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Research

Performance Evaluation of the LSBLG 1200/MCF Water-cooled Chiller Air Conditioning System

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Abstract
Air conditioners regulate temperature and humidity and improve air quality. After several years of immaculate operation, the system started malfunctioning, resulting in several resident complaints. This study aims to assess the effectiveness of the central water chiller air conditioning system. In order to analyze the effect of local time and temperature on the performance parameters of the LSBLG 1200/ MCF model central water chiller and cooling tower, the intake and output temperatures were measured for a period of 8 hours using the in-built temperature display. Coefficients of Performance and Energy Efficiency Ratios of the cooling system were determined using empirical governing equations of the performance parameter, and the SAS package was utilized to construct characteristic curves. The results revealed that local time has a dynamic effect on the performance parameter, but temperature has a direct proportionate effect on the cooling system's effectiveness. The maximum coefficients of performance for the chiller and cooling tower are 52 and 20, respectively. The chiller and cooling tower have respective Energy Efficiency Ratios of 177 and 68. The greatest amount of cooling happened between 1p.m and 3 p.m. A greater coefficient of performance indicates enhanced performance and decreased electrical energy use. Variable speed retrofits are recommended for increasing chiller effectiveness because variable speed drives will benefit the majority of components in a chiller water system.

Nomenclature and units

COP	Coefficient of Performance
EER	Energy Efficiency Ratio
SEER	Seasonal Energy Efficiency Ratio

1.0 Introduction

Air conditioners are a vital device in the building for many reasons. Air conditioners not only regulate moisture and temperature, but also improve air quality. Air conditioners bring filtered, fresh air into a home. This clean air is free of exterior dirt particles, dust, and even bacteria that enter through the doors and windows. This filtered air creates a healthier, cleaner environment that is ideal for children, families, and commercial settings where large groups of people work together for long periods of time. Hot weather causes weariness more quickly. The same is true in hot and humid climates, which is why commercial property owners should invest in an air conditioner (Zhao and Yang, 2003; Butler and Perry, 1999)

People spend between 80% and 90% of their time indoors, and the interior environment has a significant impact on human health and productivity. Air conditioning systems have been employed in a variety of locations throughout the world to provide occupants with thermal comfort and acceptable Indoor Air Quality (IAQ). (Graudenz et al, 2005). Seppanen and Fisk (2002) discovered an increase in the occurrence of Sick Building Syndrome (SBS) of between 30% and 98%. SBS is a warning sign for interior environment problems associated with air conditioning systems. Since the 1970s, buildings have become more airtight and incorporate a greater amount of insulation materials to decrease energy loss via the building envelope. In air-conditioning systems, fresh air is restricted to reduce energy use in an air-tight building. (Jo and Park, 2004)

R134a is used as a regular substitute for CFC12 in the industry since 1994. Due to the fluorine concentration of this refrigerant, it has a very high Global Warming Potential. There is a need to identify R134a substitutes under the Kyoto and Montreal Protocols. Jabardo et al.(2002) investigated the performance of an R134a air conditioning system with a variable capacity compressor. Simulations were run to determine the effect of design parameters on compressor speed, return air to the evaporator, and condensing air temperatures. According to study conducted by Alkan and Hosoz (2010), the variable speed compressor typically has a higher coefficient of performance (COP) than the fixed speed compressor in R134a air conditioning systems with fixed and variable capacity compressors. It also costs more because the cooling capacity is reduced, while the working temperature is increased Alternative refrigerant technologies were discussed by Verma et al. (2013). R152a were used in place of R134a with no modifications. It operates similarly but cools more efficiently. R152a has a tenfold lower global warming potential than R134a, which is an environmental benefit.

Ghodbane (1999) used a variety of hydrocarbons to imitate the functioning of air cooling systems and found that R152a and R270 systems perform better than R134a systems. Navarro et al.(2013) examined the performance of R1234yf, R134a, and R290 in an open piston compressor used in air conditioning under a variety of operating circumstances. The compressor and volumetric efficiency of R290 were found to be significantly improved. Navarro-Esbr et al.(2013) conducted experimental investigations using a vapor compression device and R1234yf has a cooling capacity approximately 9% less than R134a.

Liu et al. (2021) presented a method for evaluating the plant rooms of commercial air conditioning systems. This innovative technique merges BPS models and HVAC design situations. Data and weighting requirements for energy efficiency indices are produced using BPS and Rough Set theory. Othman et al. (2013) presented a study conducted to evaluate the performance of an actual building's air-conditioning system using Malaysian Standard MS1525 as a reference. Although the results reveal that the building's coefficient of performance is adequate despite its age, recommendations for system enhancements are provided.

