RESEARCH ARTICLE OPEN ACCESS

Experimental Analysis Of 80 Tr Capacity Air Cooled Scroll Chiller Using R-22 & R-407c.

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ABSTRACT
In air conditioning systems, chilled water is typically distributed to heat exchangers, or coils, in air handling units or other types of terminal devices which cool the air in their respective space(s), and then the water is re-circulated back to the chiller to be cooled again. These cooling coils transfer sensible heat and latent heat from the air to the chilled water, thus cooling and usually dehumidifying the air stream. The experiment works on 80 TR capacity Air Cooled Scroll Chiller systems. Vapour compression refrigeration cycle is used for cooling chilling water. Capacity of compressor is taken same for the different refrigerants used for experimental analysis. During experimental work used R-22 and R-407C as refrigerants. Theoretical COP of system with R-22 refrigerant is 4.166 and actual COP is 2.227. For 80 TR capacity scroll air cooled chiller, theoretical COP of system with R-407c refrigerant is 3.465 and actual COP is 2.745 respectively. Based on the result analysis the same capacity of air cooling system with scroll compressor Actual COP of R-407C is higher than R-22. It means R-407C is also a alternative refrigerant for air cooled chilling system and also for HVAC system.
Keywords – *Air Chiller**,** Scroll Compressor, Vapour compression cycle, COP, HVAC system*

I. INTRODUCTION

A chiller is a system that removes heat from a liquid via a vapor-compression or absorption refrigeration cycle. This liquid/refrigerant can be circulated through a heat exchanger to cool air or equipment as required. As a necessary byproduct, refrigeration creates waste heat that must be exhausted to ambient or, for greater efficiency, recovered for heating purposes. Concerns in design and selection of chillers include performance, efficiency, maintenance, and product life cycle environmental impact.

In air conditioning systems, chilled water is typically distributed to heat exchangers, or coils, in air handling units or other types of terminal devices which cool the air in their respective space(s), and then the water is re-circulated back to the chiller to be cooled again. These cooling coils transfer sensible heat and latent heat from the air to the chilled water, thus cooling and usually dehumidifying the air stream. A typical chiller for air conditioning applications is rated between 15 and 1500 tons in cooling capacity, and at least one manufacturer can produce chillers capable of up to 6,000 tons of cooling. Chilled water temperatures can range from 35 to 45 °F (2 to 7 °C), depending upon application requirements.

Industrial application, chilled water or other liquid from the chiller is pumped through process or laboratory equipment. Industrial chillers are used for controlled cooling of products, mechanism and factory machinery in a wide range of industries. They are often used in the plastic industry in injection and blow molding, metal working cutting oils, welding equipment, die-casting and machine tooling, chemical processing, pharmaceutical formulation, food and beverage processing, paper and cement processing, vacuum systems, X-ray diffraction, power supplies and power generation stations, analytical equipment, semiconductors, compressed air and gas cooling. They are also used to cool high-heat specialized items such as MRI machines and lasers, and in hospitals, hotels and campuses.

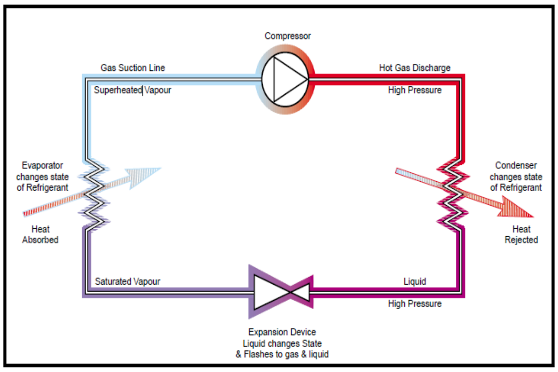
Chillers for industrial applications can be centralized, where a single chiller serves multiple cooling needs, or decentralized where each application or machine has its own chiller. Decentralized chillers are usually small in size and cooling capacity, usually from 0.2 tons to 10 tons. Centralized chillers generally have capacities ranging from ten tons to hundreds or thousands of tons. Chilled water is used to cool and dehumidify air in mid- to large-size commercial, industrial, and institutional (CII) facilities. Water chillers can be water-cooled, air-cooled, or evaporative cooled. Water-cooled chillers incorporate the use of cooling towers which improve the chillers' thermodynamic effectiveness as compared to air-cooled chillers. This is due to heat rejection at or near the air wet-bulb temperature rather than the higher, sometimes much higher, dry-bulb temperature. Evaporative cooled chillers offer higher efficiencies than air-cooled chillers but lower than water-cooled chillers.

