Analysis of Air Cooling (AC) System Auditorium Venue Third Floor Main Building of Politeknik Negeri Lhokseumawe

Syamsuar*, Ariefin, Sumardi
Mechanical Engineering Department, Politeknik Negeri Lhokseumawe. Jl. Banda Aceh – Medan Km.280 Buketrata Lhokseumawe 24301

*Corresponding author: syamlsm@yahoo.co.id

Abstract. The aims of this study are to calculate the cooling load system on the auditorium space of Politeknik Negeri Lhokseumawe (PNL). This calculation is expected to contribute the energy savings is the system of air (STU). This study is conducting on the third floor of PNL, at the Auditorium venue. The cooling load system by using Cooling load temperature difference (CLTD) system based on ASHRAE Handbook Fundamental, 1993. The calculation of cooling load based on secondary date, and then the result was compared to cooling load installed capacities. The result of the research found that the maximum cooler burden at culminate condition is equal to 116957 Btu/hr (9,74 ton of refrigerant), While the installed refrigeration capacities is 61080 Btu/hr (5,09 ton of refrigerant), here fond a lacking (decreasing) of refrigeration burden equal to 55857 Btu/hr (4,65ton of refrigerant). If the installed burden (load) as according to re-calculation result, hence thrift gap still can be obtained equal to 14%, by paring down the illumination of light; altering set temperature pint in room; minimizing SC (Shading of coefficient); and lessen of infiltrate external air.

1. Introduction
The increasing use of AC machines in housing, office buildings, shopping centers, and other buildings in our country is also followed by increasing energy consumption, where 55-65% of the energy used in buildings is used by the air system (STU). Energy plays an important role in economic development, a quite significant correlation exists between energy consumption and gross domestic product of a society.

The proper and efficient use of energy is the main requirement in order to save energy in a country. Therefore, polytechnics as institutions of higher education naturally participate in saving energy use and play a role in developing technology, especially those related to energy conservation.

Energy saving gaps in an existing building are still possible to be implemented, without much need for changes in existing devices, such as in the air conditioning system of the Lhokseumawe State Polytechnic auditorium. The gap in question includes; energy savings by operating control methods, energy savings with maintenance and management methods, and energy savings by modification methods.

The energy conservation activities aforementioned aim to minimize the energy consumption within reasonable limits without having to reduce the function of a system. In other words, this activity is intended to obtain the optimum energy consumption.
In this discussion, many energy savings are associated with the operational control and energy savings with maintenance and management. The choice of this method is used because it does not require many changes to the existing equipment and does not reduce the function of a system.

The objectives of this study are:
1. Recalculating the cooling load from the existing air conditioning system (ACS).
2. Improving the existing ACS with several possible savings gaps that have been chosen (by calculations).
3. Comparing the results of the calculation of the cooling load of both conditions before and after the repairs.
4. Analyzing the calculation results
5. Concluding the results of the study.

2. Materials and Methods

2.1. Air Conditioning.
Stocker (1994) [1] explains that the air conditioning is the treatment of air to regulate temperature, humidity, cleanliness, and distribution simultaneously in order to achieve the comfortable conditions needed by humans in the system.

Air conditioning is an application of the refrigeration. Refrigeration is the process of the decreasing temperature and keeping room/material temperature below the ambient temperature [2].

2.2. Energy saving definition
Energy saving in architecture is a minimization of energy consumption without limiting or changing the functions and comfort of a buildings and the productivity of its inhabitants.

More broadly, energy saving must be started from each method of the building operation. In general, more than 60 per cent of the electricity generated by National Electricity Enterprise of Indonesia (NEI) is consumed by settlements. So, if the increasing of the building comfort, in its preliminary study, is associated with existing savings, significant figures will be obtained nationally. The generated energy supply is relatively stagnant, while the demand increases from year to year, and energy prices continue to rise. So that the energy saving measures are needed, starting from the design understanding stage, as well as the energy utilization management.

2.3. Energy savings opportunities
Sinaga (1984) [3] explains that energy saving opportunities in an air conditioning system can be done through energy savings in cooling machines and energy savings in air distribution systems.

The opportunity of energy saving on a cooling machine can be done, among others by: reviewing the location and position of the evaporator and condenser from the air conditioner (AC), where if the location of the two components is too far away, it will cause an increase in the value of losses in the piping system; paying attention to the placement of a condenser that is located outside the room, because the locating of an ineffective and unprotected condenser will cause the excessive consumption of the energy in the AC.

The opportunity of energy saving in the air distribution system can be done by reviewing the pattern of air flow in the conditioned room. By knowing the pattern of the existing air flow in a conditioned room, we can streamline the position of the evaporator. So that the distribution of cold air sprayed from the evaporator becomes more efficient and evenly distributed.

