DEFROSTING METHODS OF AIR CONDITIONER SYSTEMS OF SPLIT AIR CONDITIONER

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Khaled A. A. BABAY

ABSTRACT

Master Thesis

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As the population has increased, the area of cooling and air conditioning has become extremely important. Freezing on the heat exchanger surface is an inevitable process that reduces the performance of heat pumps and cooling systems. Air Source Heat Pump (ASHP) units are used in applications worldwide due to the advantages of high efficiency, environmental protection, low cost and easy modification.

This study reveals a defrost method of air conditioning systems of split air conditioners. In split air conditioning systems, four-way valves are used to assist the transition of heating and cooling. Many problems such as difficulty in the installation of the four-way valve, slow defrost, lack of maintenance and repair, weakness against high temperatures, and many other problems affect the operation of split air conditioners negatively. Alternative solutions are sought to eliminate these problems.

The experiment results in the study show that there is a significant improvement in system performance during the defrost cycle by increasing the evaporation temperature and successively increasing the condensation temperature. Freeze melting is the result of heat transfer from the air conditioner during condensation. The increase in the condensing temperature is directly related to the defrost duration.

Keywords : Cooling, Hydraulic Valve, Heat Pump.
Science Code : 92808

ÖZET

Yüksek Lisans Tezi

SPLİT KLİMA İKLİMLENDİRME SİSTEMLERİNİN DEFROST YÖNTEMLERİ

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Nüfus artış gösterdikçe, soğutma ve iklimlendirme alanı son derece önemli bir hale gelmiştir. Isı eşanjörü yüzeyinde oluşan donma, ısı pompalarının ve soğutma sistemlerinin performansını azaltan kaçınılmaz bir süreçtir. Hava kaynaklı ısı pompası (ASHP) üniteleri, yüksek verimlilik, çevre koruma, düşük maliyet ve kolay modifikasyon avantajlarından dolayı dünya çapındaki uygulamalarda kullanılmaktadır.

Hava kaynaklı ısı pompalarına dair çalışmalar, esas olarak geleneksel teknolojilere kıyasla artan enerji verimliliğinden dolayı kritik bir araştırma ve geliştirme konusu haline gelmiştir. Bununla birlikte bir hava kaynaklı ısı pompası ünitesi, alan ısıtması için çalıştırıldığında ve ortam hava sıcaklığı çok düşük ve bağıl nem ise nispi düzeyde yüksek olduğunda don oluşacak ve sürekli performans alınmasının önündeki büyük bir engel olan hava kaynaklı ısı pompasının dış bobini üzerinde birikecektir.

Bu çalışma, split klimaların iklimlendirme sistemlerinin bir defrost yöntemini ortaya koymaktadır. Split klima sistemlerinde ısıtma ve soğutma geçişine yardımcı dört yollu vana kullanılmaktadır. Dört yollu vananın montajındaki zorluk, defrost yavaşlığı, bakım ve onarımının olmaması, yüksek sıcaklıklara karşı dayanıksızlığı ve bunlar gibi birçok problemler split klimaların çalışmasını olumsuz yönde etkilemektedir. Bu olumsuzlukların giderilmesi için alternatif çözümler aranmaktadır.

Split klimalarda kullanılan dört yollu vana ile hidrolik sistemlerde kullanılan popet tip valfin çalışma prensipleri aynıdır. Dört yollu vana ile popet tip hidrolik valfin arasındaki fark kullanıldığı yerler ve çalışma akışkanlarıdır. Bu tezde dört yollu vananın problemlerini göz önünde bulundurarak alternatif bir çözüm yolu aranmıştır. Dört yollu vananın çalışma yapısına benzeyen dört yollu iki geçişli ve basınç şartlarını sağlayan en uygun vana olarak popet tip hidrolik valf kullanılmıştır.

Yapılan çalışmadaki deney sonuçları, buharlaşma sıcaklığını yükselterek ve peş peşe yoğuşma sıcaklığını artırarak defrost döngüsü esnasında sistem performansında önemli bir iyileşme olduğunu göstermektedir. Donma erimesi, yoğuşma esnasında iklimlendirme cihazından ısı transferinin bir sonucudur. Yoğuşma sıcaklığının artması defrost süresiyle doğrudan olarak ilişkilidir.

Yeni nesil defrost kontrolünün belirlenmesi için daha fazla araştırma yapılmasına ihtiyaç bulunmaktadır. Günümüzde ticari olarak hazır durumda, uygun maliyetli çözümler çok az durumdadır veya mevcut değildir. Devam eden verimli ısı pompası çözümleri arayışında, özellikle soğuk iklimler için olmak üzere, don oluşumunu sınırlandırmak, oluşan donları hızlı bir biçimde azaltmak ve mal-defrost vakalarını önlemek amacıyla mümkün olan en iyi yaklaşım dikkate alınarak yeterli zamanın harcanması kaçınılmazdır.

Anahtar Kelimeler: Donma, Hidrolik Valf, Isı Pompası, Borular.

Bilim Kodu **:** 92808

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LIST OF SYMBOLS AND ABBREVIATIONS

SYMBOLS

CO_2	:	Carbon Dioxide
$Na_2SO_4.10H_2O$	:	Paraffin Wax
$CaCl_2.6H_2O$	:	Calcium Chloride Hexahydrate
Q_C	:	Cooling capacity
Q_H	:	Heating capacity
Q	:	Useful heat supplied
W	:	Work required by the considered system
T_H	:	Thermodynamic temperatures of the hot
T_C	:	Hermodynamic temperatures of the cold
$COP_{heating}$	:	COP for a heating process
$COP_{cooling}$	:	COP for a cooling process
°C	:	Degree in Celsius
°F	:	Degree in Fahrenheit
QL	:	Heat absorbed from the cooling room
$W_{net,in}$	:	The conservation of energy principle for a cyclic device
hr	:	Time in Hour
min	:	Time in Minute
W, kW	:	Watt

ABBREVIATIONS

GHG	:	Greenhouse Gas
FWV	:	Four Way Valve
HE	:	Heat Exchanger
ASHP	:	Air Source Heat Pump
SRCD	:	Standard Reverse Cycle Defrosting

NRCD	:	Novel Reverse Cycle Defrosting
COP	:	Coefficient Of Performance
AC	:	Air Conditioning
DC	:	Direct Current
HVAC	:	Heating, Ventilation, And Air Conditioning
Dali08	:	Data Acquistion And Logging Interface
GSHP	:	ground source heat pump
SCOP	:	Seasonal Coefficient Of Performance
SEER	:	Seasonal Energy Efficiency Ratio
DHBD	:	Dual Hot-Gas Bypass Defrosting
RCD	:	Reverse Cycle Defrosting
HEX	:	Heat Exchanger
IH	:	Induction Heater

PART 1

INTRODUCTION

The biggest human danger and problem in the 21st century is global warming. Atmospheric levels of CO_2 have risen nearly 34% since 1950 [1] and the primary reason is the combustion of fossil fuel. Consequently, the oil industry is blamed for this situation in various industries. Many attempts were taken to solve the challenge of climate change [2]. The EU has planned, for example, to reduce GHG emissions by 20 per cent, to boost energy efficiency by 20 per cent and to increase its share of renewable energy in gross consumption by 20 per cent by 2020 [2].

The world's ultimate demand for electricity is projected to be 50% thermal [3]. Many of the clean energy efforts have already been made to satisfy the need for thermal energy. Renewable heating and cooling was a central part of the climate change action strategy. Heat pumps enter homes and earn more electricity market share. Heat pumps for domestic and room heating usage more than 90 percent of newly designed family houses [4]. Ambient air is the most commonly used by common heat sources with 68 per cent of Europe's market share in 2014 [5].

The explanation may be that such systems are available from a heat source, inexpensive, and quickly mounted. An integrated heating and cooling system can be equipped with a reversible air to air heats pumps. In heating mode, heat is collected from the ambient air of low temperature and delivered to elevated indoor temperatures. In other words, the heat is injected for indoor use. This method invariably involves freezing at outside heat exchangers, particularly if the ambient air is very poor in winter [4].

The need for cooling in summer and for heating in the winter were increasing as a result of global climate change. Because more energy is used in the cooling process, the desired comfort requirements must be met with ecologically sustainable economic solutions. Many researchers were able to draw attention to the secret energy Storage Systems, phase changes systems because they need less volume per unit of stored energy, and many researchers attracted the narrow temperature range that occurs during the phasing heat transfer [3].

In split air conditioning systems, four-way valves are used to assist in the passage of heating and cooling. Many problems such as the difficulty in assembling the four-way valve, slowness of defrost, lack of maintenance and repair, instability to high temperatures and such problems adversely affect the operation of split air conditioners. Alternative solutions are sought in order to overcome these problems [6].

The operating principles of the four-way valve used in split air conditioners and the popet type valve used in hydraulic systems are the same. The difference between the four-way valve and the popet type hydraulic valve is where they are used and working fluids. In this thesis, an alternative solution is sought considering the problems of the four way valve. Popet type hydraulic valve is used as the most suitable valve which provides the pressure conditions and four-way two pass similar to the working structure of the four way valve [7].

The frost decreases the thermal transfer potential of the heat exchanger, which allows the device to lower evaporation temperature and less steam. During operation, the freeze should be removed from the machine at different intervals. This causes a variety of technical problems with the operation of the heat pump, interrupts thermal comfort and undermines the reliability of these systems [4].

The developed frost can be stopped from the heat exchanger by several methods, including self-defrusting [6], electric defrosting, bypassing of hot gas [8], advanced heat exchanger partially defrost circuits, heat pump processing by means of thermal energy storage and a reversed loop. This is the most common approach for industrial heat pumps. This is the most common method. The indoor heat exchanger is a condenser and the heat exchanger is an evaporator during the heating mode of the system. A 4-way valve, which turns the indoor heat exchanger (HE) into a disconnector and the outside condenser HE is used for running the reverse cycle. This approach has some disadvantages such as interrupting thermal comfort and hysteresis of the device [9]. Different strategies are also offered to boost the reversed cycle e.g. by using thermal energy storage to maximise the freeze cycle and to speed up frost melting. Some researchers have numerous approaches to dealing with the frost problem by stopping or slowing its development. HE surfaces can be covered with new materials and hydrophobic or hydrophilic requirements can be given on heat exchanger surfaces. This influences the forming time of the frost and the consistency of formed frost, which may increase the times between the congelations and the length of the congelation cycle. The dehumidification of the intake air before the heat exchanger can even be prevented from freezing. A normal dehumidity unit, a separate evaporator, particularly for dehumidification of air, the special design of flanges etc could be added before the heating exchanger [10].

The broad demand for these devices and their long lasting placement and energy market share is evidenced by the rapid growth of the air to air heat pump market. The machine and performance enhancement have tremendous promise, which will save massive quantities of energy in the long run. The solution or alleviation of the freezing problem will lead not only to this goal, but also to a stable device with longer life [6].

PART 2

LITERATURE REVIEW

2.1. PREVIOUS STUDIES

Thermal energy conservation methods allow the energy usage of heating and cooling systems more effective and efficient, while substantially saving the overall energy costs. This leads to less fossil fuel use and the creation of air conditioning techniques in an environmentally sustainable manner [7,10]. As a consequence of the implementation of thermal energy storage processes [11,12], effective systems can be built by utilising local renewable energy sources. If experiments are investigated on portable coolers using phase shifts, Dietz has established a rectangular heat storage model [13]. Cylindrical storages in the built model are in a certain vertical location. The material for the shift of the process is calcium chloride hexahydrate. The air circulated into the pipes with heat transfer fluid. Accordingly, a basic mathematical model that will provide the thermal efficiency of the device has been developed based upon findings of the experiment during the charging and discharge of the phase change material. The inspection of a thermal storage device developed by Farid and Kanzawa [14] as a body-tube heat exchanger revealed that the pipes had been filled with material for phase-changing and the air flow was given around the pipes through the body. This simulation showed that different phase change materials with different melting temperatures in the same unit would improve unit production. Lacroix [15] investigated a device with a heat exchanger style body tube where the material for phase change is contained in the body and the heat transfer fluid is transferred through the vertical tube. The device was numerically investigated using simulation techniques and laboratory experiments were performed to demonstrate the model's accuracy. The efficiency of a cylindrical tank with a phases-changing material in a solar heat storage device was experimentally tested by Esen and Ayhan [16].

A number of cylinders have been inserted vertically into the tank during this analysis, the cylinders have been filled with materials of phase shifting, and the heat transfer fluid has been flowed parallel. The phase-changing compounds is CaCl 2.6H2O, Calcium Chloride hexahydrate, Paraffin Wax (Na_2SO4.10H2O) and Paraffin. A numeric enthalpy technique was used to calculate the flow and intake temperature of the various heat transfer liquids and the adjustment of the melting behaviour for each substance.

Turnpenny et al. [17,18] have been working on a unit that has a heat pipe inserted in the material for phase transition. This machine has been used to ventilate and cool houses. The thermal energy storage device has been numerically tested by Vakilaltojjar and Saman [19]. A horizontal rectangular portion and a phase shift content consisting of some layers is given for the storage container. The fluid (ambient air) of heat transfer was circulating through the layer gaps. Taking in account the influence of natural transport on the mathematical model, the method of enthalpy and the finite differential method were employed. The results on heat transfer rate and melting time of thermal performance such as air inlet and airflow are demonstrated. In Mozhevelov's study [20], a mobile room in a real room, in a mobile cooler 3D, time-based simulations of the various types of the cooling elements in the body (vertical plates, horizontal plates, horizontal square section pipes in properly ordered and surprising sequenced settlements). Mozhevelov et al. [21] also experimented with vertical thin warehouse units parallel to a space wall. During the day the present heat was drained from the space and the substance was melted by natural convection. In the evening, heat was thrown from the unit and the phase shift content transformed with natural and induced convection. Arye and Guedj [22] experimented with a heat exchange unit style body tubing, with pipes in a vertical location filled with material for phase transition. Space air was pushed into the body with fans by forcing convection. If the substance of the phase varies, paraffin melts at 22-24 °C during the day and at about 18-19 °C at night. The atmospheric temperature was 30 to 35 °C during the day. The material shifts during the day and solidifies during the night, maintaining thermal comfort in the room. Kozak et al. [23] performed computational and experimental experiments on a hybrid heat exchanger composed of material and air for phase transition. In the numerical model developed, the enthalpy method was used. There is a certain harmony between the numerical and test results. We also performed a computational analysis by Letan and Ziskind [24] on the thermal nature of a portable coolant for transition. The analytical solution of the cooler phase shift substance used in the heat exchanger body tube was developed by Dubovsky et al. [25]. The refrigerant model was taken into consideration, but different material for phase shift was used.

If an air source heat pump (ASHP) unit is used to heat the room at low temperatures in winter, frost can be framed on the surface of its open-air loop. In a few months, the frost collection on the loop surface may become sufficient to reduce the air input through the curl and increase the heat movement opposition between the round air and curling surface, contributing to the open air loop output corruption or even the shutdown of the ASHP machine. Intermittent defrosting is important in this way. Today, cycle demolition is the most commonly used traditional demolition technique for an ASHP unit. The indoor loop in an ASHP device really acts as an evaporator during a normal cycle-deployment (SRCD) operation. Since indoor fans are usually killed during defrosting, the vitality of the indoor loop is inconsequential and various operational problems occur. For instance, an expanded defrosting range and the possibility of a lower air temperature inside a heated space during defrosting etc. A new NRCD (cycles frosting) technique, which is based on a warm energy storage strategy using refrigerant's sub-cooling vitality for ASHPs, has been developed to tackle the fundamental problem of inadequate heat accessible during frost removal while at the same time maintaining an efficient and healthy framework operation. An enlarged defrost spectrum and the likelihood of a lower air temperature during defrosting, etc for example. In order to tackle the fundamental problem of the insufficient heat that is accessible during the removal of freeze, while preserving an effective and stable frame function, a new technique of NRCD (cycle frosting) based on a warm energy storage approach using coolant subcooling vitality for ASHPs [26].

Because of its essential vitality, ASHPs have been widely used around the world. An ASHP in the form of a higher ability in colder times to satisfy the high heating loads of a building at low exterior temperatures would be equivalent to a standard boiler. It is also necessary to provide an additional heat source and additional heaters (Figure 2.1). However when an ASHP device is operating for space heating, frost may be formed on the open air loopp surface. Curl surfaces freeze collection reduces the loop's capacity, or even allows the ASHP device to be shut down. The most widely used standard frosting technique is turn period defrosting [27].

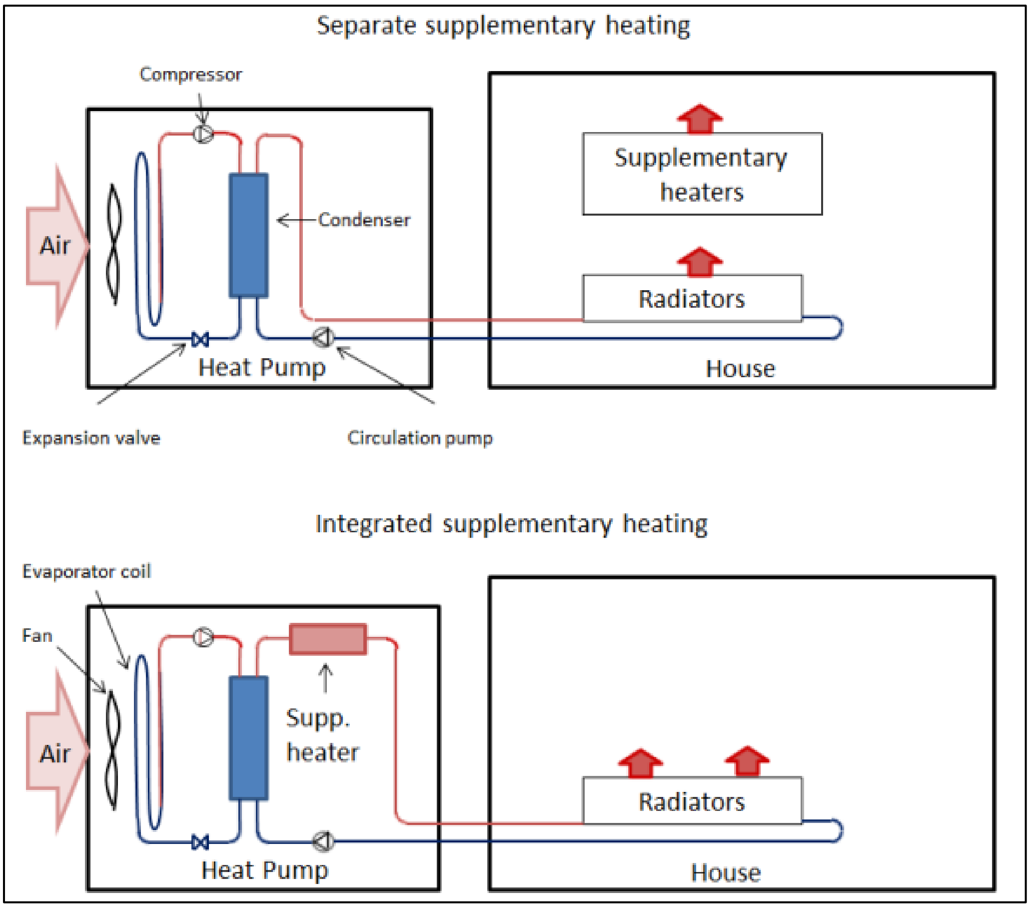

Figure 2.1. Heat pump systems [27].

