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Cooling Load Estimation and Air Conditioning Unit Selection for Hibir Boat

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--ABSTRACT--
The variables affecting cooling load calculations are numerous, often difficult to define precisely, and always intricately interrelated. Many cooling load components vary in magnitude over a wide range during a twenty four hour period. Since these cyclic changes in load components are often not in phase with each other, each must be analyzed to establish the resultant maximum cooling load for a building or zone.
Not only does this over sizing impact the heating and cooling equipment costs, but duct sizes and numbers of runs must also be increased to account for the significantly increased system airflow.

Cooling load estimation for Hibir Boat undertake different variables were considered to give optimum air conditioning unit to deliver conditioned air to the rooms to meet the occupant's comfort expectations at the indoor conditions.
For the larger room a total capacity of 171,322 BTU/hour should be provided to meet the requirement. In addition 55,490 BTU/h is also required for the two passenger rooms.

Due to the limitation of space for the duct system it is proposed that split type air conditioning unit is better due to the fact that there is no sufficient space to pass the duct between the roof and the ceiling or between the metal hull and the inner insulation wood.

***KEY WORDS**: Hibir Boat, Cooling Load Estimation, Internal Cooling Load, Air Conditioning Unit*

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I. INTRODUCTION

Hibir boat was built by Ethiopian professions at a cost of more than 19 million Ethiopian birr, launched on eve of nation nationalities and people day on December, 2012 in Bahir Dar. The boat has capacity to transports more than 170 persons at time. The boat is dove shaped, special purpose marine vessel having meeting hall which can accommodate up to 100 participants. The boat body is made of steel metal and the outer body painted white color which contributes in the reduction of heat conducted from the outré metal body to the inner wood insulation. Even if there is wood insulation it is not sufficient to block the outdoor temperature not to pass to the indoor. Hence it requires to the meeting hall and passenger rooms to provide air conditioning unit to maintain proper indoor temperature for the comfort of the users.

During designing a heating, ventilating, and air-conditioning (HVAC) system, perhaps the first thought that comes to mind is to select a system that is large enough to keep the indoors at the desired conditions at all times even under the worst weather conditions. But sizing an HVAC system on the basis of the most extreme weather on record is not practical since such an oversized system will have a higher initial cost, will occupy more space, and will probably have a higher operating cost because the equipment in this case will run at partial load most of time and thus at a lower efficiency.

Air conditioning sizing is based on heat gain from indoor and outdoor. In this design the boat only need to be cooled due to the fact that outside temperature is greater than the inside temperature, therefore for the boat hall and rooms cooling load estimation is needed only to select appropriate capacity air conditioning unit.
In this design it is desired to make the inside space of the boat comfortable to the occupants. To meet the desired objective it is needed to reject heat from the boat to the surrounding environment because temperature outside the boat is greater than the indoor temperature. The total heat gain from the internal and external will be determined with grate accuracy not to under size or over size of the air conditioning system.

One of the constraints that exist in this boat design air conditioning system is space for the duct and the electric power supply to run the units.

The components of the boat cooling load are; direct solar radiation, transmission load, ventilation/ infiltration load and internal load. Calculating all these loads individually and adding them up gives the estimate of total cooling load. The load, thus calculated, constitutes total sensible load. Normal practice is that, depending on the building type, certain percent of it is added to take care of latent load [1].

Matching its size to meet the comfort of the occupants would need to consider the internal environments; equipments, occupants and also the building make up materials in addition the external environments the air conditioning efficiency, performance, durability, and cost.

1.1 Design Parameters

The critical inputs during estimating the cooling load are:

i. Design conditions

- Location
- Latitude
- Elevation
- Outdoor temperature and relative humidity

ii. Orientation

iii. Internal conditions

- Indoor temperature and relative humidity

iv. Building enclosure

- Insulation levels of walls, ceilings and floors
- Window specification
- Thermal conductivity
- Solar heat gain coefficient (SHGC)
- Infiltration and ventilation levels
- Interior and exterior shading

v. Internal loads

- Number of occupants
- Electronics, lighting and appliances

The cooling load calculation is the first step of the iterative air conditioning (AC) design procedure; a full AC design involves more than the just the load estimate calculation. Right-sizing the AC system, selecting AC equipment and designing the air distribution system to meet the accurate predicted cooling loads, begins with an accurate understanding of the cooling loads on a space [2].

