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A Study on Energy Audit of a Cold Storage

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ABSTRACT
Energy consumption of a cold storage was measured for different storage temperatures. Suction temperature and pressure temperature of the compressor and working time of the compressor were determined to reach evaporator set up temperatures. An axial fan located back of the evaporator was used to distribute the cooled air into the cold store. An electrical heater was used to defrost.
The compressor suction temperatures and discharge temperatures varied between 1.8^0 C - 07^0 C and 27^0 C - 35^0 C respectively. Condenser output temperature is varies 4^0 C - 10^0 C. Compressor suction pressure (p_1) = 3.5 Kg/cm^2 and discharge pressure (p_2) = 10.5 Kg/cm^2.
Key words: Energy, Cold Storage, Refrigeration

I. INTRODUCTION

Energy auditing in a integral part of energy conservation and energy management is also part and parallel of conservation. Damage and supply gap is large energy to lead to similar natural defects, Energy disaster such as Tsunami and earth quake. The next generation generating yet to come will be completely light blind. It is because power never be available after this disaster and not ever rehabilitate the reconstruction of buildings. To avoid the energy calamity proposed auditing report use the innovative energy utilization schemes through which the ferocious of situation might blindness can be eradicated.

Cold Storage is a special kind of room, the temperature of, which is kept very low with the help of machines and precision instruments. India is having a unique geographical position and a wide range of soil thus producing variety of fruits and vegetables like apples, grapes, oranges, potatoes, chillies, ginger, etc. Marine products are also being produced in large quantities due to large coastal areas. The present production level of fruits and vegetables is more than 100 million MT and keeping in view the growth rate of population and demand, the production of perishable commodities is increasing every year. The cold storage facilities are the prime infrastructural component for such perishable commodities. Besides the role of stabilizing market prices and evenly distributing both on demand basis and time basis, the cold storage industry renders other advantages and benefits to both the farmers and the consumers. The farmers get opportunity of producing cash crops to get remunerative prices. The consumers get the supply of perishable commodities with lower fluctuation of prices. Commercially apples, potatoes, oranges are stored on large scale in the cold storages. Other important costly raw materials like dry fruits, chemicals, essences and processed foods like fruit juice/pulp, concentrate dairy products, frozen meat, fish and eggs are being stored in cold storages to regulate marketing channels of these products.

Energy consumption of an experimental cold storage was measured for different storage temperatures. Suction temperature and pressure temperature of the compressor and working time of the compressor were determined to reach evaporator set up temperatures. Capacity of compressor, condenser, and evaporator were 10460 kJ/h, 12552 kJ/h , and 10460 kJ/h, respectively. An axial fan located back of the evaporator was used to distribute the cooled air into the cold store. An electrical heater was used to defrost. Refrigerant was R22.

Energy use in a cold storage facility is affected by the amount of heat the refrigeration equipment must remove and the efficiency of the equipment. The main sources of heat in a facility for long-term storage are transmission through walls, evaporator coil fans, lights, air leakage, and respiration of the stored commodity.

The electric energy consumption of existing cold stores ranges between 30 and 50kWh/m3/year for storage. It is depends on the quality of the building, on the activities (chilled or frozen storage), room size, stock turnover, temperature of the incoming produce, outside temperatures, etc. The total cost of electric energy is about 10 to 15% of the total running costs of a store. Improving Energy Efficiency (EE) has two goals: cost reduction and environmental protection.

Objective of this research is to determine energy consumption of a cold storage for different storage temperatures. Energy consumption of the system elements such as compressor, condenser and fan of the evaporator were measured and evaluated. In addition, suction and pressure temperatures of the compressor, condenser output temperature and required time to reach to the each set up temperature were determined and evaluated.

