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Energy Efficient Air Conditioning System Design And Equipment Selection For Building

N.Srinivasan[1], M.Soundarrajan[2], K.Venkatesh[3], P.Ramesh[4], K.Pasupathi[5]

[1]Department of Mechanical Engineering, Muthayammal College of Engineering, Rasipuram, Tamilnadu, India
[2,3,4,5]Department of Mechanical Engineering, Muthayammal Engineering College, Rasipuram, Tamilnadu, India

Abstract

Air conditioning accounts for approximately 50 % of the annual power requirement in almost all types of commercial buildings such as IT parks, Malls, office complexes, Hospitals, Hotels, Entertainment centers, Educational institute and Government establishments.
The air conditioning for commercial buildings is only going to increase, with the growth in the number of buildings. Inefficient building envelopes, Unnecessary lighting, inefficient air conditioning systems all contribute to higher cooling capacity requirement which ultimately leads to high energy consumption and cost.
The aim of this project is to find energy efficiency air conditioning design and find methods to reduction in the energy requirement of the AC System in a building. The sizing of air conditioning plant, Selection of chillers, cooling towers, chilled water pumps and air handling units will be studied
Keywords: *Air conditioning, Inefficient building envelopes, energy efficiency air conditioning design, Selection of chillers*

1. Introduction

Air conditioning accounts for approximately 50 % of the annual power requirement in almost all types of commercial buildings such as IT parks, Malls, office complexes, Hospitals, Hotels, Entertainment centers, Educational institute and Government establishments.
The air conditioning for commercial buildings is only going to increase, with the growth in the number of buildings. Inefficient building envelopes, Unnecessary lighting, inefficient air conditioning systems all contribute to higher cooling capacity requirement which ultimately leads to high energy consumption and cost.
We performed the energy audit in HVAC system of a textile store. By doing the energy audit in HVAC, we understood the performance of the system. Our aim is to improve the performance of HVAC, subsequently saving energy and cost

1.1 HVAC Air Energy Conservation In Handling Units

The frame of the filter panels must be tightly fit into the fixing arrangement and no leakage/by pass should be allowed. Considering the role they play in protecting the system components and by desired clean (conditioned) air output, maintenance of filter should be given their due importance

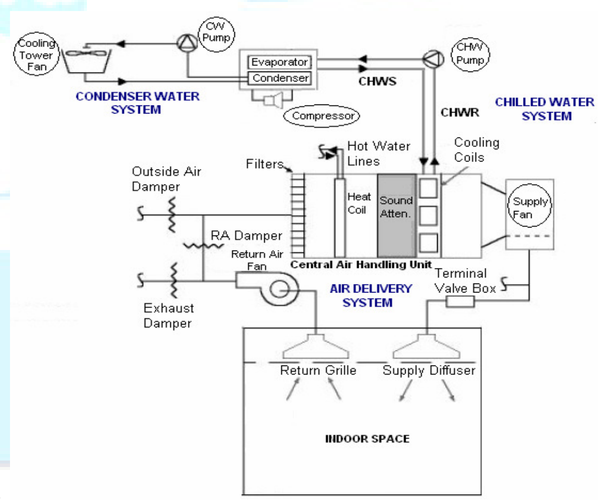

Fig .1 HVAC system

Filter collect the dust and if not cleaned or replaced in time the element can give way, allowing the dust collected to spread to the conditioned space/cooling coil. Therefore the filters should be periodically cleaned without fail and cared for just like any other mechanical equipment.
It is difficult to stipulate the frequency of cleaning/replacement of the various types filters. Coarse and fine dust filters must be cleaned or replaced when air

flow across them drops by 10% or when the air side resistance reaches two are three times of initial value that when the filter were cleaned.

Washable filter element should be washed with water of recommended temperature. Excessive temperature can affect the fiber bonding agent. If any element is hardened or has lost elastically. It should be replaced.

