Improvement of Efficiency of Air Refrigeration System by lowering the Inlet Temperature of Air

Prabal Roy[1], Surjeet Singh Rajpoot[2]
[1]M.Tech Scholar, College of Engineering, Bhopal
[2]Assistant Professor, Department of Mechanical Eng, Scope College of Engineering, Bhopal

ABSTRACT: *In many process industries Dry air flow is used to make the raw-materials dry and moisture free for better transportation from one stage to other during the process. This air-flow is obtained from big industrial Compressors and the output air of which contains atmospheric moisture. A case study was undertaken at a company viz. HEG Ltd where carbon rods are produced from graphite powder. These graphite powders are dried by flowing dry & moisture free air over them for pneumatic conveying the powder from one process to another. The flow of high pressure air from compressor is generally hot and contains moisture. This moisture of air is removed from the air through a Refrigeration system. Now as the efficiency or COP of the refrigeration system depends on the inlet temperature of the air which comes from an air-compressor which remains hot. The heat of inlet air is removed by using the cold air through the introduction of an additional Heat-exchanger. As a result the temperature of the inlet air to the refrigeration system is reduced thus improving the efficiency & COP of the Refrigeration system.*

Key Words: *COP, Compressor, Evaporator, Temperature.*

INTRODUCTION

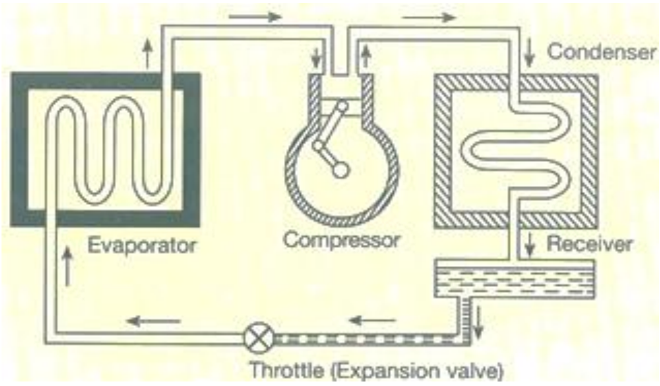
Refrigeration is the method of removal of heat from a low temperature zone to a high temperature zone under controlled conditions. The work of heat removal is done through mechanical work. Refrigeration has many applications, viz. domestic refrigerators, industrial freezers, cryogenics, and in air conditioning.

Types of Refrigeration Systems:

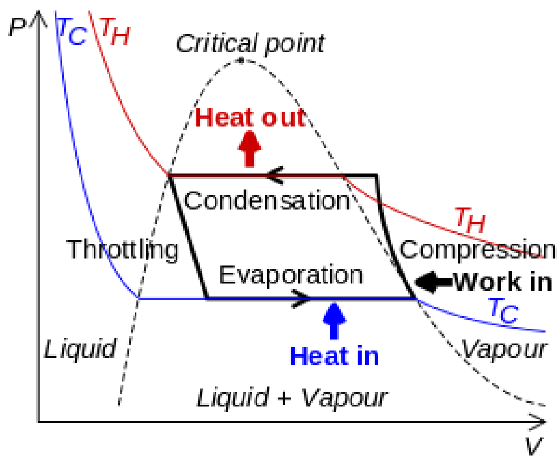
Refrigeration as it is known these days is produced by artificial means. Based on the working principle, refrigeration systems can be classified as:

a) Vapor Compression refrigeration ,
b) Vapor Absorption refrigeration,
c) Gas refrigeration,
d) Steam jet water vapor refrigeration,
e) Vortex tube refrigeration,
f) Thermoelectric refrigeration,
g) Magnetic cooling
h) Liquefaction of natural gases

Vapour Compression Refrigeration Systems:



Simple Vapor Compression Ref. System



Pressure-Volume Diagram For a Typical Refrigeration Cycle

There are four main components in this refrigeration system:

a) The Compressor
b) The Condenser
c) The Metering Device or expansion valve

d) The Evaporator

Compressor:

Two different pressures exist in the refrigeration cycle. The evaporator or low pressure and the condenser, or high pressure. These pressure areas are divided by the other two components. On one end, is the metering device which controls the refrigerant flow, and on the other end, is the compressor. The compressor is the heart of the system. The compressor does just what its name is. It compresses the low pressure refrigerant vapor from the evaporator and compresses it into a high pressure vapor. The inlet to the compressor is called the "Suction Line". It brings the low pressure vapor into the compressor. After the compressor compresses the refrigerant into a high pressure Vapor, and the outlet of the compressor is called the "Discharge Line".