According to Nugroho (1990) [4], energy savings in the existing building system can be done by several methods, including: methods of operating control, maintenance and management methods, and methods with modifications. The first two methods are preferred, because they do not require a lot of changes to the existing equipment.
2.4. Energy saving by reducing fresh air

The energy consumption of an air conditioning system (ACS) for the need for ventilation (outside air conditioning) is quite dominant. The amount is proportional to the quantity of outside entering air. Thus, the saving effort is to minimize the outside air flow rate. The efforts made include:

1. Re-examine occupant ratio requirements versus fresh air flow rate. This ratio should be based on: respiratory metabolism, CO₂ concentration; level of environmental contamination: odor or residue / result of combustion.
2. Reviewing the control of the flow rate of fresh air. The control can be done with fixed settings, manually or automatically.

2.5. Energy Saving by Changing the Temperature Setpoint.

Some studies show that the comfortable temperature depends on climate, season and clothes worn. For example, in Indonesia, the temperatures ranging from 26 until 27°C are still within the comfortable limits. Thus, we can increase the room temperature setpoint. So that the sensible cooling heat savings will be obtained.

2.6. Energy Saving by Preventing Overcooling

Excessive cooling does not only waste energy, but it also does not provide comfort and health. When the space cooling load decreases, the total load in the cooling coil should also reduce. This is easy to do if the control used is automatic. For example, by using a thermostat and humadistat that will regulate the air flow rate in the cooling coil.

2.7. Energy Saving by Changing the Humidity Setpoint.

In fact, the comfortable humidity limit for humans ranges from 40 to 70% RH. So that we can recheck the setpoint of room humidity and take the optimal RH for the purpose of comfort and energy savings.

2.8. Energy Savings by Changing Lighting Levels

Heat dissipation from lighting has a considerable contribution to the sensible load of a room. Thus, reducing the lighting level to the optimum comfort and energy-saving limit (approximately 300 lux), and scheduling the right lighting, will have a positive effect on energy savings.

2.9. Cooling Load

Cooling load is the total amount of heat energy that must be removed in a unit of time from the cooled room. This load is needed to deal with external and internal heat loads. External heat loads are caused by the heat entering through conduction (walls, ceilings, glass, partitions, and floors), radiation (glass), and convection (ventilation and infiltration). Internal heat load is caused by heat arising from people / occupants, lights, and equipment / machinery.

2.9.1. External Heat Load. External heat loads for all buildings caused by conduction, radiation, and convection can be calculated using the following equations:

\[
\text{RSHG} = U \times A \times \text{CLTDcorr} \times F_c
\]  

Where:

\[
\text{RSHG} = \text{room sensible heat gain (Btu/h).}
\]

\[
A = \text{Area of roof, wall, or glass (ft}^2\).}
\]

\[
U = \text{Material conductance (Btu/ ft}^2\text{.°F.h).}
\]

\[
\text{CLTDcorr} = \text{CLTD table+ (78-indoor) + (outdoor-85) (°F).}
\]

\[
F_c = \text{Correction factor}
\]

Conduction through roofs, walls and glass:

Conduction through partitions, ceilings and floors:
RSHG = U x A x ∆T  \hspace{1cm} (2)

Where:

A = Partition area, ceiling, or floor (ft²).

∆T = outdoor temperature – indoor temperature (°F).

Radiation through glass:
RSHG = A x SC x SCL x Fc  \hspace{1cm} (3)

Where:

A = glass area (ft²).

SC = shading coefficient.

SCL = solar cooling load (Btu/h.ft²).

Ventilation:
RSHG = 1.10 x n x CFM x ∆T and RLHG = 4840 x n x CFM x ∆W  \hspace{1cm} (4)

2.9.2. Internal heat load. External Heat Load for all buildings caused by the presence of occupants, lights and equipment, can be calculated using the following equations:

Occupant:
RSHG = n x Qs x CLF and RLHG = n x Ql  \hspace{1cm} (5)

Where:

Qs = human sensible heat load (Btu/h).

Ql = human latent heat load (Btu/h).

CLF = cooling load factor, for human.

Light:
RSHG = 3.412 x Input x Fu x Fs x CLF  \hspace{1cm} (6)

Where:

Input = number of light (W).

Fu = lighting use factor.

Fs = special allowance factor = 1.20.

CLF = cooling load factor, for light

Equipment:
RSHG = Input x CLFeq  \hspace{1cm} (7)

Where:

Input = number of equipment (Btu/h).

CLFeq = cooling load factor, for equipment.

Ton of refrigeration:
TR = (RSHG total + RLHG total)/12000  \hspace{1cm} (8)

Where:

TR = Ton of Refrigeration, cooler capacity (TR)

2.10. Methods

The research methodology used in solving this problem is to recalculate the cooling load in two conditions, namely in the existing ACS condition, and the ACS condition after repairs. The Cooling Load Temperature Difference (CLTD) method based on the ASHRAE 1993 Fundamental Handbook [5] was used in this research.

The data used in this study is secondary data which includes:
• Floor area, building surface area, building volume, glass surface area, each distinguished between conditioned and not.
• The surface area of the sheath / facade consists of the area of the wall and glass.
• The area of each building material in the direction of it.
• Type of material, thickness and color of the building envelope and roof material.
• U value for materials used in both walls, glass and roof.
• Shade coefficient value (SC).

With this method, the cooling load profile will be shown. It will also show the composition of the external and internal cooling loads experienced by the building. Then, the analysis will be carried out from the result of calculation.