Al-Yasiri et al. (2022).investigated solar cooling and air-conditioning systems (SCACS) for building applications. Popular SCACS that use solar thermal energy were thoroughly examined in terms of their operation and development. The literature assessment revealed a number of research gaps including the need for envelope approaches in regions where ambient temperatures are high for lengthy periods of time, and enhancing the building envelope performance. Poor ventilation rates and the presence of multiple synthetic chemicals contribute to indoor particle pollution. This is considered to be a significant contributor to compound hypersensitivity in the environment; nonetheless, it is encouraging that some comfortable and healthful air-conditioning solutions have been developed in recent years. This study provides an experimental evaluation of the performance of the LSBLG 1200/MCF water-cooled Chiller Air Conditioning System in order to produce its performance characteristic curve as a function of local time, inlet and outlet temperatures.

2.0 Materials and Methods

The influence of local time, inlet and outlet temperatures on the effectiveness of the cooling system was investigated experimentally; using the LSBLG 1200/MCF central water-cooled Chiller Air Conditioning System with Cooling Capacity of 1200 kW and Power Input of 206 kW. .

2.1 *Principle of Central Water-cooled Chiller Air Conditioning System.*

A typical water chiller system includes the following components: a pump, cooling coils, expansion tank, and pipe valves and controls. The thermostats regulate the temperature in the cooled areas. This is the point at which the chilled water absorbs heat from the air passing over the air handling coil or fan coil devices. Water runs through the condenser of a water cooled chiller to cool the hot discharge gas to condensing temperature. A water-cooled condenser is used in conjunction with a cooling tower. Water is constantly fed to the cooling tower through the use of water pipes. The diagram of LSBLG 1200/MCF central water-cooled Chiller Air Conditioning System is shown in Figure 1.0.

Figure 1.0. LSBLG 1200/MCF central water-cooled Chiller Air Conditioning System

The operating parameters of the AC system, such as the temperature of the LSBLG 1200/MCF model chiller, the temperature of the cooling tower, and the temperature of the lubricating oil, were recorded for 8 hours at one-hour intervals using the in-built data display unit. The AC system's noise level was measured using a sound level meter during a period of eight hours at one-hour intervals. The results are presented using profiles in order to develop characteristic curves for the air conditioning system. The performance parameters were determined using equations (1-8).

2.2 Performance Evaluation

The Coefficient of Performance, COP, Energy Efficiency Ratio, EER, and Seasonal Energy Efficiency Ratio, SEER ratings are used for performance evaluation of cooling system. A greater ratio indicates a more efficient system and serves as the basis for determining an air conditioners star rating, and when purchasing an air conditioner, a model with a high efficiency rating is chosen.

The coefficient of performance of a chiller is the amount of heat removed from the cold reservoir divided by the amount of work, W, required to remove the heat as expressed in equation (1)

$$COP = \frac{Q_{cold}}{W} \quad (1)$$

The chiller is more effective and efficient when it can remove more heat Qcold from the interior of the chiller for a given amount of effort. Because the first law of thermodynamics must apply in this instance as well, eqn. (2) is used to represent the expression.

$$COP = \frac{Q_{cold}}{W} = \frac{Q_{cold}}{Q_{hot} - Q_{cold}} \tag{2}$$

It can be analyzed that for an ideal chiller, COP is given in eqn.(3)

$$COP = \frac{T_{cold}}{T_{hot} - T_{cold}} \tag{3}$$

The Coefficient of Performance is used to determine the efficiency of cooling systems as expressed in eqn.(4)

$$\text{COP} = \frac{\text{Output cooling (Wh)}}{\text{Input electrical energy (Wh)}} \tag{4}$$

Energy Efficiency Ratio, EER is suitable for cooling system evaluation. EER and COP are related in the form shown in eqn (5)

$$\text{EER} = \text{COP} * 3.41 \tag{5}$$

Energy Efficiency Ratio is a metric used to analyze the performance of cooling systems as presented in eqns, (6 & 7)

$$\text{EER} = \frac{\text{Output cooling (BTUh)}}{\text{Input electrical energy (Wh)}} \tag{6}$$

$$\text{EER} = 1.12 * \text{SEER} - 0.02 * \text{SEER}^2 \tag{7}$$

Where SEER is Seasonal Energy Efficiency Ratio, It is used to represent the relative amount of energy needed to achieve a certain cooling output and the expected overall performance for a typical year's weather in a given location, as presented in eqn.(8)

$$\text{SEER} = \frac{\left(1.12 - \sqrt{(1.2544 - 0.08 * \text{EER})}\right)}{0.04} \tag{8}$$

3.0 Results and Discussions

The effect of local time, inlet and outlet temperatures on the efficacy of the chiller and cooling tower were conducted experimentally and the results were presented in figures (2-12). The performance parameter charts were constructed, after acquiring the critical parameters from the LSBLG 1200/MF water chilled air conditioning system and cooling tower. Figures 2.0 illustrates the influence of outlet chiller temperature on the COP and EER. The results indicate that as the outflow temperature of the chiller cooling water increases, the COP and EER increase as well. This means that the air conditioner performs optimally at lower chiller and cooling water outlet temperatures.