1.2 Factor which Affect the Heat Gain

The heat gain in the boat depends on:

a. The temperature difference between outside temperature and the desired temperature.
b. The type of construction and the amount of insulation on ceiling and walls.
c. How much shade is on building's windows, walls, and roof.
d. Size of the room and surface area of the walls.
e. The amount of air leaks into indoor space from the outside. Infiltration plays a part in determining the air conditioner sizing.
f. The number occupants.
g. Activities and other equipment within a building. Cooking? Hot bath? Gymnasium? Meeting? etc
h. Amount of lighting in the room.
i. How much heat the appliances generate.

The air conditioner's efficiency, performance, durability, and cost depend on matching its size to the above mentioned factors heat gain factors. Many designers use a simple square foot method for sizing the air-conditioners. The most common rule of thumb is to use "1 ton for every 500 square feet of floor area". Such a method is useful in preliminary estimation of the equipment size. The main drawback of rules-of-thumb methods is the presumption that the building design will not make any difference. Thus the rules for a badly designed building are typically the same as for a good design.

For estimating cooling loads, one has to consider the unsteady state processes, as the peak cooling load occurs during the day time and the outside conditions also vary significantly throughout the day due to solar radiation. In addition, all internal sources add on to the cooling loads and neglecting them would lead to underestimation of the required cooling capacity and the possibility of not being able to maintain the required indoor conditions. Thus cooling load calculations are inherently more complicated.

The size of a cooling system for a boat is determined on the basis of the desired indoor conditions that must be maintained based on the outdoor conditions that exist at that location.

Over sizing the AC system is detrimental to energy use, comfort, and indoor air quality and equipment durability. All of these impacts derive from the fact that the system will be "short cycling" in cooling modes. To reach peak operational efficiency and effectiveness, a cooling system should run for as long as possible to meet the loads.

1.3 Heat Flow Rates

In air-conditioning design, the following four related heat flow rates, each of which varies with time, must be differentiated:

a. Space heat gain: - how much heat (energy) is entering the space
b. Space cooling load: - how much energy must be removed from the space to keep temperature and relative humidity constant
c. Space heat extraction: - how much energy is the AC removing from the space
d. Cooling load (coil): - how much energy is removed by the cooling coil serving various spaces plus any loads external to the spaces such as duct heat gain, duct leakage, fan heat and outdoor make up air?

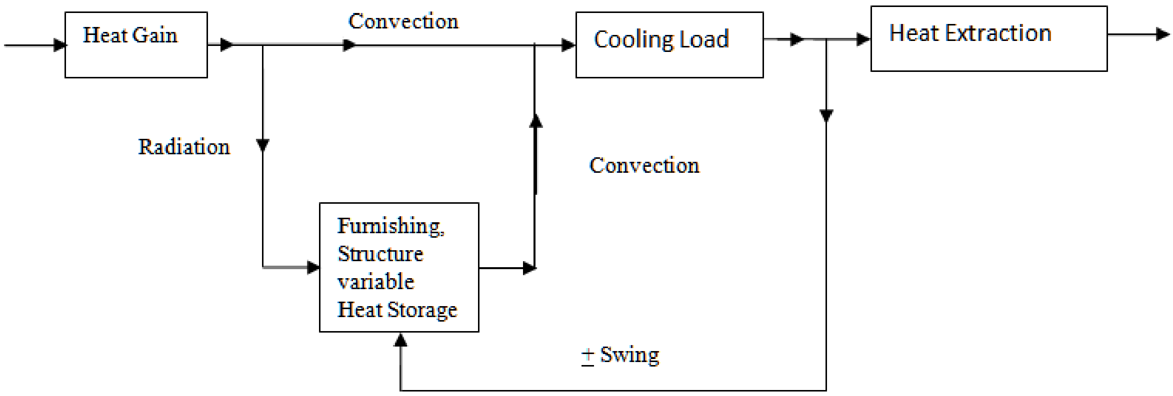

Figure 1 Conversion of heat gain into cooling load [6]

