Organisation of Islamic Cooperation

DETERMINATION OF THE OPTIMUM PHENOMENA OF UNIVERSAL REFRIGERATION SYSTEM & DEVELOPMENT OF A TESTING BENCH TO MEASURE COOLING LOAD OF A/C SYSTEM

A thesis submitted to the department of MECHANICAL AND CHEMICAL ENGINEERING (MCE), ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)

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Abstract

Air conditioning and refrigeration definitely belong in the most important engineering achievements of the 20th century. Both technologies make the lives of others far more comfortable and enjoyable. In our project, we have focused on analyzing the optimum phenomena of the universal refrigeration system, which have helped us to find and understand the characteristics of the refrigeration system by Coefficient of performance. Based on our experience, we have also developed a design of a testing bench to find the cooling load of the air conditioning system. We have done all of our works in the Refrigeration and air conditioning lab of Islamic University of Technology (IUT).

Chapter One

Universal refrigeration system

1.1 Introduction

Universal refrigeration system is the most basic setup of all kinds of refrigeration and air conditioning system. The works of refrigeration and air conditioning are interrelated. Air conditioning is the heating, cooling, dehumidification, humidification, ventilation, and sterilization of air. The refrigeration process removes heat from an enclosed space to reduce and maintain the temperature for the contents of that space. While air conditioning regulates the air in a large building, refrigeration solely cools and is generally used in a smaller space.

The most common and most important use for refrigeration is food preservation. Industrially refrigeration is very important for preserving food, chemicals, medicines etc for future usage or distribution to another place. The chemical and processing industries include the manufacturers of chemicals, petroleum refiners, petrochemical plants, paper and pulp industries etc. Refrigeration units are used to chill waters, dehumidify air, ice making industries, in special case, desalting of seawater etc.

By air conditioning the temperature of a room, building, or structure can be easily modified. The most important implication of this ability is that it allows people to live more comfortably in harsh climates. Ventilation improves the quality of indoor air. It lessens the temperature inside room while there’s scorching heat outside. Air conditioning also helps to keep inside of the room less contagious and infectious by maintaining temperature, for which it’s very important for hospitals, operation theaters, pharmacies etc.

Air conditioning and refrigeration definitely belong in the most important engineering achievements of the 20th century. The comfort, ease, and happiness they bring to our everyday lives are immeasurable. Food preservation, medicine, and industry would not be what they are today without refrigeration. Air conditioning brings a comfort and environmental flexibility that has impacted people more than they realize. Both technologies make the lives of others far more comfortable and enjoyable.

1.2 Components

The basic components of the universal refrigeration system are:

- Condenser
- Expansion valve
- Evaporator
- Compressor

1.3 Vapor-Compression Refrigeration system

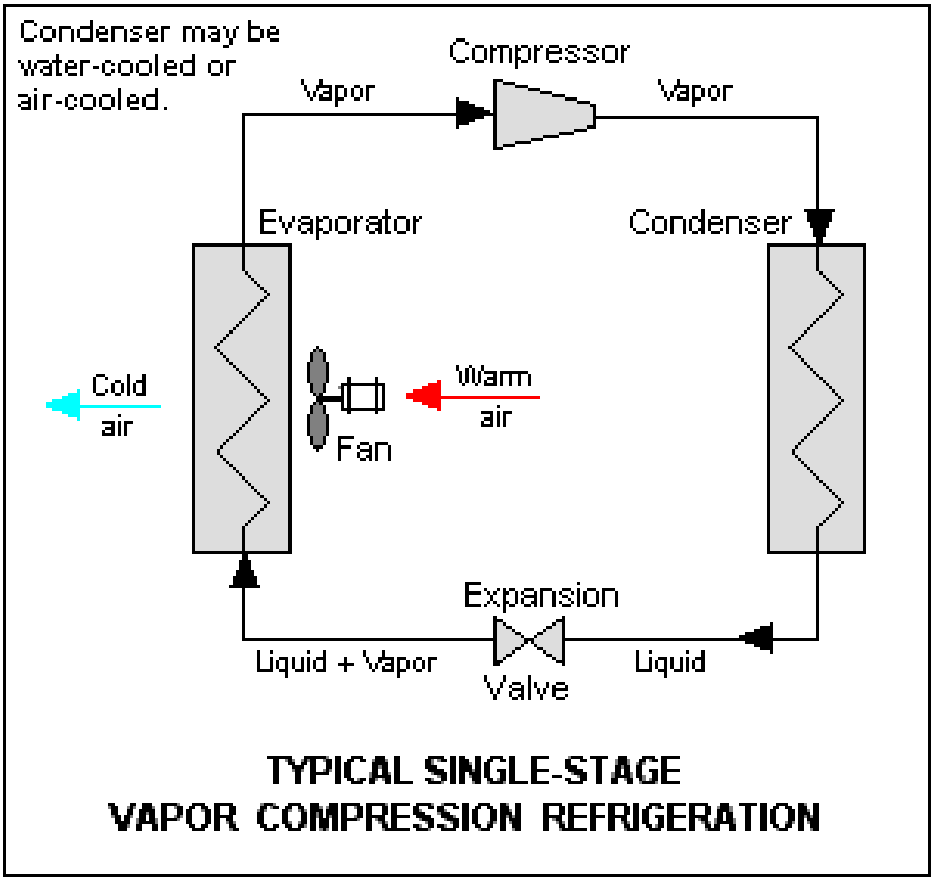

Figure 16: Vapor-Compression Refrigeration

The vapor-compression uses a circulating liquid refrigerant as the medium which absorbs and removes heat from the space to be cooled and subsequently rejects that heat elsewhere. Figure 1 depicts a typical, single-stage vapor-compression system. All such systems have four components: a compressor, a condenser, a thermal expansion valve (also called a throttle valve or Tx Valve), and an evaporator. Circulating refrigerant enters the compressor in the thermodynamic state known as a saturated vapor and is compressed to a higher pressure, resulting in a higher temperature as well. The hot, compressed vapor is then in the thermodynamic state known as a superheated vapor and it is at a temperature and pressure at which it can be condensed with typically available cooling water or cooling air. That hot vapor is routed through a condenser where it is cooled and condensed into a liquid by flowing through a coil or tubes with cool water or cool air flowing across the coil or tubes. This is where the circulating refrigerant rejects heat from the system and the rejected heat is carried away by either the water or the air (whichever may be the case).

The condensed liquid refrigerant, in the thermodynamic state known as a saturated liquid, is next routed through an expansion valve where it undergoes an abrupt reduction in pressure. That pressure reduction results in the adiabatic flash evaporation of a part of the liquid refrigerant. The auto-refrigeration effect of the adiabatic flash evaporation lowers the temperature of the liquid and vapor refrigerant mixture to where it is colder than the temperature of the enclosed space to be refrigerated.

The cold mixture is then routed through the coil or tubes in the evaporator. A fan circulates the warm air in the enclosed space across the coil or tubes carrying the cold refrigerant liquid and vapor mixture. That warm air evaporates the liquid part of the cold refrigerant mixture. At the same time, the circulating air is cooled and thus lowers the temperature of the enclosed space to the desired temperature. The evaporator is where the circulating refrigerant absorbs and removes heat which is subsequently rejected in the condenser and transferred elsewhere by the water or air used in the condenser.

