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A COMPREHENSIVE ENERGY AUDIT OF A CHILLING PLANT IN AUTOMOBILE PARTS MANUFACTURING INDUSTRY

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***Abstract*— A Comprehensive energy audit is an important process to be carried out for energy conservation. Energy audit is monitoring and analysis of the use of energy using observations and technical report containing recommendations for improving energy efficiency with cost-benefit analysis including the action plan which reduces energy consumption. In other words, an energy audit is a beneficial tool for defining and pursuing detailed energy management programs. It has positive approach aiming at continuous improvement in energy utilization in contrast to financial energy audit which stresses to maintain regularity. A comprehensive i.e. detailed energy audit is an important tool in transforming the fortunes of any organization. Conservation and efficient use of energy in industry has been a priority of the Government of India for a long time. As a result, among industrial consumers, the aspect of the energy conservation is gaining importance due to the realization that energy saved is energy produced and that too at an economical cost. Chillers consume more than 35% of the total energy used in the manufacturing industry for space conditioning. In this paper, energy consumption by chillers, chilled water pumps, condenser pumps, and cooling tower fan motors has been estimated using data collected by a detailed energy audit.**

For energy conservation, recommendations and improvements proposed through the analyses and observations are discussed in this paper.

Keywords- Chiller unit, Air Handling Unit, energy efficiency, savings in cooling tower, seasonal variations, temperature sensor.

I. INTRODUCTION

Energy efficiency is a matter of individual behaviour. Without affecting individual comfort & productivity, the individual energy consumption is to be minimized by avoiding unnecessary consumption of energy and selecting the most appropriate equipment. In the manufacturing industry chillers are the major energy consumers therefore, efficiencies have a considerable effect on the overall energy performance of the industry.

Chillers are major energy user i.e. more than 35% of total energy consumption is by chillers. In automobile parts manufacturing industry where the detailed case study is performed, there are 6 number of water-cooled chillers out of which 4 chillers are of 108TR & remaining two of 101TR and there are 6 cooling towers and the cooling tower fan motor rating is 3.7 kW, 8 Condenser pump of 7.5 kW & 8 chilled water pump of 11kw. In this manufacturing industry, the total load of AHU is 351.4 kW. The water requirement of chiller varies between 23kL to 36 kL according to seasonal variations and load requirements.

I. LOAD DISTRIBUTION PATTERN

The load distribution of various sections is represented in graphical form below.