1.4 Space Heat Gain

This instantaneous rate of heat gain is the rate at which heat enters into and/or is generated within a space at a given instant. Heat gain is classified by the manner in which it enters the space:-

a. Solar radiation through transparent surfaces such as windows
b. Heat conduction through exterior walls and roofs
c. Heat conduction through interior partitions, ceilings and floors
d. Heat generated within the space by occupants, lights, appliances, equipment and processes
e. Loads as a result of ventilation and infiltration of outdoor air

1.5 Sensible and Latent Heat Gain

Sensible heat is the heat which a substance absorbs, and while its temperature goes up, the substance does not change state. Sensible heat gain is directly added to the conditioned space by conduction, convection, and/or radiation. Note that the sensible heat gain entering the conditioned space does not equal the sensible cooling load during the same time interval because of the stored heat in the building envelope. Only the convective heat becomes cooling load instantaneously. The sensible cooling load refers to the dry bulb temperature of the building and the latent cooling load refers to the wet bulb temperature of the building.

1.5.1. Sensible heat load

Sensible heat gain is directly added to the conditioned space by conduction, convection, and/or radiation. Note that the sensible heat gain entering the conditioned space does not equal the sensible cooling load during the same time interval because of the stored heat in the building envelope. Only the convective heat becomes cooling load instantaneously.

Sensible heat load is total of:-

a. Heat transmitted through floors, ceilings and walls
b. Occupant's body heat
c. Appliance and light heat
d. Solar heat gain through glass
e. Infiltration of outside air

1.5.2. Latent Heat Loads

Latent heat gain occurs when moisture is added to the space either from internal sources (e.g. vapor emitted by occupants and equipment) or from outdoor air as a result of infiltration or ventilation to maintain proper indoor air quality. Latent heat load is total of:-

a. Moisture-laden outside air form infiltration and ventilation
b. Occupant respiration and activities

To maintain a constant humidity ratio, water vapor must condense on cooling apparatus at a rate equal to its rate of addition into the space; this process is called dehumidification and is very energy intensive.

1.6 Cooling Load Calculation Method

For a thorough calculation of the zones and whole building loads, one of the following three methods should be employed:

i. Transfer Function Method (TFM): This is the most complex of the methods proposed by ASHRAE and requires the use of a computer program or advanced spreadsheet.
ii. Cooling Load Temperature Differential/Cooling Load Factors (CLTD/CLF): This method is derived from the TFM method and uses tabulated data to simplify the calculation process. The method can be fairly easily transferred into simple spreadsheet programs but has some limitations due to the use of tabulated data.
iii. Total Equivalent Temperature Differential/Time-Averaging (TETD/TA): This was the preferred method for hand or simple spread sheet calculation before the introduction of the CLTD/CLF method.

II. DESIGN DATA

To calculate the space cooling load, detailed building information, location, site and weather data, internal design information and operating schedules are required. Information regarding the outdoor conditions and desired indoor conditions are the starting point for the load calculation.

1. Outdoor design weather conditions
2. Indoor design conditions and thermal comfort
3. Indoor air quality and outdoor air requirements
4. Building characteristics

To calculate space heat gain, the following information on building envelope is required:

a. Architectural plans, sections and elevations – for estimating building dimensions/area/volume
b. Building orientation (N, S, E, W, NE, SE, SW, NW, etc), location etc
c. External/Internal shading, ground reflectance etc.
d. Materials of construction for external walls, roofs, windows, doors, internal walls, partitions, ceiling, insulating materials and thicknesses, external wall and roof colors.
e. Amount of glass, type and shading on windows

5. Operating Schedules

Obtain the schedule of occupants, lighting, equipment, appliances and processes that contribute to the internal loads and determine whether air conditioning equipment will be operated continuously or intermittently (such as, shut down during off periods, night set-back, and weekend shutdown). Gather the following information:

- Lighting requirements, types of lighting fixtures
- Appliances requirements such as computers, printers, fax machines, water coolers, refrigerators, microwave, miscellaneous electrical panels, cables etc
- Heat released by the AC equipment
- Number of occupants, time of building occupancy and type of building occupancy

2.1 Design Information

Hibir Boat will give service between Bahir Dar and Gorgora port and also sailing throughout Lake Tana. In this cooling load analysis it is assumed that the boat is at Bahir Dar port and the window having large glass size is facing to the south. The following data is considered for the calculation of the cooling load.