To complete the refrigeration cycle, the refrigerant vapor from the evaporator is again a saturated vapor and is routed back into the compressor.

1.4 Shell and Tube Heat Exchanger

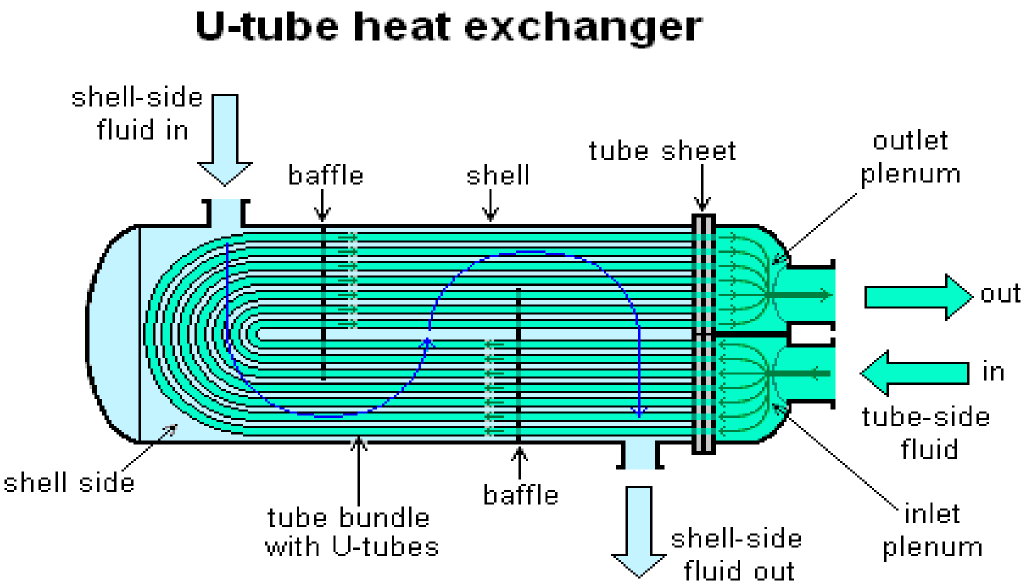

Figure 17: Shell & Tube Heat Exchanger

Shell and tube heat exchangers consist of a series of tubes. One set of these tubes contains the fluid that must be either heated or cooled. The second fluid runs over the tubes that are being heated or cooled so that it can either provide the heat or absorb the heat required. A set of tubes is called the tube bundle and can be made up of several types of tubes: plain, longitudinally finned, etc. Shell and tube heat exchangers are typically used for high-pressure applications (with pressures greater than 30 bar and temperatures greater than 260 °C). This is because the shell and tube heat exchangers are robust due to their shape. In our setup refrigerant was flown through the tube and water was flown through the shell. So the water was heated.

1.5 Expansion Valve

A **thermal expansion valve** (often abbreviated as TEV, TXV or TX valve) is a component in refrigeration and air conditioning system that controls the amount of refrigerant flow into the evaporator thereby controlling the superheating at the outlet of the evaporator. Thermal expansion valves are often referred to generically as "metering devices".

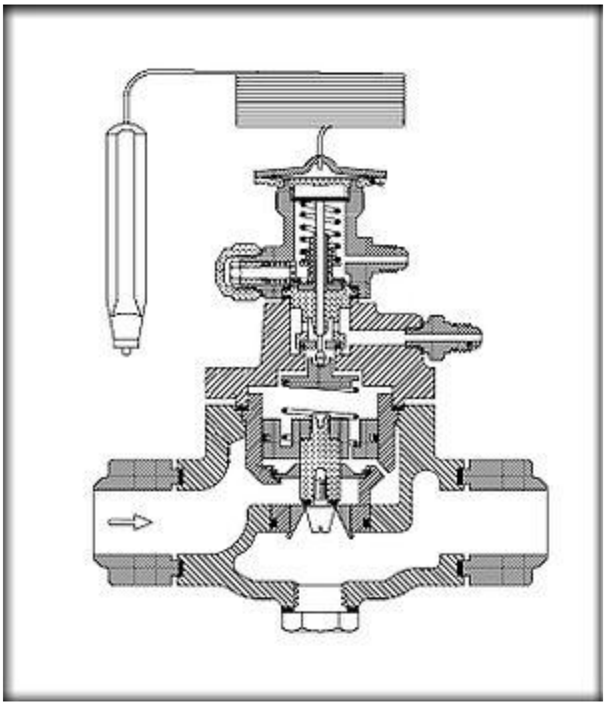

Figure 18: Thermo-static expansion valve

Flow control, or metering, of the refrigerant is accomplished by use of a temperature sensing bulb filled with a similar gas as in the system that causes the valve to open against the spring pressure in the valve body as the temperature on the bulb increases. As the suction line temperature decreases, so does the pressure in the bulb and therefore on the spring causing the valve to close. An air conditioning system with a TX valve is often more efficient than other designs that do not use one.

A thermal expansion valve is a key element to a refrigeration cycle; the cycle that makes air conditioning, or air cooling, possible. A basic refrigeration cycle consists of four major elements, a compressor, a condenser, a metering device and an evaporator. As a refrigerant passes through a circuit containing these four elements, air conditioning occurs. The cycle starts when refrigerant enters the compressor in a low pressure, low temperature, gaseous form. The refrigerant is compressed by the compressor to a high pressure-and-temperature gaseous state. The high pressure-and-temperature gas then enters the condenser. The condenser precipitates the high pressure-and-temperature gas to a high temperature liquid by transferring heat to a lower temperature medium, usually ambient air. The high temperature liquid then enters the expansion valve where the TX valve allows a portion of the refrigerant to enter the evaporator. In order for the higher temperature fluid to cool, the flow must be limited into the evaporator to keep the pressure low and allow expansion back into the gas phase. The TXV has sensing bulbs connected to the suction line of the refrigerant piping. The sensing bulbs give temperature reading to the TXV to adjust flow of refrigerant.

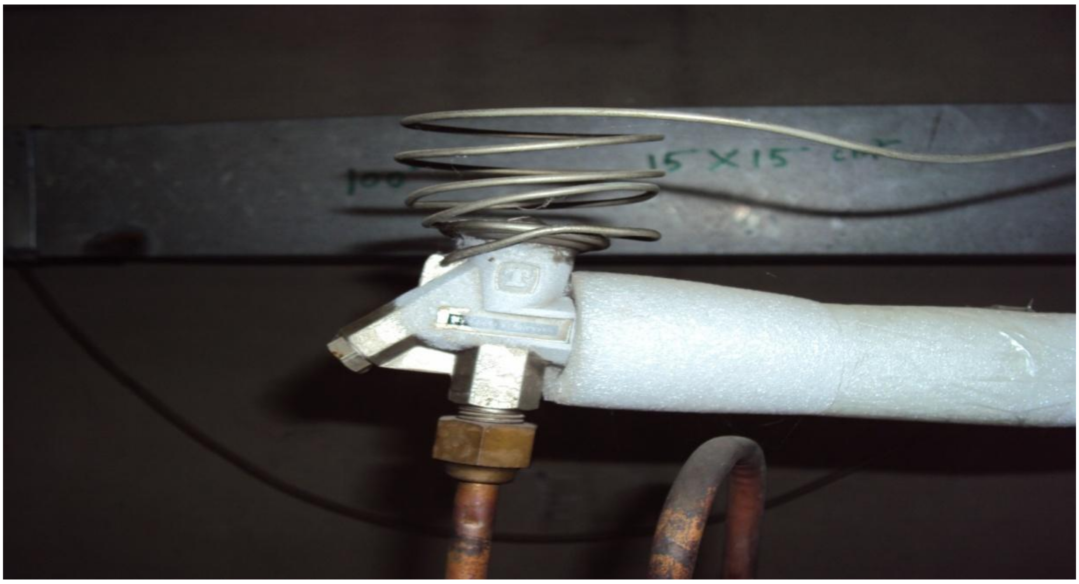

Figure 19: Expansion Valve

1.6 Compressor

A gas compressor is a mechanical device that increases the pressure of a gas by reducing its volume.