The results of the analysis in the form of cooling load data information and cooling load profile of the two conditions will be concluded of whether in the ACS of the Lhokseumawe State Polytechnic auditorium the energy saving can be done or not.

The procedures taken in this study include:
• Retrieval of initial auditorium space data, in the form of room size, wall material, roof and floor, number of lighting systems used, tools offices, etc. as the initial data for calculating cooling loads
• Calculation of cooling load from the initial data.
• Make the improvements to the ACS that has some possible savings, and calculate the cooling load
• Analysis of the results of calculations of the two conditions.
• Taking conclusions.

3. Results and Discussion
Secondary data are obtained in the form of:
1. Size and area of walls, roofs, floors, glass and glass windows of the auditorium.
2. Electric appliances and lighting.
3. The maximum capacity of visitors is 150 people

Cooling load is calculated using the cooling load temperature difference (CLTD) method with the data as follows:
• Lhokseumawe outside air condition is taken by dry bulb temperature (DBT) = 34 °C, and relative humidity (RH) = 76%.
• Internal air condition (DBT) = 25 °C, RH = 60%
• The maximum cooling load occurs in October, at 4:00 p.m.

From the secondary data, the external and internal heat loads can be calculated using formula (1) to (8). The maximum cooling load can be seen in table 1.

Table 1. Recapitulation of cooling loads.

| No | Description       | Information          | HS (Btu/hr) | HL (Btu/hr) |
|----|-------------------|----------------------|-------------|-------------|
| 1  | External load     | Radiation through glass | 4546,8      | -           |
|    |                   | Heat transmition through wall | 24255,2  | -           |
|    |                   | Ceiling               | 16637,8     | -           |
|    |                   | Floor                 | 8318,7      | -           |
|    |                   | Ventilation           | 2673        | 3245        |
| 2  | Internal load     | Human                 | 31500       | 21000       |
|    |                   | Light                 | 2346,5      | -           |
|    |                   | Sound system          | 2414        | -           |
| 3  | Total load        | -                     | 92692       | 24245       |

The total cooling load is 116937 Btu/ hr (Total HS + Total HL).
The installed capacity of the air conditioner in the auditorium is 61080 Btu / hr (5.09 tons of refrigerant). While the calculation results obtained, the cooling load is 116937 Btu / hr (9.74 tons of refrigerant). This means that the design of ACS of the auditorium is inaccurate.

The gap in energy saving is done by reducing several cooling load factors, including:
1. Change the lighting level by changing the lamp type.
2. Change the temperature setpoint in space ranging from 25°C to 27°C
3. Reducing the SC (shading of coefficient) on glass windows and other wall glass, by installing darker curtains.
4. Reducing outside air infiltration by reducing doors and windows that are often opened and closed.

By trying to follow the advices above, the possibility of reducing cooling loads can be seen in table 2.

| No | Description                        | HS (Btu/hr) | HL (Btu/hr) |
|----|------------------------------------|-------------|-------------|
| 1  | Replacing light                    | 173,3       | -           |
| 2  | Changing the temperature setpoint  | 11932       | -           |
| 3  | Minimizing the SC                  | 755         | -           |
| 4  | Deceasing the infiltration         | 623         | 1530        |
|    | Total load                          | 14483,3     | 1530        |

The total reduction of the cooling load is 16013.3 Btu/day. From the results of calculations in table 2, an energy saving of 4,695 Kw was obtained, from the installed capacity of 34,285 Kw. This means that there is an energy saving of 13.69%, or about 14%.

4. Conclusions
From the results of the analysis and studies on the ACS on the third floor of the auditorium in the main building of State Polytechnic in Lhokseumawe, it can be concluded that:
1. The maximum cooling load at peak load is 116937 Btu/hr (9.74 tons of refrigerant). While the installed cooling capacity is 61080 Btu/hr (5.09 tons of refrigerant). This means that there has been a shortage of cooling loads of 55857 Btu/hr (4.65 tons of refrigerant).
2. The cooling load profile of 92692 Btu/hr comes from the sensible heat loads; and 24245 Btu/hr comes from latent heat loads.
3. Factors that can reduce the cooling load are: changing the level of lighting by replacing energy-saving lamps, changing temperature setpoints in space, reducing shading of coefficient(SC) in glass windows and other wall glass, and reducing the infiltration of outside air.

5. References
[1] Stocher, WF. Jones. Jerold. W, Refrigerasi dan Pengkondisian Udar, Erlangga, Jakarta, 1989.
[2] Dossat, Roy. J, Principle of refrigeration, 2nd Edition, John Willey and Son, New york, 1981.
[3] Sinaga. N. “ Beberapa Peluang Penghematan Energi pada Gedung Belantai Banyak”, Jurnal Teknik FT. Undip, Edisi Agustus 1994, hal 42-45
[4] Nugroho,W. "Studi Sistem Tata Udar Ruang Bersih Dalam kaitannya Dengan Pemakaian Energi", Teknik Fisika ITB, Bandung, 1990.
[5] ASHRAE, Hand Book Fundamentals, USA, 1993