City/Town	Latitude	Longitude	Elevation [4, 7]
Bahir Dar	$11^{0}37'N$	$37\ ^{0}10'E$	1800 m

Maximum DBT 32.39 ^{o}c (90 $^{o}{}_{F}$)
Minimum DBT 8.8 ^{o}c (47.5 $^{o}{}_{F}$)
Monthly Daily Range 23.59 ^{o}c (74.5 $^{o}{}_{F}$)

Table 1 Hibir Boat Basic Dimensions

Purpose of the Room	Width/ Floor/Ceiling [ft]	Length [ft]	Ceiling Height [ft]	Number of Occupant	Computer/Laptop	Number of Bulbs	Speakers [watt]
Meeting Hall	23	63	7.5	90	90	20	1500
Passenger rooms (2 in number)	8	40	6.0	50	-	8	-
Door	8.0	6.5	-	-	-	-	-

III. COOLING LOAD CALCULATION

The total cooling load on a building consists of external as well as internal loads. The orientation of Hibir boat must be considered in the cooling load calculation due to changing solar heat gains at various times of the day and the impact of those gains.

The orientation of the boat can greatly affect the sensible heat gain on the house depending on the ratio of windows to opaque walls and the degree of shading from the sun.
Often times, the peak cooling load for the worst case orientation is acceptable for system sizing; however, if there is a significant difference between loads at various orientations, system sizing may vary for the same boat.

Table 2 Basic calculation of wall, door and window area for the meeting hall

Wall Orientation	Wall Area [ft^2]	Window Area [ft^2]	Door Area [ft^2]
North	466	186	-
South	466	186	-
West	172	69	-
East	172	-	109
Roof/ Ceiling/Top	1187	-	-
Floor/Bottom	1448	-	-

Note:-

- The window covers 40% of the total wall area of the three faces except the East wall
- Single window type
- No shadow at window

Table 3 Basic calculation of wall, door and window area for the passenger rooms

Wall Orientation	Wall Area [ft^2]	Window Area [ft^2]	Door Area [ft^2]
North	248	49.6	20*
South	248	49.6	20*
West	49	-	-
East	49	-	-
Roof/ Ceiling/Top	266	-	-
Floor/ Bottom	314	-	-

Note:-

- the window covers 20% of the total wall area of single wall
- Single window type
- No shadow at window
- *The doors of the passenger room is inside the hall and there is no infiltration introduced from outside

Table 4 Components and Contribution of heat load

Cooling Load Components	Sensible Load	Latent Load	Space Load	Coil Load
Conduction through roof, walls, window, exterior walls ceiling and sky lights window	✓	X	✓	✓
Solar radiation through	✓	X	✓	✓
Conduction through ceiling interior partition walls and floor	✓	X	✓	✓
People	✓	✓	✓	✓
Lights	✓	X	✓	✓
Equipment appliance	✓	✓	✓	✓
Infiltration	✓	✓	✓	✓
System heat gains	✓	X	X	✓

3.1 Internal Cooling Loads

The various internal loads consist of sensible and latent heat transfers due to occupants, processes appliances and lighting. The lighting load is only sensible. The conversion of sensible heat gain (from lighting, people, appliances, etc.) to space cooling load is affected by the thermal storage characteristics of that space and is thus subject to appropriate cooling load factors (CLF) to account for the time lag of the cooling load caused by the building mass. The weighting factors equation determines the CLF factors.
CLF = Q cooling load / Q internal gains

