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# VRF AND CHILLER SYSTEM

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## ABSTRACT
Air-conditioning application engineering is as much an art as it is a science. Science has evaluated all the factors required to determine a heating or cooling load through years of experimentation, testing and analysis. It is the application of these factors in determining the building or space load that much care and judgment must be exercised. This Paper report provides data and procedures for the load calculations for the summer and winter air-conditioning in Hospital applications. The intent is primarily for the summer though, but can as well be adopted for winter and year round conditioning system design. An air cooled Variable Refrigerant flow/Variable refrigerant volume air-conditioning system is employed in this Hospital building. For applications such as this project where life safety and air quality is important, or for specific processes conditions, a consulting engineer in that particular application should be employed. In order to perform an accurate estimate of the cooling loads and accurate survey of the load components of the space to be conditioned must be made.

**KEYWORDS:** Air-conditioning, Refrigerant, Variable refrigerant volume, air cooled Variable Refrigerant flow.

## INTRODUCTION

### Refrigeration Cycle

Once the heat energy leaves the refrigerant, it transforms back into a liquid, and then travels back into the evaporator to repeat this cooling cycle. To maximize the operating life of a refrigerator, owners must perform routine maintenance tasks, which include cleaning the refrigerator condenser coils. The cold gas circulates into the refrigerator again, absorbing heat from the inside, before being routed into the compressor again. The purpose of the refrigeration cycle is to take heat from the inside of the refrigerator and transfer it to the outside. To understand the refrigeration cycle better, one must be familiar with the idea of a phase change.

### Different types of refrigeration systems

Industrial refrigeration units are not the same as residential refrigeration units. When it comes to cooling food items at an industrial level, different refrigerants are used, including anhydrous ammonia, carbon dioxide, and propane. In order to choose the best refrigeration system for your industrial space, it's best to first understand how each unit functions. Anhydrous ammonia is used frequently, and it is often the type of coolant in most industrial refrigeration units. Due to ammonia's excellent heat transfer capabilities, this coolant can keep food cold for a long period of time. In addition, ammonia does not harm the environment, and it is also biodegradable. Carbon was once the only form of industrial refrigeration. Even though carbon dioxide was largely phased out over the past few years, this type of coolant is resurfacing once again. The main advantage to carbon dioxide is that it can cool foods quickly, which is often crucial for industrial applications.

There are several common types of commercial refrigeration units that are used by different industries. Units come in a variety of sizes from small display cases to entire refrigerated warehouses. Industries such as restaurants, florists, and food processing companies commonly use refrigeration. One of the more common types of commercial refrigeration units is the walk-in refrigerator or freezer. These units form an entire room that workers can enter. They are able to store a large number of goods and can keep them cold or frozen economically. The materials used in these units retain the cold while offering easy access to the goods through a door. Refrigerated warehouses are also used in businesses that require a large area to be cooled or for those that must perform work in refrigerated areas.