Fig. I Chiller load distribution

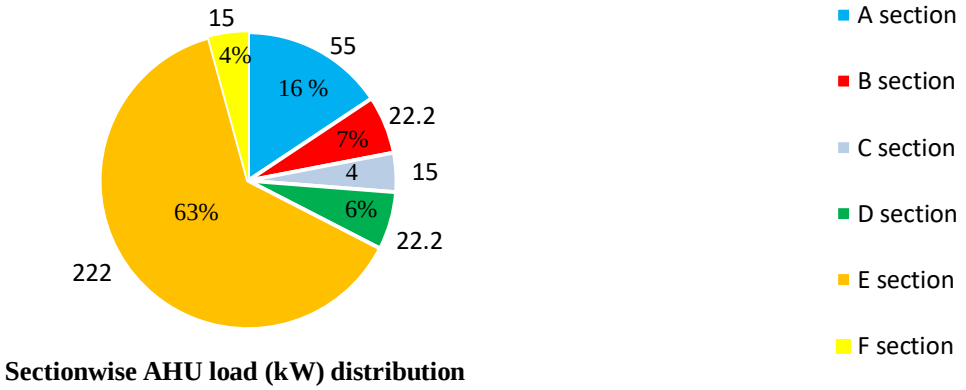

Fig. II: AHU load (kW) distribution

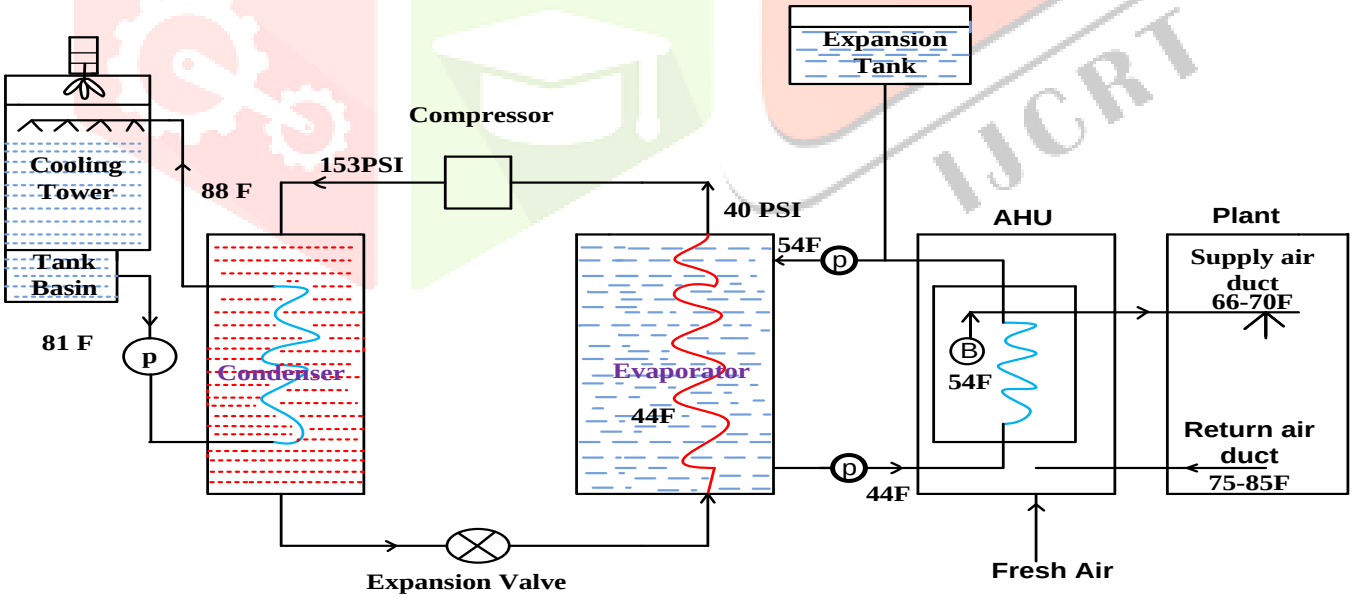

Fig III. Chiller's system layout

Table I: Energy consumption details of chiller plant

Energy consumption details	
Month	Consumption (kWh)
Aug	2,59,753.60
Sep	2,56,027.80
Oct	2,16,996.50
Nov	1,88,785.60
Dec	1,30,623.40
Jan	1,18,405.30
Feb	1,41,411.90

In August, the energy consumption of the chiller was 2,59,753.60 kWh. This was the highest consumption amongst all the above months from August to February. In January, the energy consumption was 1,18,405.30 kWh and this was the lowest consumption amongst all the above months. From February the energy consumption started increasing and it reached to 1,41,411.90 kWh which was 23,006.60 kWh more than January.

Table II: Various parameters and values of chiller unit

Parameters	Value
Chilled water temp	45-50 F
Suction pressure	33-43 PSI
Discharge pressure	121-166 PSI
Amps	121-131 Amps
Discharge line temperature	121-176 F
Discharge superheat	26-46 F
FLA	Internal Cal.
Target	Depends on demand
Capacity	Depends on demand

Note : FLA– Full Load Amperes

- The settings of the chiller unit including the safe limit is showed in table II.
- If one of the parameter exceeds or drops down below the pre-stated value then we can easily know that there is some problem and we can easily find out the reason according to the parameters.
- During the summer season, there was a problem of continuous tripping of chillers due to high pressure and temperature and even in monsoon and winter they faced various problems like drop in pressure in pumps, oil leakages, burning of compressor winding, etc. so we decided to keep eye on various parameters like discharge temperature, discharge pressure, suction pressure, leaving water's temperature, capacity, ampere, targets and full load amperes of the chiller unit.