Condenser

The "Discharge Line" leaves the compressor and runs to the inlet of the condenser. Because the refrigerant was compressed, it is a hot high pressure vapor. The hot vapor enters the condenser and starts to flow through the tubes. Cool air is blown across the outside of the finned tubes of the condenser (usually air by a fan or water with a pump). Since the air is cooler than the refrigerant, heat jumps from the tubing to the cooler air (energy goes from hot to cold – "latent heat"). As the heat is removed from the refrigerant, it reaches its

"saturated temperature" and starts to change state,

Equipment	Type / Material	Specification / Capacity	Manufacturer
Compressor	Industrial type, Hermatically Sealed	20 TR Suction Pr. – 25 to 40 psi Discharge Pr – 230 to 240 psi Supply Voltage – 440 AC, Frequency - 50 Hz.	Danfoss make
Refrigerent	R 132 A		
Condesor	Water Cooled		

into a high pressure liquid. The high pressure liquid leaves the condenser through the "liquid line" and travels to the "metering device" through a filter dryer to remove any dirt or foreign particles.

The condenser can be free air cooled (domestic refrigerator), forced air cooled (window air conditioner), water cooled (Central air conditioning plant in a library, cinema house and evaporative cooled (ice plant unit or a cold storage unit).

Expansion Device

Metering devices regulate how much liquid refrigerant enters the evaporator as per heat load on evaporator.

Common used metering devices are, small thin copper tubes referred to as "capillary tubes", thermally controller diaphragm valves" (thermostatic expansion valves, called "TXV's. This valve has the capability of controlling the refrigerant flow. If the loads on the evaporator change, the valve can respond to the change and increase or decrease the flow accordingly. As the metering devices regulates the amount of refrigerant going into the evaporator, the device lets small amounts of refrigerant out into the line and looses the high pressure to low pressure.

Evaporator:

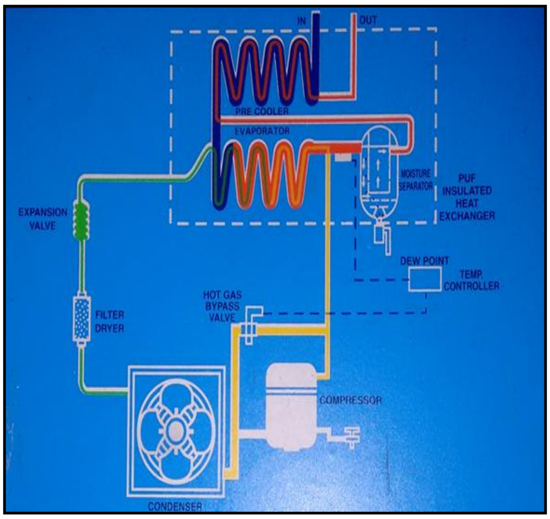
The evaporator is where the heat is removed from the space or the area/ products to be cooled. Low pressure liquid leaves the metering device and enters the evaporator. The cooler refrigerant in the evaporator tubes, absorb the warm room air. The change of temperature causes the refrigerant to "flash" or "boil", and changes from a low pressure liquid to a low pressure cold vapor. The low pressure vapor is pulled into the compressor and the cycle starts over.

Refrigerated Dryer:-

Refrigeration dryers employ two heat exchangers, one for air-to-air and one for air-to-refrigeration. The compressors used in this type of dryer are usually of the hermetic type and the most common gas used is R-134a and R-410a for smaller air dryers up to 100 cfm. Older and larger dryers still use R-22 and R-404a refrigerants. The goal of having two heat exchangers is that the cold outgoing air cools down the hot incoming air and reduces the size of compressor required. At the same time the increase in the temperature of outgoing air prevents re-condensation.