Compressors are similar to pumps, both increase the pressure on a fluid and both can transport the fluid through a pipe. As gases are compressible, the compressor also reduces the volume of a gas. Liquids are relatively incompressible; while some can be compressed, the main action of a pump is to pressurize and transport liquids. Here we used hermetically sealed compressor.

Hermetically sealed, open, or semi-hermetic

A small hermetically sealed compressor in a common consumer refrigerator or freezer; it typically has a rounded steel outer shell that is permanently welded shut, and which seals operating gases inside the system. There is no route for gases to leak, such as around motor shaft seals. On this model, the plastic top section is part of an auto-defrost system which uses motor heat to evaporate the water.

Compressors are often described as being either open, hermetic, or semi-hermetic, to describe how the compressor and motor drive is situated in relation to the gas or vapour being compressed. The industry name for a hermetic is hermetically sealed compressor, while a semi-hermetic is commonly called a semi-hermetic compressor.

In hermetic and most semi-hermetic compressors, the compressor and motor driving the compressor are integrated, and operate within the pressurized gas envelope of the system. The motor is designed to operate and be cooled by the gas or vapor being compressed.

The difference between the hermetic and semi-hermetic, is that the hermetic uses a one-piece welded steel casing that cannot be opened for repair; if the hermetic fails it is simply replaced with an entire new unit. A semi-hermetic uses a large cast metal shell with gasket covers that can be opened to replace motor and pump components.

The primary advantage of a hermetic and semi-hermetic is that there is no route for the gas to leak out of the system. Open compressors rely on either natural leather or synthetic rubber seals to retain the internal pressure, and these seals require a lubricant such as oil to retain their sealing properties.

An open pressurized system such as an automobile air conditioner can leak its operating gases, if it is not operated frequently enough. Open systems rely on lubricant in the system to splash on pump components and seals. If it is not operated frequently enough, the lubricant on the seals slowly evaporates, and then the seals begin to leak until the system is no longer functional and must be recharged. By comparison, a hermetic system can sit unused for years, and can usually be started up again at any time without requiring maintenance or experiencing any loss of system pressure.

The disadvantage of hermetic compressors is that the motor drive cannot be repaired or maintained, and the entire compressor must be removed if a motor fails. A further disadvantage is that burnt out windings can contaminate whole systems requiring the system to be entirely pumped down and the gas replaced. Typically hermetic compressors are used in low-cost factory-assembled consumer goods where the cost of repair is high compared to the value of the device, and it would be more economical to just purchase a new device.

Accumulator

It is a device which is used to superheat the refrigerant before entering into the compressor. It is situated before the compressor and smaller in size. It is important because if saturated refrigerant enters into the compressor it may damage it. So to make refrigerant superheat, an accumulator is used before our compressor.

Figure 20: Compressor

1.7 Refrigerant

A refrigerant is a substance used in a heat cycle usually including, for enhanced efficiency, a reversible phase transition from a liquid to a gas. Traditionally, fluorocarbons, especially chlorofluorocarbons, were used as refrigerants, but they are being phased out because of their ozone depletion effects. Other common refrigerants used in various applications are ammonia, sulfur dioxide, and non-halogenated hydrocarbons such as propane. Many refrigerants are important ozone depleting and global warming inducing compounds that are the focus of worldwide regulatory scrutiny.

The ideal refrigerant has favorable thermodynamic properties, is noncorrosive to mechanical components, and is safe (including nontoxic, nonflammable, and environmentally benign). The desired thermodynamic properties are a boiling point somewhat below the target temperature, a high heat of vaporization, a moderate density in liquid form, a relatively high density in gaseous form, and a high critical temperature. Since boiling point and gas density are affected by pressure, refrigerants may be made more suitable for a particular application by choice of operating pressure.

Chlorodifluoromethane or difluoromonochloromethane is a hydrochlorofluorocarbon (HCFC). This colorless gas is better known as HCFC-22, or R-22. It is commonly used as a propellant and refrigerant. These applications are being phased out in developed countries due to the compound's ozone depletion potential (ODP) and high global warming potential (GWP), although global use of R-22 continues to increase because of high demand in developing countries. R-22 is a versatile intermediate in industrial organofluorine chemistry, e.g. as a precursor to tetrafluoroethylene.

R-22 is prepared from chloroform: $HCCl_3 + 2\ HF \rightarrow HCF_2Cl + 2\ HCl$

1.8 Insulation

Thermal insulation is the reduction of heat transfer (the transfer of thermal energy between objects of differing temperature) between objects in thermal contact or in range of radiative influence. Thermal insulation can be achieved with especially engineered methods or processes, as well as with suitable object shapes and materials.

Heat flow is an inevitable consequence of contact between objects of differing temperature. Thermal insulation provides a region of insulation in which thermal conduction is reduced or thermal radiation is reflected rather than absorbed by the lower-temperature body.

The insulating capability of a material is measured with thermal conductivity (k). Low thermal conductivity is equivalent to high insulating capability (R-value). In thermal engineering, other important properties of insulting materials are product density (ρ) and specific heat capacity (c).

In this project, foam insulation is used for thermal insulation. The pipelines of refrigerant between expansion valve and evaporator & between compressor and evaporator are covered by insulating foam. The insulation is given to resist the thermal conduction. The insulation resists the cool refrigerant entering the evaporator to absorb heat from the environment.

1.9 Auxiliary elements

Digital thermometer is used for precise temperature reading. As instantaneous temperature readings are required, multiple thermometers are used.

Clamping multi-meter is used to take the reading of the load. By clamping multi-meter, the Voltage (V) and Current (I) readings are taken.

Beaker and stop watch are used to measure the flow rate of the water coming out of the outlet of both heat exchangers.

Pressure gauges are used to measure the high pressure of the condenser and the low pressure of the evaporator.

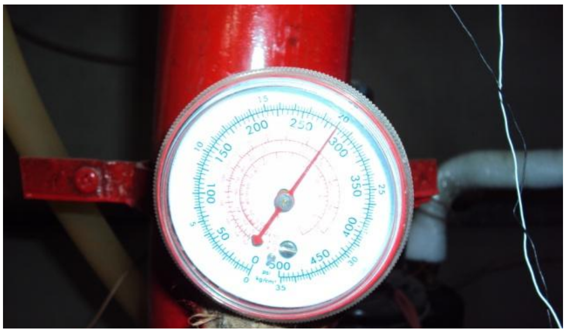

Figure 21: Pressure gauge

A **power supply unit** is used to supply power to the compressor. The power supply unit consists of socket, plug, multi-plug, wires etc.