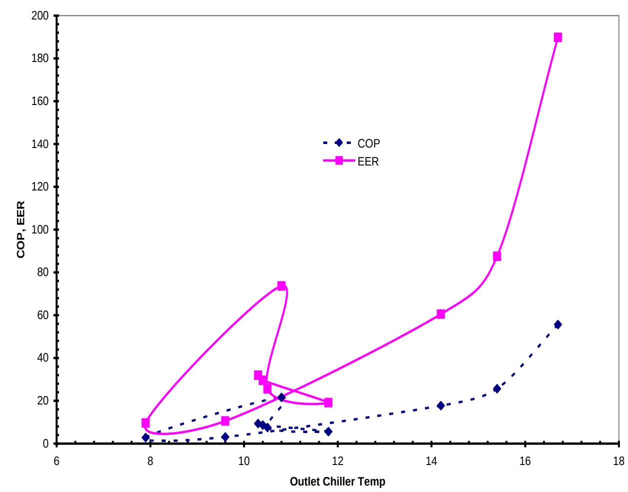

Fig. 2.0 Plot of COP and EER against Outlet Chiller Temperature

Figures 3.0 and 4.0 illustrate the influence of outlet cooling water temperature on the COP and EER. According to Figures 3.0 and 4.0, output cooling water temperature has a direct proportional effect on cooling water performance.

Figures 5.0 and 6.0 illustrate the influence of outlet cooling tower temperature on the COP and EER of cooling tower. The findings show that cooling tower performance is proportional to the temperature at the cooling tower outlet.