Flow diagram of the proposed Cycle:

Existing System	Modified System
Temp of the compressed air at the entry to the Evaporator is higher.	Temp of the compressed air at the entry to the Evaporator is much lower.
Size of the Compressor is bigger.	Size of the Compressor is smaller.
Temp of the outgoing air is lower at Evaporator temp.	Temp of the outgoing air is higher after Heat exchange.
There is a possibility of re-condensation in the outgoing air in end use.	No Possibility of re-condensation in the outgoing air in end use.
Initial cost is low as there is no additional H Exchanger.	Initial cost is high for installation of H Exchanger.



Flow diagram of the proposed Cycle

OBJECTIVE OF WORK

- Improvement of System Efficiency by using Heat Recycling in a Refrigeration System.
- Increasing the COP of the refrigeration unit by introducing a modified system.
- Re-using the waste heat from the hot compressed air in heating the cold dry air from the refrigerator.
- An air–to-air heat exchanger is used to exchange the heat from the compressed air to the cold dry air coming out from the refrigerator and increase its temperature.
- The heat of the air from the compressor unit would have otherwise wasted in the atmosphere, or would have otherwise acted as an additional load on the inlet of refrigeration unit.
- The heating of the cold dry air also ensures that no condensation takes place in the pneumatic pipe line while conveying the graphite powder.

Heat Recovery: The goal is to cool down the hot incoming air by the cold outgoing air thus reducing the size of compressor required. At the same time the increase in the temperature of outgoing air prevents re-condensation.

Comparison of existing V/s modified System

Coefficient of Performance of Refrigerator:

The efficiency of a refrigerator or heat pump is given by a parameter called the Coefficient of Performance (COP). The COP of a refrigerator is given by the following equation: COP = Desired Output/Required Input = Cooling Effect/Work Input = Q_L/W.

The equation is: COP = Q/W

Where,

Q is the useful heat supplied or removed by the considered system.

W is the work required by the considered system.

The COP for heating and cooling are thus different, because the heat reservoir of interest is different. When one is interested in how well a machine cools, the COP is the ratio of the heat removed from the cold reservoir to input work. However, for heating, the COP is the ratio of the heat removed from the cold reservoir plus the input work to the input work:

$COP_{heating} = Q_H / W = (Q_C + W)/W$

$COP_{cooling} = Q_C /W$

Where, Q_C is the heat removed from the cold reservoir

Q_H is the heat supplied to the hot reservoir

Both means the same for understanding,

Derivation:-

According to the First Law of Thermodynamics, in a reversible system we can show that, $Q_{hot} = \{Q_{cold} + W\}$ and $W = \{Q_{hot} - Q_{cold}\}$, where Q_{hot} is the heat transferred to the Hot reservoir and Q_{cold} is the heat collected from the cold reservoir.
Therefore by substituting for W ,

$$COP_{heating} = Q_{hot} / (Q_{hot} - Q_{cold})$$

For a heat pump operating at maximum theoretical efficiency (i.e. Carnot efficiency), it can be shown that : $Q_{hot} / T_{hot} = Q_{cold} / T_{cold}$

$$Q_{cold} = Q_{hot} . T_{cold} / T_{hot}$$

Where T_{hot} and T_{cold} are the temperatures of the hot and cold reservoirs respectively in Kelvin or Rankine.
At maximum theoretical efficiency,

$$COP_{heating} = T_{hot} / (T_{hot} - T_{cold})$$

Data Collected by introducing the modification

I. Data taken before the introduction of the Addl. Heat Exchanger			
Reading	Temp of Hot moist Air entering in to the Evaporator directly from Compressor plant **T_H**	Temp of Cold Dry Air coming out from the Evaporator **T_C**	COP of the **Original** Refrigeration Cycle = **COP = T_H / (T_H - T_C)**
1.	45^0 C	5^0 C	7.95
2.	47^0 C	6^0 C	7.80
3.	46^0 C	6^0 C	7.98
4.	47^0 C	7^0 C	8.0
5.	48^0 C	6^0 C	7.64
6.	48^0 C	5^0 C	7.47
7.	49^0 C	8^0 C	7.85
8.	50^0 C	7^0 C	7.51
9.	50^0 C	6^0 C	7.34
10.	47^0 C	5^0 C	7.62
	Average COP =		7.716

which is equal to the reciprocal of the ideal efficiency for a heat engine, because a heat pump is a heat engine operating in reverse. Similarly,

$$COP_{cooling} = Q_{cold} / (Q_{hot} - Q_{cold}) = T_{cold} / (T_{hot} - T_{cold})$$