1.2 System Design And Equipment Selection For Energy Efficient Operation

- Provide air conditioning only for small areas when required for manufacturing process. Comfort air
- Conditioning should be minimized to the extent possible.
- Avoid over sizing to the extent possible – try to match the actual load, provide efficient method of
- Modulation.
- Use larger heat transfer areas of evaporators and condensers.
- Sub-cooling of liquid refrigerant can be considered to reduce flashing of refrigerant in evaporator.
- Consider the use of vapor absorption machines when waste heat or other economical heat energy
- Sources are available.
- Larger pipe diameters especially vapor lines.
- Thicker insulation on pipes and vessels.
- Thicker insulation on the structure, provide building insulation.
- Use smooth, well-rounded air inlet cones for fan air intakes.
- Avoid poor flow distribution at the fan inlet.
- Minimize fan inlet and outlet obstructions.
- Use airfoil shaped fan blades.
- Use low slip or no-slip (timing) belts.
- Use variable speed drives for large pump and fan loads.
- Use energy efficient motors for continuous or near continuous operation.
- Eliminate or reduce reheat whenever possible.
- Purchase only high efficiency machines, even at a premium.

1.3 Energy Conservation In Cooling Towers

- Control cooling tower fans based on temperature range and temperature approach. Ensure as low
- An approach as possible at the rated temperature.
- Control to the optimum temperature as determined from cooling tower and chiller performance data.
- Lower cooling water temperatures generally help reduce compressor power consumption
- Turn off unnecessary cooling tower fans when loads are reduced.
- Cover hot water basins (to minimize algae growth that contributes to fouling.
- Periodically clean plugged cooling tower distribution nozzles.
- Install new nozzles to obtain a more uniform water pattern.

Cooling Towers

- On old counter flow cooling towers, replace old spray type nozzles with new square spray ABS
- Replace slat type drift eliminators with low pressure drop, self extinguishing, and PVC cellular units.
- Follow manufacturer's recommended clearances around cooling towers and relocate or modify
- Optimize cooling tower fan blade angle on a seasonal and/or load basis.
- Correct excessive and/or uneven fan blade tip clearance and poor fan balance.

1.4 Energy Saving Opportunities in Normal Operation

- Use Building Thermal Inertia.
- Put HVAC Window Air Conditioners and Split Units on Timer or Occupancy Sensing Control
- Interlock Fan Coil Units in Hotels with Door Lock or Master Switch
- Improve Utilization Of Outside Air.
- Maintain Correct Anti-freeze Concentration
- Install a Control System to Co-Ordinate Multiple Chillers.
- Permit Lower Condenser Pressures during Favorable Ambient Conditions
- Defrosting Optimize Water/Brine/Air Flow Rates
- Match the Refrigeration System Capacity to the Actual Requirement

- Monitor Performance of Refrigeration Machines

2. Energy Auditing Methodology Adopted

A walk-through survey of a building may reveal several ECOs to the experienced eye of the auditor. The survey could be divided into three parts.

2.1 Preliminary Survey

Prior to the walk-through survey, the auditor may need to know the building and the way it is used. The information can be obtained from:

- rchitectural blueprints,
- ir-conditioning blueprints,
- lectrical lighting and power blueprints,

2.2 Operator's Input

The auditor may discuss with the building maintenance staff further on the operating schedules and seek clarification on any unusual pattern in the trend of the utility bills. Unusual patterns such as sudden increase or decrease in utility bills could be caused by changes in occupancy in the building, or change in use by existing tenants. It is not uncommon for tenants to expand their computing operations that may increase the energy use significantly.

2.3 Measurements

- We measured chiller inlet, outlet temperature and pressure, Refrigerant suction and pressure, chiller power, etc.
- Pump head, flow rate and power are measured.
- Condenser and cooling tower inlet and outlet temperature is measured.
- Area of cooling tower is measured.
- Air handling unit flow rate and motor power is mesa

2.4 Equipment Used

- Digital thermometer
- psycho meter
- Anemometer
- Measuring tape

2.5 Energy Auditing Of Commercial Building

2.5.1 Introduction About Plant

- Three Chiller plants each of 150TR
- Three Chiller pumps
- Three Condenser pumps
- Two Cooling towers
- Twelve Air Handling Unit

2.5.2 System Operating Conditions During The Study

Out of three chiller plants, one chiller plant was running during the study.

Usually primary and secondary pumping systems are used for centralized air conditioning system. But primary pumping system is being used in this plant.

Out of two cooling towers, one cooling tower was running during the study.

Out of twelve air handling units, tens air handling units are running during study. When we were took the readings due to atmospheric change two air handling units are switched off.