Figure 23: Digital Thermometer

Figure 22: Power supply unit

Chapter Two

Methodology

2.1 Arrangement

The cylinder shaped shell and tube heat exchangers (Evaporator & Condenser) are prepared. The tubes for refrigerant are welded to the cylinders. One tube is directly connected between them with expansion valve and the other goes through the compressor. Both of the heat exchangers have water inlet and outlet ways. Inside the shell around the tubes of refrigerant, the fluid flows. Both of the cylinders are clamped to the rods which are welded with a base tray. The base tray has a well design with water drainage. The compressor is clamped with the base tray. The pipeline of refrigerants is attached to the compressor. Between the condenser and evaporator, the refrigerant pipeline goes through the thermostatic expansion valve. The refrigerant pipelines between thermostatic valve and evaporator & between compressor and evaporator are covered by insulator. Two individual pressure gauges are attached to the heat exchangers. These pressure gauges show high pressure of the condenser and low pressure of the evaporator. A power unit is attached to the base tray which supplies electricity to the compressor. From the water source, a plastic pipeline is attached to a Y joint from which two pipelines supply water to the inlet of both of the heat exchangers. From the outlet of the heat exchangers, two individual pipes are attached. These two pipes are attached to two individual taps. All of the plastic pipe joints are tightened by circular clamps. A beaker and a stopwatch is used for measuring the flow-rate. For visual ease, the hot condenser is colored red and the cold evaporator is colored blue.

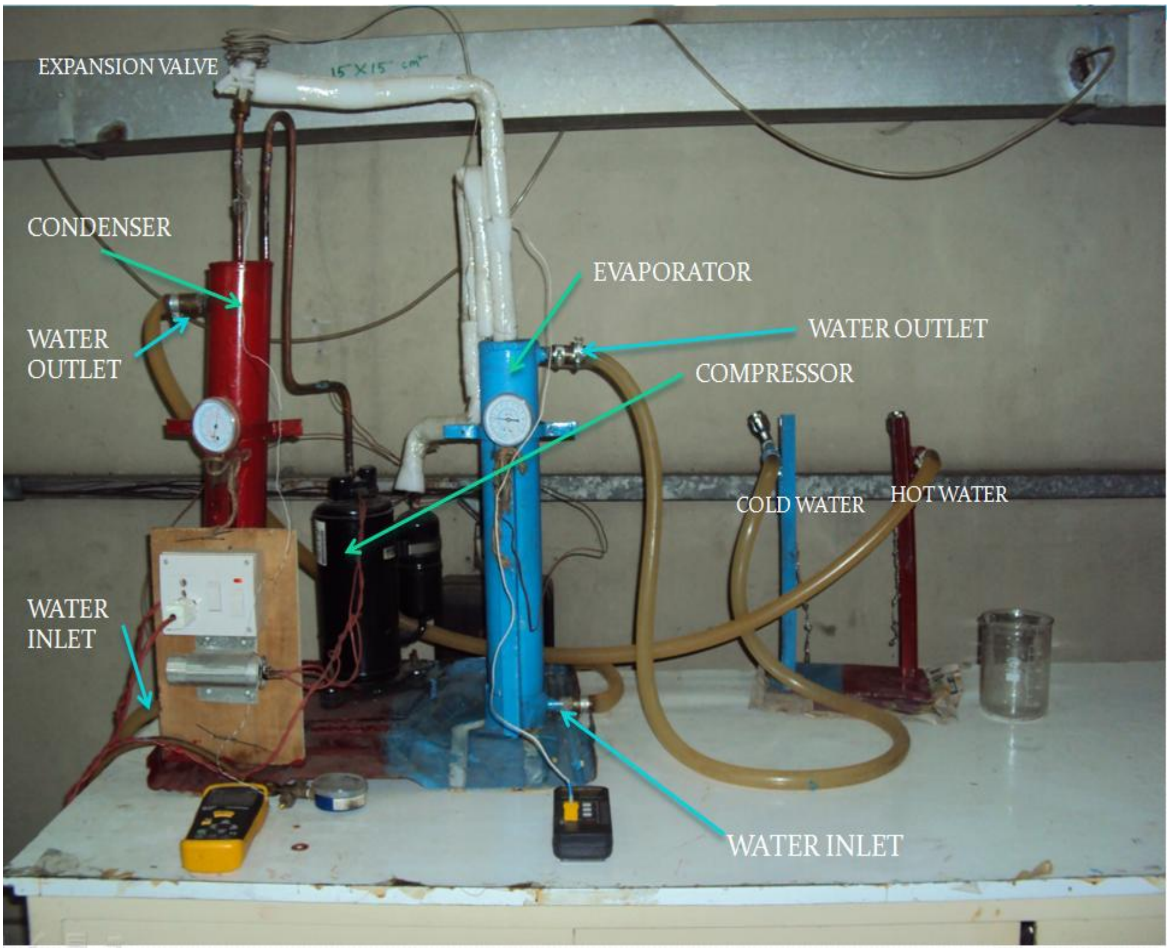

Figure 24: The experimental setup

2.2 Working procedure

The water source is opened for the water flow through the heat exchangers. The outlet taps are opened for constant flow of water. The water flows through the pipes with its own pressure. No extra pressure is given by pump or something else. A specific velocity of water was maintained as the high pressure of water might hamper the linkage of the pipes. High pressure tends to lose the pipe joints. As flow rate of water should be kept constant, the taps of heat exchangers' outlet are adjusted so that flow rate through condenser and evaporator are same. The beaker and stop watch are used to measure the flow rate.

The digital thermometers are attached to the considered area. One thermometer is attached to the refrigerant tube between condenser and expansion valve, one thermometer is attached to the tube between expansion valve and evaporator, one between the compressor and evaporator & one between compressor and condenser. The wires of the digital thermometer are attached by masking tape to get perfect reading.

Now, connecting the power supply unit to the power source, the compressor is switched on. The compressor regulates the refrigerant with high pressure through the tubes. The tubes also go through the heat exchangers and expansion valve. The high pressurized refrigerant reaches the expansion valve. The thermostatic expansion valve expands the liquid refrigerant from condenser to evaporator. It lessens the pressure of the high pressurized refrigerant coming from the condenser by controlling the valve inside it. Then the low pressured refrigerant enters the tubes inside the evaporator. The refrigerant absorbs the latent heat from the water around the tubes to form liquid phase. Therefore, the flowing water inside the evaporator gets cold rejecting the latent heat to the refrigerant. Through compressor, the high pressurized refrigerant enters the condenser where it rejects the latent heat to the water flowing around the tubes. As water absorbs the latent heat rejected by the refrigerant, the outlet water is hot. The temperatures of the inlet and outlet water of the heat exchangers are measured. All the readings are taken until a certain high pressure is reached.

All the readings from thermometer, pressure gauges are taken carefully and instantaneously. By the clamping multi meter, the dimensions of load (Voltage, Current) are measured.

Problems like- leaking of the cylinder, leaking of refrigerant have been faced. By welding the leakage was sealed.

