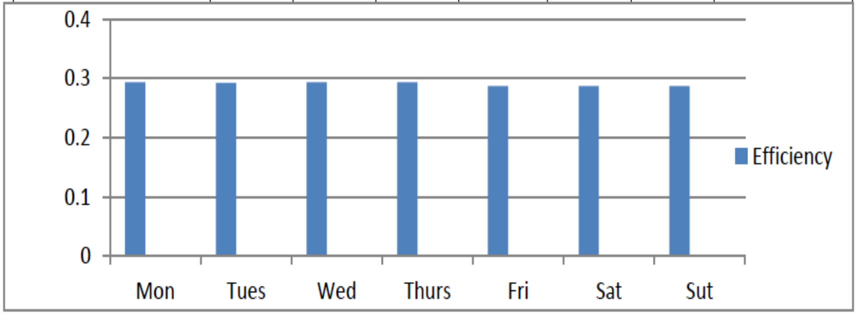


Table 2: Radiator Temperature for Geneset #1(DATE: 01-21/10/2012).

PARAMETERS	Mon	Tues	Wed	Thurs	Fri	Sat	Sun
LT INLET	50	50	50	50	50	50	50
LT OUTLET	34	33.5	33.5	36	36.5	36.5	36.5
HT INLET	96	96	96	96	96	96	96
HT OUTLET	73.5	74	74	72	71	71.5	74
EFFICIENCY	0.284	0.286	0.285	0.288	0.290	0.289	0.282

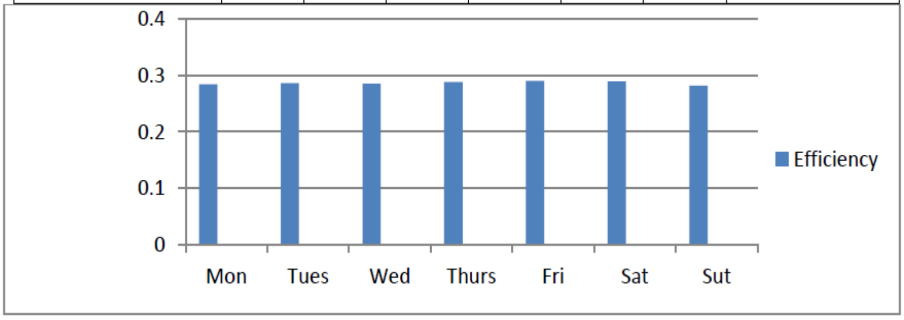


Table 3: Radiator Temperature for Geneset #3(Date: 05-25/11/2012).

PARAMETERS	Mon	Tues	Wed	Thurs	Fri	Sat	Sun
LT INLET	50.5	50.5	50	50.5	50.5	50	50.5
LT OUTLET	29.5	29.5	30	29.5	30	30	29.5
HT INLET	95	95	96	96	96	96	96.7
HT OUTLET	74	74	74	74	75	75	75
EFFICIENCY	0.289	0.289	0.289	0.290	0.290	0.289	0.289

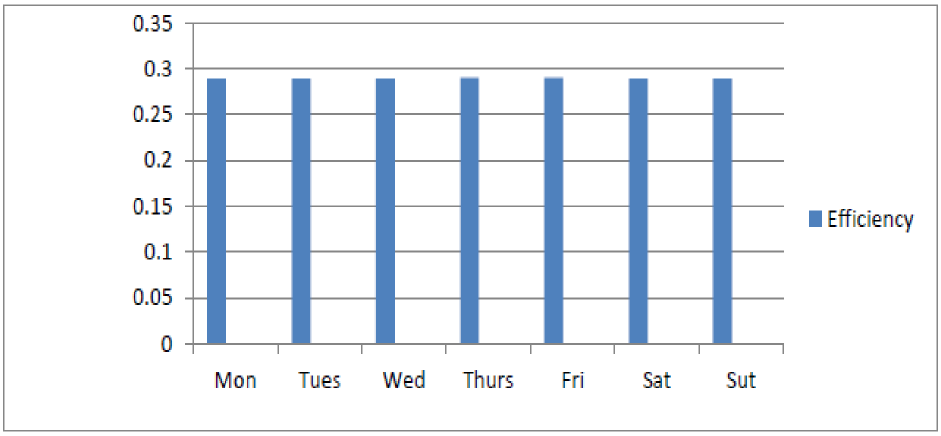


Table 4: Radiator Temperature for Geneset #2(DATE: 10-16/12/2012).