Table III (a) Observed parameters of Chiller unit

CHILLER NO	OFF /ON STATUS	DATE/ TIME	DISCHARGE TEMP	DISCHARGE PRESSURE	SUCTION PRESSURE	LEAVING WATER TEMP	AMPS	FLA	TARGET	CAPACITY
1	Off	17-02-2020 /9:45 AM	- -	- -	- -	- -	- -	- -	- -	- -
2	On		90.9	40	50	53	0	99	0	0
3	Off		83.3	43	50	54	0	99	0	0
4	Off		80.3	46	54	66	0	103	0	0
5	Off		90.2	45	51	53	0	0	0	0
6	Off		120	140	36	61	130	121	100	100
1	Off	17-02-2020 /10:45 AM	- -	- -	- -	- -	- -	- -	- -	- -
2	On		93.1	45	56	59	0	99	0	0
3	Off		86.5	51	57	60	0	99	0	0
4	Off		82.9	53	61	69	0	103	0	0
5	Off		89.2	53	58	59	0	0	0	0
6	Off		105	78	59	60	0	96	0	0
1	Off	17-02-2020 /11:45 AM	87.3	34	44	45	0	91	0	0
2	On		111	93	63	67	94	99	54	94
3	Off		90.1	63	69	69	0	99	0	0
4	Off		115	66	73	75	0	103	0	0
5	Off		79.8	65	70	68	0	0	0	0
6	Off		122	85	69	67	0	96	0	0
1	Off	17-02-2020 /12:45 PM	87.3	34	44	45	0	91	0	0
2	On		153	131	34	48	123	117	100	100
3	Off		90.1	43	49	53	0	99	0	0
4	On		126	145	37	55	140	133	100	100
5	Off		81.6	45	50	52	0	0	0	0
6	On		111	100	36	44	83	96	83	84
1	Off	17-02-2020 /1:45 PM	87.9	35	44	46	0	91	0	0
2	On		147	109	38	46	100	101	95.8	97.1
3	Off		91.2	38	44	49	0	99	0	0
4	On		127	133	36	54	133	123	100	100
5	Off		83.1	40	46	48	0	0	0	0
6	On		113	91	39	45	65	96	60.7	58.6
1	Off	17-02-2020 /2:45 PM	- -	- -	- -	- -	- -	- -	- -	- -
2	On		140	107	37	46	99	101	100	98.5
3	Off		92.1	38	44	49	0	99	0	0
4	On		125	135	36	55	134	126	100	100
5	Off		83.8	40	45	48	0	0	0	0
6	On		113	94	39	45	66	96	60.3	60
1	On	18-02-2020 /10:45 AM	141	112	33	48	100	97	100	100
2	Off		91.5	38	48	51	0	99	0	0
3	Off		82.7	42	48	52	0	99	0	0
4	Off		80.2	45	52	71	0	103	0	0
5	Off		74.6	44	49	51	0	0	0	0
6	On		115	108	36	44	92	98	91.6	90.7
1	On	18-02-2020 /11:45 AM	143	118	33	49	100	99	100	100
2	Off		93.6	38	49	52	0	99	0	0
3	Off		85.2	42	49	53	0	99	0	0
4	Off		82.7	45	53	71	0	103	0	0
5	Off		77.1	44	50	52	0	103	0	0
6	On		115	106	37	45	91	98	91.6	91.9
1	On	18-02-2020 /12:45 PM	143.9	124	33	50.2	108	100	100	100
2	Off		95.4	40	51	53.6	0	99	0	0
3	Off		87.6	45	51	54.5	0	99	0	0
4	Off		84.8	48	55	73.1	0	103	0	0
5	Off		79.5	46	52	53.7	0	103	0	0
6	On		117.8	108	36	45.2	103	98	100	100