2.3 Coefficient of performance (COP)

Coefficient of performance (COP), is an expression of the efficiency of a refrigeration cycle. When calculating the COP for a refrigeration cycle, the heat output from the condenser (Q) is compared to the power supplied to the compressor (W).

The formula to calculate COP;

$$\text{COP} = \text{useful refrigeration} / \text{net work}$$

$$= Q/W$$

In other words, COP is defined as the relationship between the power (kW) that is drawn out of the heat pump as cooling or heat, and the power (kW) that is supplied to the compressor.

2.4 Experimental data and results

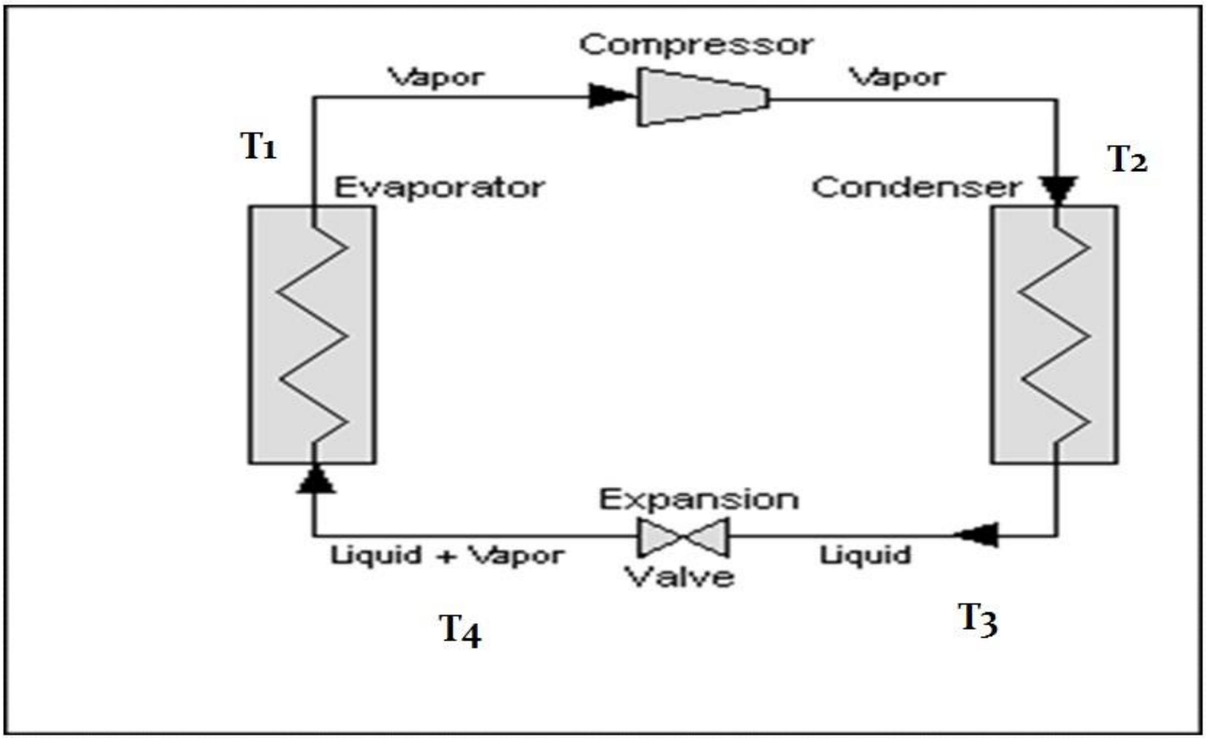

Figure 25: Refrigeration Cycle

	T_1	T_2	T_3	T_4	P_H	P_L	Condition of Evaporator			Condition of Condenser			V	I
	°C	°C	°C	°C	kPa	kPa	Q (liter/sec)	T_{e1} °C	T_{e2} °C	Q (liter/sec)	T_{c1} °C	T_{c2} °C	(V)	Amp
1	21	101	42	4	930.15	124.02	0.083	26	16	0.063	26	39		
2	15	119	42	-1	937.04	117.13	0.052	26	16	0.048	26	37		
3	15	127	43	-9	964.6	130.91	0.042	26	14	0.050	26	43	273	4.5
4	15	132	45	-9	916.37	124.02	0.048	26	14	0.075	26	34		
5	17	137	40	-8	916.37	120.58	0.070	26	14	0.087	26	34		