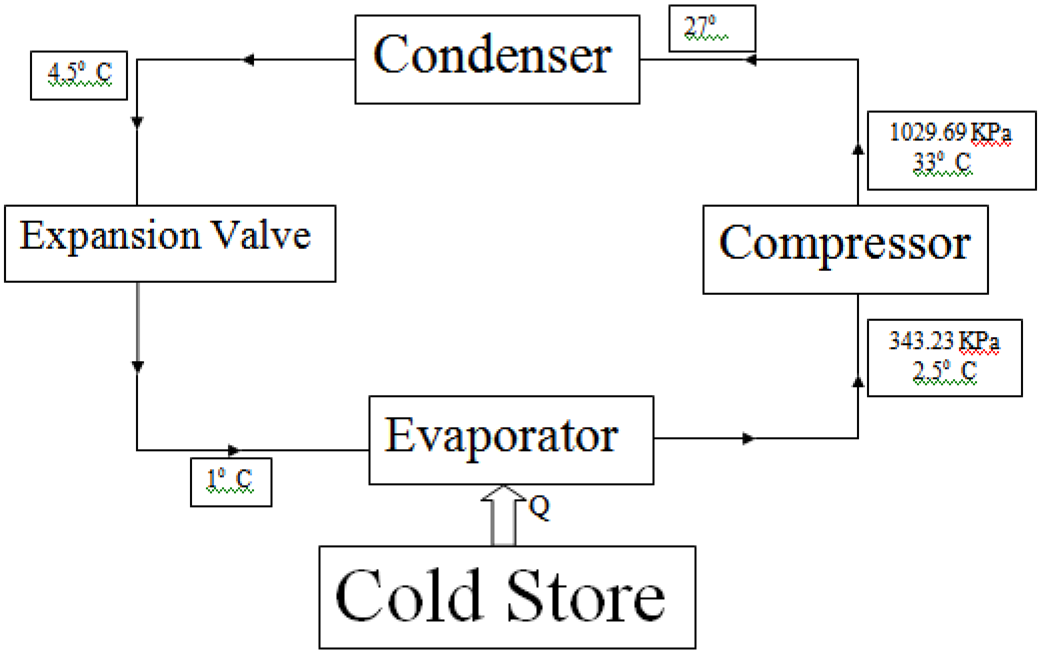
Energy auditing is one tool through which balancing of demand and supply is determined and the positive mismatch cannot be compensated either by organic way or it might be difficult task.

This paper deals with different aspects of design of cold storage and includes all standard refrigeration principles and heat load factors which are normally considered in a cold storage design and various energy audits.

II. MODEL ANALYSIS

(a) Technical analysis –

I visit a cold storage at West Bengal , INDIA and collect the data which is given below :-



$T_1 = 2.5\,^0\,C$, $T_2 = 30\,^0\,C$
$T_3 = 4.5\,^0\,C$, $T_4 = 1\,^0\,C$
$P_1 = 3.5\ kg/cm^2$, $P_2 = 10.5\ kg/cm^2$

Calculation for Actual energy : -

At first I take the data of actual energy by a compressor (KC 2) for one chamber from reading, this is equal to = **55 KW** per hour.

Now also I got this actual energy by the electricity bill for that cold storage --

Month	**Electricity bill**
July , 2014	73,890 KWH
August , 2014	86,135 KWH
September , 2014	60,295 KWH

So, the average of this three months electricity bill is

$$= \frac{73890 + 86135 + 60295}{3} = \frac{220320}{3} = \mathbf{73440}\ \boldsymbol{KWH}$$

This unit is for one month and for 2 chambers only.
The running time for a month is **540** Hours.
Now, Total unit consumption for one hour and for one chamber