There are various variables which affect the dynamic attributes of an SRCD operation for an ASHP device. The SRCD activity discovery for ASHPs known from the open source available in comparison with the frosting activity is moderately limited [28]. The analysis revealed that the SRCD practises recognise mainly enhances the operating characteristics of ASHPs or the complex recreation of the system. The transitor defrosting output of 3-ton (or 3.514 kW) private ASHP unit using a thermostat valve was tentatively reviewed by O'Neal et al [29]. The ASHP collector and the TEV were found to have a significant effect on the complex reactions of the system. Furthermore the period displays of an asphp device comprising either a perchment or a reacting blower, as per ANSI/ASHRAE Norm 116-198, have been tentatively discussed and considered [29].

The findings of the investigation indicated that an ASHP device using a scroll blower had obtained a marginally higher cyclic execution coefficient (COP) and a lower release temperature overheated during frosting and defrosting. In addition, more comprehensive experiments were performed with a view to reducing congestion and vitality disasters. For example, O'Neal et al. considered extending the calculation to include an improvement in deconfrosting period (Figure 2.2), and Huang et al [30] found that the releasing pressures in a fan pre-start fan device were 742. kPa below that of traditional fan starting technology towards completion of an SRCD operation. Dynamic ASHP re-enactments were also held and promoted during the SRCD case (Figure 2.3) [31].

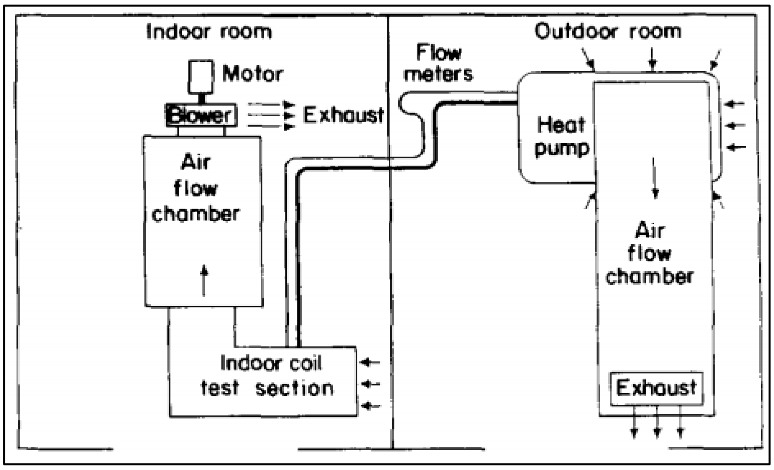

Figure 2.2. Placement of the test heat pump in the psychometric rooms [30].

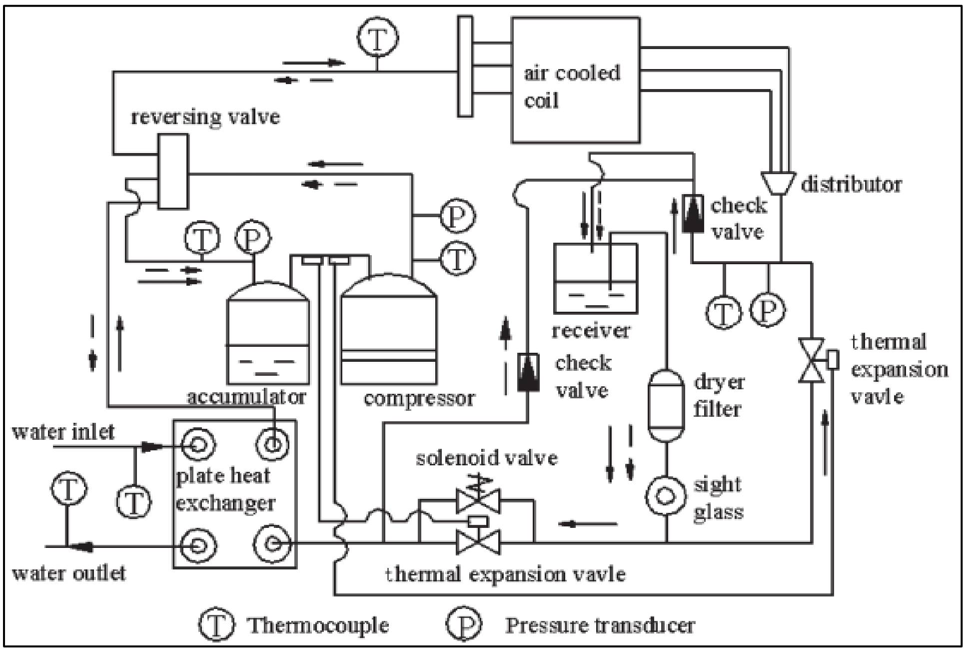

Figure 2.3. Schematic diagram of a SRCD activity [31].

In addition, fluid suction line heat exchangers are usually used in customary cold frameworks in order to enhance work effectiveness and to guarantee the safe frame operation. A fluid heat exchanger suction line cools a condenser outlet fluid refrigerant by transferring the reasonable heat into a refrigerant at the evaporator exit (or blower gulf). Right now the framework execution can be developed, the possibility of fluid coolant gleaming can be decreased before a production gadget is arrive, and any residual fluid coolant that exists in the liquid suction that precedes the blower can be fully dissipated [32].

The COP of a heat pump was 12 percent higher in an ice storage sub-cooler than the COP of the ice storage sub-cooler in charge mode and the COP was 15% higher in release mode, as shown by Hsiao et al. [33] (Figure 2.4). The results of weight drops by the fluid heat exchanging line on framework execution were broken down by Klein et al. [34]. Moreover some new knowledge about coolant sub-cooling methods has been disclosed. Khan and Zubair [35] have created a technique for undercooling refrigerants that can be subcooled by a way of preserving a strategic distance from overheating refrigerants at the blower gulf before arriving at the extension unit. Furthermore, a further study has been carried out using heat pipe heat exchangers or warm batteries as sub-coolers (Figure 2.5) [36].

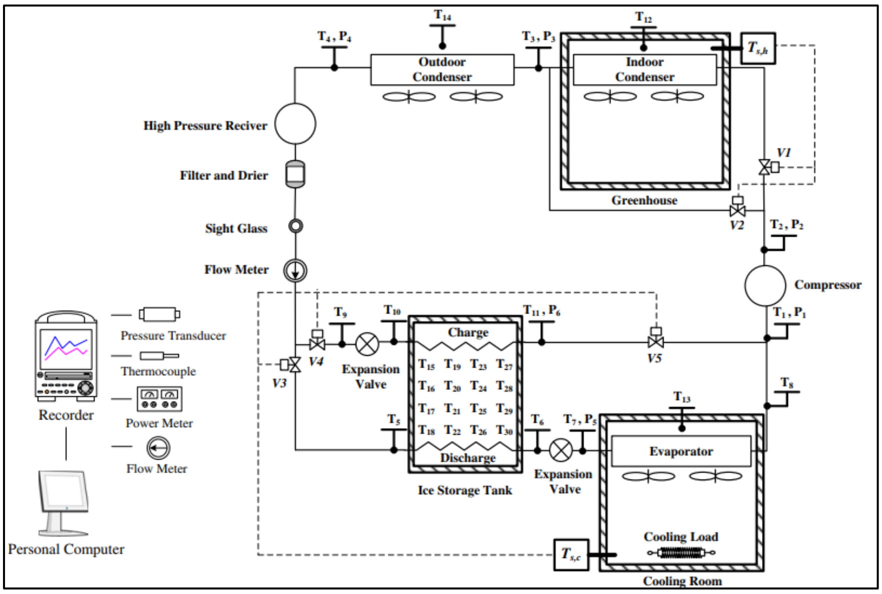

Figure 2.4. Heat pump system with ice storage subcooled and measurement apparatus [33].

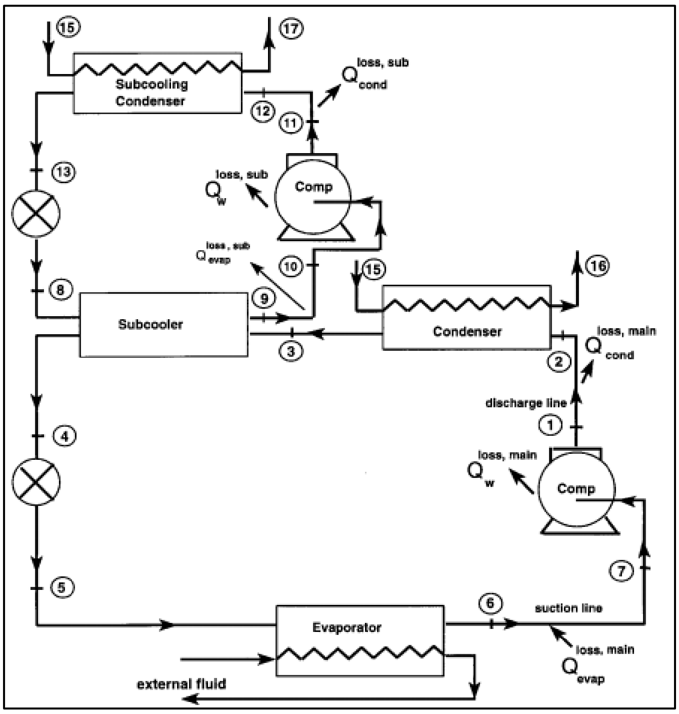

Figure 2.5. Schematic diagram of a dedicated mechanical-subsoiling refrigeration system [36].

2.2. MATHEMATICAL STUDY

The heat pump, refrigerator or air conditioning system output or COP (sometimes a CP/COP) coefficient is a reasonable heating or cooling ratio to the necessary work [37]. Increased Police are tantamount to reduced running costs. In heat pumps, the COP is normally above 1 since it pumps additional heat from a heat source to anywhere heat is needed instead of merely turning work into heat (which would be 100 per cent efficient). COP estimates should include electricity consumption of all energy-intensive auxiliaries for complete structures. The COP is very dependent on working conditions, in particular absolute temperature and relative temperatures of the device and device. The absorption refrigerator chillers usually have much lower efficiency, because they do not use compressed heat pumps but rely instead on heat-driven chemical reactions [38].

The equation is:

$$COP = \frac{Q}{W} \tag{2.1}$$

Where

Q is the usable heat that the device supplies or eliminates.
W is the role that the device in question requires.

The heating and cooling COP is also different since the interest heat reservoir is different. The COP is the ratio of the heat taken from the cold tank to the induction work when one is involved in how much a system cools. For heating, therefore the COP is the ratio of heat from the cold reservoir and the input work is provided by:

$$COP_{\text{heating}} = \frac{|Q_H|}{W} = \frac{|Q_C| + W}{W} \tag{2.2}$$

$$COP_{cooling} = \frac{|Q_C|}{W} \tag{2.3}$$

Where

Q_C is the cold storage heat extracted.
Q_H is the hot reservoir is provided with heat.

We will demonstrate this in a reversible device in line with the first law of thermodynamics:

$$Q_H = Q_C + W \tag{2.4}$$

and

$$W = Q_H - Q_C \tag{2.5}$$

Where

Q_H is the heat transferred to the hot reservoir
Q_C is the heat collected from the cold reservoir.
Therefore, by substituting for W,

$$COP_{heating} = \frac{Q_H}{Q_H - Q_C} \tag{2.6}$$

It can be seen that for a heat pump with optimum theoretical efficiency (i.e. carnot efficiency):

$$\frac{Q_H}{T_H} = \frac{Q_C}{T_C} \text{ and } Q_C = \frac{Q_H\, T_C}{T_H} \tag{2.7}$$

In which T_H and T_C are heat and heat reservoir thermodynamic temperatures.

At the most effective theoretical level,

$$COP_{heating} = \frac{T_H}{T_H - T_C} \tag{2.8}$$

This is the same as the desired reciprocal efficiency of a heat engine, as a heat pump is a reverse heat engine.

Remember that a heat pump COP is subject to its responsibilities. The heat that is refused in the hot sink is lower than the heat consumed in the cold spring, so that the heating COP is 1 more than the heating COP [38].

Similarly, a potentially full working refrigerator or air conditioner Officer,

$$COP_{cooling} = \frac{Q_C}{Q_H - Q_C} = \frac{T_C}{T_H - T_C} \tag{2.9}$$

Heat pump $COP_{heating}$ and air conditioners and coolers apply $COP_{cooling}$. Values are often smaller than such potential maximums for real structures. In Europe, normal ground heat pump measurements are conducted at T_H at 35 °C (95°F) and T_C at T_H at 0 °C (32 °F). The highest probable COP will be 8.8, according to the above formula. The best systems evaluation scores are about 4.5. When units are assessed during the season and the energy used to pump water into piping systems is taken into account, seasonal COPs are about 3.5 or lower. This shows space for change. The AC COP is derived using a 20° C (68°F) dry bulb tempering for T_H and 7° C (44.6°C) for T_C [39]. The COP is derived from the AC COP.

As already explained, a refrigerator's efficiency is represented by output coefficients (COP). In a refrigerator, heat (QL) is absorbed from the cooling room. In order to achieve this goal, a Wnet job feedback is necessary. The COP can then be expressed as the refrigerator [40]:

$$COP_{refrigerator} = \frac{desired\ ouput}{required\ input} = \quad Q_{LW}(net, in) \tag{2.10}$$

The conservation of energy principle for a cyclic device requires that:

$$W(net, in) = QH - QL \text{ (kJ)} \tag{2.11}$$

Then the COP relation becomes:

$$COP_{refrigerator} = QL/\ (QH - QL) = 1/QH/QL - 1 \tag{2.12}$$

Note that the COP_R value could be higher than unity.

The heat pump is also an instrument that converts heat from a medium of low temperature to a high temperature. Heat pumps and refrigerators work in the same round, but their aims vary. However the function of a heat pump is to hold a high temperature heated environment. This is achieved by absorption of heat from a low temperature source, such as water or cold outside air in winter, which is transmitted to a house such as a high temperature medium.

The efficiency calculation of the heat pump is also represented in the $COP_{Heat\ Pump}$ performance coefficient, as:

$$COP_{Heat\ Pump} = (desired\ ouput)/(required\ input) = Q_{HW}\ (net, in) \tag{2.13}$$

This can also be expressed as:

$$COP_{Heat\ Pump} = QH/\ (QH - QL) = 1/(1 - QL/QH) \tag{2.14}$$

Comparing previous equation reveals that:

$$COP_{Heat\ Pump} = COP_{refrigerator} + 1 \quad (2.14)$$

This relationship means that the heat pump's efficiency coefficient is always higher than unity, as COP_R is a positive quantity.

PART 3

THEORETICAL STUDIES

3.1. VAPOR COMPRESSION CYCLE

The vapor compression cycle (Figure 1.3) is the most widely used thermodynamic cycle in refrigeration machines, air conditioning devices and heat pumps. In this chapter, we will examine this cycle [41].

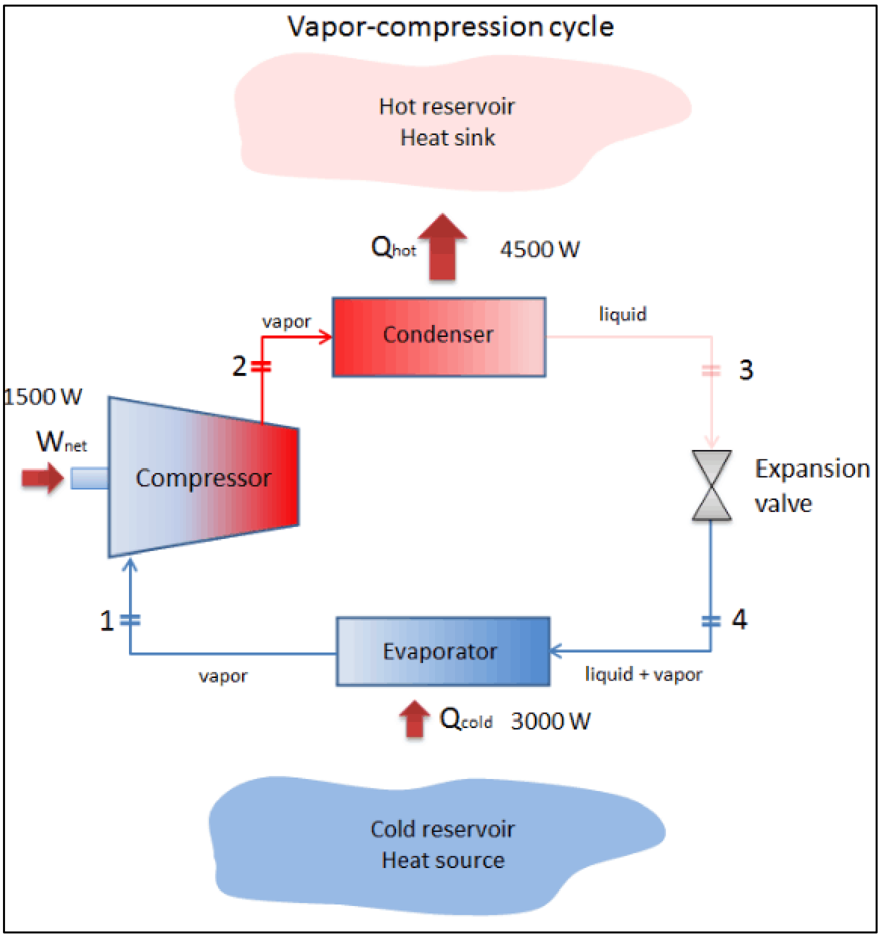

Figure 3.1. The vapor compression cycle [42].