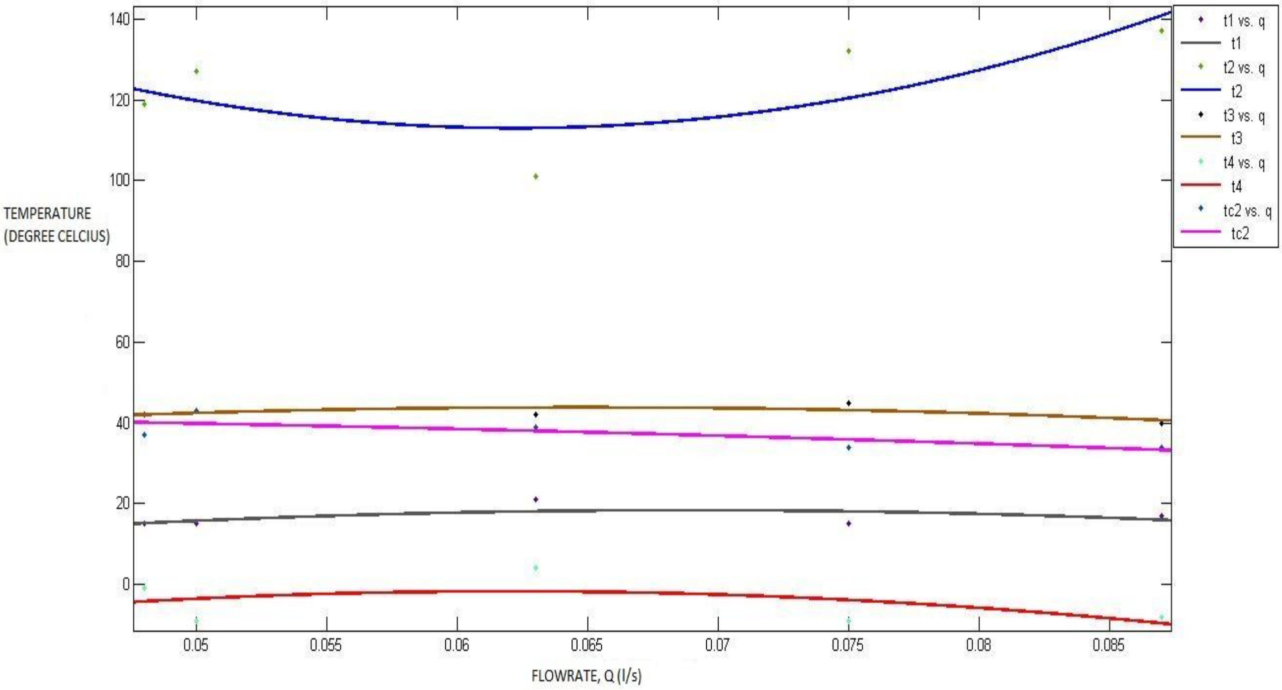

Figure 26: Temp. vs Q for condenser

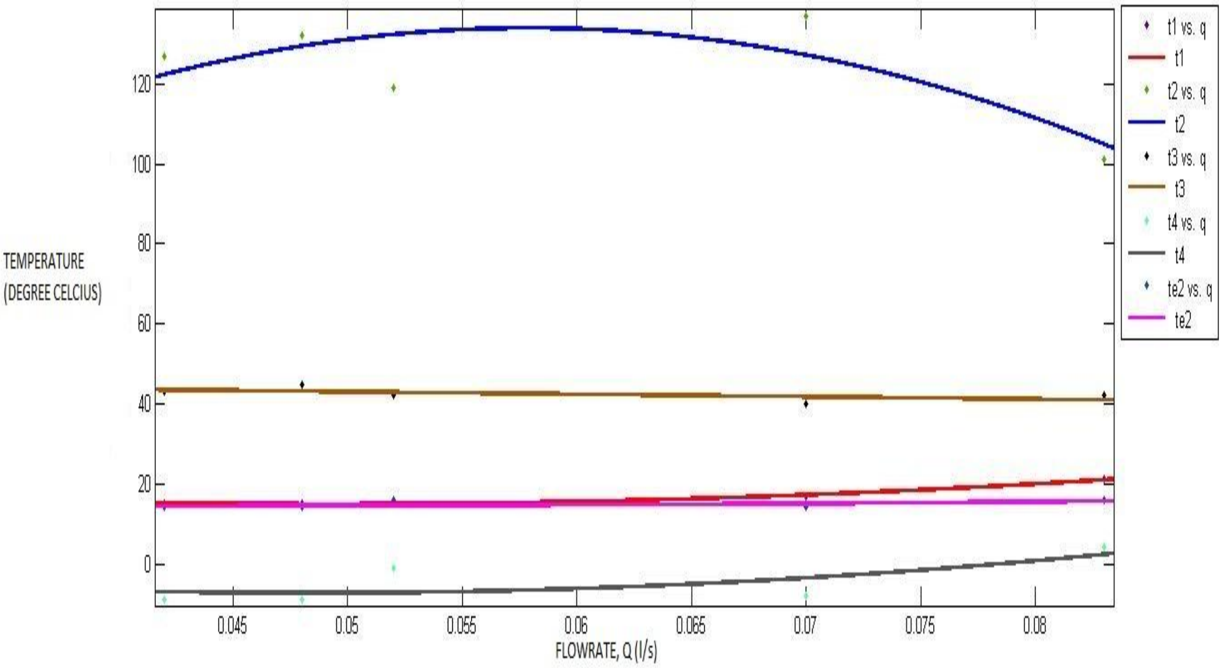

Figure 27: Temp. vs Q for evaporator

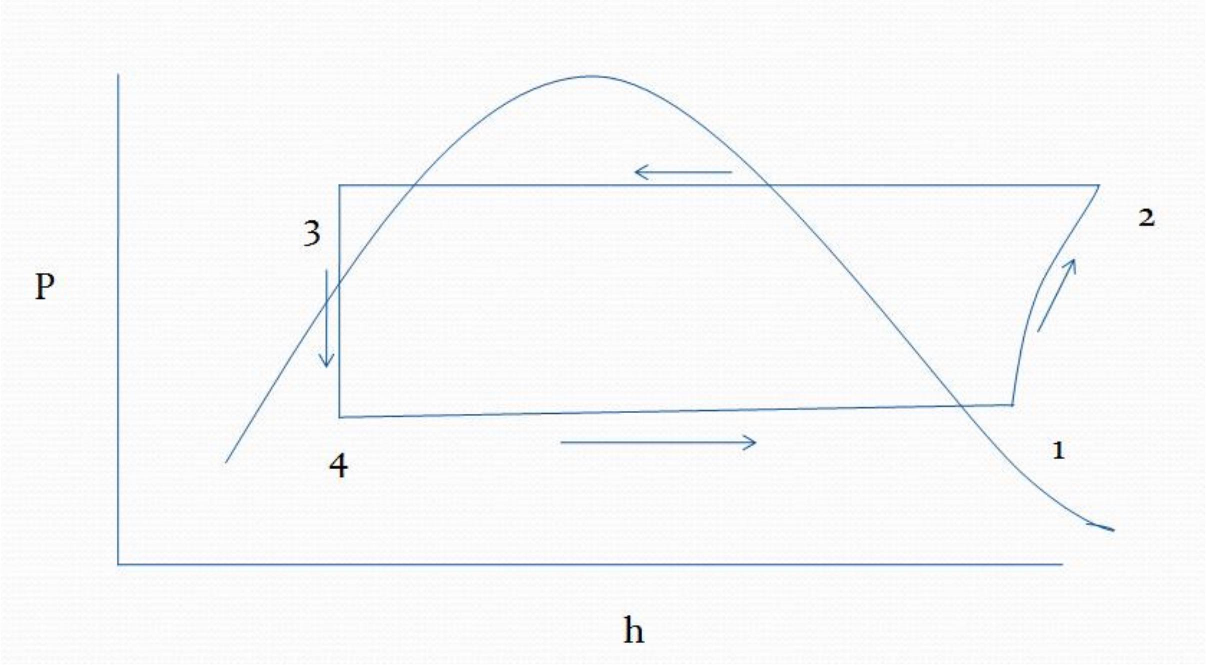

Figure 28: P-h Diagram

Results

- COP=evaporator heat absorbed/compressor work

  $= (h_1-h_4)/ (h_2-h_1)$
- For observation 1, COP =4.22
- For observation 2, COP=4.126
- For observation 3, COP=3.88
- For observation 4, COP=4.3
- For observation 5, COP=4.28
- Observation 4 has the highest COP. So this can be considered as the optimum position.

2.5 Conclusion

The optimum phenomena are analyzed. From different observations of the experiment, the highest COP value will give the proper optimum phenomena. By conducting more observations, a more perfect result can be found. Also from this experiment we can observe the performance of the evaporator, condenser, heat absorbed and heat rejected. Higher efficiency can be obtained from this experiment. The experimental data can be useful to other experiments. By proper modification with microcontroller this system can be developed with high efficiency, automation and perfection. Different equations can be solved by using proper numerical code which will be developed in future.

Chapter Three

Cooling Load

3.1 Introduction

Cooling load is the rate of heat which must be removed from the space to maintain a specific space air temperature and moisture content. The parameters affecting cooling load calculations are numerous, for example, the outside air temperature, the humidity ratio, the number and activity of people and etc. These parameters are often difficult to precisely define and always intricately interrelated. Many cooling load components vary in magnitude over a wide range during a 24 hr period. These cyclic changes in load components are not often in phase with each other. Each must be analyzed to establish the maximum cooling load for a building or zone. Moreover effects of thermal accumulation also involve in calculating procedure. Therefore various models and assumptions are developed. The estimated results at the specific time of calculation are normally expected and not the exact ones. By referring to or using difference values of parameters at the same specific time of calculation will result in difference outcomes of the calculation. Most of the reference data for the parameters used in calculation are from the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) standards which obtained from data collection and experiments. However the standards do not present the probability and variance of those data as well as the chances that other data apart from standard data might occur. ASHRAE standards define the design conditions in the form of maximum temperature for dry-bulb and wet-bulb temperature. However cooling load calculations depend not only on temperature but also on other parameters such as lighting or occupants.