Note that the COP of a heat pump depends on its duty. The heat rejected to the hot sink is greater than the heat absorbed from the cold source, so the heating COP is 1 greater than the cooling COP. $COP_{heating}$ applies to heat pumps and $COP_{cooling}$ applies to air conditioners or refrigerators.. Values for actual systems will always be less than these theoretical maximums. In Europe, the standard tests for ground source heat pump units use 35 °C (95 °F) for T_{hot} and 0 °C (32 °F) for T_{cold}. According to the above formula, the maximum achievable COP would be 8.8. Test results of the best systems are around 4.5. When measuring installed units over a whole season and accounting for the energy needed to pump water through the piping systems, seasonal COP's are around 3.5 or less. This indicates room for improvement.

RESULTS DISSCUSSION & ANALYSIS

Experimentation

Experiments are conducted by taking readings as follows:
Temp of Hot moist Air entering in to the Evaporator directly from Compressor plant (T_H) and the Temp of Cold Dry Air coming out from the Evaporator (T_C) is measured by digital thermometer in a set of observation is noted before the introduction of the Addl. Heat Exchanger. Similar sets of Temperature readings / Observations were taken after the introduction of the Addl. Heat Exchanger (after modification).

Data taken after the introduction of the Addl. Heat Exchanger

II. Data taken after the introduction of the Addl. Heat Exchanger (after modification).			
Reading	Temp of Partly cooled moist Air entering in to the Evaporator through the addl. Heat Exchanger, **T_H**	Temp of Cold Dry Air coming out from the Evaporator, **T_C**	COP of the **Modified** Refrigeration Cycle , **COP = T_H / (T_H - T_C)**
1.	35^0 C	5^0 C	10.27
2.	36^0 C	6^0 C	10.30
3.	37^0 C	6^0 C	10.00
4.	38^0 C	8^0 C	10.37
5.	39^0 C	8^0 C	10.06
6.	40^0 C	10^0 C	10.43
7.	37^0 C	8^0 C	10.68
8.	35^0 C	7^0 C	11.00
9.	42^0 C	12^0 C	10.50
10.	41^0 C	10^0 C	10.13
	Average COP =		10.374

Therefore we find that the Average COP is increased by (10.374 – 7.716) = 2.658

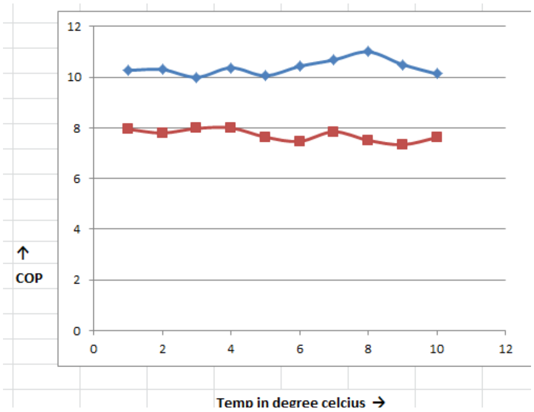


Fig: COP Vs Temp Graph

Improvement in COP

Where T_{hot} and T_{cold} are the temperatures of the hot and cold reservoirs respectively in Kelvin or Rankine.

At maximum theoretical efficiency,

$$COP_{heating} = T_{hot} / (T_{hot} - T_{cold})$$

From this relation ,we got actual COP is 7.716 and improved COP is 10.314

Therefore, improvement in

$$COP = COP_{improved} - COP_{actual}$$

% Improvement in COP

$$= (COP_{improved} - COP_{actual}) / COP_{improved} \text{ X } 100 \%$$

$$= (10.314 - 7.716) / 10.314 \text{ X } 100 \%$$

$$= 25.19\%$$

CONCLUSION

"Heat recycling in a Refrigeration System" is an efficient tool to conserve available energy. An attempt is made to recover the waste heat from air compressor plant used in industrial purpose. As indicated in this paper, recovered heat can be utilized in heating the cold dry air for pneumatic conveying, so one can save lot of energy. The study provides the following conclusions:

a) Suitable heat recovery system can be designed and developed for every such industrial refrigerator.
b) The experimentation has shown that such a system is practically feasible.
c) Technical analysis has shown that it is economically viable and energy efficient.
d) The additional cost for the Heat Exchanger can be recovered by using the recycling system in the long run.
e) Thus it leads to energy conservation.
f) The system prevents condensation in air in the pneumatic pipe line.