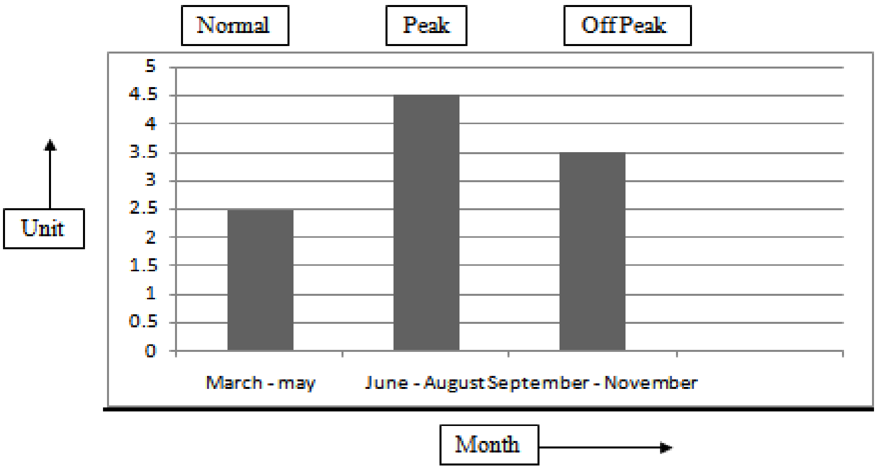
$$= \frac{73440}{540 \times 2} = \mathbf{68}\ \boldsymbol{KW\ per\ hour}$$

[One compressor is running for one chamber]

Now , there is also a pump, 336 pieces of fan & 800 lights are running .

Unit consumed by the pump = 11.19 KW
Unit consumed by the fan = 0.06 KW
Unit consumed by the light = 0.018 KW
So, the total unit consumed by this three
= [11.19 + 0.06 + 0.018] KW
= **11.27 KW**
So, unit consumed by a compressor is = [68 - 11.27] KW
= **56.73 KW**
This value is approximately similar to the actual energy by a compressor from reading. So, I take 55 KW/h
So,

E_{actual} = 55 KW per hour.



Calculation for Theoretical energy : -
I have done this theoretical energy calculation with three process :-
(i) The power of compressor = V . I . CosØ

Here , V = 415 volt
I = 125 Amp.
CosØ = 0.8
So, $\mathbf{E_{theoritical}}$ = **V . I . CosØ**
= 415 X 125 X 0.85
= 44093.75 Watt
$E_{theoritical}$ = 44.09 KW per hour

(ii) Also we know,
$\mathbf{E_{theoritical}}$ = work done by a compressor

$$\mathbf{E_{theoritical}} = \frac{n}{n-1} \mathbf{p_1 v_1} \left\{ \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} - 1 \right\}$$

Where,
n = 1.4
p_1 = 3.5 kg/cm^2 = 35000 kg/m^2
= 35000/101. 972 KPa
= 343.23 KPa

$v_1 = \frac{\pi}{4} D^2 L$ where D = Bore = 160 mm
L = Stroke = 110 mm
$= \frac{\pi}{4} (0.16)^2 \times 0.11$
= 0.00221 m^3

p_2 = 10.5 kg/cm^2 = 105000 kg/m^2
= 105000/101.972 KPa = 1029.69 KPa

$$\mathbf{E_{theoritical}} = \frac{1.4}{1.4-1} 343.23 \times 0.00221 \times \left\{ \left(\frac{10.5}{3.5}\right)^{\frac{1.4-1}{1.4}} - 1 \right\}$$

= 2.665 x [1.375 - 1]
$\mathbf{E_{theoritical}}$ = **0.996 Joule**
Here the speed of motor for compressor is = 1440 rpm and number of cylinder is = 2, then

$$\mathbf{E_{theoritical}} = \frac{0.996 \times 2 \times 1440}{60}$$

$E_{theoritical}$ = 47.8 KW per hour

(iii) Now,
Co-efficient of performance (COP) = Heat grade energy output (KWH) / Electrical/Mechanical energy input (KWH)

$$\mathbf{COP} = \frac{Q}{W}$$

Also, $\mathbf{COP} = \frac{dt_1}{dt_1 - dt_2}$

Where, dt_1 = Condensing temperature difference
dt_2 = Evaporating temperature difference

So, $\frac{Q}{W} = \frac{dt_1}{dt_1 - dt_2}$

$$W = \frac{Q(dt_1 - dt_2)}{dt_1}$$

Here Q = 55 KW per hour. [It is calculated from a journal paper]

Then, $$W = \frac{55[(T_2-T_3)-(T_1-T_4)]}{(T_2-T_3)}$$

$$W = \frac{55[(303-277.5)-(275.5-274)]}{(303-277.5)}$$

$$W = \frac{55[25.5-1.5]}{25.5}$$

$$W = 51.76 \ KW \ per \ hour$$

$E_{theoritical}$ = ***51.76 KW per hour***

Now , the average of this three

$$E_{theoritical} = \frac{44.09 + 47.8 + 51.76}{3}$$

= **47.88 KW per hour**

So, when I take mechanical/electrical energy loss of the compressor then this energy is equal to

$E_{theoritical}$ = 50 KW per hour.