The vapor compression cooling process began in 1834 when British Jakop Perkins patented a closed-loop ice machine, using a number of volatile fluids such as ether as refrigerant. Although a prototype of this ice machine was made, it was never started commercially.

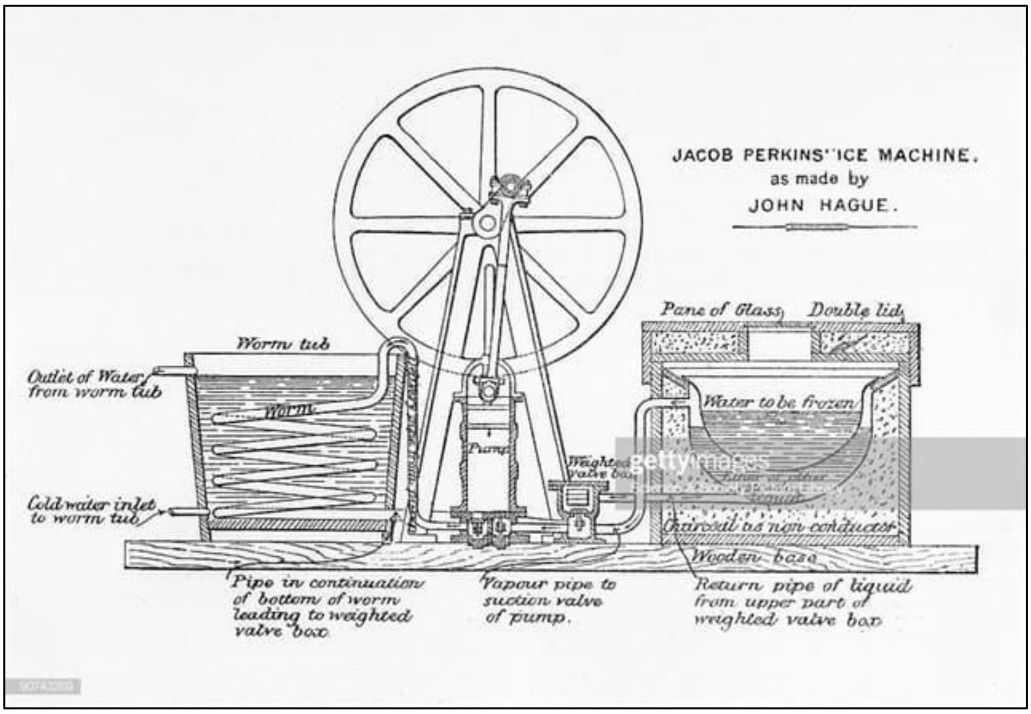

Figure 3.2. Jakop Perkins's ice machine [43].

In 1850, Alexander Twining succeeded in producing a commercial ice machine that operates with the vapor compression refrigeration cycle and uses ethyl ether as the refrigerant. The first machines working with the refrigeration cycle were small, often used in ice making, soft drink and cold storage. Steam machines provided the operation of these systems, which did not have any automatic control [37].

In the 1890s, smaller cooling machines as auto-controlled size replaced the old ones and entered the houses and butchers. By 1930, the machines working with the cooling cycle started to be produced as efficient, reliable, small and extreme.

The cooling cycle is the general cycle of cooling machines. In other words, the purpose of this cycle is to draw the heat from the environment to be cooled and transfer it to the high temperature region. This process is done with refrigerants with low evaporation temperature.

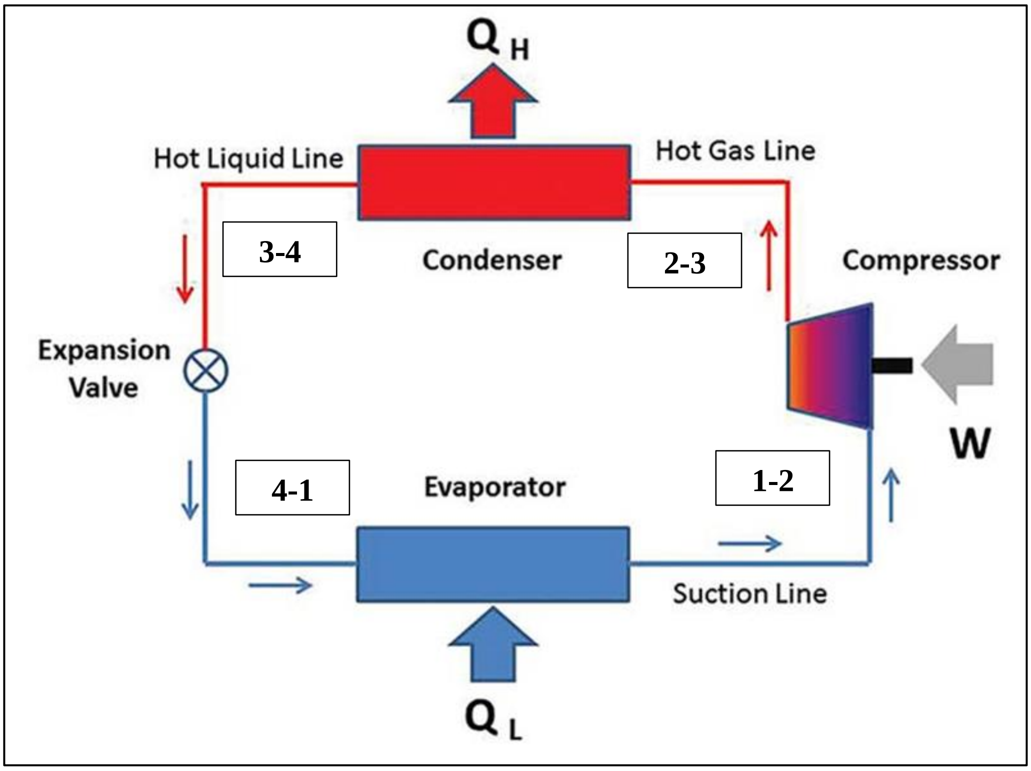

Figure 3.3. Cooling cycle chart [37].

The ideal refrigeration cycle consists of four basic components: condenser, evaporator, throttle valve and compressor. A refrigerant is used in the system. The cycle basically consists of 4 state changes, (Figure 3.3) [37]:

- 1-2: Isentropic compression in the compressor
- 2-3: Transfer of the heat of the fluid from the condenser to the environment
- 3-4: Shrinkage in the expansion valve
- 4-1: Heat in the evaporator under constant pressure

The refrigerant enters the compressor completely in the form of steam, i.e., saturated steam in part 1 and is compressed to the condensing pressure isentropic ally (constant entropy). The temperature of this compression fluid rises above the ambient temperature. This superheated fluid enters the condenser and is completely converted into a liquid phase. The temperature of the fluid is still higher than the ambient temperature at the end of this process.

The refrigerant entering the throttle valve is compressed here to the evaporator pressure and its temperature becomes lower than the cooled medium and turns into a saturated liquid phase. Thus, in accordance with the second law of thermodynamics, the heat of the cooled environment in the evaporator passes to the fluid and cooling process is performed. The completely evaporated refrigerant enters the compressor again and completes the cycle [41].

You can observe almost the same refrigeration cycle in a domestic refrigerator. The pipes you see at the back of the cabinet are the condenser of the system and the evaporator of the system in the pipes inside the cabinet. This is why the pipes behind the refrigerator are also hot.

$T - s(Temperature - Entropy) Graph\ of\ Cooling\ Cycle$:

The Ts enters the temperature entropy indicates heat transfer. In other words, the area under 4-1 state change gives us the heat drawn from the cooled environment, and the area under 2-3 state change gives the amount of heat removed from the condenser.

Refrigeration Cycle Ph (Pressure-Enthalpy) Graph:

- 1-2: Due to isentropic (constant entropy) compression process, the temperature increases and entropy remains constant.
- 2-3: Since the fluid transfers its heat to the environment, entropy and temperature drop occur.
- 3-4: The temperature and entropy of the refrigerant decreases with the shutoff valve.
- 4-1: The temperature of the fluid, which evaporates by taking the heat of the cooled environment, the fixed mold entropy, increased.

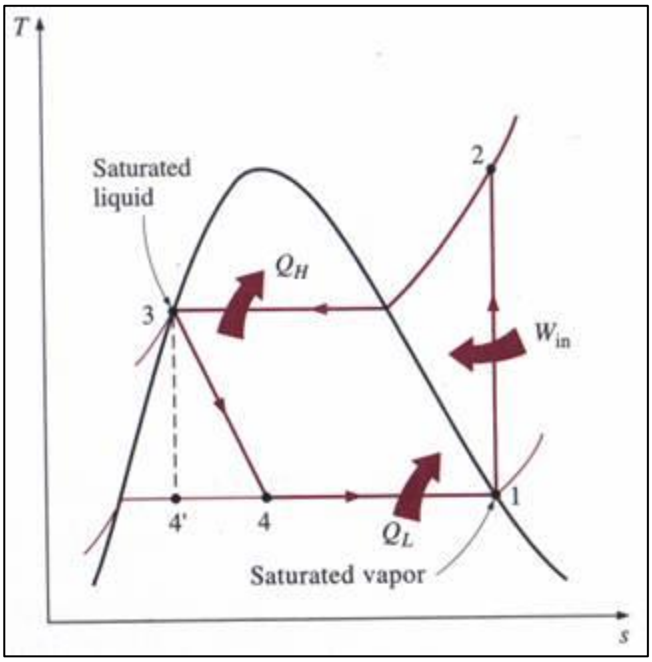

Figure 3.4. Cooling cycle temperature-entropy graph [41].

The the pressure-enthalpy diagram (log P/h diagram). is another diagram used to analyse the vapour compression cooling period. You can see the status of the 4 state changes in the cycle with the diagram (Figure 3.5) [42].

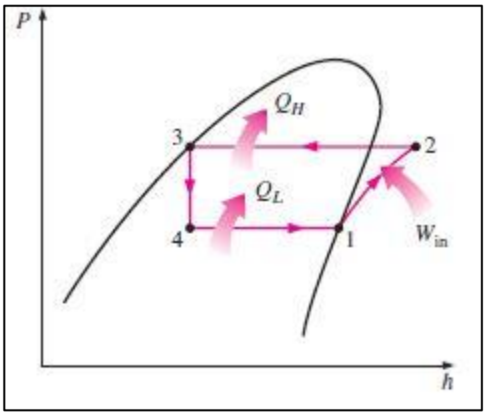

Figure 3.5. Refrigeration cycle pressure-enthalpy chart [42].

- 1-2: Pressure and enthalpy increase due to compression
- 2-3: Since the fluid transfers the heat to the surrounding environment, the pressure constant mold enthalpy is decreased.

- 3-4: The enthalpy of the cooled fluid with the shutoff valve has decreased the fixed mold pressure.
- 4-1: The pressure of the fluid, which evaporates by taking the heat of the cooled medium, fixed mold enthalpy, increased.

The vapor compression refrigeration cycle has enabled many systems and machines to be produced and increased efficiency, such as refrigerators, air conditioners, industrial refrigeration and cold storage tanks, which contribute to humanity. Today, many studies are carried out to increase the efficiency of these machines by using the cooling cycle [42].

The heat exchangers can be classified as follows:

- Classification according to the shape of heat change
- Classification according to the ratio of heat transfer to heat transfer volume (compactness)
- Classification by heat transfer mechanism
- Classification according to construction characteristics
- Classification by flow [41].

3.2. HEAT PUMP SYSTEM

3.2.1. HEAT PUMP SYSTEMS TYPES

Heat pumps are classified according to the external source of heat, and they are a device used to transfer heat energy from a hot source to a thermal tank. It is designed to transfer thermal energy in the opposite direction to automatic heat transfer by absorbing heat from the cold body and transferring it to the hot body. It consumes a small amount of external energy to complete the energy transfer from the hot source to the heat tank. We also explain the types of heat pumps.

3.2.1.1. Air To Air Heat Pump

According to Kim study [8], the Dual Hot-Gas Bypass Defrosting (DHBD) cycle is an efficient defrosting technique compared to the reverse cycle defrosting method (RCD) to remove freezes from an air-to-air heat pump, especially the outside temperature is above 0°C. The reverse cycle defrosting method can remove freeze. However, the DHBD procedure has an inconvenience when the heat pump is working in cold outside conditions below 0°C as the temperature of the cold pump is rapidly decreased and the temperature of the hot gas is low bypass. A combined freezing cycle with DHBD and the accumulator heating system is built to resolve the compressor's low discharge temperature (Figure 3.6). As the accumulator heater, an induction heater (IH) is used. In the case of a medium-size air-to-air heat pump, 16 kW are used in the case of the standard RCD system to equate the combined DHBC-IH method with the 0°C outside temperature. The combined DHBD-IH process maintained higher compressor discharge temperatures and decreased the freezing time by 15 percent compared with the RCD process by continuously operating the internal heating. The DHBD-IH cycle, including the defrosting mode, had a total heating capacity of 2.5 kW higher than the RCD cycle.

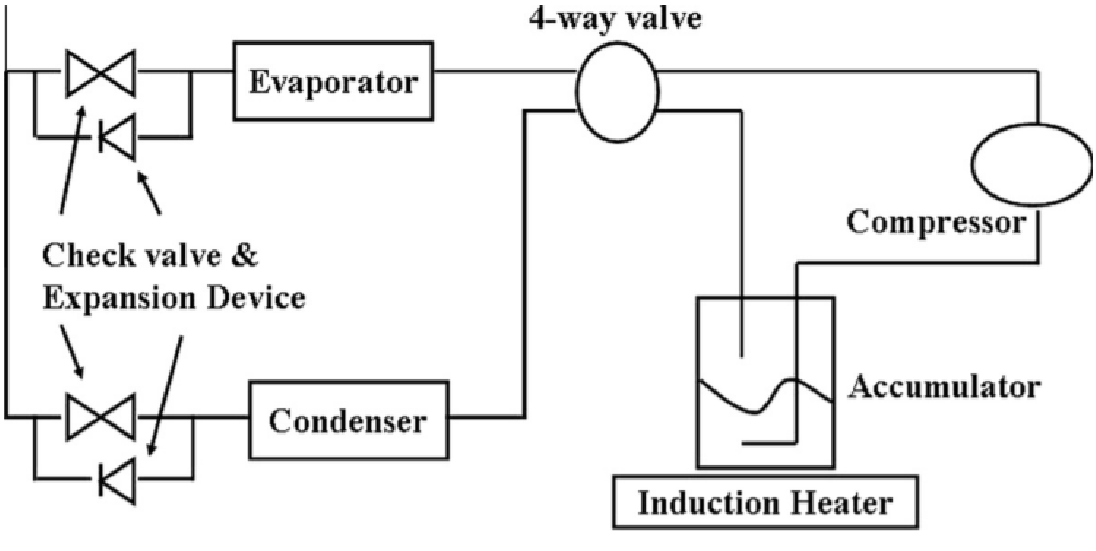

Figure 3.6. Schematic of accumulator heating cycle with the induction heater [8].

3.2.1.2. Air to Water Heat Pump

For the seasonal efficiency measurements for various types of electrical air to water heat pumps, Dongellini [44] proposed a numerical model. This model was based on the method suggested for calculating seasonal perforations of heat pump (SCOP), the cooling season (seer), and the domestic hot water output guidelines, as set forth by the European standard EN 14825 and the Italian standards UNI/TS 11300-4. The developed model uses a bin-method to take into account the variance of outside conditions (Figure 3.7). The paper suggests various processes for the evaluation of the seasonal efficiency of air-to-water heat pumps for monocompressor, multicompressor and variable speed compressors. The numerical results show the effect of the efficient operating mode of the thermal pumps on the SCOP value and show the impact of the design regulations upon these devices' saisonary energy consumption.

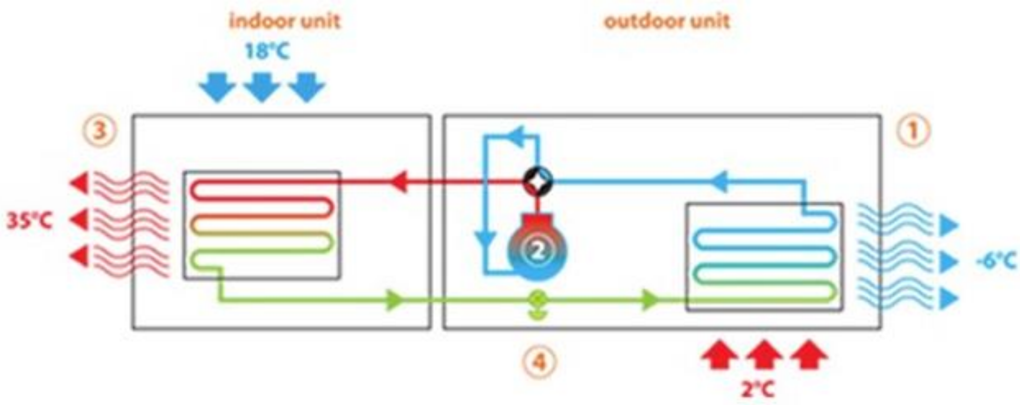

Figure 3.7. Electric air-to-water heat pumps [44].

3.2.1.3. Water to Water Heat Pump

The Hervas-Blasco [45] work shows experimental results from a new heat pump water-to-water composed by the fundamental heat pump components (condenser, compressor, evaporating mechanism, expansion valve and liquid reliever) (Figure 3.8). As an experimental application for testing this heat pump, domestic hot water output from waste water heat recovery has been selected. The result indicates COP values up to 5.5 at the design condition and an optimum degree of subcooling of 47 K (20–15 °C at the evaporator inlet outlet and 10–60 °C at the condenser inlet outlet).