Table III (b) Observed parameters of Chiller unit

CHILLER NO	OFF /ON STATUS	DATE/ TIME	DISCHARGE TEMP	DISCHARGE PRESSURE	SUCTION PRESSURE	LEAVING WATER TEMP	AMPS	FLA	TARGET	CAPACITY
1	On	18-02-2020 /1:45 PM	142.5	116	33	52.8	102	99	100	100
2	Off		97	43	53	56.4	0	99	0	0
3	Off		89.4	48	54	57.3	0	99	0	0
4	Off		86.6	51	58	75.8	0	103	0	0
5	Off		81.5	50	55	56.5	0	103	0	0
6	On		117.1	114	39	47.7	104	104	100	98.8
1	On	18-02-2020 /2:45 PM	145	123	35	55.4	105	102	100	100
2	Off		98.3	45	56	58	0	99	0	0
3	Off		91.2	50	56	58.8	0	99	0	0
4	Off		87.7	53	60	76.7	0	103	0	0
5	Off		82.7	51	57	58	0	103	0	0
6	On		118	113	40	48.4	106	101	100	100
1	On	19-02-2020 /09:45 AM	85.2	36	44	45.6	0	91	0	0
2	Off		92	33	43	46.4	0	99	0	0
3	Off		92.3	37	43	47.5	0	99	0	0
4	Off		136.5	151	36	68.8	143	138	100	100
5	Off		145.9	112	37	44.4	74	101	65	67
6	On		115.5	100	39	44.1	68	96	61.7	62.7
1	On	19-02-2020 /10:45 AM	85.4	35	44	44.8	0	91	0	0
2	Off		93.6	33	43	46.1	0	99	0	0
3	Off		87.2	36	43	47.2	0	99	0	0
4	Off		123.4	130	35	67.8	133	123	100	100
5	Off		134.9	103	37	44.4	71	101	69	71
6	On		112.6	91	39	44.5	65	96	59.9	58.6
1	On	19-02-2020 /11:45 AM	142.8	118	33	48.8	100	99	100	100
2	Off		93.6	38	49	51.7	0	99	0	0
3	Off		85.2	42	49	52.6	0	99	0	0
4	Off		82.7	45	53	71.2	0	103	0	0
5	Off		77.1	44	50	51.8	0	103	0	0
6	On		115.3	106	37	44.7	91	98	92	92
1	Off	19-02-2020 /12:45 PM	87.8	36	45	46	0	91	0	0
2	Off		97	33	44	46.5	0	99	0	0
3	Off		88.7	38	43	47.6	0	99	0	0
4	On		127.3	136	35	68.7	136	126	100	100
5	On		137.6	114	34	43.2	80	101	81	83
6	On		114.4	93	39	44.1	63	96	58	56
1	Off	19-02-2020 /1:45 PM	87.9	36	45	47.4	0	91	0	0
2	Off		98.3	34	44	47.3	0	99	0	0
3	Off		90.5	38	44	48.4	0	97	0	0
4	On		126.1	133	36	69	134	124	100	100
5	On		134.9	105	36	44.8	72	101	82	84.
6	On		113.9	91	39	44.7	64	96	58	57
1	Off	19-02-2020 /2:45 PM	87	37	46	48	87.2	37	46	48
2	Off		100	35	45	48	99.7	35	45	48
3	Off		92	39	45	49	92.3	39	45	49
4	On		129	138	36	67	129	138	36	670
5	On		137	115	35	44	137	115	35	44
6	On		115	95	38	44	115	95	38	44

Note: (- -) Represents off by system

- Table no III (a) and (b) showing the details of observed values of the chiller unit on 17-02-2020 to 19-02-2020.

II. RECOMMENDATIONS AND ENERGY CONSERVATION MEASURES

A. Evaluation of motors

- Energy-efficient motors, also called as premium or high- efficiency motors, are 2 to 8% more efficient than standard motors.
- Motors are qualify as "energy-efficient" if they meet or exceed the efficiency levels listed in the National Electric Manufacturers Association (NEMA)

OBSERVATIONS

- Currently they are using IE2 motors. Most motors are well loaded – above 50%
- Motors can be upgraded to IE3/IE4 motors
- Energy-efficient motors give a very competent output for the energy they consume. With energy-efficient motors, we would have the following benefits:

❖ Low maintenance because of the higher standard materials used. The chances of breakdown are very less.

❖ Less heating of motors due to the efficiency factor being high which means that you can run these motors for long periods at a time.

➢ **Based on the detailed analyses, the following recommendations and improvements were proposed to reduce the energy consumption by the chiller unit**

- AHUs are provided with VFDs, which would help in changing the fan/motor speed, based on its occupancy.
- Throughout peak occupancy hours, they can be set at 85%, so that the occupier satisfaction level is not compromised with.
- While other times, such as early mornings and evenings, they can be set back to 55% - 65%, rely upon the necessity.

III. OTHER PARAMETERS AND RECOMMENDATIONS

❖ Coefficient of performance of Chiller number 1, 2, 3 & 6 is 0.56 to 0.58 while the COP of 4 & 5 is very less so the EER is also low for 4 & 5.

❖ Due to this the Specific power consumption of these two chillers are very high.

❖ The first step is to improve the SPC in kW/ton to a good rating which is done by cleaning the dirty chiller and the evaporator.

❖ We found that the evaporator's inlet and outlet temperature difference of chiller number 4 & 5 is very less.

❖ The condenser inlet-outlet temperature difference of these chiller units is also very less, the heat exchange process is not proper.

❖ Condensers required descaling as heat exchange is not proper and it's because of the formation of sludge inside the condenser.

❖ There is a requirement for proper maintenance of the chiller unit.

❖ Regular maintenance of chiller evaporators and condenser piping is required.

❖ We recommend them to go for the auto descaling unit it will be beneficial to them.