FUTURE SCOPE

It is expected that knowing the above parameters & readings, we can calculate the two sets of Results. For further improvement in the quality of the output air we may implement some more modifications as follows;-

a) For better exchange of heat from hot incoming air to the cold dry air we may replace the material of the inner tubes of the Heat exchanger with Copper tubes which is better conductor of heat.
b) For enhancing heat exchange we may also increase the surface area of the heat exchanger. To achieve that we may increase the number of inner tubes for complete transfer of heat.
c) In case the situation demands there is a possibility that the output air can be reheated by passing it through an air-heater.

REFERENCE

[1] Shambhu Kumar Rai and Parmeshwar Dubey "A REVIEW ON HEAT EXCHANGER" in Vol-3 Issue-1, 2017 IJARIIE-ISSN(O)-2395-4396 3678.

[2] Ratchaphon Suntivarakorna and Wasakorn Treedetb, "Improvement of Boiler's Efficiency Using Heat Recovery and Automatic Combustion Control System", ICPESE 2016, 8-12 September 2016.

[3] Marija Lazova , Henk Huisseune , Alihan Kaya , Steven Lecompte , George Kosmadakis and Michel De Paepe et al,"Performance Evaluation of a Helical Coil Heat Exchanger Working under Supercritical Conditions in a Solar Organic Rankine Cycle Installation" Vol 8, Issue 5, 2016.

[4] Chetan Papade, and Biranna Solankar , A Review on Analysis of Vapour Compression Refrigeration System Using Matrix Heat Exchanger Vol 6 Issue 3 January 2016 , ISSN : 2278-621X , International Journal of Latest Trend in Engineering & Technology (IJLTET).

[5] S. Sudhakar & C.M. Raguraman "Improvement in Efficiency of Air Preheater in Boiler" IJRDO - Journal of Mechanical and Civil Engineering ISSN-2456-1479 Volume-2, Issue-6, June,2016, Paper-1

[6] Amey Sharad Majgaonkar et al , 'Use of Nanoparticles In Refrigeration Systems': A Literature Review Paper Published in : (2016). International Refrigeration and Air Conditioning Conference. Paper 1704.

[7] N. B. Chaudhari, P. N. Chaudhary "Heat Recovery System from the Condenser of a Refrigerator" International Journal on Theoretical and Applied Research in Mechanical Engineering (IJTARME), ISSN (Print): 2319-3182, Volume -4, Issue-2, 2015

[8] David Cygan Derek Wissmiller "Demonstration of Waste Heat Recovery for Power Generation", MARCH 2015, CEC-500-2015-066

[9] R. Pachaiyappan & J. Dasa Prakash, "Improving the Boiler Efficiency by Optimising the Combustion Air" in Applied Mechanics and Materials Vol. 787 (2015), 238-242,

[10] T.Venkateshan , Dr. M. Eswaramoorthi , PG Scholar, "Performance Of Heat Exchangers With Different Configurations" in International Journal for Research in Applied Science & Engineering Technology (IJRASET) , Volume 3 Issue VII, July 2015 IC Value: 13.98 ISSN: 2321-9653.

[11] Shruti Saxena published 'Increasing the Efficiency of Refrigerator by Reducing the Losses in evaporator, Compressor and Condenser' in International Journal of Scientific & Engineering Research, Volume 6, Issue 5, May-2015 ISSN 2229-5518.

[12] Taliv Hussain; Arjun Sharma; Navin; Rahul Wandra; Gaurav Roy, 'Effect of Sub-cooling in VCRS as compared to Simple VCR System' Published in : ELK Asia Pacific Journals – Special Issue ISBN: 978-81-930411-4- In the Year 2014.