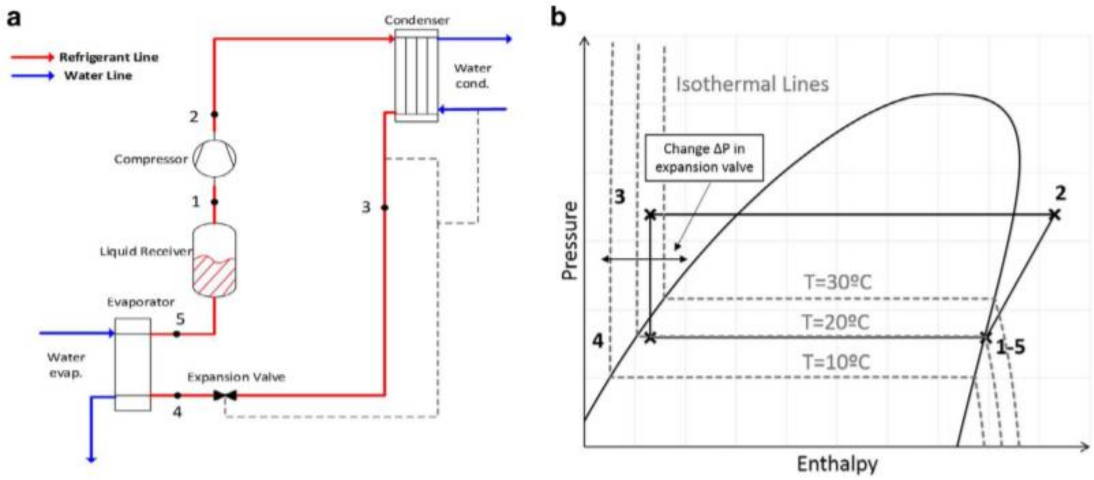

Figure 3.8. 0K1V configuration a) System lay-out, b) Refrigerant cycle [45].

3.2.1.4. Ground to Water Heat Pump

A comprehensive literature review of the GSHP systems and its recent developments is given in the Sarbu and Sebarchievici papers [46]. The most popular simulation and thermal response test models currently available for the vertical ground heat pump, include the heat transfer processes outside and inside the boreholes (Figure 3.9). The use of GSHP technology is seen in cold and warm weather regions and there is considerable energy efficiency (Figure 3.10).

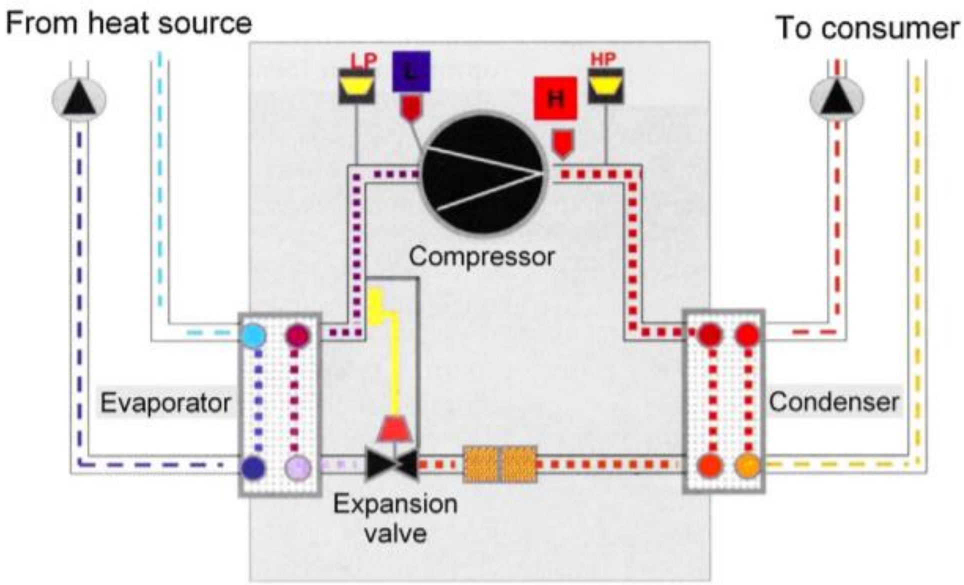

Figure 3.9. Principle diagram of a ground heat pump [46].

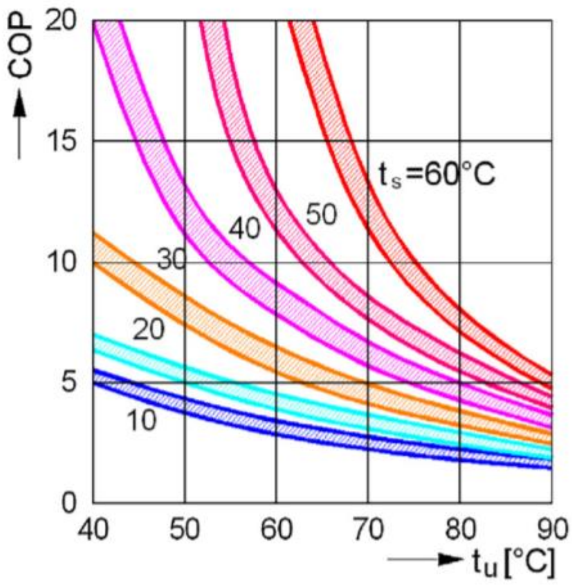

Figure 3.10. Efficiency variation of ground heat pumps [46].

3.2.2. Air Source Heat Pumps

The characteristic of heat pumps that follow sustainability requirements is gaining more and more interest. They transfer heat from the cold to the colder side of the body and calculate this heat as green energy. Floods, reservoirs and sea water or outdoor air may be used for cooking. ASHP air heater pumps have been very popular among the various forms of heat pumps due to their simple installation, cost efficiency and efficient operation [47].

As seen previously, ASHP uses the vapour pressure cycle. Residential units of ASHP contain two units, one external and the other internal.

The other unit is thus the interior. The inner device consists of a coil that operates according to the method of operation as an evaporator or condenser. The outside unit is wide in scale where the majority of the steam cycle parts, such as the compressor, the four-way valve, the expansion van and the heat exchanger are mounted. Indoor heating machine.

The heat exchanger in the indoor machine functions as an evaporator while the ASHP acts as an air conditioner on the one side. This extracts heat from the inside and other warmers installed in the outside device and rejects the heat derived from external sources. In the other hand, the heat exchanger serves as a heat pump while ASHP is used to reject the absorbed heat from the outside. The condenser is used. This is due to the outdoor heat exchanger [48].

These heat pumps take the energy required for heating from the air to the system inside the building. Air source heat pumps are the easiest systems to install. Air source heat pumps are manufactured in two different models.

3.2.2.1. Monoblock Air Source Heat Pumps

They are heat pump devices consisting of a single piece. In these types of devices, there is no unit of heat pump n the building; all parts are gathered in a single unit outside. The installation system must be suitable for such use in the installation of nonblack heat pumps (Figure 3.11).

Figure 3.11. Monoblock air source heating heat pump [49].

Monoblock heat pumps are used for gas, etc. after installation. They do not require adjustment. In heat pumps, hydraulic indoor units installed according to the structure of the system. However, there is no gas connection between the indoor unit and the outdoor unit.

3.2.2.2. Discrete Type (Split) Air Source Heat Pumps

They are heat pump devices consisting of two parts. Discrete type heat pumps have an outdoor unit and an indoor unit. Copper pipe connection s made between the indoor unit and the outdoor unit. Service and material costs are also pad for copper pipes. It is more difficult to install than the monoblock heat pump (Figure 3.12).

Figure 3.12. Discrete type heat pumps [50].

It is impossible to talk about a fixed COP value in air source heat pumps because the temperature of the air, which is the source of the energy, is constantly variable. COP values written in the catalog values of air source heat pumps are the values obtained under certain laboratory conditions. Tests are for + 7 or + 2 outdoor temperature and + 35 °C leaving water. For studies above + 35 °C, the COP value will be lower than the catalog values. The desired comfort can be achieved with suitable designed underfloor heating and wall heating systems with + 35 °C leaving water.

High efficiency heat pump systems in suitable climates:

Air source heat pump usage areas (Designed according to maximum 55 °C) [51]:

- House / Apartment
- Space heating and cooling.
- Hotel heating and cooling.
- Heating and cooling of the apartment.
- Heating the detached house.
- Pool Heating and cooling.
- Heating of bath and domestic hot water.
- Hotel hot water systems Greenhouse heating
- Heating animal shelters.

3.2.2.3. Air Conditioner Parts

Refrigerant:

Coolant is a particular fluid that is important for refrigeration and freezing. It functions on a closed loop, and heats you from the inside to the outside of your house. You can speak of the coolant as the courier. We use coolant as it switches conditions from liquid to vapor for the cooling process at suitable temperatures.

Coolant flows into the cooling tubing and copper coils of an air conditioner linking the inner device to the external panel. It extracts heat from the indoor climate, converting gas to liquid conditions. The refrigerant then transfers into the exterior tank, where the heat is forced outside, until it is drained from within.

If the coolant disperses the heat outside it returns to its gaseous state and returns to its interior. The revolutionary fan blasts air over the cold coils after it gets cool again and then pushes fresh air across the room. Will when the air conditioner is running, this loop continues [51]:

Compressor:

Pressurizing the coolant and increasing the temperature is the function of the compressor. Because of combined gas law that states the temperature decreases as the refrigerant becomes squeezed, it can heat up if the demand rises. It achieves so by firmly pressing the air.

In order to increase the temperature above outside air, we heat the refrigerant. The coolant must be hotter than the outside because it flows naturally from the hotter to the colder, to provide heat outdoors. Therefore, to raise their pressure and thus their temperature, we need the compressor [28].

Condenser Coil:

In the outdoor air conditioning device, the condenser coil is installed. The high-pressure coolant is collected from the compressor at an elevated temperature. The inverse of the evaporator spindle may be thought of. Although cool refrigerant in evaporator containers, heavy refrigerant in condenser cups.

The condenser coils have been designed to allow heat transfer to the outside air feasible. With the aid of the condenser fan, the refrigerant releases heat energy and blows air across the spindles. As the temperature leaves the refrigerant to the outside, a fluid flows back to the diluting valve, which depressors and cools the refrigerant [52].

Expansion Valve:

Once the condenser is withdrawn from the coolant, heat is scattered; nevertheless, it is too warm for the evaporator coils. The coolant must be cooled down before moving to the evaporator coils. In this scenario, a thermostatic expansion valve (also regarded as a measurement device) is added.

Using the rules of the Combination Gas Act, the expansion valve depressors the refrigerant and cools it back as the heat falls in its own temperature. The expansion valve releases friction from the liquid coolant that enables the coolant to turn from a fluid to a steam / gas in the evaporator. It also controls the amount of refrigerant/voltage flow entering the evaporator [53].

Evaporator Coil:

For air conditioners, evaporator spindles are quite necessary. It is where the electricity inside the house is stored by the air conditioner. The expansion valve with a depressed liquid refrigerant provides the copper tubes. The heat inside the house becomes drained as the warm air flows through the cool spindles. The second rule of thermodynamics suggests heat moves spontaneously from warm to cool.

Much like the condenser rollers require the assistance of the condenser fan, the evaporator rolls rely on the indoor air handler's ventilator to blast air over the rolls. With the coolant receiving heat from the indoor climate, it continues to evaporate into steam [54].

3.2.2.4 Air Conditioner Gas

Refrigerant fluids, which are used as an intermediate in transferring a heated air to another environment in a heated environment in a cooling cycle, generally provide heat exchange by converting from liquid state to vapor and vapor from liquid state. Materials that absorb heat during evaporation are called refrigerants. In other words, what is air conditioning gas? The most correct answer to the question is the substances that carry the heat inside out or to another refrigerant [53].

With the discovery of new chemical compounds, air conditioning gas has been carefully evaluated the advantages and disadvantages of all refrigerants in use. At the end of this, new refrigerants emerged. These refrigerants are known as environmentally friendly (ozone friendly) gases such as R-410A, R-407C, which have very little damage to the ozone layer.

Air Conditioning Gases Today, with the increase of environmental awareness, the use of ozone friendly gases is becoming widespread. In parallel, important decisions have been taken all over the world and legal measures have also been taken. As of 2010, no new cooling equipment requiring the production of the new R-22 A / C gas refrigerant will be produced. However, R-22 refrigerant production will be reduced until 2020 in order to meet service maintenance needs.

Since R22 gas properties are gases that damage the ozone layer, they have been banned by European Union standards and their production has stopped. As of 2010, this banned R22 air conditioner gas also stopped air conditioning production. The difference between R22 and R410 is not used as R22 air conditioner gas damages the bard layer. R410A air conditioner gas is environmentally friendly gas that does not damage the ozone layer. Import and production of air conditioners produced with R22 refrigerant gas stopped after 2010 [55].

3.2.2.5. Inverter Valve

The technology of inverter (DC) is the latest technical advancement about compressor electric motors. The compressor motor is operated by an inverter, which regulates the temperature continually. DC inverters have an electrical inverter adjustable for control of electric motor rpm, which means the compressor and cooling/heating output [56]. The electric inverters can be powered by an electric inverter.

The drive transforms the incoming AC current into DC and then creates the current of desired frequency with a modulation in an electrical inverter. Any ambient air temperature can be sampled with a microcontroller to adjust the compressor rpm. Contracting performance of conventional air conditioners, longer life cycles for their modules and extreme load shifts are avoided by the reversible air conditioning systems. This quieters the AC inverter modules, decreases running costs and reduces breakdown. The AC inverter systems can be costlier than constant air conditioners, although this can be compensated by lower energy costs. The reimbursement time depends on your use for about two years.

An inverter valve is a valve type and a thermo pump part that changes coolant flow path. The heat pump cooling cycle has shifted from cooling to heating, or vice versa by reversing coolant flow. This makes a single piece of equipment, using the same means, and using the same hardware, to heat and cool a household or a facility [56].

Two states include the Inverter valve, relaxed from energised (inactivated). Usually, a 240 volt AC, commonly found in HVAC systems is used to attain the power supply status. The heat pump may be configured by the manufacturer for cooling or for heating in a comfortable state with the inverter valve. The heat transfer from its relaxed state is accomplished when the inversion valve is operated. For example, the heating is produced if the inverter valve is mounted to create cooling when relaxed. Also an inverter valve for heating when comfortable provides refreshment when electricity is supplied.

The Inverters Valve can, by use of a defrost control board, be controlled by the Inverter Valve or may be directly driven by a thermostat (usually from the thermostat terminal "O") depending on the building and use of the heat pump [56].

The manufacturer shall mount inverter valves in the heat pump and if they fail, they should be replaced by the HVAC technician. As the valve is a feature of the enclosed coolant circuit, proper recovery protocols and eventual refilling need to be followed to avoid the refrigerant being lost to the atmosphere.

Advantages of Inverter:

Advantages of inverter can be summarized as follows [56].

- Consumes Less Power: The motor running at low speed saves the electricity bill by 30-50%.
- Quiet AC Units: Since the motors run at a low speed, these are very silent in comparison to our conventional split ACs.
- Cools Faster: Inverter AC unit works more efficiently on startup, reducing the time to cool the room by 30%.

- Less Varying Temperature: The room has less fluctuation of temperature as the ACs aims to maintain the temperature and does not cuts off.
- Works on Low Load: The ACs can work on a Solar panel, as they are low power consuming units. These are better in saving fuel when they are running on generators.
- Safe on Household Wiring: The inverter ACs do not overload making it safe for the rest of household wiring.

Disadvantages of Inverter:

Disadvantages of inverter can be summarized as follows [56]:

- The cost: The initial cost of the ACs are high, anyway after a long run, it will payback by cost cutting on our electricity bills!
- Fewer Technicians: These belong to a new technology system. In case of repair or issue, they will demand skilled or knowledgeable technicians for solving the issues.
- The cost of Internal Parts: Since the ACs maintains the temperature by controlling the speed of the motor, it consists of more movable parts within the AC unit. These parts are costly and many times not available in the companies.
- Its files are corrupted and this is determined when the file is fed to the current and does not respond. When the ends of its files are measured in ohms and no reading is given, the file is damaged and only then, the file is replaced.
- Mechanical malfunction because of the annihilation of its internal mechanical parts and replacing it with a new one if you want to do so or leave it and cancel its file and then the device only cools. It can be a little tricky to remove the dial if the mechanical failure.

3.3. DEFROSTING CYCLE

3.3.1. Frost Formation

To date it has become an inescapable part of ASHP as frost formation in the externer heat exchanger has interfered with ordinary activity, dramatically reduced power, and lowers the length of ASHP. Frost occurs when the evaporation temperature is usually less than zero during the vapour pressure period of the heat pump and less than the external dew point. The less heat pump power is due to the lower evaporator transfer rate, a thermal exchanger for forced airflow fins and tubes [57].

The heat transfer method of the heat exchanger has two major effects on Frost. Next the applied frost coating serves as a heat transfer resistance and reduces the coefficient of heat transfer of the fins. The second and most significant consequence is that the accumulating freeze between the fins obscures the air flow and allows the heat exchanger to decrease high pressure. Airflow and air velocity reduces, which greatly influences the rate of heat transfer of the heat exchanger [58].

3.3.2. Defrost Techniques

To continue to provide adequate and productive fuel, the frost formed on the evaporator must be removed. Several attempts were made to minimise the impact on the activity of heat pumps from frost formation. This can be done in various ways. The defrosting cycle was improved mainly by reducing the number, reducing energy efficiency and reducing thermal comfort. Some researchers tried to use various defrosting strategies without messing with the loop, such as by the complicated heat switch circuit setup. The aim is to postpone froster forming mainly by special surface treatment with another approach. Another strategy is to minimise, for example by use of space between the ends, the effect of the formed frost upon the heat transfer requirements of the heat exchanger and thereby delay the frosting period. The following parts describe several traditional de-icing techniques [6].

3.3.2.1. Electric/Electronic Defrosting

This line of processes vary from the easiest to the simplest, such as using a deicing resistor or merely shutting the device off so that the evaporator will melt. The electrical resistance means that COP 1 provides all the heat required to extract the gel, which is a very inefficient defrosting process. Compared to a modern thermal energy storage solution the consumption of this sort of process. This is an efficient tool, but it requires much resources. The surplus defrosting energy is used to heat the surrounding areas, which ensures that the energy used to cool the room is increased (Figure 3.13).