Air-cooled and evaporative cooled chillers are intended for outdoor installation and operation. Air-cooled machines are directly cooled by ambient air being mechanically circulated directly through the machines condenser coil to expel heat to the atmosphere. Evaporative cooled machines are similar, except they implement a mist of water over the condenser coil to aid in condenser cooling, making the machine more efficient than a traditional air-cooled machine. No remote cooling tower is typically required with either of these types of packaged air-cooled or evaporative cooled chillers.

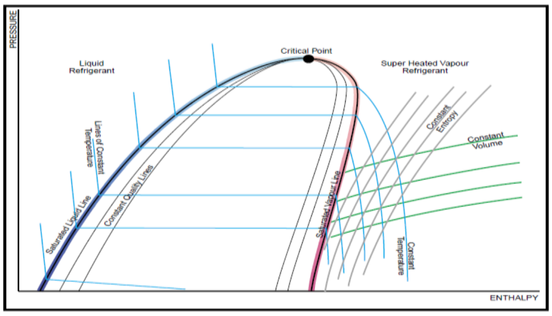
II. VAPOUR COMPRESSION REFRIGERATION CYCLE IN CHILLER

Air cooled chiller working on vapour compression refrigeration cycle. Four main components of refrigeration cycle. Compressor, condenser, evaporator and expansion device are the components of chiller system.

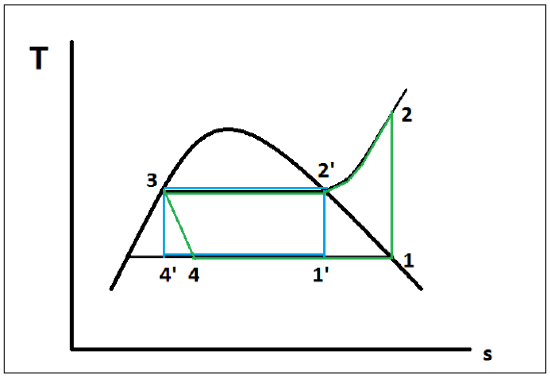
Basic Refrigeration Cycle



Schematic diagram of vapour copmression refrigeration cycle



P-h diagram of the ideal vapor-compression refrigeration cycle



T-s diagram of the ideal vapor-compression refrigeration cycle

The refrigeranion cycle of an air-cooled chiller includes two processes:

1. The evaporation of the liquid refrigerant in the evaporor, which absorbs heat and lowers the temperature of the chilled-water system.
2. The condensation of the refrigerant vapor in the air cooled condenser and rejection of heat to the atmosphere.

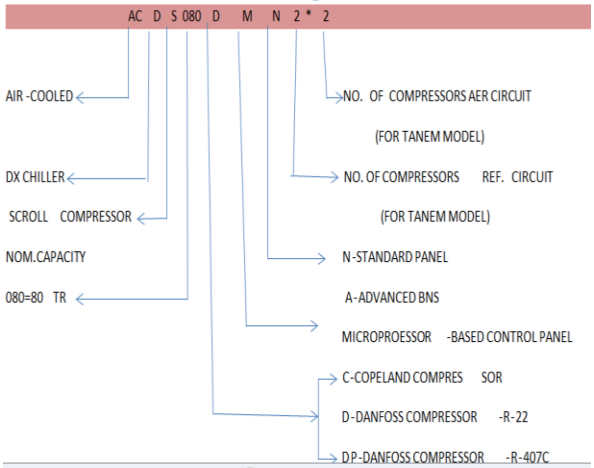
In the air cooled chiller refrigeration cycle, water the evaporator(also known as the cooler) and is cooled dy the colder refrigerant flowing through the other circuit inside the evaporator.The chilled water is pumped from the building coils to provide cooling. In the evaporator, the chilled cooled the building or process load and the cycle is completed when warmer water flows back to the evaporator.A mixture of liquid refrigerant and flash gas passes through the evaporator circuit opposite the water to be chilled.