PARAMETERS	Mon	Tues	Wed	Thurs	Fri	Sat	Sun
LT INLET	48	49	50	50	50	50	50
LT OUTLET	32	32	32	32	32	32	32
HT INLET	94	95	96	97	98	98	98
HT OUTLET	72	73	78	78	78	78	78
EFFICIENCY	0.286	0.287	0.276	0.278	0.279	0.279	0.279

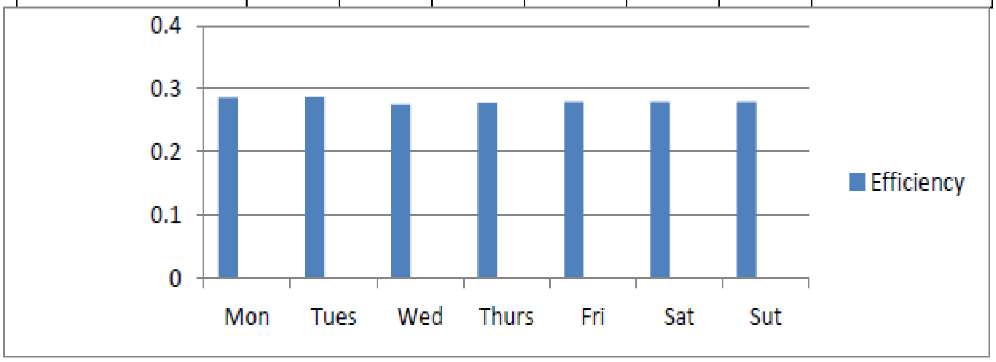


Table 5: Radiator Temperature for Geneset #1(DATE: 04-24/02/2013).

PARAMETERS	Mon	Tues	Wed	Thurs	Fri	Sat	Sun
LT INLET	50	50	50	50	50	50	50
LT OUTLET	30.5	30.5	30.5	30.5	33.5	33.5	33.5
HT INLET	93	93	93	93	93	93	93
HT OUTLET	74	74	74	74	73	73	73
EFFICIENCY	0.285	0.285	0.285	0.285	0.285	0.285	0.285

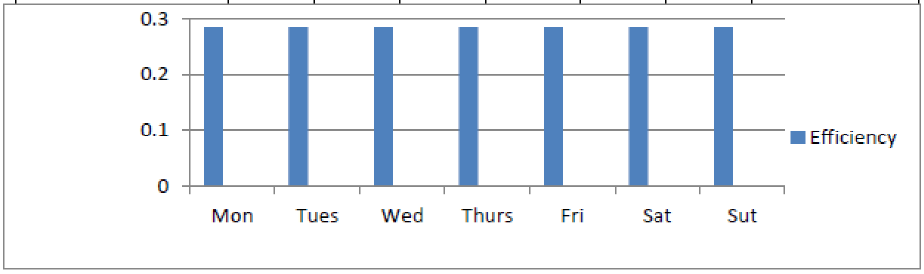
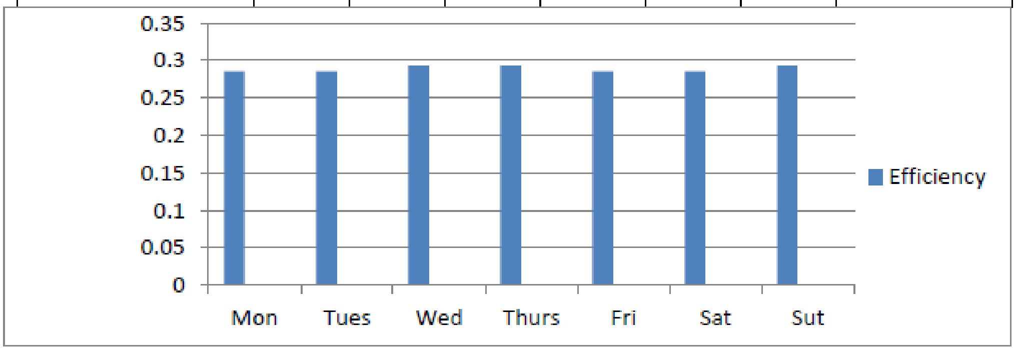


Table 6: Radiator Temperature for Geneset #1(DATE: 04-24/03/2013).