3.3.1 Heat Gain from Occupants

Q Sensible= N *QS*CLF ………………………………………………………….…..1
Q latent=N *QL ……………………………………………………………………..…2

Where

N = number of people in space

QS, QL= Sensible and Latent heat gain from occupancy
CLF = Cooling Load Factor, by hour of occupancy
Occupants steady at rest because they are assumed in meeting
Q Sensible = 239 BTU/hr
Q Latent = 137BTU/hr [3, 5]

a. For the Hall

Q Sensible = Number of people*Sensible heat gain /person*CLF
Q Sensible = 90*239 = 21510 BTU/hr
Q Latent = 90*137 = 12330 BTU/hr

b. For the Passenger Rooms

Q Sensible = 50*239 = 11950 BTU/hr
Q Latent = 50*137 = 6850 BTU/hr

3.3.2 Heat Gain from Lighting

$Q = Watt * 3.14 * Blast\ factor * CLF$ ……………………………………………….....….3

Where

Blast Factor = 1.2 for florescent
= 1.0 for incandescent
Watt - energy consumed by the light [w]
3.41 - Conversion factor from watt to BTU/hr
CLF - 1.0 (for conditioning system shut off at night) [3]

a. For the Hall

Q lights = 20*60*3.41*1.0*1.0 = 4092 BTU/hr

b. For the Passenger Rooms

Q lights = 8*60*3.41*1.0*1.0 = 1638 BTU/hr

3.3.3 Heat Gain from Electrical Equipments

1. Lap tops (50-150 BTU/hr)
   a. For the Hall
   Q Sensible = 90*150 = 13,500 BTU/hr
   b. For the Passenger Rooms
   Q Sensible = 50*150 = 7,500 BTU/hr
2. Sound System
   Larger room on speaker having power consumption of 680 BTU/hr
   Q Sensible = 1*680= 680 BTU/hr
3. LCD TV it consumes 250 Watt
   a. For the Hall
   Q Sensible =1*250*3.41 = 853 BTU/hr
   b. For the Passenger Rooms
   Q Sensible = 2*250*3.41= 1705 BTU/hr
4. Audio system consumes 35Watt and it is available only in the meeting hall
   Q Sensible = 2*35*3.41= 239 BTU/hr

3.4 External Cooling Load

The external loads consist of heat transfer by conduction through the building walls, roof, floor, doors etc, heat transfer by radiation through fenestration such as windows and sky lights. All these are sensible heat transfers [3].

3.4.1 Heat Gain from Solar Radiation Through Windows

Solar cooling load (SCL) depends on the following factor: - direction of window faces, time of day, month, latitude construction of interior partition walls, and type of floor covering and existence of internal shading device.

Solar cooling load is to estimate the rate at which solar energy radiates directly into space as a sensible heat gain. SCL factor is account for the capacity of the space to absorb and store heat.

Solar load through glass has two components: Conductive and Solar Transmission

a. For the Hall

Q = A*SC*SCL ………………………………………………..………………………. 4

Where:-

Q - Heat gain by solar radiation through glass [BTU/hr]
SC- Shading coefficient of window [dimensionless parameter]
SCL- Solar cooling load factor [BTU/hr*ft^2]

Since the SCL value for 11^{o}37'N is not available in any air conditioning data books it requires developing specified value or approximating using recommended techniques like interpolation, extrapolation by knowing one relevant value of latitude beyond the required one

SCL value for 24^0 N latitude = 275BTU/hr*ft^2

SCL value for 36^0 N latitude= 265BTU/hr*ft^2

SCL value for 48^0 N latitude=242 BTU/hr*ft^2 [4]

For the SCL values not given it is possible to interpolate or extrapolate, therefore by using extrapolation it is obtained that:-

SCL= 277 BTU/hr ft^2

SC = 0.61(Recommended value)

Q = 441*0.61*277

= 74,515 BTU/hr

b. For the Passenger Rooms

Q = A*SC*SCL

= 266*0.61*277

= 44946 BTU/hr

3.4.2 Heat Gain from Solar Conduction Through Windows

a. For the Hall

Q Glass Conductive = U * A * CLTD Glass Corrected

U = 0.98 for single glass fixed frame vertical installation

Q Glass Conductive = 0.98*441*13

= 5618 BTU/hr

b. For the Passenger Rooms

Q Glass Conductive = 0.98*99.2*13

= 1264 BTU/hr

3.4.3 Heat Gain form Infiltration

Infiltration or air leaks into or out of a space through doors, windows and small cracks in the building envelop. The uncontrolled introduction of fresh air into a building, it is most subjective of all losses and oftentimes the largest of all heat losses, sometimes comprises up to 30% of the total heating load.