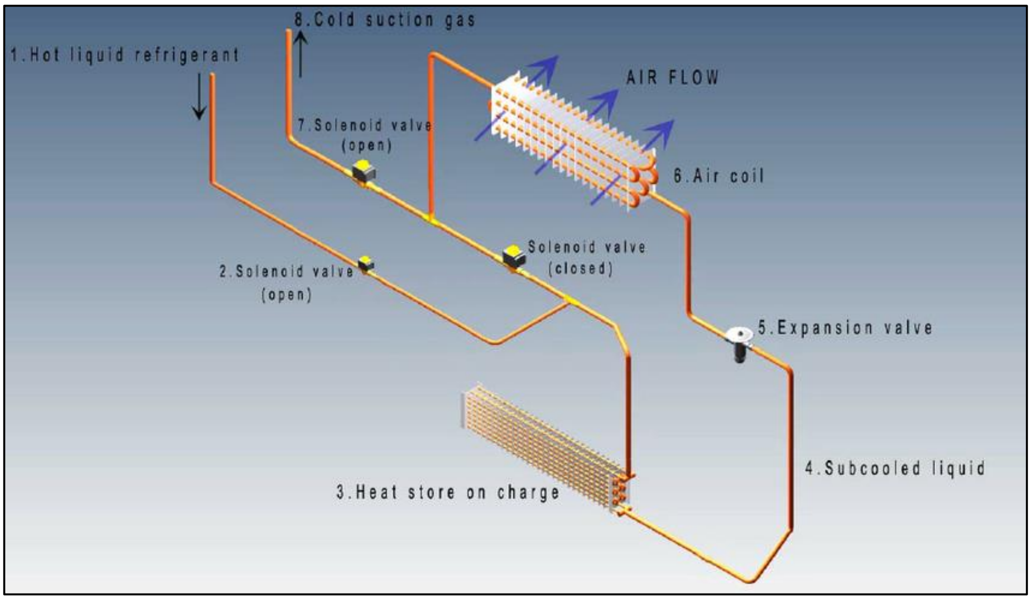

Figure 3.13. Defrosting based on the storage of thermal energy [57].

3.3.2.2. Hot Gas Injection Methods

The cycle is transferred back from the evaporator into the condenser and the external units are one of the most commonly used in cooling and ASHP devices.The condensation temperature permits a molten gel and a fall of the fins. In that time, the unit does not only provide heat to the interior, but the internal heat switch functions as a heat source and consumes heating internally, which disrupts the room's thermal comfort. There is also important energy for defrosting and for restoring intermittent thermal comfort after freezing time [59].

For the normal defrosting process, the different heat sources. The results of this analysis are that 71.8 percent of the energy available for defrostation was generated by indoor air and only 59.6% by melting freeze. Indoor heat disposal also affects the temperature and the comfort of the inside [60].

The hot gas de-icing method is another variant of this technology. This difference is related to the evaporator inlet (Figure 3.14), depending on the lateral passage accompanying the compressor. This process requires a hot gas injection discharged to the evaporator inlet from the compressor. This raises low pressures, thereby preserving uninterrupted cooling ability. In addition, a recent modification to hot gas defrosting consists of two hot gas paths, one known as a hot gas diode, one of which is attached to the exchanger's input, and the second is to the exchanger port. Compare the reverse loop, skip the normal hot gas and the new process. They say that it takes longer for a hot double gas to defrost, but taking into account the recovery period following defrosting, this new process is shorter than the reverse cycle. Furthermore, similar to the other two types, hot gas bypass takes a long time. Finally, the double hot gas bypass system improves the reverse cycle energy efficiency by 13%.

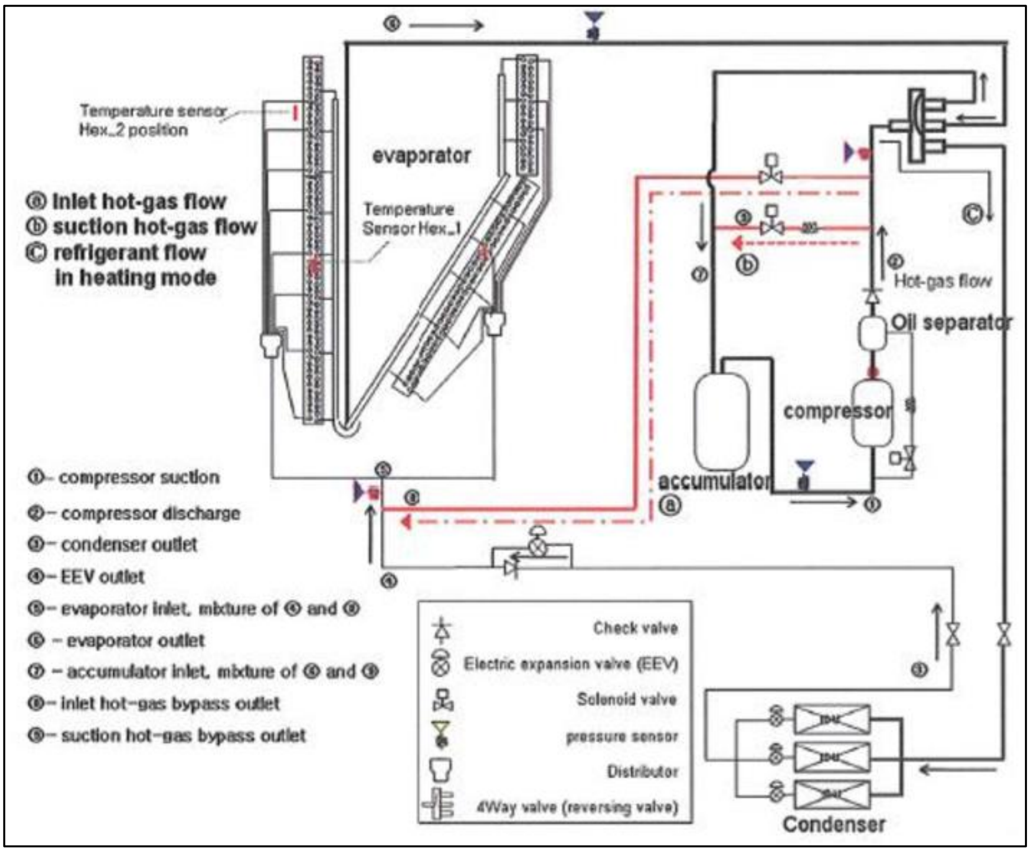

Figure 3.14. The hot gas de-icing process method [60].

3.3.2.3. Advanced Circuiting Systems

This approach is based on three or more heat exchangers in multifunctional systems. The power to switch defrost heat sinks or heat sources. This devices can simultaneously provide refrigeration and heating (Figure 3.15).

He developed a new heat exchanger design that solved the issue of the formation of ice. The heat exchanger is twisted. Since condensation water cannot be stopped, they have been able, without external pumps or valves, to quickly extract water. The heat exchange is located upright and the water is absorbed by gravity. Frost is created in some fashion such that the heat exchanger is split in two sections and defrosting can be achieved at the same time with efficiency due to the proper check of the two valves. The effectiveness of the heat exchange in freezing temperatures exceeds 88 percent. The only odd thing is the scale [61].

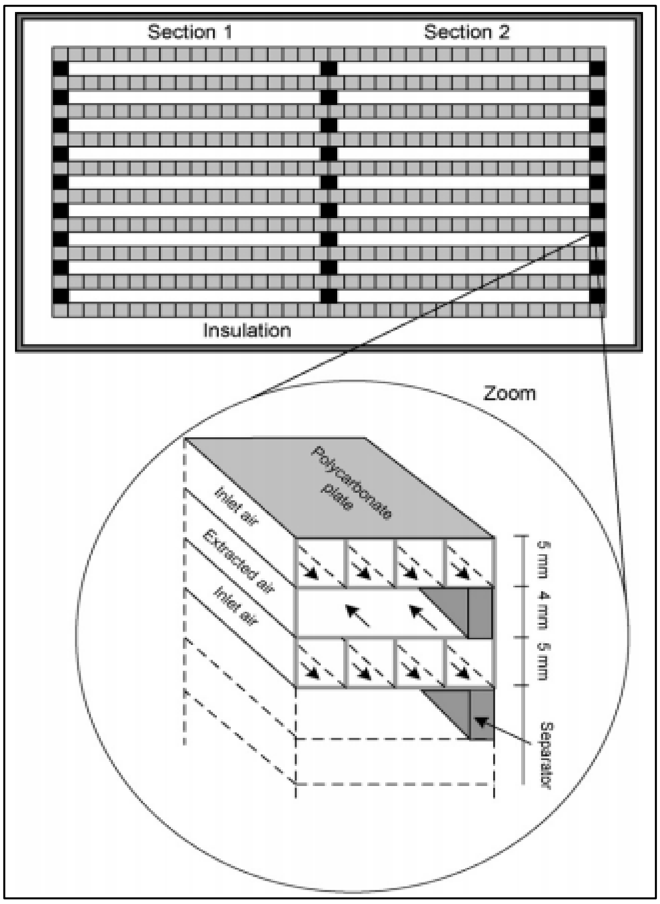

Figure 3.15. An invert heat exchanger [61].

3.3.2.4. Pre-Dry Treatment of Air

The above methods apply to quick defrosting in this chapter. Methods are for freezing thermal pumps in this section. Humidity in the air is the primary cause of frost formation. The air dry until the evaporator enters is one way to prevent moisture.

According to Dai et al. [62], analysis of liquid dryer use in order to avoid the formation of ice. The improved efficiency of this hybrid system that blends best dewetting and vapour pressure. This is because the latent thermal suppression promotes the air's cooling. The main problem with this solution is the size of the course and it is so enormous that a small unit cannot be solved. Similar approach was developed by Wang et al. [63] but a robust dryer was used. Frost is stopped, but when the dryer is saturated and under almost realistic conditions like a reverse cycle from the thermal comfort stage, the regeneration cycle is required (Figure 3.16).

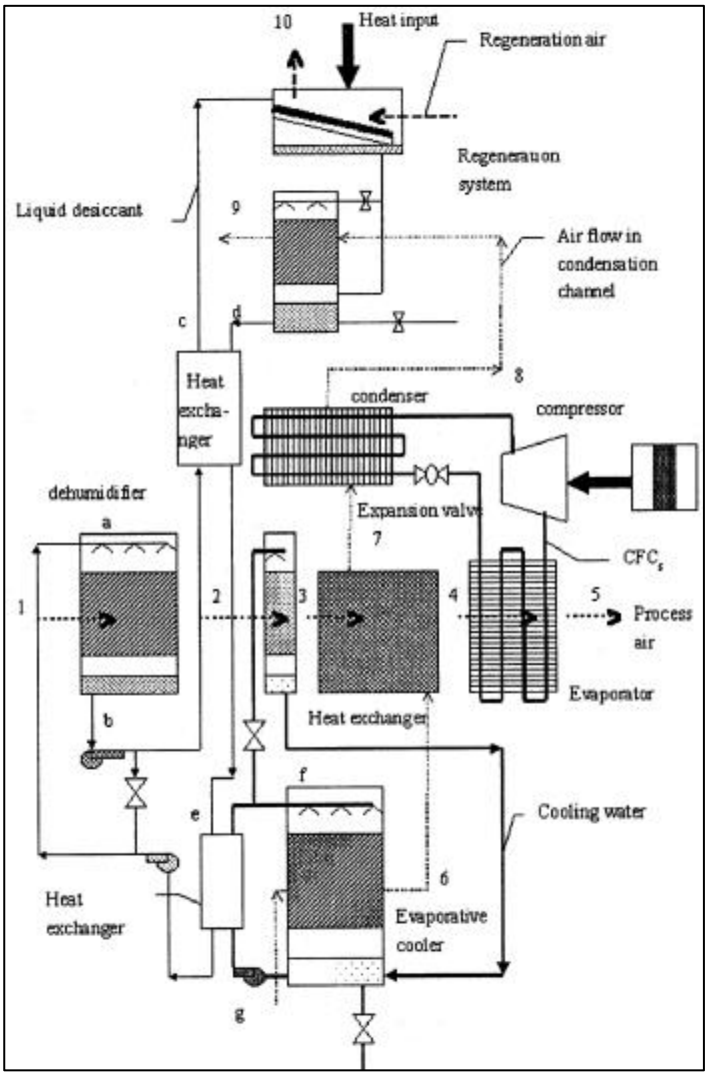

Figure 3.16. The hybrid cooling system [63].

3.3.2.5. Other Defrosting Methods

Other solutions were explored by the science community. Simply categorise these solutions as before. Qu et al. [64] explore the control technique in two separate ways while defrosting the EEV, leaving the EEV completely open and regulating the SH degree. They concluded that regulating the SH degree increases the efficiency of dissolution. Figure 3.17 shows the chematics of the experimental ASHP unit installed in an environmental chamber.

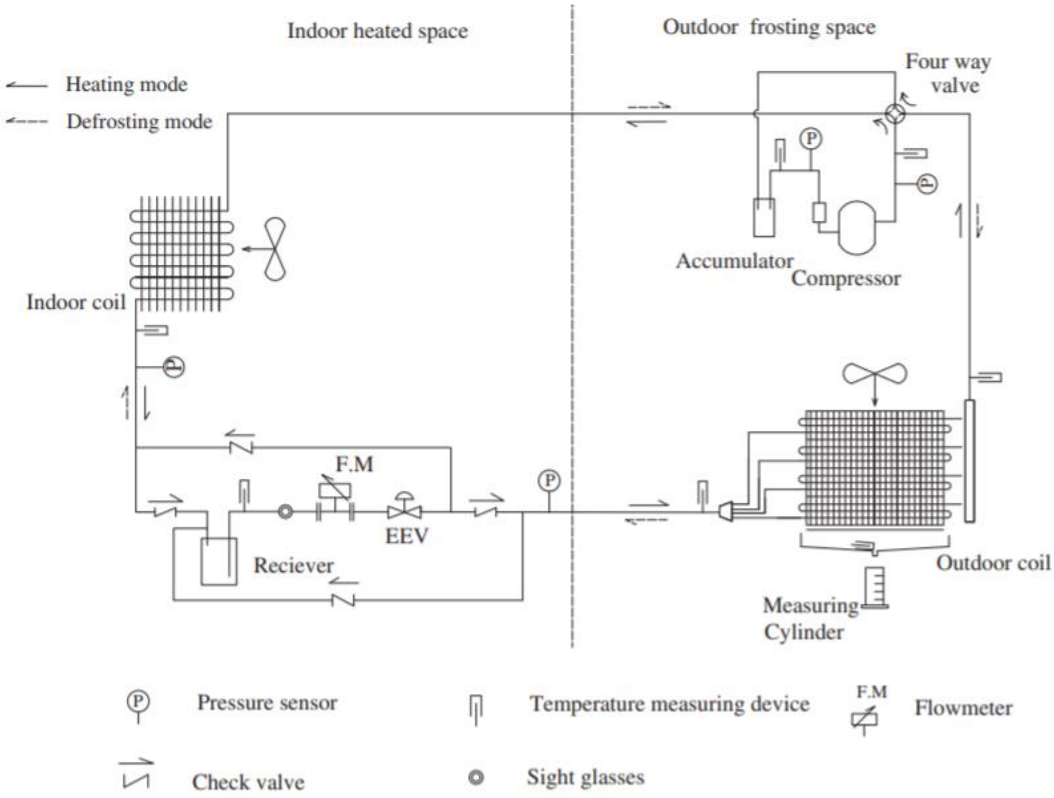

Figure 3.17. Schematics of the experimental ASHP unit installed in an environmental chamber [64].

The anti-frost technique was analysed by Jiang et al. [65]. When defrosting is required, SH monitors the device they say. ASHP deals with this technique until it runs a system risk. Figure 3.18 shows the schematics of the experimental setup of the ASHP unit.

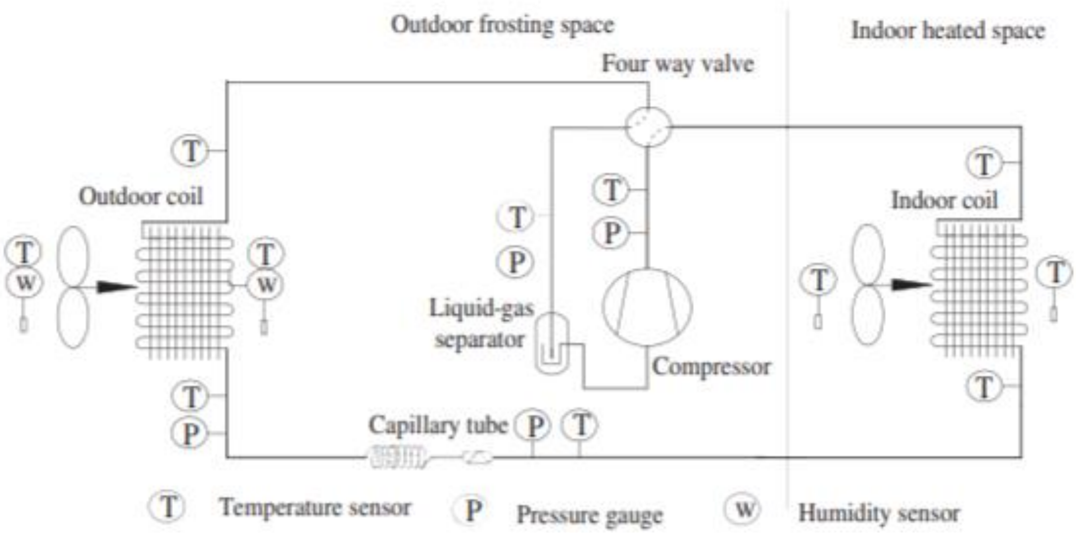

Figure 3.18. Schematics of the experimental setup of the ASHP unit [65].

Wang et al. [63] developed a modern control approach to defrosting with new photoelectric sensors in the shape of ice. The research indicates that maldefrost really exists, which is a means of stopping it. Figure 3.19 shows the schematic diagram of the novel frost-free ASHPWH system.