3. Performance Evaluation and Energy Saving Of Major Utilities

3.1 Chiller

Design Specifications:

Capacity	= 150TR
Compressor motor	= 140 kw/kw
Main supply	= 415 v
Control supply	= 230 v
Refrigerant	= R134a
Nominal capacity	= 456600 kcal/hr

Measured Values

Chilled water outlet temperature	=13.1℃
Chilled water inlet temperature	= 17.3℃
Specific heat of water	= 1000kcal/kg.℃
Operating hour	= 12 hr

Calculation

$$\text{Capacity } Q = m \times cp \times \Delta t / 3024$$

M1 =mass flow rate of water (kg/hr)

Cp = specific heat of water (kcal/kg.℃)

Δt =temperature difference ℃

Capacity Q

$$= m \times cp \times \Delta t / 3024$$

$$= 88.75 \times 1000 \times 4.2 / 3024$$

=123.26TR

Specific power consumption $= KW/TR$

$$= 140/123.26$$

= 1.13 KW/TR

As per design the specific power consumption water cooled chiller within 0.s75 to 0.95 KW/TR.

4.Proposal-1: Reduce condenser inlet temperature from 32.2℃ to 29℃ to reduce the power consumption of the chillers

Present system

At present the inlet temperature to chiller condenser is around 32 to 33 deg C. This will increase the condensing temperature of the refrigerant and subsequently increases the discharge pressure and power consumption of the compressor.

Measured parameters before Improvement

Inlet temperature = 32.2 ℃
Discharge pressure =136 psi
Power = 140 KW

Proposed system

Improve the cooling tower performance to reduce the inlet water temperature to the condenser.

Present condition of cooling tower

- Air flow area is covered therefore the flow velocity is low.
- The fan is run slowly.
- The water falls slow through the fins.

Recommended

Parameters after improvement

Inlet temperature = 29 ℃
Discharge pressure = 125 psi
Power = 118 KW

Expected energy savings after improvement

Now specific power consumption $= 118/123.26$
=0.95 KW/TR

Operating hour = 12 hr
Energy saving per day $= 22 \times 12$
= 264 KWh/day

Cost per unit = Rs.7/unit
Total energy saving @ Rs.7/unit $= 264 \times 7$
= Rs.1848/day

Number of working day = 345 days
Annual energy saving $=264 \times 345$
=91080KWh/year

Annual energy saving cost $= 1848 \times 345$
= Rs.6, 37,560/annum

Investment = Rs.1, 00, 000
Simple payback period= $\text{investment}/\text{annual saving} \times 12$
$= 100000/637560 \times 12$
= 2 months

Summary

Annual Energy savings = 91080 kWh/year
Annual cost savings =Rs.6, 37560 /year
Approximate investment =1, 00,000
Simple payback =2 months

Pump Performance

Specification:

Type: NB80 – 160/150 A-F-B-AQE
Model: A9637608 P110470083
Q = 179.6 m^3 /hr
H = 21.2 m
N =2910rpm
P/T= 16/120 bar/℃

Calculation

Hydraulic power $P_h = q \times h \times \rho \times g / 3600 \times 1000$
Q=flow velocity (m^3/s)
H = head (m)
ρ= Density of the fluid (kg/m^3)
G= Acceleration due to gravity (m^2/s)
$P_h = 179.6 \times 21.2 \times 996 \times 9.81 / 3600 \times 1000$
= 10.3KW

Pump Shaft Power

$P_s = P_h \times \eta_m$ (efficiency of motor)
$= 10.3 \times 0.894$
= 13.41KW

Pump Efficiency

$\eta_P = \text{hydraulic power}/\text{shaft power}$
$= 10.3/13.41$
= 78%

Chilled Water Pump

Type: NB 65 – 200/162 A-F-B-BAQE
Model: A699394911045003 GRUNDFOS
Q = 89.2 m^3/hr
H = 30.3m
N = 2930 rpm
P/T = 16/120 bar/℃
Motor efficiency (η_m)= 88.48%
Hydraulic power $P_h = q \times h \times \rho \times g / 3600 \times 1000$
Q =flow velocity (m^3/s)
H = head (m)
ρ =Density of the fluid (kg/m^3)
G =Acceleration due to gravity (m^2/s)
$P_h = 89.2 \times 30.3 \times 996 \times 9.81 / 3600 \times 1000$
= 7.3 kW