The refrigerant in the evaporator absorbs heat from the warmer return water, evaporates to a and finally exits the evaporator as a superheated vapor. The superheated refrigerant vapor then enters the suction inlet of the compressor. In compressor, the refrigerant is compressed, raising its pressure and temperature. High pressure and temperature refrigerant gas exits the compressor, passes through the discharge line and enters the condenser. While in the air cooled condenser coil, the hot gas condenses to liquid inside the tubes as it gives up heat to the cooler outside air being drawn across the condenser coil by the condenser fans.

The condensed liquid refrigerant then leaves the condenser and enters the expansion device. As the refrigerant passes through the expansion device, its pressure and temperature is decreased to the liquid flashes to vapor. The expansion device controls the amount of flashing in order to maintain a certain superheat to ensure no liquid droplets enter into the compressor suction. After leaving the expansion device, the refrigerant enters the evaporator and the cycle is repeated

III. NOMENCLATURE OF SELECTED AIR COOLED SCROLL CHILLER SYSTEM

Experimental work carried out at Voltas Pvt. Ltd. at Dadra Nagar & Haveli. ACDS080DMN22 model of Chiller system used for 80 TR with R-22 & R-407C refrigerants for maintain chilling water temperature 5-7^{0}C. The refrigerant R-407C is a blended refrigerant, being a mixture of R32, R125 and R134A, and is known as a ZEOTROPE fluid, and at a given pressure each component part of the blend will boil at a different temperature. R-407c boiling temperature is -43.6^{0}C. Electrical expansion



valve is used.

IV. ANALYTICAL CALCULATION

1. The vapor compression cycle is analyzed as follows:

➢ According to Energy Equation,

$$h_1 + C_1^2/2 + Q + W = h_2 + C_0^2/2$$

Neglecting the kinetic energy transfer by assuming that: $C_1^2/2 = C_0^2/2 = 0$,

Gives: $h_1 + Q + W = h_2$

Where: h_1 = Enthalpy at inlet to the process,
h_2 = Enthalpy at outlet,
W = Work done during the process,
Q = Heat transferred

2. Work Done by Compressor, W_C:
The work done to compress the refrigerant vapor,
$h_1 + Q + W = h_2$
But, Q = 0 since heat is usually neglected nor extracted nor added during compression process.

Thus: $h_1 + W = h_2$

$\therefore Wc = h_2 - h_1$

This is the work done per kg of the refrigerant.

3. Compressor Capacity, P:.

$$P = m (h_2 - h_1)$$

Where: m = the mass flow rate of the refrigerant.

4. Mass flow rate of refrigerant, m:
This is the quantity of refrigerant (in kg) that must flow through a system per unit time to produce a ton of refrigerant. This is defined and stated as: m = (refrigeration capacity of system)/(refrigeration effect of refrigerant)
Mathematically,

$$m = C_R/(h_1 - h_4)$$

Where: C_R = the refrigeration capacity (or total heat load of the cold room, HT).

5. Condenser capacity, C_C:
This is the heat rejected by the refrigerant in unit time in the condenser.

$$h_2 + Q_{23} + W = h_3$$

But: W = 0 (as no work is done in the condenser).