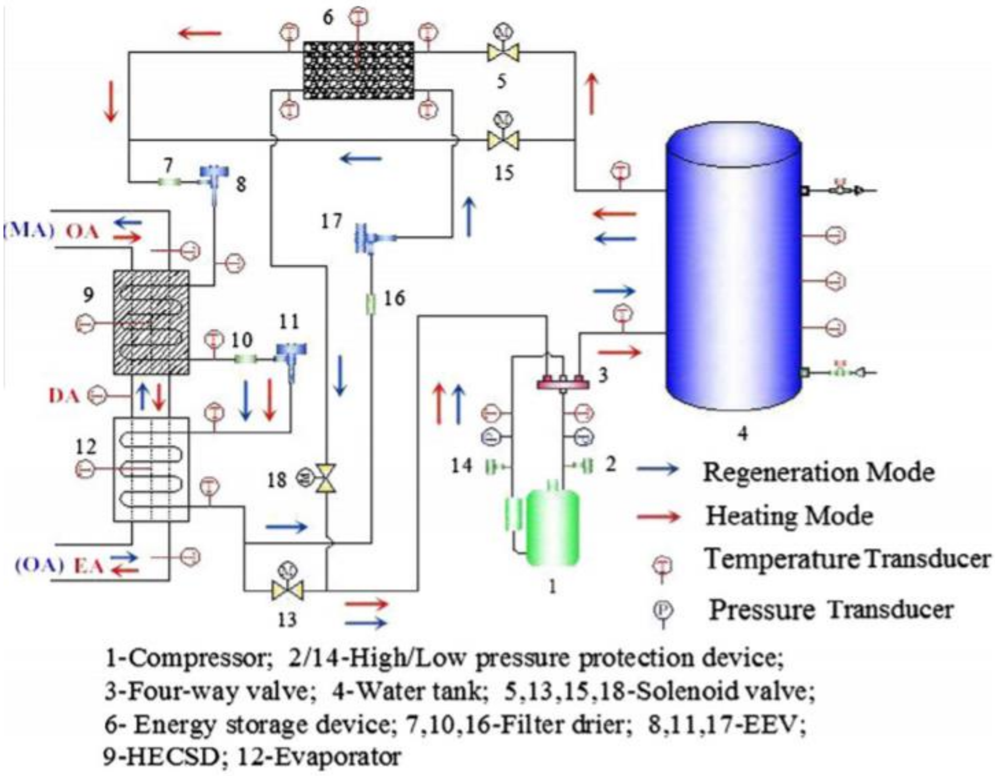

Figure 3.19. Schematic diagram of the novel frost-free ASHPWH system [63].

Tan et al. [66] A new approach for avoiding the development of frost has been established with the application of the ultrasonic vibrations. The experiment findings were between 6.51 and 15.33 per cent of small layer of frozen and COP forming.

The process has been tested by Sonobe et al. [67] using particles thrown into the heat swap by the aeroplane and the effects have been improved when the aeroplane frequency is higher. Figure 3.20 shows the schematic of the experimental setup.

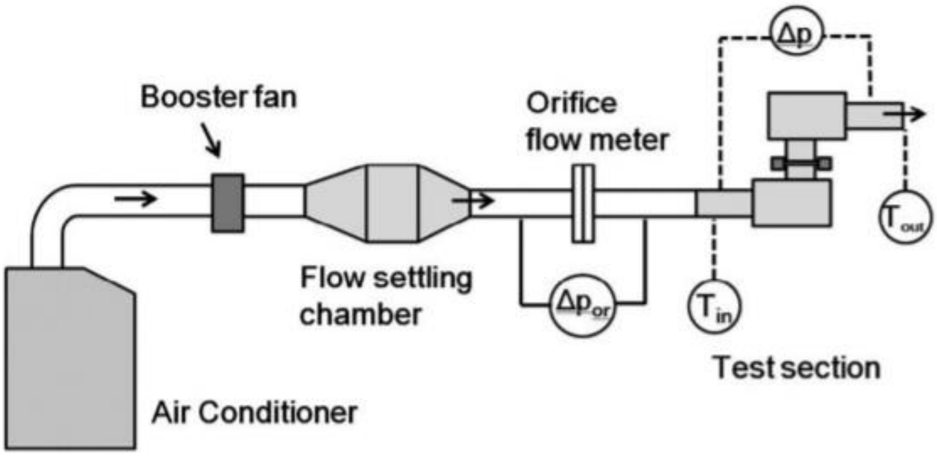

Figure 3.20. Schematic of the experimental setup [67].

PART 4

METHODOLOGY

4.1. MATERIAL AND METHOD

The system comparing the poppet type hydraulic valve used as an alternative solution to the problems of the four-way valve used in split air conditioning systems (Figure 4.1).

Figure 4.1. System view.

Table 4.1. shows the main and auxiliary materials used with its technical specifications.

Table 4.1. Main and auxiliary materials used

Material Used	Technical Specifications
Compressor	EGAS 80HLR EMBRACO COMPRESSOR (0.186 KW)
High Pressure Manometer	REFCO MODEL
4 Way Valve	BRISCOOL DHF-5-A 5/16 * 3/8
Popet Type Hydraulic Valve	HİDROKONTROL A.Ş 24VDC - 19W
Solenoid Valve	PARKER ZB09 9W
Condenser	GÜNAY COOLING ½ HP 3,8 m2
Expansion Element	COPPER KILCAL PIPE
Evaporator	COLD CABINET (0.17 KW)
Low Pressure Manometer	REFCO MODEL
Control Staff	I-0 KEY
Measuring Device	ORDEL DATA LOGGER

The experimental setup, which is designed and manufactured, mainly consists of a compressor, condenser, capillary tube, four-way valve, poppet type hydraulic valve, solenoid valves and evaporator. The 2-dimensional system design of the designed mechanism has been made and measurement points (Figure 4.2).

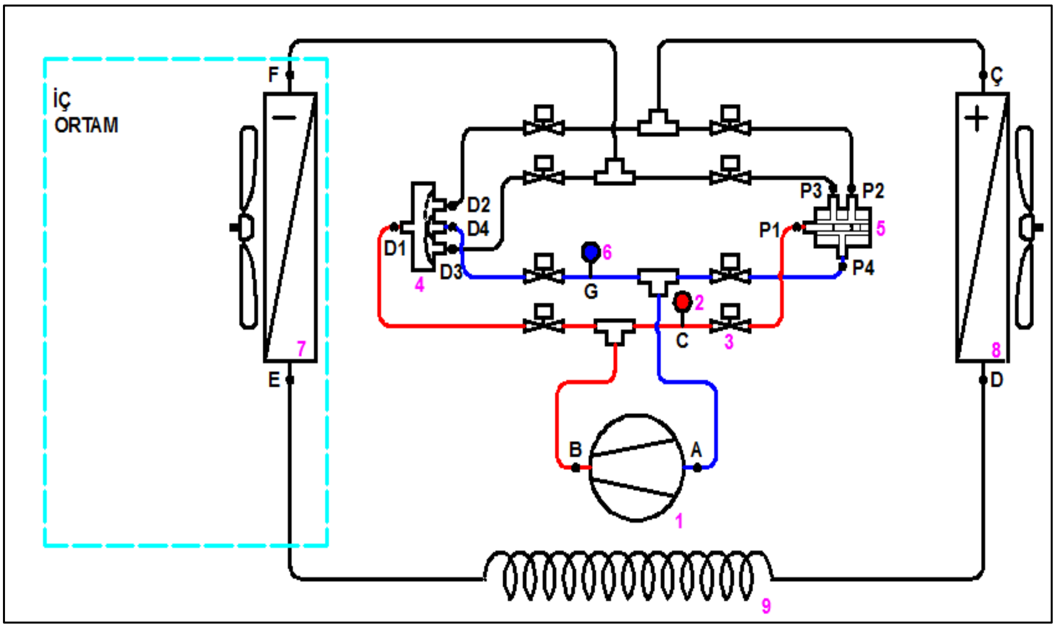

Figure 4.2. Schematic 2D view of the system and measurement points.

Table 4.2. shows definitions of measurements taken from split air conditioner desk study.

Table 4.2. Definitions of measurements taken from split air conditioner desk study.

Measurement Point	Measured value
A	Compressor Inlet Temperature
B	Compressor Outlet Temperature
C	High Pressure Line Pressure Value
Ç	Condenser Inlet Temperature
D	Condenser Outlet Temperature
E	Evaporator Inlet Temperature
F	Evaporator Outlet Temperature
G	Low Pressure Line Pressure Value
D1	Four Way Valve Discharge Temperature
D2	Four Way Valve Condenser Going Temperature
D3	Four Way Valve Coming Temperature From Evaporator
D4	Four Way Valve Suction Temperature
P1	Popet Valve Discharge Temperature
P2	Popet Valve Condenser Going Temperature
P3	Coming Temperature from Popet Valve Evaporator
P4	Popet Valve Suction Temperature

After the cooling system (Figure 4.2) was ready, a leak check was made. Air has been pumped into the system for leak control. The sources and other connection points have been checked for leakage. It was observed that the values did not change and there was no leakage after the system waited for 3 days. The vacuuming process was carried out by evacuating the air in the system. Gas pumping was then applied to the system. Solenoid valves are used to control the four-way valve and the poppet type valve. By using switches, the controls of the compressor, evaporator fan, condenser fan, solenoid valves and diverter valves were provided.

The comparison of four-way valve and poppet type valve on the same system has been made. While the system works with four-way valve, the solenoid valves of the four-way valve are in the open position, and the solenoid valves of the poppet valve are in the closed position. In this case, measurements were taken from the measurement points (Figure 4.2).

4.2. COMPRESSOR

Compressors can be considered as the heart of the cooling system. Compressor is the device that provides the heat transfer from the cold heat source to the hot heat source by circulating the refrigerant throughout the cycle. In other words, the compressor is work-swallowing machines that absorb low pressure vapor refrigerant and send it to the condenser at higher pressure. The following features are sought in an ideal compressor [28]:

- Low torque at first take-off
- Ability to maintain safety and security in different working conditions
- Low vibration and noise level, no change at different working loads
- Low cost, long life
- Working efficiency is high; efficiency does not change at different working loads.

Different types of compressors are used to compress the vapor from the evaporator in the condenser. These [28]:

- Piston compressors,
- Relative (Rotary, Rotor, Rotary) compressors,
- Helical (Screw) compressors,
- Centrifugal (Turbo) compressors,
- Scroll compressors.

Piston compressors are divided into two types, open type and hermetically. Open type compressors are belt-driven or direct-linked external motor-driven. The advantages of adjusting the speeds of the open type compressors according to the cooling capacity, having different engine options that can be changed for uneven voltages and frequencies are always on-site maintenance and repair, not to disassemble the entire compressor when the engine is burned [28]:

However, hermetic compressors have the same advantages compared to open types. The most important of these is the absence of shaft seals. Other advantages of hermetic compressors are that they are small, more compact, less affected by vibrations, and a good lubrication of the motor with constant cooling. Piston hermetic type compressor is used in the system. The internal structure of the hermetic compressor used is given below (Figure 4.2).

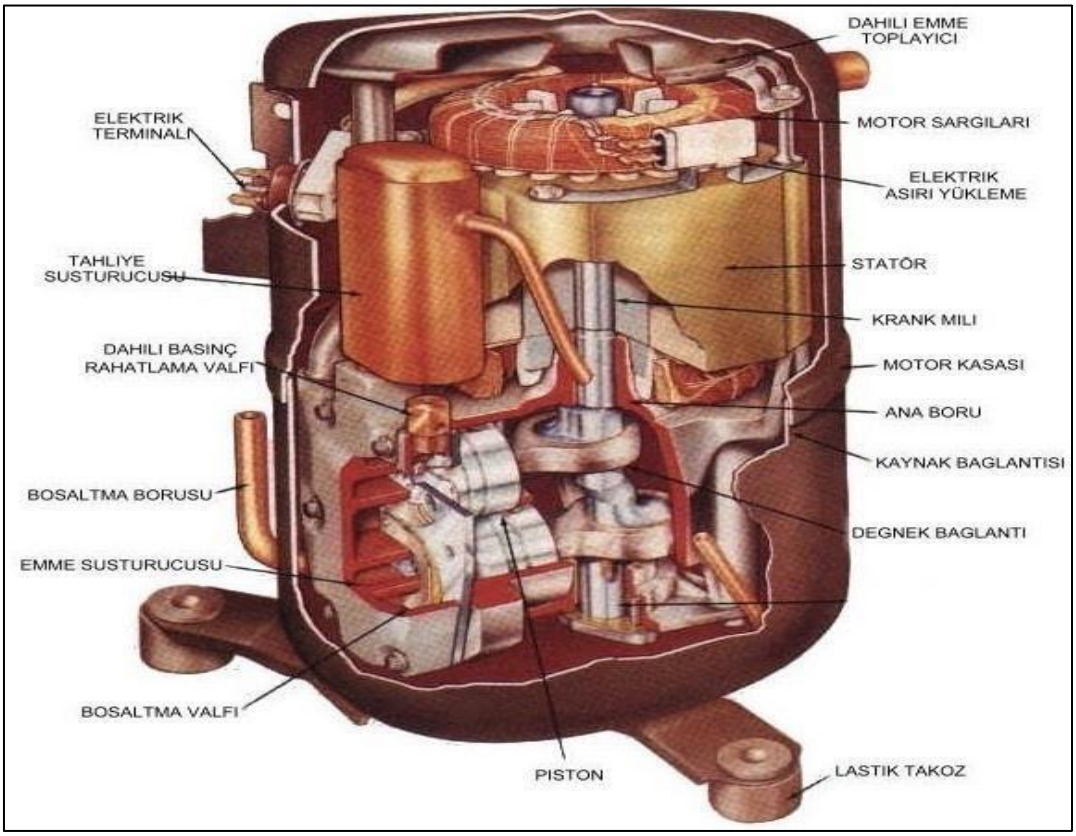

Figure 4.3. General appearance and internal structure of a hermetic compressor [28].

4.3. CONDENSER

The heat pumps are elements which allow high pressure and temperture heated super-heated steam to become liquid when another fluid is heated. They are one of the basic elements of the heat pump system. On the high pressure side of the device, condensers are installed. The power of the condenser is called the capacity of condenser to transfer heat from hot coolant vapour to another fluid. The capacity of the condenser depends on the material used in the manufacture of the condenser, the condenser surfass, the difference in temperature between the temperature of the condenser and the coolant vapour, and the surface cleaning of the condenser. Three key condenser forms exist [68]:

- Air cooled condensers,
- Water cooled condensers,
- Evaporative (evaporative, air and water) type condensers. Water-cooled condensers are made in two types, with pipes and plates.

Figure 4.4. Air cooled condenser [61].

4.4. EVAPORATOR

Evaporators, also called cooling coils in a cooling system, are devices that draw heat from the environment in which the liquid refrigerant evaporates. It cools an evaporator using the coolant latent heat of the coolant. The amount of cooling depends on the evaporator surface area, the total heat transfer coefficient and the temperature difference between the refrigerant and the coolant. According to the refrigerant feeding method, evaporators are divided into dry-type evaporators and wet-type evaporators. Dry-type evaporators are generally fed by thermostatic throttling valve or small-capacity fixed pressure automatic throttling valve or capillary tube. In dry-type evaporators, throttle valves send enough fluid to the evaporator to evaporate [53].

In wet type (liquid overflow) evaporators, almost the entire inside of the evaporator is filled with liquid refrigerant. Boiling the refrigerant with the heat it receives from the environment ensures that the entire evaporator surface is wet. Wet type evaporators are more efficient than dry type evaporators of the same size are. They are more expensive to operate because they need more refrigerant need.

Evaporators are usually classified into two, depending on the environment under which they draw heating, as air cooler evaporators and cooler evaporators. Air coolers can be used as natural or forced convection evaporators in two ways. If the relative humidity is high enough in the atmosphere in which the heat is drawn, the air falls above the evaporator and falls below the dew-point and the moisture condenses. The condensate on the evaporator surface can freeze when the temperature falls below 0°C. The frozen fluid on the evaporator surface seals the fin which stops air from going through and heat transmission. In order to avoid this the frozen liquid on the evaporator surface has to be freezed.

The most commonly used defrost methods in air cooler evaporators are electric, hot gas and water defrost methods. Evaporators can be made in different constructions, some of which are bare tube, plate, finned tube, lamellar, double tube, spiral tube, pool type, and body tube and spray type evaporators. Some of these are only used in heat extraction from air or water environment, while others can be used in both environments [53].

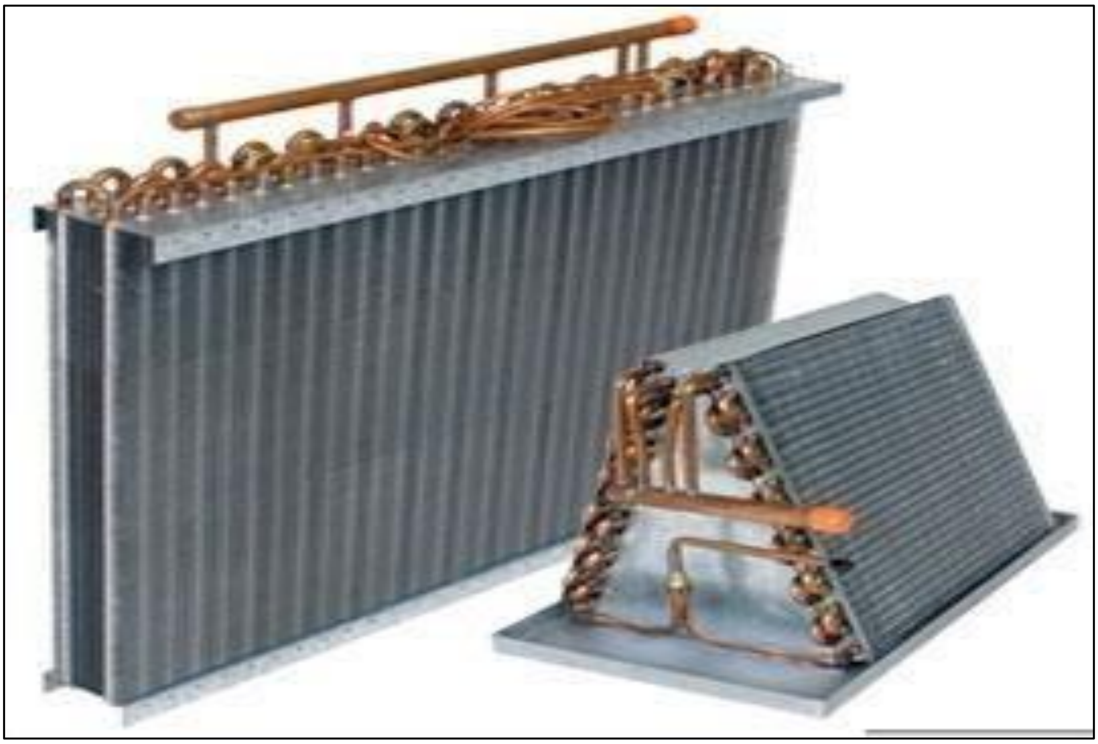

Figure 4.5. Evaporative [53].