(b) Energy Gap Analysis –

There is a huge gap when I calculating the energy difference.

Gap energy = E_{actual} - $E_{theoritical}$

= (55 – 50) KW per hour = **5 KW per hour**

If I take per month then it becomes :-

Gap energy = (5 × 540) KW per hour

= **2700 KW per hour**

If I take per year it becomes :-

Gap energy = (2700 × 12) KW per hour

= **32400 KW per hour**

(c) Cost Analysis –

This data is collected from total electricity bill of that cold storage –

Month	**Unit**	**Cost**
July 2014	73890 KWH	Rs. 5,38,972 /-
August 2014	86135 KWH	Rs. 5,42,071 /-
September 2014	60295 KWH	Rs. 4,66,395 /-

So, the average cost of one month = $\frac{538972 + 542071 + 466395}{3}$ = Rs. **5,15,813 /-**

Now the excess energy for a month is equal to 2700 KWH and for a year is equal to 32400 KWH.

So the saving money is = 2700 x 7.5 = **Rs. 20,250** /- in a month.

= 32400 x 7.5 = **Rs. 2,43,000** /- in a year.

III. RESULT & DISCUSSION

At first I make a programming for the equation

$$E_{theoritical} = \frac{n}{n-1} \times 2 \times 24 \times p_1 v_1 \left\{\left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} - 1\right\}$$

in KW

Where n = 1.4

The program is -

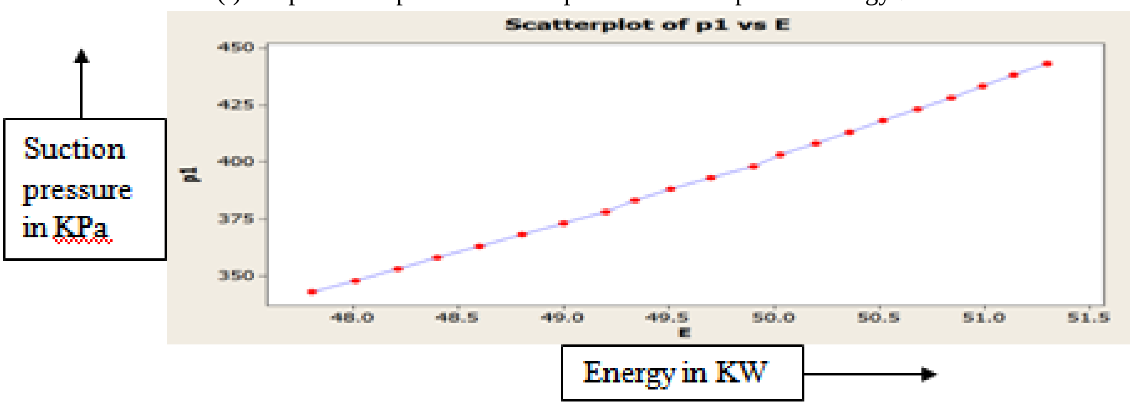
```
#include<iostream.h>
#include<conio.h>
#include<math.h>
int main( ) {
double p1 , p2 , v1 = 0.00221, e , x ;
cout<< "give the value of p1 , p2 / n";
cin>> p1 >> p2
x = pow (p2 / p1 , 0.29);
e = 3.5 * 2 * 24 *(p1 * v1 * x – p1 * v1);
cout << e ;
return 0 ;
}
```

This programming is done for the twenty values of p_1 , p_2 and E which is used for making the graph plotting –