Pump Shaft P

$P_s = P_h \times \eta_m$

$= 7.3 \times 0.8848$

$= 9.732$kw

Pump Efficiency

$\eta_P = \text{hydraulic power} / \text{shaft power}$

$= 7.3 / 9.732 \times 100$

$= 75\%$

Cooling Tower

Readings

Inlet air dry bulb temperature= 32°C
Inlet air wet bulb temperature= 29°C
Outlet air dry bulb temperature= 34.5°C
Outlet air wet bulb temperature= 29.5°C
Cooling water inlet temperature= 35.5°C
Cooling water Outlet temperature = 32.8°C

Range = Cooling water inlet temperature - Cooling water outlet temperature

$= 35.5 – 32.8$

$= 2.7$°C

Approach = Cooling water Outlet temperature - Inlet air wet bulb

$= 32.8 – 29$

$= 3.8$°C

Cooling water effectiveness

$= \text{range} / (\text{range} + \text{approach}) \times 100$

$= 2.7/(2.7 + 3.8) \times 100$

$= 41.5\%$

From psychometric chart

Enthalpy of inlet air h_1 = 77 kJ/kg
Enthalpy of outlet airh_2 = 94 kJ/kg

Capacity Q $= m \times Cp \times \Delta T / 3024$

M=mass flow rate of water (kg/hr)
cp= specific heat of water (kcal/kg.°C)
Δt=temperature difference

$Q = m \times Cp \times \Delta T / 3024$

$= 177.5 \times 1000 \times (35.5 - 32.8) / 3024$

$= 158.48$ TR

5. Proposal 2: Replace aluminum fan blade with Fiber Reinforced plastic blade

The weight of the FRP blade is less compare to aluminum fan blade. Hence low torque is enough to induce the fan.

$N \propto T$

From above the relation the speed is reduced.

$N \propto P$

When the speed reduces, the power is also automatically reduced.

Present system

Power = 7.5 KW
Outlet temperature= 32.8 °C
Capacity =158.48 TR
Operating hour = 12 hr
Total power consumption per day $= 7.5 \times 12$
= 90 kWh/day

Proposed system

Using FRP blades will give approximate energy savings of 12%

Energy saving

$= 90 \times 0.12$

= 10.8 KWh/day

Cost per unit = Rs.7/unit

Energy saving cost per day $= 10.8 \times 7$

= Rs.75.6/day

Number of working day = 345 days

Annual energy saving

$= 10.8 \times 345$

=3726 KWh/year

Annual cost saving $= 75.6 \times 345$

= Rs.26, 082/annum

Investment = Rs.25, 000

Simple payback period

$= \text{investment} / \text{annual saving} \times 12$

$= 25000 / 26082 \times 12$ =11 months

Summary

Annual Energy saving = 3726 kWh/year
Annual cost saving
=Rs.26, 082 /year
Approximate investment = 25,000
Simple payback = 11 months

Air Handling Unit

6. Ahu 1 :(ground floor) Part sheet

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Design CFM=16000CFM

Table -5.1 (ground floor) Part sheet

FILTERS	VELOCITY (× 10 ft/min)					AVERAGE
1	17	8	15	5	5	10
2	26	30	23	20	33	26.4
3	35	15	35	19	34	27.6
4	27	14	28	20	32	24.2
5	20	41	26	33	34	30.8
6	7	14	16	20	12	13.8
7	18	10	8	4	5	9
8	19	18	24	17	15	18.6
9	21	15	28	16	27	21.4
AVERAGE						22.725

Calculation

Average air flow rate = 227.25 ft/min
Length of cooling coil = 6.07 ft
Breath of cooling coil = 7.9 ft

Area of cooling coil = l × b
= 6.07 × 7.9
= 47.953 ft^2

CFM = Average flow rate (ft/min) × Area of cooling coil (ft)
= 227.25 × 47.953
= 10897.32 cfm