Method of estimation:-

i. Air change method
ii. Crack method
iii. Effective leakage area method

Among these method of infiltration air change method is used to approximate the cooling load because it is easy for manual calculation without AC computers.

a. For the Hall

Q sensible = 1.085 * air flow*ΔT ………………………………………………………………. 5

Q Latent = 0.7 * air flow * ΔW ……………………………………………………………… 6

ΔT = To- Ti where To/Ti is outside/inside dry bulb temperature, °F

ΔW = To- Ti where To/Ti is outside/inside wet bulb temperature, °F

Infiltration air flow = (Volume of space *Air change ratio)/60

Where:-

Infiltration air flow = quantity of air infiltrating in to space [cfm]

Volume of space = Length * width * ceiling height [ft^3]

60 = conversion factor from hour to minute

Volume of space = 63*23*7.5 = 10 868 ft^3

Air change rate = air change per hours (Designer will use 0.3 to 2.0 room air changes per hour)

Infiltration air flow = 0.3*10 868/60 = 55 cfm = 0.3*10 868/3600 =0.9cfs

Density of air = 0.075lb/ft^3

Specific heat = 0.24BTU/lb^{o}F

Latent heat of water vapor = 1076 BTU/lb

Q sensible = 1.085 * 55*[90-70]

=1194 BTU/hr

Q Latent=0.7*20*[110-75]

= 490 BTU/hr

b. For the Passenger Rooms

The doors are facing inside the hall hence the infiltration is neglected.

3.4.4 Conduction Through Walls

Building components construction, proper details, and materials are critical components of the heating and cooling load calculations. The R-value of the building wall, roof, and foundation construction components can be accurately calculated using the insulation levels specified combined with the remainder of the components that make up the construction assembly.

a. For the Hall Wall Area

Sixty percentage of the total area of the wall is made of carbon steel and wood composite for all the sides of the wall except the eastern side.

40% = 441 ft^2

60 % =?

= 662ft^2

A total = A east wall + 662

= 3.3 [2.25+7] + 662 = 833ft^2 =77 m^2

$$R\ Total = \frac{1}{77m^2}\left(\frac{1}{50w/m^2k} + \frac{25*10^{-3}}{0.17w/m^2k} + \frac{6*10^{-3}}{54w/m^2k} + \frac{1}{50w/m^2k}\right) \quad \text{.......... 7}$$

= 2.446*10^{-3} k/w

$$Q = \frac{\Delta T}{R} = \frac{[32.39-21]}{2.446*10^{-3}\ k/w} = 4657\ watt = 15879\ BTU/hr \quad \text{.......... 8}$$

b. For the Passenger Rooms Wall Area

20% = 99 ft^2

80 % = ?

= 397ft^2

A total = A east wall + 397

= [1.90*2.4*3.3] + 397

= 6.27*7.9+379 = 429ft^2

$$R\ Total = \frac{1}{39m^2}\left(\frac{1}{50w/m^2k} + \frac{25*10^{-3}}{0.17w/m^2k} + \frac{6*10^{-3}}{54w/m^2k} + \frac{1}{50w/m^2k}\right)$$

= 4.8*10^{-3} k/w

$$Q = \frac{\Delta T}{R} = \frac{[32.39-21]}{4.8*10^{-3}\ k/w} = 2373 Watt = 8092\ BTU/hr$$