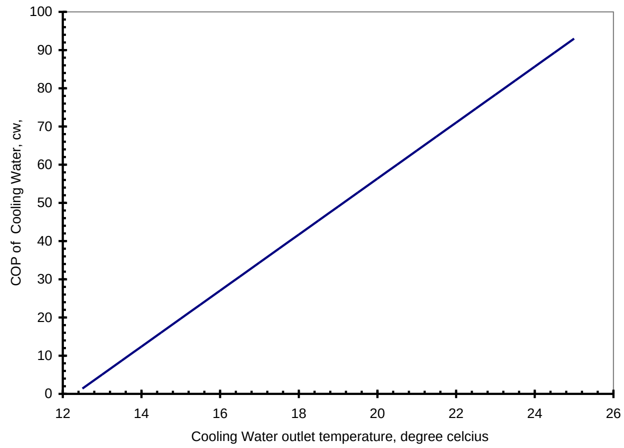

Fig. 3.0 Plot of COP of Cooling Water against Cooling Water Outlet Temperature

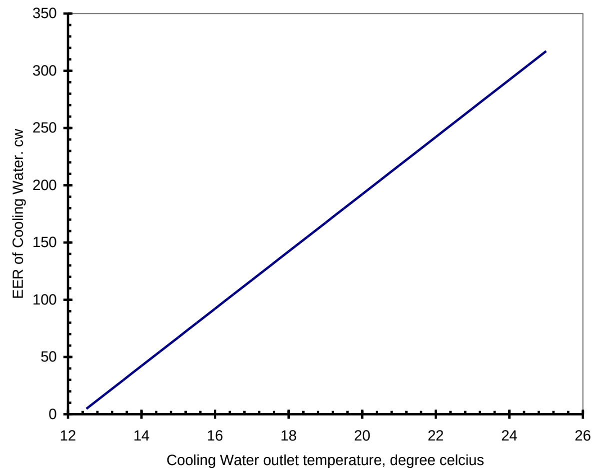

Fig. 4.0 Plot of EER of Cooling Water against Cooling Water Outlet Temperature

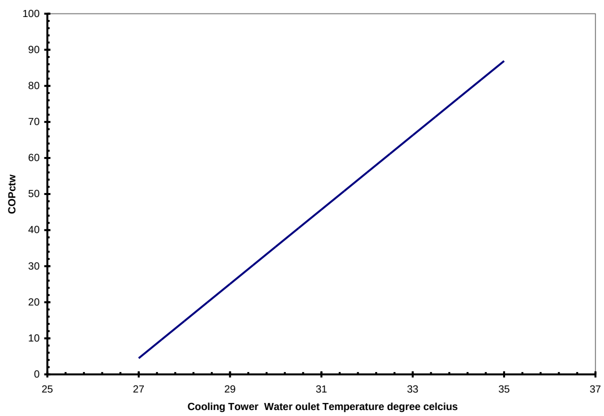

Fig. 5.0 Plot of COP of Cooling Tower against Outlet Cooling Tower Temperature

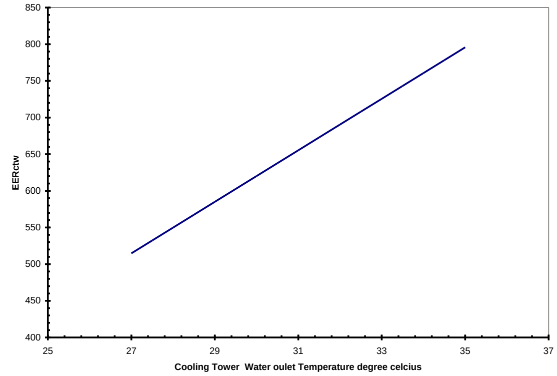

Fig. 6.0 Plot of EER of Cooling Tower against Outlet Cooling Tower Temperature

Figures 7.0 and 8.0 illustrate the impacts of local time on the COP and EER of cooling water towers, ct, and cooling water, cw. The findings show that the cooling tower's efficacy and energy efficiency ratios behave dynamically when local time changes, which is related to the dynamic nature of climatic weather factors. The energy efficiency ratio is at its peak between 1p.m and 3 p.m., when the ambient temperature and solar intensity are at their peak.

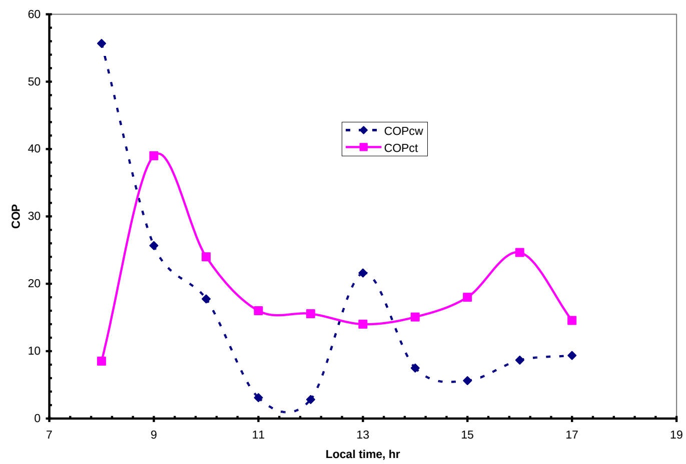

Fig. 7.0 Plot of COP of Cooling Water Tower And Cooling Water against Local Time

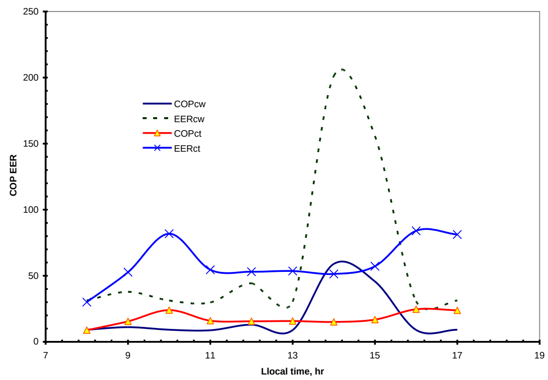

Fig. 8.0 Plot of COP, EER of Cooling Water Tower And Cooling Water against Local Time

Fig. 9.0 depicts a plot of noise level, in decibels against local time at different days. Figure 10.0 illustrates the typical curves of the Chiller's water entry and outflow temperatures as a function of local time. Figure 11.0 illustrates the characteristic curves of the cooling tower water entry and output temperatures as a function of local time. Figure 12 illustrates the characteristic curves for relative humidity and noise level as a function of local time. The graphs show how local time affects operating functional characteristics such noise, humidity, chiller water entry and outlet temperatures, and cooling tower water inlet and outlet temperatures. The results demonstrate that these parameters are dynamic as a function of local time. The dynamic nature of meteorological conditions dictates these behaviours.