4.5. FOUR WAY VALVE

The four-way valve makes it possible to change the flow direction of the coolant in combined or divided air conditioners, central thermal pump systems, between heats and coolers. There are three basic components of the valve [69]:

- Pilot valve
- Main valve body including valve spool
- Solenoid coil

The four-way slip is changed by the pilot solenoid valve adjustments in the differential pressure [69].

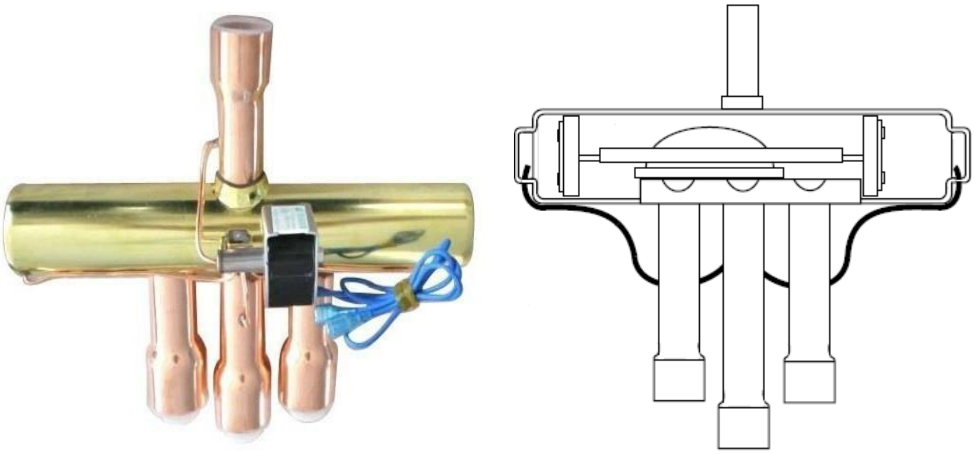

Figure 4.6. Four way valve [69].

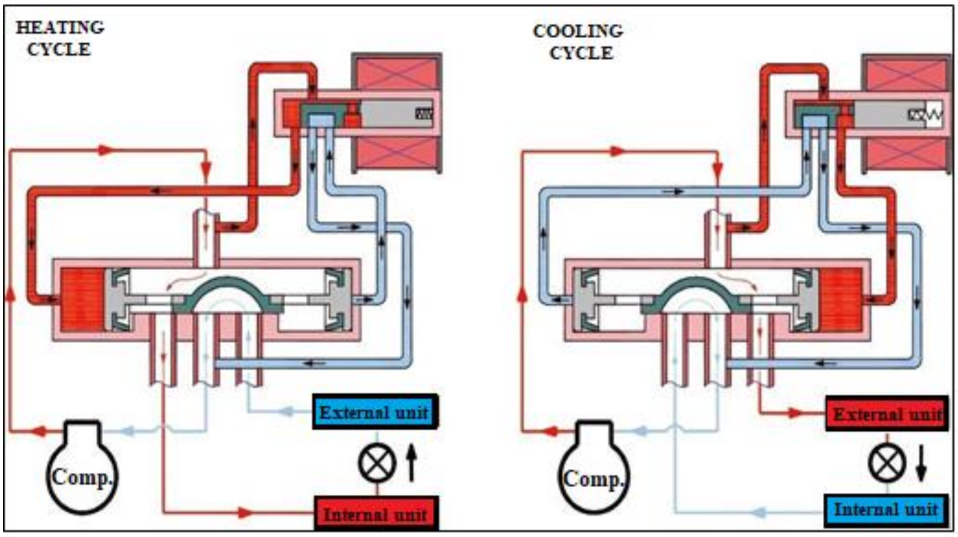

Figure 4.7. Four way valve working principle [69].

When the heating mode of the device is used the pilot valve switches to the right when the solenoid coil is driven and the high-pressure flow into the piston cavity. The piston chamber releases the low pressure oil, while the piston and door valve shift right.

In cooling mode, as the solenoid coil is deenergised, the pilot Valve turns left. High-pressure fluid joins the piston chamber and the capillary conduit along the discharge side. In the other side, the piston chamber releases the low-pressure fluid and pushes the piston and the spool valve part towards the left [69].

It is the result of excessive heat caused by the operation of the system without making a thermostat and locking occurs when the Teflon gaskets melt and adhere. In this case, there is an internal leak, the discharge and suction pressures converge. This situation occurs due to the failure of reaching the set temperature due to the selection of a device below the desired capacity of the environment in the devices with incorrect discovery, or operating the air conditioner in the continuous operating position [70].

As a result of not cleaning the copper piping during the installation of the device, the copper slag, plaster, paint, dust and other dirt that may remain in the system block and lock the four-way valve. Touching the flame to the four-way valve while welding processes may melt Teflon seals [70].

4.6. POPET TYPE HYDRAULIC VALVE POPET SOLENOID VALVES,

In the processes where 3-way solenoid valves are used, when more air is needed, large size 3/2 solenoid valves can produce solutions with different design.

These valves can pass more air. Such operated solenoid valves are referred to as Poppet valves. According to the condition of the process [71];

- There are series manufactured for the pressure line.
- There are series manufactured for the vacuum line. (Vacuum types have two different designs in themselves)
- Both main series have both coil-controlled and air-controlled types.
- Popet solenoid valves are 3-way and are manufactured in 1/4 "11/2" dimensions.
- Body material is Aluminum injection.

Figure 4.8. Popet type hydraulic valve [71].

Four-way and two-position (4/2) valves are often used when achieving linear motion with double acting cylinders [72].

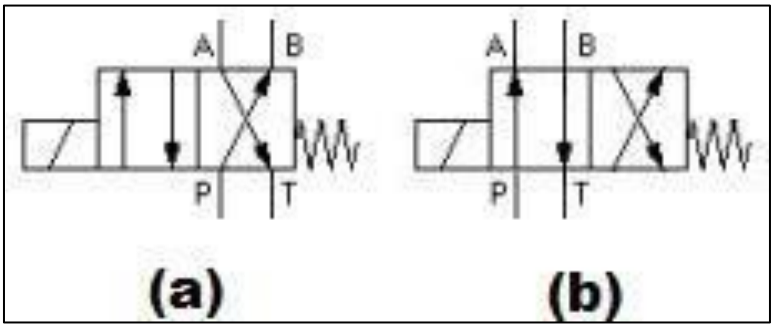

Figure 4.9. Popet type hydraulic valve flow control [72].

In the case of valve a, the pressurized fluid goes from P to B and the fluid returning from A turns from T to tank. In the case of valve b, the pressurized fluid travels from P to A and the fluid returning from B turns from T to tank. In the normal position of the valve shown here, the pressurized fluid moves from P to A in the b position and from B to T. When the valve is affected, the spring is compressed and as it can be seen in the case a, the pressurized fluid turns from P to B and returns to T in the fluid returning from A [72].

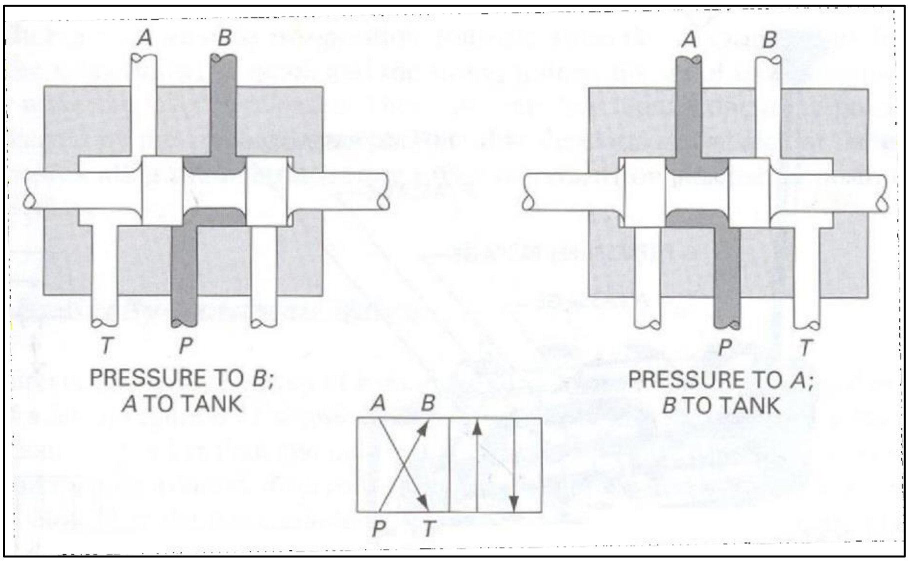

Figure 4.10. Popet type hydraulic valve flow direction [72].

4.7. SOLENOID VALVE

Electric valves are electromechanical valves which regulate the flow of liquids including gas, air, water, vapeur and oil. Electromagnetic valves in nature are solenoid valves used for fluids below a temperature of 150 °C.

The electrical current is exerted on the coil of the valve in order to drive the piston through the valve. The inlet channel applies the fluid directly to the outlet where the solenoid absorbs the electrical signals. The valve returns to its old status and stops the fluid passage if the electric signal is disturbed.

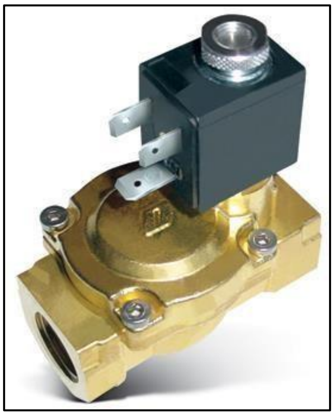

Figure 4.11. Solenoid valve [62].

4.8. CAPILLARY TUBE

The diameter and length placed between the condenser and the evaporator have been chosen according to the capacity of the cooling system, and is a very small diameter pipe section, usually between 0.5 and 2.16 mm in diameter. It is called a capillary tube because the inner diameter is very small. It is used in package type and household refrigerators as devices with low cooling loads (10 kW and below). Advantages [73];

- They are simple, easily manufactured and inexpensive.
- It sends and checks according to the amount of refrigerant, there is no need for a fluid tank.
- When the cooling system stops, the pressure is the same everywhere throughout the cycle.

They are used as pressure reducers in small capacity cooling systems without evaporator load variation. The evaporator cannot respond to load changes and has no heat setting. Capillary tube is an expansion element that has a low risk of failure because it has no cheap moving parts [73].

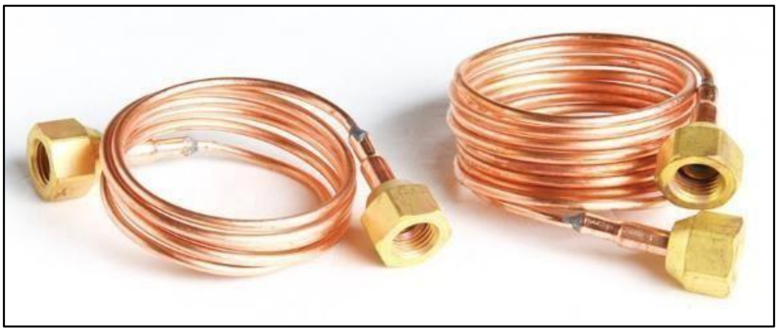

Figure 4.12. Capillary tube [73].

It is not very easy to establish the system balance point in systems with capillary pipes. In capillary tube systems, the fluid flow rate pumped by the compressor and the fluid flow rate that the capillary tube will carry must be equal. If the amount of fluid sent by the compressor and the fluid amount that the capillary tube will carry are not equal, the system operating conditions will not be formed according to the design conditions.

4.9. DATA LOGGER

These devices are devices that convert various analog signals used in industrial environments to numerical values and move them to the computer environment. It can be configured and used on a computer. Configuration on the computer and saving the values received from the device on the computer are done with DALI 08 software [74].

Figure 4.13. Data logger device [74].

PART 5

RESULTS AND FINDINGS

In the graphs comparing the four-way valve and the popet valve, the values after the 30th minute are shown as the system becomes stable after the 30th minute. The indoor ambient temperatures where the four way valve and poppet valve are measured separately (Figure 5.1).

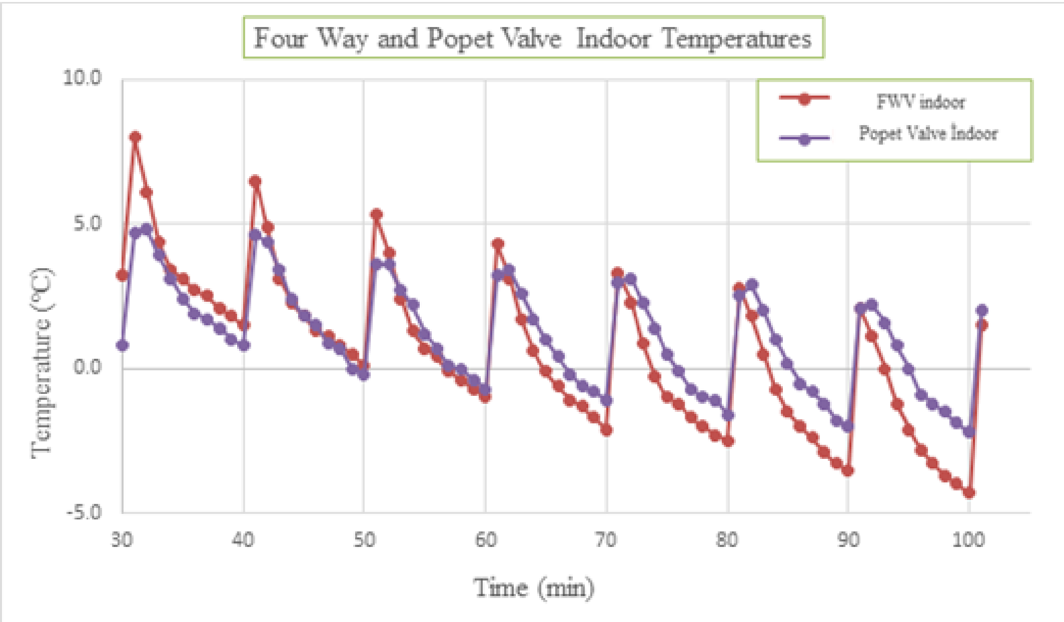

Figure 5.1. Four way and popet valve indoor temperatures.

The system entered the defrost every 10 minutes for 1 minute. In this one-minute period, the following average temperature increase was observed in the indoor temperature of the poppet valve.

In the system where popet valves are used for defrost operation, the indoor temperature rises up to 4.8 °C, whereas in the system where four-way valves are used, this temperature has reached approximately 8 °C.

When the indoor temperature is taken as 3 ℃ on average and 20 ℃ on the outdoor temperature;

$$Condensation\ temperature: t_c + k = outdoor + 10\ ℃ = 20 + 10$$
$$= 30\ ℃$$
$$Evaporation\ temperature: t_e - k = indoor\ environnment - 10\ ℃ =$$
$$3 - 10 = -7\ ℃$$

Evaporation-7 ℃, condensation temperatures 30 ℃.

Evaporator Superheat = Useful Superheat = Evap. Outlet temperature - Evap. Evaporation temperature

The evaporator superheater was calculated as 17.7 ℃ in the four-way valve and 6.4 ℃ in the popet valve. The power of the compressor is 0.186 kW. Accordingly, in a four-way valve system;

$$\dot{W}_{komp} = \dot{m} \times (h_2 - h_1) \tag{5.1}$$

$$0.186\ kJ/s = \dot{m} \times (436.48 - 408.82) kJ/kg\ \dot{m} = 0.0067\ kg/s$$
$$\dot{Q}_{evap} = \dot{m} \times (h_1 - h_4) = 0.0067 \times (408.82 - 241.46) = 1.121 kW$$
$$\dot{Q}_{kond} = \dot{m} \times (h_2 - h_3) = 0.0067 \times (436.48 - 241.46) = 1.307 kW$$
$$\dot{Q}_{kond} = \dot{Q}_{evap} + \dot{W}_{komp} \tag{5.2}$$

Evaporation, condensation temperatures and compressor power are entered in the CoolPack Program and mass flow is calculated (Figure 5.2).

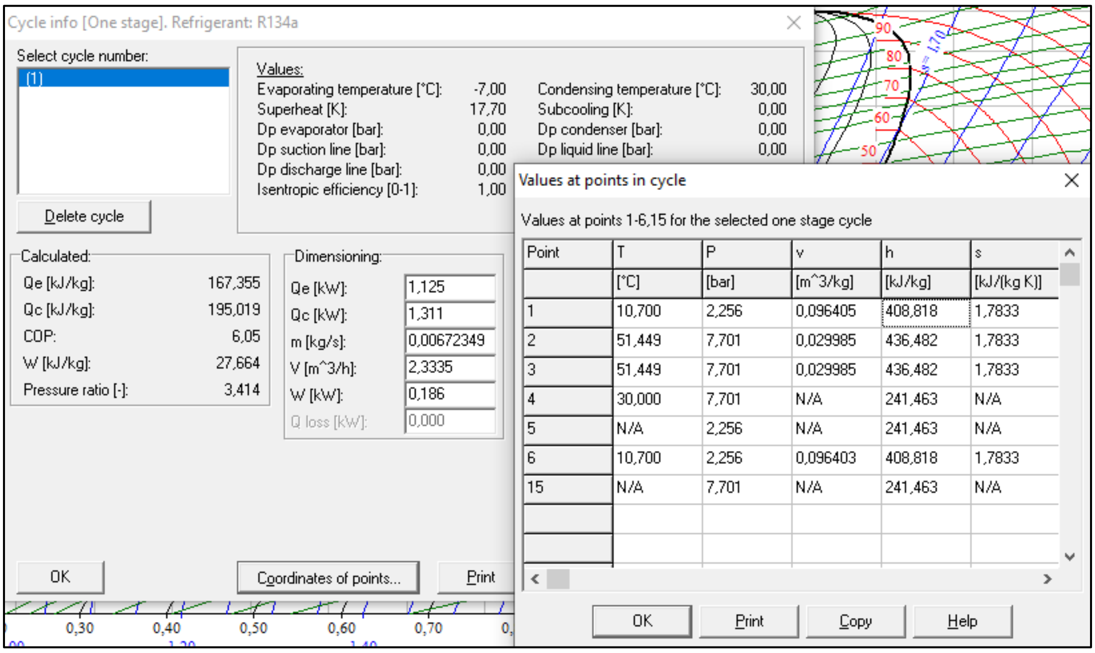

Figure 5.2. Mass flow calculation in cool pack program.