3.4.5 Conduction Through the Roof

The basic conduction equation for heat gain is q = U A ΔT

$$Q = U * A * (CLTD) \quad \text{.......... 9}$$

Where:-

Q = cooling load, Btu/hr

U = coefficient of heat transfer roof, Btu/hr.ft².°F

A = area of roof, ft^2

= (19*3.3+7*3.3) = 85.8 ft^2

CLTD = cooling load temperature difference, °F

CLTD at max T^o 13^{o}F

U = 18.22 Btu/hr.ft².°F

Q roof= 5.34328*3.41*85.8*13

= 20,323 BTU/hr

IV. RESULT AND DISCUSSION:

Table 5:- Summary of space cooling load for hall

Space Load Component	Sensible Heat Load [BTU/hr]	Latent Heat Load [BTU/hr]
Conduction through roof	20323	-
Conduction through windows	5618	-
Conduction through exterior walls	15879	-
Solar radiation through Windows	74515	-
Occupants	21510	12330
Lights	4092	-
Electrical Equipments (Laptop and sound system)	15271	-
Infiltration	1194	490
Total	**158402**	**12920**

Table 6: - Summary of space cooling load for passenger rooms

Space Load Component	Sensible Heat Load [BTU/hr]	Latent Heat Load [BTU/hr]
Conduction through roof	-*	-
Conduction through windows	1264	-
Conduction through exterior walls	8092	-
Solar radiation through Windows	16762	-
Occupants	11950	6850
Lights	1638	-
Electrical Equipments (Laptop)	7500	-
Infiltration	434	Neglected
Total	**47640**	**6850**

*the roof of the passenger room is inclinde and included in the wall area

The values of the sensible heat load and latent heat load for the meeting hall and the two passenger rooms of Hibir boat which contributes for the change in temperature of the indoor will be summed up to choose the appropriate size of the air conditioning unit.

The meeting hall required air conditioning unit with the capacity of 171,322 BTU/hour, it might be appropriate to make all the capacity for the AC unit of 24,000 BTU/hour which is currently available in Ethiopian market hence it is needed to provide 7 units to meet the total cooling load. More over during the component failure the total system may not collapse and making different unit has the advantage in this aspect.

These units should be located based on the architectural feature, size of the room and for the comfort of the occupants it is proposed to keep them 2 units of the AC unit to the Southern wall, 2 to the Northern, 2, Western and 1 to the eastern wall.

The passenger rooms located to the right and left side of the meeting hall each demanding 27,245 BTU/hr AC unit, hence with the available capacity 24,000 BTU/hr it is recommended to use one AC unit for each room located at the rare wall.

To have uniform indoor condition it is needed to fix the AC unit in different location to give the same load share among the AC units. And it should not directly distribute the conditioned air to the occupants' body, which discomforts them during operation. Considering all this constraints it is advisable to fix them on the wall close to the ceiling of rooms or the hall.

V. CONCLUSION:

Right-sizing the AC system begins with an accurate understanding of cooling loads on a space. The values determined by the cooling load calculation process dictate the equipment selection.

To get the information which required for equipment selection, system sizing and system design the detail cooling load estimation has been made.

The load estimation considered all factors which affect the indoor condition. Internal heat gain from occupants, equipments and the external heat gain from radiation, conduction and convection are considered during the analysis.

Based on the results of the sensible heat load and the latent heat load for the rooms capacity of the AC unit was determined to meet the desired indoor condition.

In the selection of the AC unit it was anticipated to have AC equipment available in the country market which may not require special order and can be obtained directly on the market hence can be fixed without any time delay.

Due to the existence of space constraints to pass the duct system, it is not workable design to use a central type AC unit and to distribute the conditioned air from the central unit to the rooms through the duct system. Therefore split type AC unit is recommended which satisfy the constraints.

The available spilt type AC unit in the market has a capacity of 24,000 BTU/hr; to meet the total demand of the cooling load nine AC units were selected for the rooms and for the hall. During fixing them it was considered the comfort of the occupants, the architectural views, loads shared by the units and the space availability of the rooms.

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Figure 2. Hibir Boat sailing at Lake Tana on eve of the 7th Nations, Nationalities and Peoples' day celebration, Bahir Dar, Ethiopia, December, 2012