(i) p_1 vs E and (ii) p_2 vs E (iii) T_1 vs E

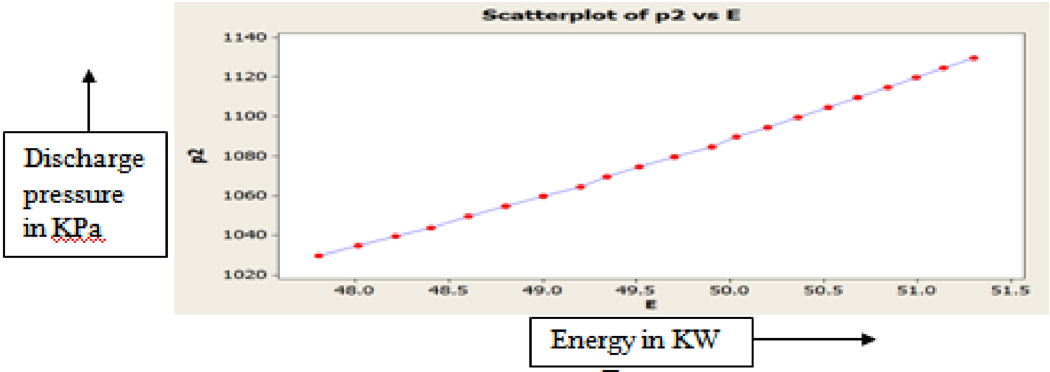
Where p_1 = suction pressure, p_2 = discharge pressure, E = energy and T_1 = suction tempera ture.

(i) Graph of compressor suction pressure vs compressor energy :-



The graph indicates that energy increases with increase in suction pressure

(ii) Graph of compressor discharge pressure vs compressor energy :-



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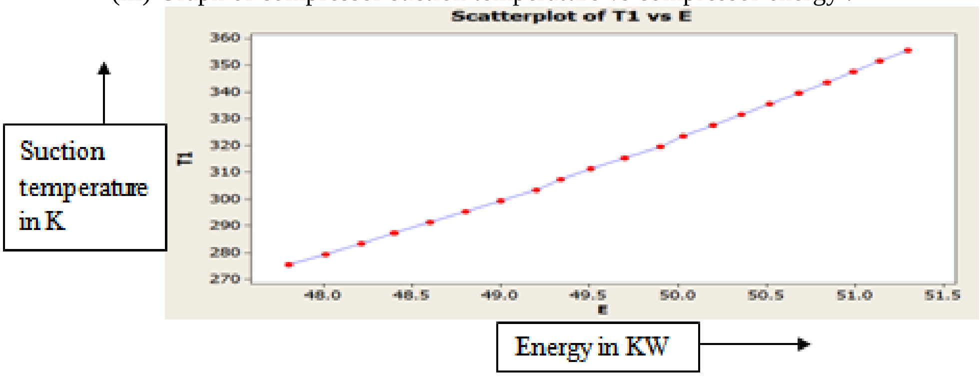
The graph indicates that energy increases with increase in discharge pressure

(iii) Graph of compressor suction temperature vs compressor energy :-



The graph indicates that energy increases with increase in discharge pressure

IV. CONCLUSION

It has been observed that the actual energy consumption of a cold storage by a compressor for one chamber is 55 KW per hour and theoretical energy consumption is 50 KW per hour. So, a gap of 5 KW per hour is found between the theoretical and actual energy consumption by a compressor. If this gap is fulfilled then a savings of Rs 20,250 /- per month will be obtained which will amount to Rs 2,43,000 /- per year.

To save energy the following practices must be implemented:-

1. Reducing Heat Loads
2. Uses of latest energy saving equipments
3. Proper Insulation
4. Efficient maintenance practices
5. Automation & Integration

There are other factor which contributes to the total energy consumption, which are (i) lights (total 800 pcs) , (ii) fans (total 336 pcs). To increase the efficiency, conventional lights will replaced by energy efficient devices that is LED, CFL etc.

If we replace three compressors for three chambers with a single equivalent compressor which will deliver the same amount of load, then maximum energy will be saved.

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