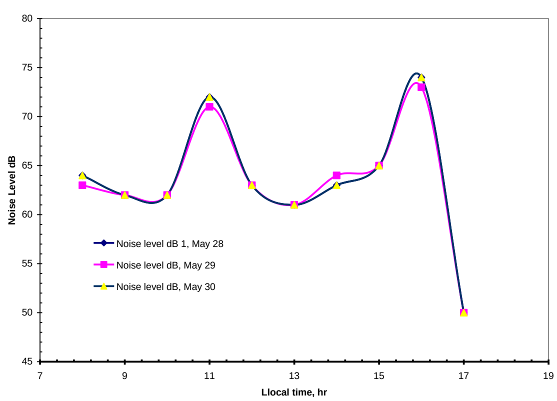

Fig. 9.0 Plot of Noise level, dB against Local Time at Different Days

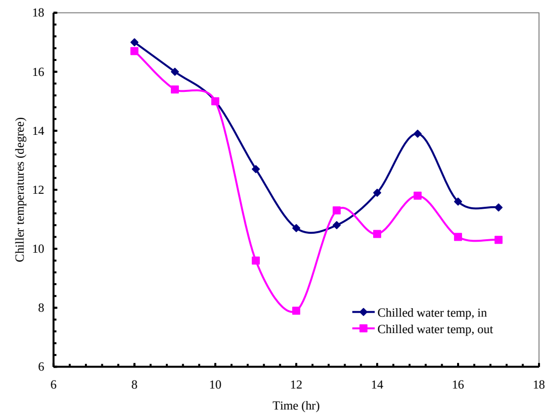

Fig. 10 Plot of Chiller Water Inlet And Outlet Temperatures against Local Time

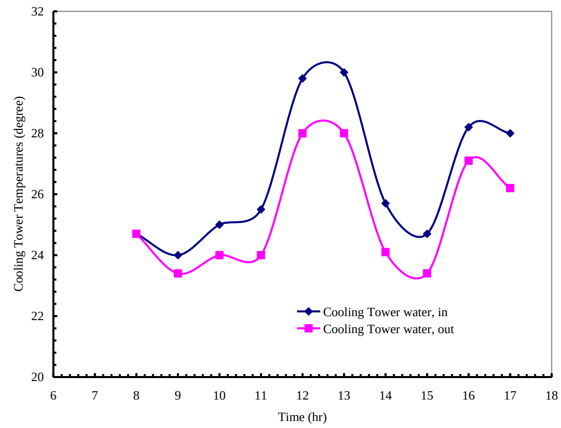

Fig. 11.0 Plot of Cooling Tower Water Entry and Exit Temperatures against Local Time

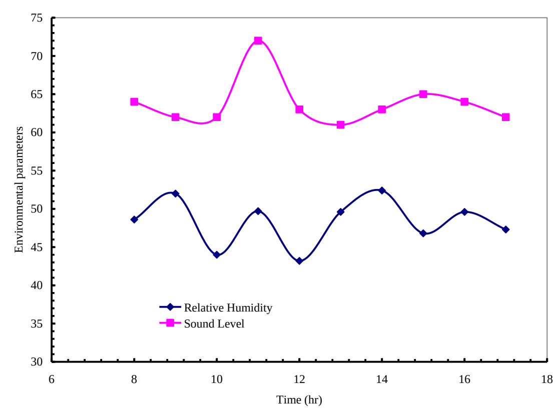

Fig. 12 Plot of Relative humidity and Noise Level against Local Time

The characteristics curves indicate that the tendency of the curves grew as the local time increased; indicating that the thermal influence in the surrounding increased and more heat was generated in the room, resulting in increased heat extraction. The air conditioner extracted the most heat, between 1:00 p.m and 3:00 p.m. This explains why heat extraction is reduced when the thermal influence on the surrounding environment is reduced and the room generates less heat.

4.0 Conclusions

The following conclusions were drawn from the findings of this study: the performance of central water-cooled Chiller Air Conditioning System was evaluated and characteristics parameters were determined. The performance curves were produced; the chiller and cooling tower have maximum performance coefficients of 52 percent and 20 percent, respectively. The chiller and cooling tower, have maximum Energy Efficiency Ratio of 177 and 68 respectively.

The results demonstrate that performance parameters are dynamic as a function of local time and the dynamic nature of meteorological conditions dictates these behaviours. The characteristics curves indicate that the tendency of the curves grew as the local time increased; indicating that the thermal influence in the surrounding increased and more heat was generated in the room, resulting in increased heat extraction.

Variable speed retrofits are recommended for improving chiller efficacy because variable speed drives will benefit most components in a chilled water system. Also running numerous parallel devices will maximize savings and chiller performance will be improved by increasing supply temperatures. A higher COP indicates more efficiency and lower electrical energy.

Declaration of conflict of interest

None

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