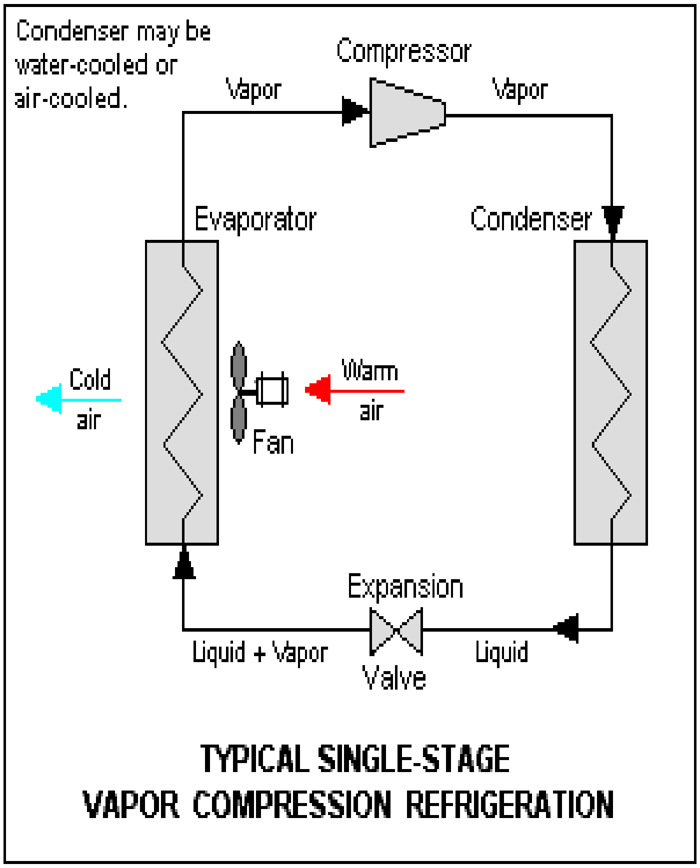
1. Ice refrigeration
2. Air refrigeration
3. Vapour compression refrigeration system.
4. Vapour Absorption refrigeration system.
5. Binary cycle
6. Special refrigeration system.

**Vapour compression Refrigeration cycle:**

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 below depicts a typical, single-stage vapor-compression system. All such systems have four components: a compressor, a condenser, an expansion valve (also called a throttle valve), and an evaporator. Circulating refrigerant enters the compressor in the thermodynamic state known as a saturated vapour 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.

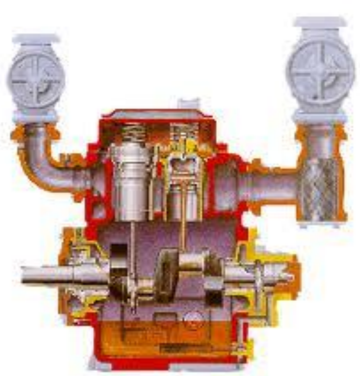
The cold mixture is then routed through the coil or tubes in the evaporator. A fan circulates the warm air in the enclosed space across the coil or tubes carrying the cold refrigerant liquid and vapor mixture. That warm air evaporates the liquid part of the cold refrigerant mixture. At the same time, 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.



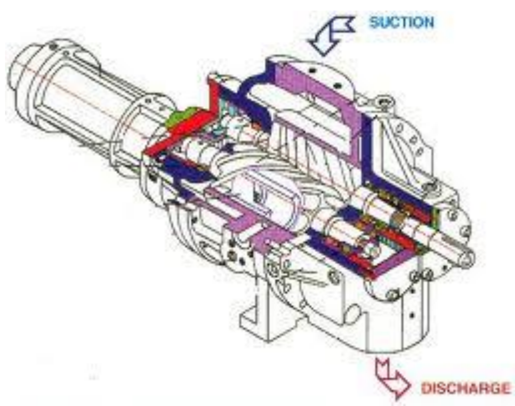

***1.4 Parts of simple Vapour Compression Refrigeration system:***

a. Compressor
b. Condenser
c. Expansion valve.
d. Evaporator.
e. Discharge line or hot gas line.
f. Receiver tank
g. Liquid line.
h. Suction line.

**Compressors:**



***1.5.1 Reciprocating compressor***




***1.5.2 Rotary compressor***

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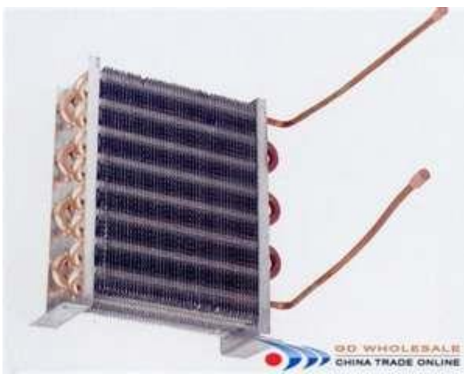
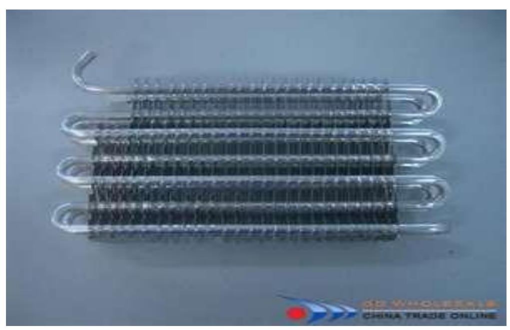
*1.5.3 Centrifugal compressor*