PARAMETERS	Mon	Tues	Wed	Thurs	Fri	Sat	Sun
LT INLET	50	50	50	50	50	50	50
LT OUTLET	30.5	30.5	30.5	30.5	30.5	30.5	31
HT INLET	96	96	96	96	96	96	96
HT OUTLET	72	72	72	72	72	72	72
EFFICIENCY	0.285	0.285	0.293	0.293	0.285	0.285	0.293



3.2.2. Data analysis

As tables above show data of temperatures and efficiencies of the cooling water system, at 20MW JABANA II thermal power plant. Temperatures have been gotten by using its appropriate measurable instrument while efficiency has been obtained by using the above formula for counter flow. Data used for specific heat capacity are constants given by agents from wartsila at JABANA (CPa =2852j/kg.OC and CPb =3857j/kg.OC). The flow rate of the cooling water at low temperature and cooling water at high temperature are the same because the pumps used to make them circulate in the system have the same specification (Q =0.058m/s) which will cause the elimination of mass flow rate. To obtain the real efficiency for each engine we divided the efficiency calculated (using the above formula) by three. The final result of the efficiency is between the range of (0.276 and 0.298) from table12 (minimum efficiency) and table4 (maximum efficiency). This means that the performance of cooling water on the engines is good and is done at time. It is observed that the inlet temperatures are at high level compared to the outlet temperatures. The inlet temperatures to the radiator is always high because it comes from different parts of the engines which are running at high speeds like piston which has periodic motion of 8.4m/s (mean speed). And goes towards the engines after to be cooled, all this path is done in a closed circuit. Generally, when the inlets either LT or HT increased, they affect the efficiencies to be increased but when the outlets either LT or HT increase the efficiencies also decreases.

4. CONCLUDING REMARKS

After analyzing and doing the necessary work on our project, the following conclusions were made:

- Cooling water must be done regularly to maintain the temperature of the engine and to avoid some damages of different parts of the engine while is running, because all parts of the engine cannot become hot at the same level according to its work, for instance the cylinders (cylinder head and cylinder line) are very hot than charge air cooler, and this is a reason why the 18v32 from wartsila is cooled into two circuit, either by HT or LT both in a closed circuit. Even its efficiency must be evaluated periodically in order to know the performance of radiator because once it performs poorly even the engine will not achieve its task.
- According to the tables above containing data recorded from EWSA, we observed that the hot water coming from the engine towards the radiator is hot than water coming from radiator towards the engines.
- Referring to the charts above, we observed that there is no value of efficiency which exceed 0.3. So, cooling water system of 20 MW JABANA II TPP is working well.
- It is preferred to use cooling water system than cooling air system because the fuel consumed by cooling water system is less than cooling air system, Even though the installation of cooling water system and maintenance is difficult and costly.

- Radiator must be considered as the most important part of this plant because without it, the engines cannot work. And if it performs badly, the engines can be overheated and cause many damages such as strength reduction of the piston and the burning of valves.

5. RECOMMENDATION

Although the objectives of this research were achieved there are some recommendations to be made as follows:

- We recommend the private sector to invest by creating many plants which produce electricity by using fuel burned at high pressure because they are not enough.
- We recommend EWSA as a company in charge of producing electricity within our country to look for other possible place which are comfortable in order to increase thermal power plant in our country this will help us to reach the sustainable energy.
- We also recommend EWSA to plan a lot of trainings to their technicians and their operators in view of improving their skills, and to avoid the call of foreigners who are coming for a help when their engine‟s parts have been broken.
- We recommend again plant manager, engineers, technicians, and operators to do maintenance regularly, and periodically in order to make their engines to perform well.
- We also recommend EWSA to empower women participation in learning mechanical engineering and improve their skills by engaging themselves in solid work.
- We recommend that more research and trainings is needed in this field in order to find out how we can satisfy ourselves like having experts.

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