3.2 Importance

Cooling load calculations can be useful for one or more of the following objectives:

- To provide information for equipment selection and HVAC design.
- To provide data for evaluation of the optimum possibilities of load reduction.
- Permit analysis of partial loads as required for the system design, operation and control.

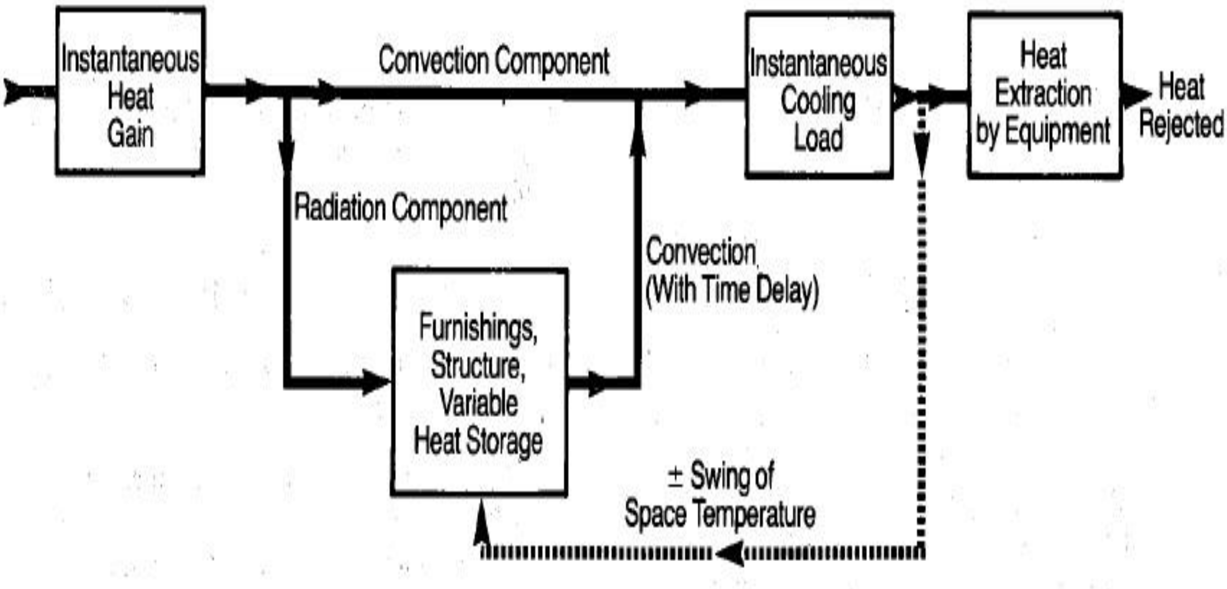

Fig. 1.1 Schematic of Load Transfer

Figure 29: Schematic of Load transfer

3.3 Cooling Load Calculating Equation

Heat gains that enter into or are generated in space are external heat gain, internal heat gain and ventilation heat gain. Only ventilation heat gain is considered in this paper to demonstrate the application of probabilistic in cooling load calculations. Heat gain from ventilation is important for areas that need high ventilation rate, for example restaurant, theater, and etc. Ventilation is used to maintain indoor air quality to standard condition. Unless the ventilation is used to maintain indoor air quality, it affects to the thermal comfort condition in the buildings. Ventilation heat gain calculations are normally referred to ASHRAE standard. The maximum dry bulb temperature is used to calculate maximum sensible heat gain. At the maximum wet-bulb temperature, if dry-bulb temperature is high, latent heat gain may decrease. In the contrary, at the maximum humidity ratio, latent heat gain is always the maximum. Moreover the maximum humidity ratio value is not necessary to be the same condition for the maximum wet-bulb temperature. This indicates that the maximum ventilation heat gain can be occurred at any point. Therefore in order to determine the ventilation load as well as its maximum heat gain value at any condition, both the dry-bulb temperature and the humidity ratio must be used.

Factors that influence to the sensible cooling load

- Glass windows or doors
- Sunlight striking windows, skylights, or glass doors and heating the room
- Exterior walls
- Partitions (that separate spaces of different temperatures)
- Ceilings under an attic
- Roofs

- Floors over an open crawl space
- Air infiltration through cracks in the building, doors, and windows
- People in the building
- Equipment and appliances operated in the summer
- Lights

Notice that below grade walls, below grade floors, and floors on concrete slabs do not increase the cooling load on the structure and are therefore ignored.

Other sensible heat gains are taken care of by the HVAC equipment before the air reaches the rooms (system gains). Two items that require additional sensible cooling capacity from the HVAC equipment are:

- Ductwork located in an unconditioned space
- Ventilation air (air that is mechanically introduced into the building)

Factors that influence to the latent cooling load

Moisture is introduced into a structure through:

- People
- Equipment and appliances
- Air infiltration through cracks in the building, doors, and windows

Other latent heat gain is taken care of by the HVAC equipment before the air reaches the rooms (system gain).

The considered equation is:

$$q= \rho Q c_p (T_o-T_i) + \rho Q h_{fg} (w_o-w_i)$$

Here,

q= Load (kW)	h_{fg} = enthalpy of water (kJ/kg)
ρ= Air density (kg/m^3)	w_o = outside humidity ratio
T_i= inside temperature	w_i = inside humidity ratio
T_o= outside temperature	c_p= specific heat of air (kJ/kg-K)
Q= air flow rate (kg/m^3)	

ρ= 1.23 kg/m^3; h_{fg} = 2500 kJ/kg; c_p = 1000 J/kg-K

On the above equation,

$\rho Q c_p (T_o-T_i)$ refers to the temperature effect and it's called **"Sensible Load".**

$\rho Q h_{fg} (w_o-w_i)$ refers to the humidity effect and it's called **"Latent Load".**

The entry of the outside air into the space influences both air temperature and the humidity level in the space. The above two terminology apply to the other load components as well, e.g. solar loads and transmission are sensible and they affect only temperature. On the other hand, internal loads arising from occupancy have both sensible and latent components.

Chapter Four

Test bench

4.1 Introduction

A test bench is a virtual environment used to verify the correctness or soundness of a design or model.

The term has its roots in the testing of electronic devices, where an engineer would sit at a lab bench with tools for measurement and manipulation, such as oscilloscopes, multi meters, soldering irons, wire cutters, and so on, and manually verify the correctness of the device under test.

In the context of software or firmware or hardware engineering, a test bench refers to an environment in which the product under development is tested with the aid of a collection of testing tools. Often, though not always, the suite of testing tools is designed specifically for the product under test.

A test bench or testing workbench has four components:

Input: The entrance criteria or deliverables needed to perform work,

Procedures to do: The tasks or processes that will transform the input into the output,

Procedures to check: The processes that determine that the output meets the standards,

Output: The exit criteria or deliverables produced from the workbench.