❖ The efficiency of the system can be improved by decreasing the leakage by timely checking it and taking required measures.

IV. CALCULATIONS

- Considered reference temperature is 28.6 °C & the selected set temperature is 24 °C
- Off hours:- 16 hours for reference temperature according to this, off-hours for set temperature will be 19hrs.24 min
- Since cooling tower fan rating is 3.7 kW and there are six cooling towers.

So, kWh consumed/per day = 3.7*19.24*6

= 427.128 kWh

kWh consumed per month = kWh/day*30

= 12814 kWh

- Since the unit per Rs charge is Rs 4.39

So, Amount to be paid in Rs for per day energy consumption

= 427.128 kWh * Rs 4.39

= Rs 1875.1

Amount to be paid in Rs/month = (Amount to be paid in Rs for per day energy consumption)*30

= 1875.1Rs*30

= Rs 56252.8

- The difference in amount to be paid for a month w.r.t to reference temperature

= Rs 56252.8 - Rs 46779.8

= Rs 9,473

Since, 3.7*6*16*30*4.39 = Rs 46779.8

For reference, off-hours at 28.6°C = 16

- The difference in amount to be paid for 3 months w.r.t to reference temperature

= Rs 9,473 * 3

= Rs 28,41

Therefore, the actual saving in Rs / month = Rs 46,779.8 - Rs 9,473

= Rs 37,306

And the actual savings in Rs in 3 months = Rs 37,306.8Rs * 3

= Rs 1,11,920.4

- So, When we are reducing the set temperature below the reference temperature our actual saving amount decreases from Rs 1,40,339.5 to Rs 1,11,920.4 and the difference in amounts is Rs 28419.1
- So it will be a beneficial to set the cooling tower basin water temperature at reference temperature or above the one of course according to the requirements and weather conditions.
- Before the implementation of temperature sensors for cooling towers, cooling tower fans were kept on irrespective of basin water temperature.
- Due to this, unnecessary utilization of a cooling tower fan was observed in the industry which was an addition to the billing amount of the industry.
- So this small temperature sensor is reducing this wastage of energy and resulted in savings.

Table no. IV

Winter Season				
Reference Temp: 28.6 (Cooling Tower Basin)				
Set Temp	26	27	28.7	28.8
kWh consumed /day	382.7	360.5	345	343.6
kWh consumed /month	11482	10816	10350	10310
Amounts to be paid in Rs/day	1680	1582.7	1515	1509
Amounts to be paid in Rs /month	50,405	49,704	45,435	45,259
The difference in amounts to be paid for a month w.r.t to reference temperature	3,625	2,924	1,345	1,520
The difference in amounts to be paid for a month w.r.t to reference temperature	10876	8772.5	4035	4561
Actual Savings per month in Rs	43,154	43,856	48,125	48,300
Actual Savings in 3 month Rs	**1,29,463**	**1,31,567**	**1,44,374**	**1,44,901**

V. SAVINGS IN COOLING TOWER

- By using temperature sensor there is a saving of Rs 1,40,339.5

➢ **The following are the details.**

- Cooling tower fan rating:- 3.7 kW
- Off hours:- 16 hours

(Since, the cooling tower fan will be switched off providing feedback of basin water).

- Considered reference temperature is 28.6 °C
- No. of chillers:- 6

Total kWh = 355.2 kWh

- Since the unit per Rs charge is Rs 4.39

So savings = Total kWh*days*Rs unit

Total savings = 355.2*30* 4.39

= 46779.84 Rs

- Therefore one-month savings is Rs 46,779.84

And for three months the total savings will be = 355.2*90* Rs 4.39

= Rs 1,40,339.5

- Total savings in three months is Rs 1,40,339.5

Note: considered only three months to calculations as it is useful only in winter.

VI. CONCLUSION

- An energy audit is a beneficial tool for identifying and pursuing a comprehensive energy management program.
- An energy audit recognizes several energy-saving measures that can be undertaken within an organization to diminish electrical energy utilization by minimizing wastes and improving energy efficiency.
- **The following conclusions can be drawn from this study:**
- By using the temperature sensor in the cooling tower and by varying the cooling tower basin water temperature setting of sensor, we can save the energy up to 355.2 kWh in one day
- There is a saving of 10,656 kWh within one month and 31,968 kWh within three months in winter.
- By observing the no. condenser pump in operation we can save a large amount of energy and can reduce the wastage of energy.

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