Hence, $h_2 + Q_{23} = h_3$

$\therefore Q_{23} = h_3 - h_2$

It should be noted here that $h_2 > h_3$. Thus, Q_{23} will be negative although its magnitude is $h_2 - h_3$. Therefore, the condenser capacity, C_C is obtained as:

$$C_C = m\, Q_{23} = m (h_2 - h_3)$$

6. Refrigeration Effect, Q_{41}:
The refrigeration effect, Q_{41}, is obtained from the refrigeration process: 4-1 by invoking the energy equation. Hence:

$$h_4 + Q_{41} + W = h_1$$

But, W = 0

Thus: $h_4 + Q_{41} = h_1$

$\therefore Q_{41} = h_1 - h_4$

7. Evaporator Capacity, C_E:
It is the rate at which heat is removed from the refrigerated space. This is also the product of mass flow rate (m) and the refrigerating effect, Q_{41}.

Hence: $C_E = m\, Q_{41}$

$\therefore C_E = m (h_1 - h_4)$

8. Throttling Process:
$\therefore h_3 = h_4$

9. Coefficient of Performance, COP:
Hence: COP = (refrigeration effect)/(work done)

$$= Q_{41} / W_{12}$$
$$= (h_1 - h_4)/(h_2 - h_1)$$

V. RESULT ANALYSIS

As per the experiment setup in Voltas Limited Company for Air cooled scroll chiller and use R -22 and R-407c refrigerant. Based on suction pressure, temperature and discharge refrigerant pressure, following results are obtained in terms of the refrigerating effect, work done, mass flow rate of refrigerant, theoretical COP and Carnot COP.

For R-22 refrigerant and scroll compressor for air cooled chiller.

Refrigerants (R-22)	Reading 1	Reading 2	Reading 3
Suction pressure Mpa	0.413	0.399	0.399
Dis-charge pressure Mpa	1.620	1.620	1.681
Suction Temperature ^{0}C	-9	-8	-8
Dis-charge Temperature^{0}C	42	42	42
Enthalpy(kJ/kg) h_1	407	406	402
h_2	443	442	438
h_3=h4	251	251	252
Entropy kJ/kg*K S1=S2	1.70	1.72	1.72
S3	0.69	0.69	0.68
S4	1.02	1.02	1.04
Refrigerant effect kJ/kg	156	155	150
Work done kJ/kg	36	36	36
Mass flow rate (kg/s)	1.794	1.806	1.866
Theoretical COP	4.333	4.305	4.166
Carnot COP	6.176	6.3	6.638
Actual COP	2.267	2.255	2.2779
Compressor Capacity kW	64.584	65.016	67.176
Actual Compressor Power Consumption (kW)	123.463	124.115	122.916
Condenser Capacity kW	344.448	344.946	347.076
Chiller Capacity kW	279.864	279.93	279.9

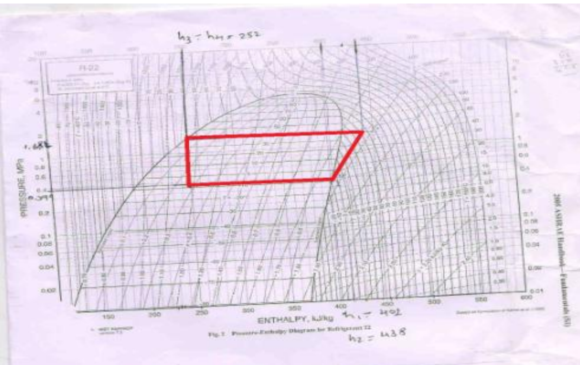


Figure 5.1 p-h chart for R-22 refrigerant with 80 TR Air Cooling scroll chiller

For R-407C refrigerant and scroll compressor for air cooled chiller.