In Popet valve system;

$$\dot{W}_{komp} = \dot{m} \times (h_2 - h_1) \tag{5.3}$$

$$\dot{m} = 0.0071\ kg/s$$

$$\dot{Q}_{evap} = \dot{m} \times (h_1 - h_4) = 0.0071 \times (398.77 - 241.46) = 1.117kW$$

$$\dot{Q}_{kond} = \dot{m} \times (h_2 - h_3) = 0.0071 \times (424.95 - 241.46) = 1.303kW$$

The compressor inlet and outlet temperatures of the two valves are compared (Figure 5.3 and Figure 5.4).

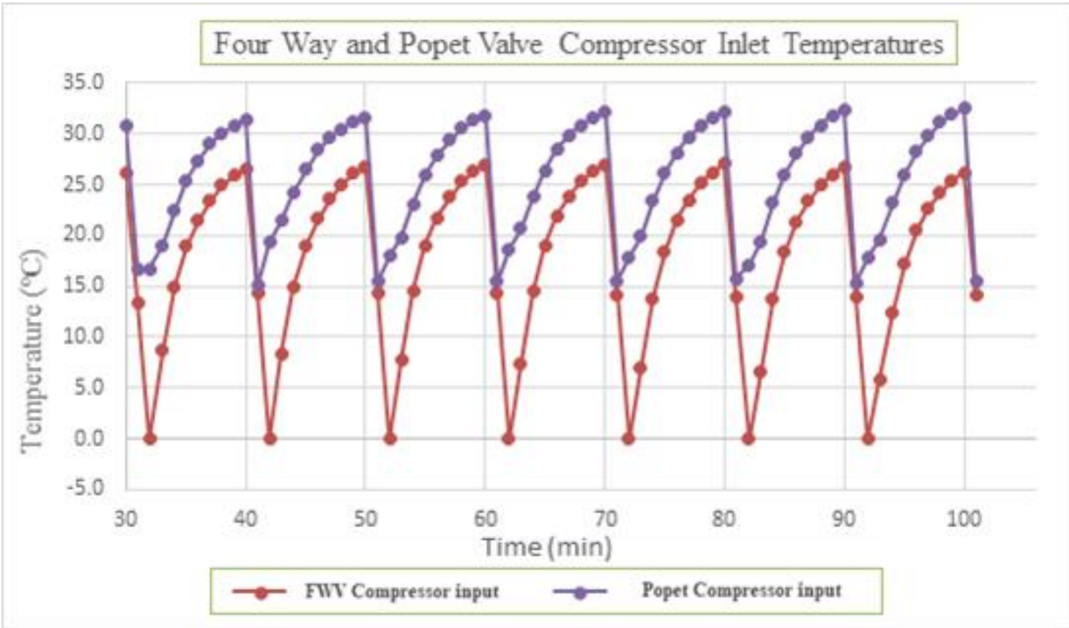

Figure 5.3. Four way and popet valve compressor inlet temperatures.

In the system where the popet valve is used, the compressor inlet temperature has decreased to 15.5 °C while the system using the four way valve has decreased to 0 °C. In the system where the four-way valve is used for defrosting, the compressor inlet temperature is 17.81 on average, whereas the system using the popet valve is 25.62.

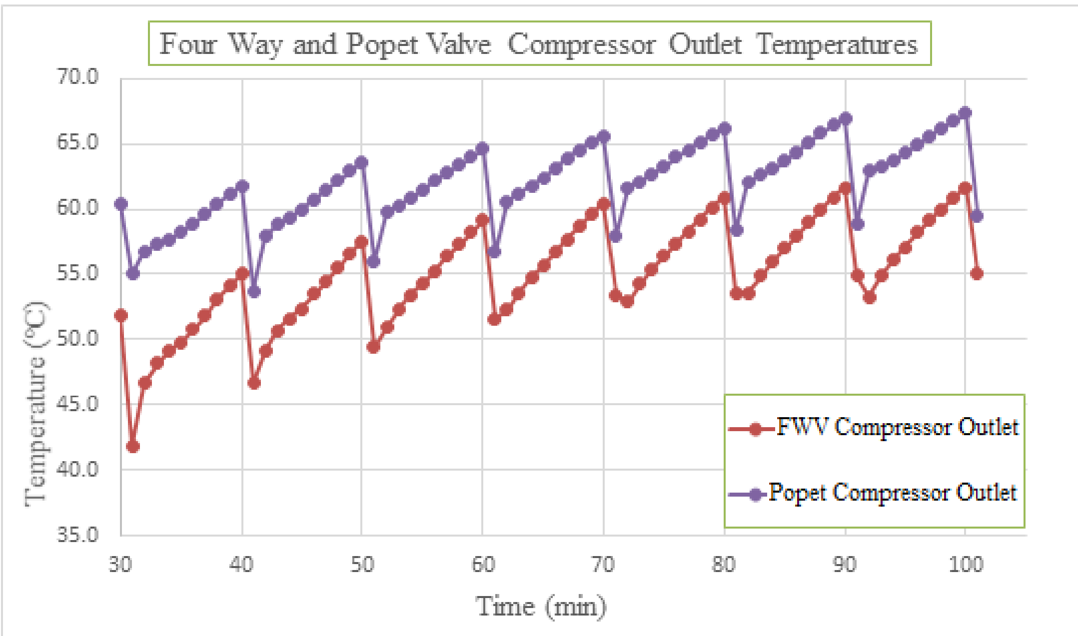

Figure 5.4. Four way and popet valve compressor outlet temperatures.

Compressor outlet temperature up to 67.3 °C in Popet valve system, up to 60.9 °C in four way valve system. Compressor outlet temperature rising to higher values is the disadvantage of popet valve. Condenser inlet and outlet temperatures of the two valves are shown below (Figure 5.5 and Figure 5.6).

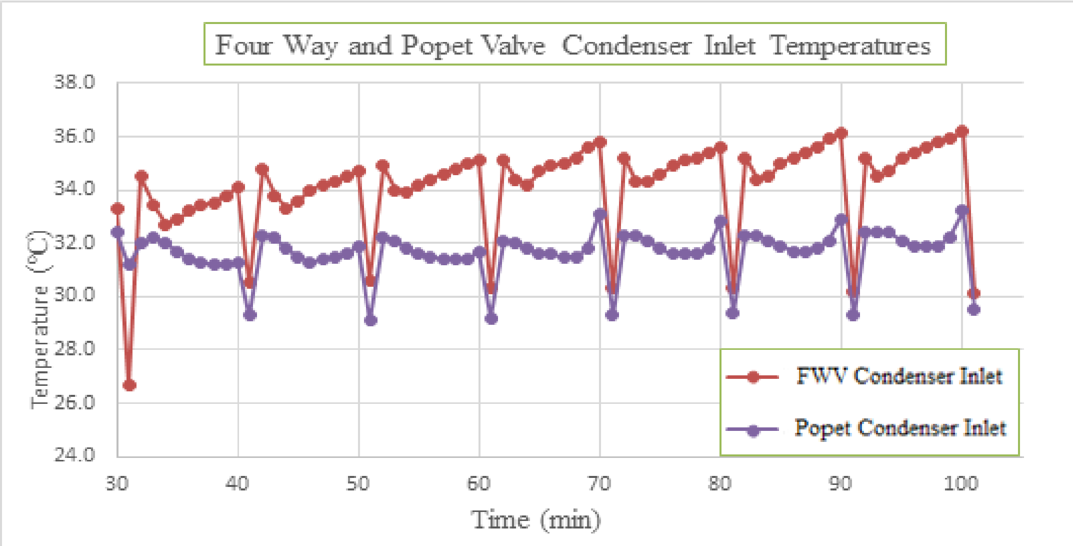

Figure 5.5. Four way and popet valve condenser inlet temperatures.

The highest value reached in the four-way valve system is 36.2 °C, in the popet valve system this value is 33.2 °C.

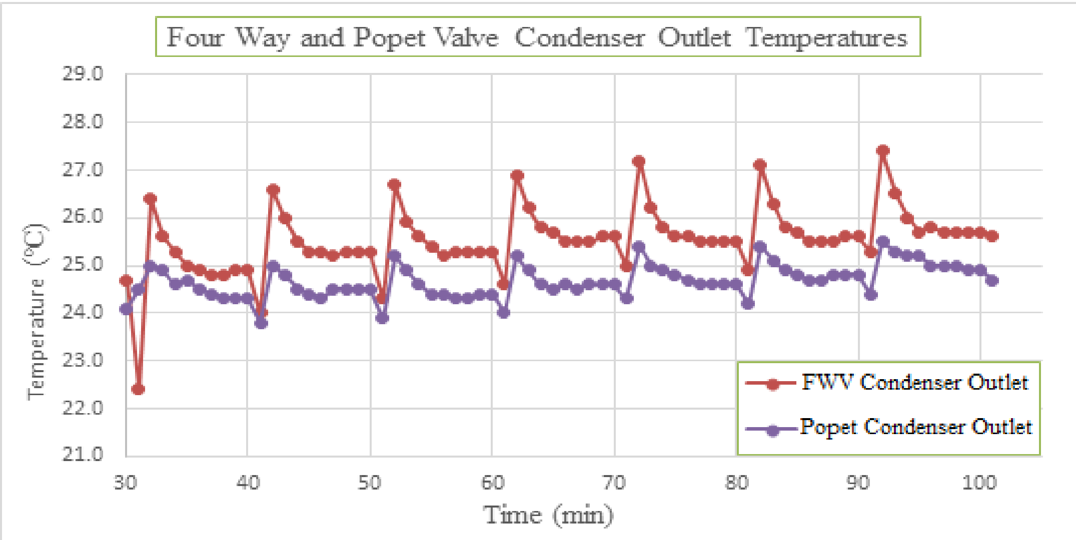

Figure 5.6. Four way and popet valve condenser outlet temperatures.

Evaporator inlet and outlet temperatures of two valves are given below (Figure 5.7 and Figure 5.8).

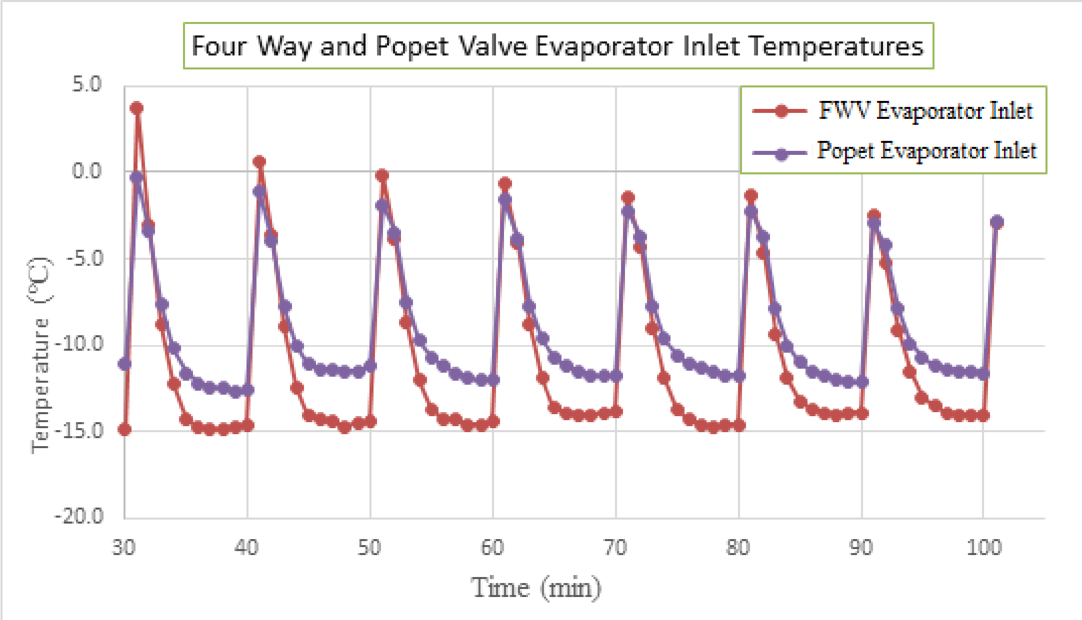

Figure 5.7. Four way and popet valve evaporator inlet temperatures.

While the evaporator inlet temperature difference is -15 °C in a four-way valve system, this value is -11 °C in a popet valve system.

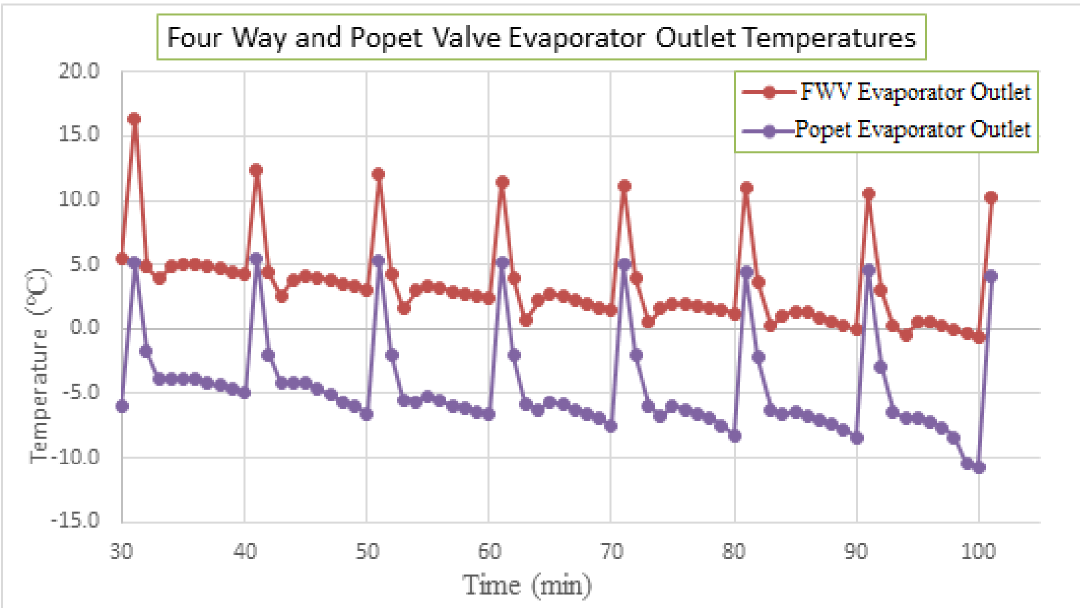

Figure 5.8. Four way and poppet valve evaporator outlet temperatures.

While the evaporator outlet temperature difference is three in average in the four-way valve system, this value is -4.5 ℃ in the system with poppet valve.

In the measurements taken with four-way valves, the average indoor temperature is 3.2 ℃, the average of the compressor inlet temperatures is 18.11 ℃, the average of the compressor outlet temperatures is 51.28 ℃, the average of the condenser inlet temperatures is 33.39 ℃, the average of the condenser outlet temperatures is 25.34 ℃, the evaporator inlet temperatures are -10.25 ℃ and the evaporator The outlet temperatures average was calculated as 5.49 ℃. In the measurements taken with poppet valve, the average temperature is as follows; indoor environment 3 ℃, compressor inlet 26.11 ℃, compressor outlet 58.51 ℃, condenser inlet 31.34 ℃, condenser outlet 24.39 ℃, evaporator inlet -9.8 ℃ and evaporator outlet -2.72 ℃. As can be understood from the figures and results, the measurements made with popet valve are more stable, less oscillating and more smooth. With this conclusion, the poppet valve can be shown as an alternative to a four-way valve. and that According to the results that shown in tables.

PART 6

CONCLUSION

Because more energy is used in the cooling process, the desired comfort requirements must be met with ecologically sustainable economic solutions. Many researchers were able to draw attention to the secret energy Storage Systems, phase changes systems because they need less volume per unit of stored energy, and many researchers attracted the small temperature range that occurs during the phasing heat transfer.

In split air conditioning systems, four-way valves are used to assist in the passage of heating and cooling. Many problems such as the difficulty in assembling the four-way valve, slowness of defrost lack of maintenance and repair, instability to high temperatures and such problems adversely affect the operation of split air conditioners. Alternative solutions are sought in order to overcome these problems.

The operating principles of the four-way valve used in split air conditioners and the poppet type valve used in hydraulic systems are the same. The difference between the four-way valve and the poppet type hydraulic valve is where they are used and working fluids. In this thesis, an alternative solution is sought considering the problems of the four way valve. Poppet type hydraulic valve is used as the most suitable valve that provides the pressure conditions and four-way two pass similar to the working structure of the four-way valve.

The four way device is flawless compared to the inverter valve currently used in air conditioners. Because the commutator valve has a magnetic coil, it often burns out from use. In addition to the presence of reinforced plastic parts that can melt with high temperature, because the inverter valve uses copper parts, and because copper is affected by heat up and down, which leads to its closure. Thus, the four-way device can be considered flawless.

The reversing valve, which reverses the hot and cold cycle, often leaks. And one of the most important areas where leakage is detected is the capillary tubes on the reversing valve, which makes it a weak component. In this case, it must be maintained, and this maintenance requires a lot of skill in order not to damage the plastic parts in the inverter valve.

Due to increased evaporation temperature and subsequently increased condensation temperature, the findings indicate a significant change in the system's efficiency during the frost period. Frost melt is a result of air conditioning heat transfer during condensation. The rise in condensation is closely related with the length of defrost.

The system entered the defrost every 10 minutes for 1 minute. In this one-minute period, the following average temperature increase was observed in the indoor temperature of the poppet valve. In the system where popet valves are used for defrost operation, the indoor temperature rises up to 4.8 °C, whereas in the system where four-way valves are used, this temperature has reached approximately 8 °C.

In the system where the popet valve is used, the compressor inlet temperature has decreased to 15.5 °C while the system using the four way valve has decreased to 0 °C. In the system where the four-way valve is used for defrosting, the compressor inlet temperature is 17.81°C on average. While the compressor outlet temperature reaches up to 67.3°C in the poppet valve system, it can rise up to 60.9 °C in the four-way valve system. Higher compressor outlet temperature is the disadvantage of the poppet valve.

The highest value reached in the four-way valve system is 36.2 °C, in the poppet valve system this value is 33.2 °C. While the evaporator inlet temperature difference is -11 °C in a four-way valve system, this value is -9 °C in a poppet valve system. While the evaporator outlet temperature difference is three in average in the four-way valve system, this value is -4.5 °C in the system with poppet valve.

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RESUME

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