Return air:
DBT = 25 ^{O}C
WBT = 22 ^{O}C

Supply air:
DBT = 24 ^{O}C
WBT = 19 ^{O}C

From psychometric chart
H_1 = 64kJ/kg.k
H_2 = 54.5kJ/kg.k

Capacity Q= $m \times \Delta h / 3024 \times 4.18$
$= 10897.32 \times (64 - 54.5) / 3024 \times 4.18$
= 13.45 TR

7. Ahu 2: (ground floor) Perusal section

Design CFM=10000

Table-5.2 (ground floor) Perusal section

FILTERS	VELOCITY (× 10 ft/min)				AVERAGE
1	9	14	10	36	17.25
2	27	22	30	35	28.5
3	8	12	35	32	21.75
4	51	21	26	20	29.5
5	46	48	54	47	48.75
6	23	22	29	51	31.25
AVERAGE					29.5

Calculation

Average air flow rate = 295 ft/min
Length of cooling coil = 2.916 ft
Breath of cooling coil = 6.166 ft
Area of cooling coil = l × b
= 2.916 × 6.166
= 18.005 ft^2

CFM= Average flow rate (ft/min) × Area of cooling coil (ft)
= 295 × 18.005
= 5311.475 cfm

Return air:
DBT = 23.5 ^{O}C
WBT = 19 ^{O}C

Supply air:
DBT = 22^{O}C
WBT = 18 ^{O}C

From psychometric chart
H_1 = 54kJ/kg.k
H_2 = 51kJ/k

Capacity Q = $m \times \Delta h / 3024 \times 4.18$
$= 5311.475 \times 1.7 \times (54 - 51) / 3024 \times 4.18$
= 2.14 TR

8.Ahu 3: (first floor) Viayaga Section

Design cfm= 17000 CFM

Table-5.3 (first floor) vicarage section

FILTERS	VELOCITY (×10 ft/min)				AVERAGE
1	42	55	38	53	47
2	56	59	48	55	54.5
3	63	54	60	48	56.25
4	54	57	55	53	54.75
5	58	44	63	50	53.75
6	51	33	52	35	42.75
7	48	53	48	33	45.5
8	56	54	45	40	48.75
9	53	48	50	42	48.25
10	36	55	32	40	40.75
AVERAGE					49.225

Calculation

Average air flow rate = 492.25 ft/min

Length of cooling coil = 3.566 ft

Breath of cooling coil = 9.233 ft

Area of cooling coil = l × b

= 3.566 × 9.233

= 32.925 ft^2

CFM = Average flow rate (ft/min) × Area of cooling coil (ft)

= 492.25 × 32.925

= 16207.3 cfm

Return air:

DBT = 26 ^{O}C

WBT = 21.5 ^{O}C

Supply air:

DBT = 24^{O}C

WBT = 19 ^{O}C

From psychometric chart

H_1 = 62.5kJ/kg.k

H_2 = 54.5kJ/kg.k

Capacity Q= $m \times \Delta h / 3024 \times 4.18$

$= 16207.3 \times 1.7 \times (62.5 - 54.5) / 3024 \times 4.18$

= 17.44 TR

9.Compare the evaluation of performance value to design value

We conduct the test in the heat ventilation and air conditioning system design and in our new method. Calculation is solved to the design and our new power consumption method. Find values are tabulated below.

Table-6.1 Compare The Evaluation Of Performance Value To Design Value

Air Handling Unit			
Floor	Description	Design Valve Of capacity(TR)	Performance Valve (TR)
Ground	Part Sheet	40	13.45
	Perusal AHU	25	2.14
First	Vinayaga Section	40	17.44

10.Result

The maintenance work on chiller, cooling tower, air handling units are done.

S.no	Description	Annual energy saving KWh	Annual cost saving	Investment	Payback
1	Chiller	91080	Rs.637560	Rs.100000	2 months
2	FRP Blade used in cooling tower	3726	Rs.26082	Rs.25000	11 months
3	Install sensor in Cooling tower	1125	Rs.7875	Rs.2000	3 months
4	Air handling Unit maintenance	2484	Rs.17388	Rs.5000	4 months
5	VFD Install AHU blower	6831	Rs.47817	Rs.49500	1 year

Annual energy saving = 105246 KWh

Total annual saving = Rs.7, 36,722

Total investment = Rs.1, 81,500

Simple payback period = 3 months

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