Refrigerants (R-407c)	Reading 1	Reading 2	Reading 3
Suction pressure Mpa	0.39	0.38	0.3846
Dis-charge pressure Mpa	1.861	1.87	1.873
Suction Temp ^{0}C	-7	-9	-9
Dis-charge Temp^{0}C	44	45	45
Enthalpy(kJ/kg) h_1	406	405	405
h_2	447	448	448
h_3=h4	255	255	256
Entropy kJ/kg *K S1=S2	1.76	1.77	1.79
S3	0.65	0.65	0.66
S4	1.03	1.03	1.04
Refrigerant effect kJ/kg	151	150	149
Work done kJ/kg	41	43	43
Mass flow rate (kg/s)	1.854	1.866	1.879
Theoretical COP	3.682	3.488	3.465
Carnot COP	6.215	5.88	5.88
Actual COP	2.702	2.729	2.745
Compressor Capacity kW	76.014	80.238	80.797
Actual Compressor Power Consumption (kW)	103.599	102.586	101.993
Condenser Capacity kW	355.968	360.138	360.768
Chiller Capacity kW	279.954	279.9	279.971

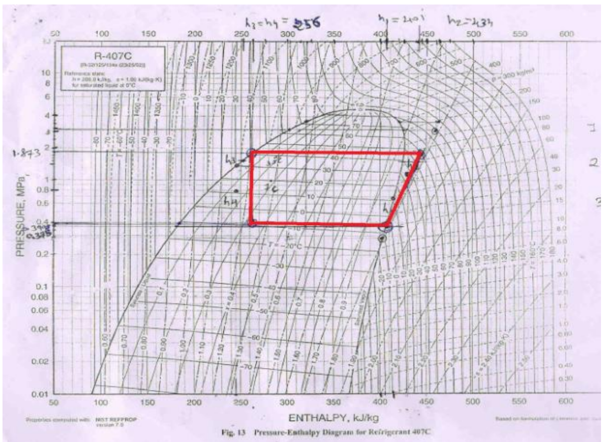
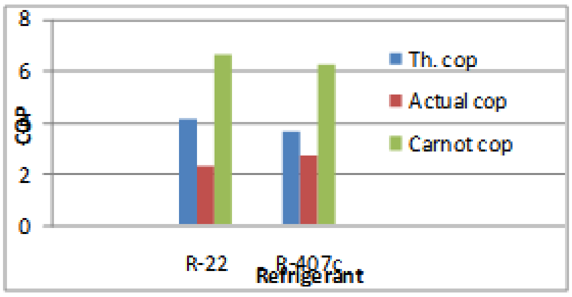


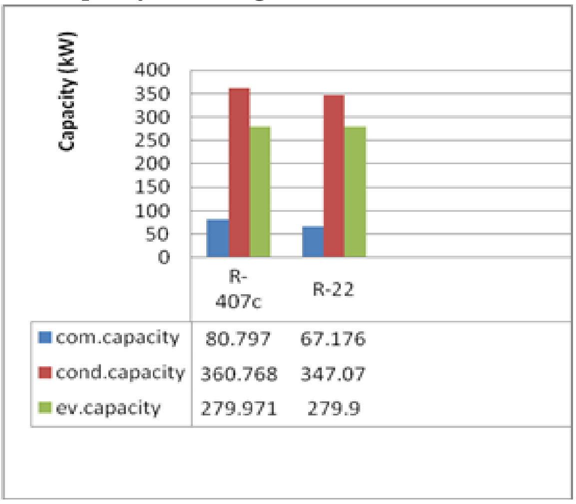
Figure 5.2 p-h chart for R-407C refrigerant with 80 TR Air Cooling scroll chiller

VI. GRAPHICAL ANALYSIS

1. COP Vs. Refrigerants



2. Capacity Vs Refrigerants



VII. CONCLUSION

Experimental work carried out with various refrigerants on scroll type air cooling chiller with capacity of 80TR. In R-22 refrigerant used for 80 TR chiller systems theoretical COP is 4.166 and actual COP is 2.227 and Carnot COP is 6.63. In R-407c refrigerant used for 80 TR chiller systems theoretical COP is 3.465 and actual COP is 2.745 and Carnot COP is 5.88. For same capacity of refrigerating system COP of R-22 is lower than COP of R-407c refrigerant and also less power consumption. It means the instead of R-22 used R-407C for better option for air cooled chilling system. This result is helpful to design and manufacture of air cooled chiller.

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