4.2 Design of the testing bench for measuring cooling load

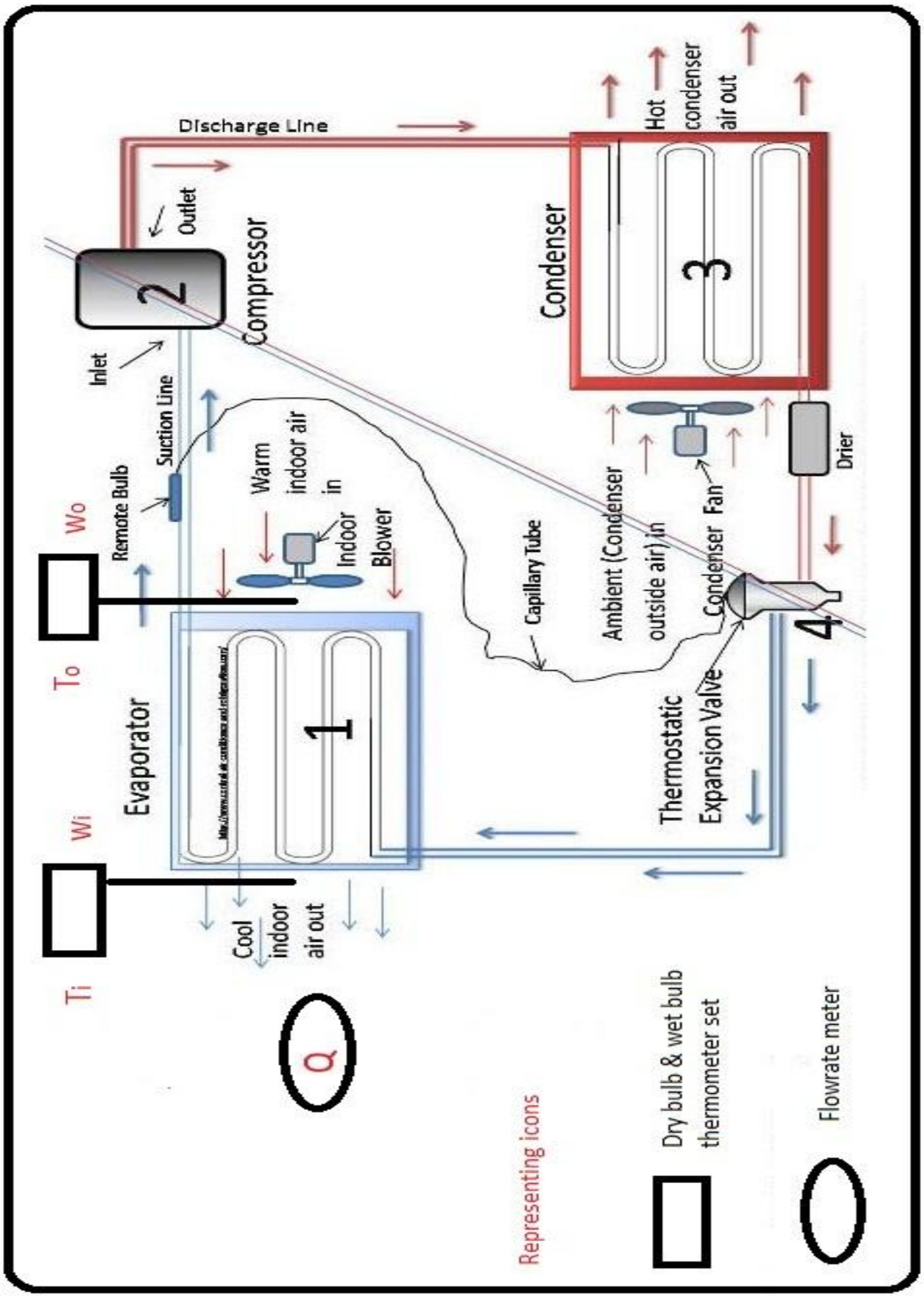

Figure 30: Design of the test bench to measure C/L

4.3 Components

Dry Bulb Thermometer

It is essentially a mercury-in-glass thermometer having a round bulb at one end and the stem is graduated in degree Celsius. The reading of this thermometer gives the free air ambient temperature at a place when exposed at a height of 1m to 1.5m inside a louvered thermometer screen installed in the open. While taking a reading, it should be made sure that no parallax error occurs.

Wet Bulb Thermometer

A wet bulb thermometer is precisely similar to dry bulb thermometer except that the bulb of the wet bulb thermometer is always kept wet by means of a muslin sheath fed by distilled water from a bottle through a wick. The bottle must be placed a little on one side of the bulb to prevent the thermometer from reading too high. The difference between the DB and WB thermometer readings is a measure of moisture content in the atmosphere.

Air Flow rate Meter

Flow-meters are devices that measure the amount of liquid, gas or vapor that passes through them. Some flow-meters measure flow as the amount of fluid passing through the flow-meter during a time period (such as 100 liters per minute). Other flow meters measure the totalized amount of fluid that has passed through the flow-meter (such as 100 liters).

Flow-meters consist of a primary device, transducer and transmitter. The transducer senses the fluid that passes through the primary device. The transmitter produces a usable flow signal from the raw transducer signal. These components are often combined, so the actual flow meter may be one or more physical devices.

Flow measurement can be described by

$Q = A \cdot v$, which means that the volume of fluid passing through a flow-meter is equal to the cross-sectional area of the pipe (A) times the average velocity of the fluid (v); and

$W = r \cdot Q$, which means that the mass flow of fluid passing through a flow-meter (A) is equal to the fluid density (r) times the volume of the fluid (Q).

Volumetric flow-meters directly measure the volume of fluid (Q) passing through the flow-meter. The only flow-meter technology that measures volume directly is the positive displacement flow-meter. **Velocity flow-meters** utilize techniques that measure the velocity (v) of the flowing stream to determine the volumetric flow. Examples of flow-meter technologies that measure velocity include magnetic, turbine, ultrasonic, and vortex shedding and fluidic flow-meters. **Mass flow-meters** utilize techniques that measure the mass flow (W) of the flowing stream. Examples of flow-meter technologies that measure mass flow include Coriolis mass and thermal flow-meters. **Inferential flow-meters** do not measure volume, velocity or mass, but rather measure flow by inferring its value from other measured parameters. Examples of flow-meter technologies that measure inferentially include differential pressure, target and variable area flow-meters.

Flow computers are often used to compensate flow measurements for actual process conditions, such as pressure, temperature, viscosity, and composition.

4.4 Procedure

Two dry bulb and wet bulb thermometer set should be placed on the both side of the evaporator. From Fig. on the right side of the evaporator, the dry bulb and wet bulb thermometer set will give the reading of outside air's temperature and humidity ratio. On the left side, the dry bulb and wet bulb thermometer set will give the reading of cooled air's temperature and humidity ratio. Taking the dry bulb and wet bulb temperature reading, humidity ratio (w_o, w_i) can be found from **Psychrometric chart.** The flow rate meter should be placed in front of the evaporator to find Air flow rate (Q). Putting all these values in the equation, the cooling load can be determined.

4.5 Conclusion

Following the design a testing bench for A/C system can be made. It leads to find Cooling load quite easily and quickly. The test bench will help to reduce the time to determine the cooling load of the A/C system, determine the eligibility of A/C system and reduce the risk in A/C system investment. Using Microcontroller the whole setup can be less sized, easier to find cooling load & very short time will be required.

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