*1.5.4 Scroll compressor*



*1.5.5 Air cooled Condenser*

*1.5.6 Expansion valve*



*1.5.7 Evaporator:*

## AIR-CONDITIONING FUNDAMENTALS

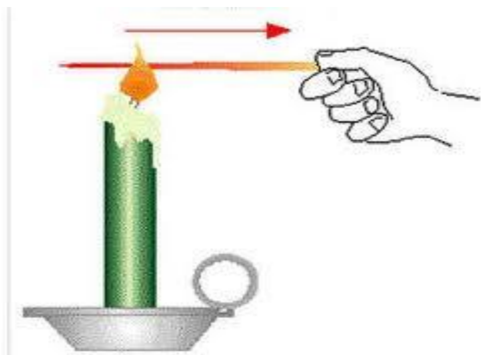
Air-conditioning is that branch of engineering science which deals with the treatment of air i.e., filtering, removal or addition of humidity, change in temperature, supplying and maintaining desirable internal atmospheric conditions for human comfort, irrespective of external conditions. This subject in broad sense also deals with the conditioning of air for industrial purposes, food processing, storage of foods and other materials.

**Atmospheric conditions for Human Comfort:**

a. Temperature of Air 21.5º C – 26º C
b. Relative Humidity of air 45 % - 55 %
c. Purity of air – Filtered, clean, dust and particulate free and odour less air.
d. Motion of air.

**Heat Transfer:**
Heat is associated with the internal potential and kinetic energy (an apparently disorganized molecular motion) of a system. If heat is a form of energy associated to the particles' rotational, translational and vibratory movements, how does the heat move through the space between the Sun and the Earth, which density is extremely low? The answer is: heat could be transferred from warmed systems by radiation. The thermal radiation is electromagnetic radiation that consists of particles and waves, i.e. photons and waves, the same as visible light. Thus, the radioactive heat transfer can take place through vacuum. The energy always moves from a warmer system to a colder system. The energy which is moving from one system to another is known as heat. The transfer or dispersion of heat can occur by means of three main mechanisms, conduction, convection and radiation:

***Conduction***
It is the flow of heat through solids and liquids by vibration and collision of molecules and free electrons. The molecules of a given point of a system which are at higher temperature vibrate faster than the molecules of other points of the same system -or of other systems- which are at lower temperature. The molecules with a higher movement collide with the less energized molecules and transfer part of their energy to the less energized molecules of the colder regions of the structure. For example, the heat transfers by conduction through the bodywork of a car.



***Heat conduction***

Metals are the best thermal conductors; while non-metals are poor thermal conductors. For comparison, the thermal conductivity (k) of the copper is 401 W/m*K, while the thermal conductivity (k) of the air is 0.0263 W/m*K. The thermal conductivity of the carbon dioxide ($CO_2$) is 0.01672 W/m*K, almost the thermal conductivity of an isolator. Formula to calculate the conductivity gradient for a given system:

$$q = - kA (\Delta T/\Delta n)$$

Where $\Delta T/\Delta n$ is the temperature gradient in the direction of area A, and k is the thermal conductivity constant obtained by experimentation in W/m.K.

***Convection***
Flow of heat through currents within a fluid (liquid or gas). Convection is the displacement of volumes of a substance in a liquid or gaseous phase. When a mass of a fluid is heated up, for example when it is in contact with a warmer surface, its molecules are carried away and scattered causing that the mass of that fluid becomes less dense. For this reason, the warmed mass will be displaced vertically and/or horizontally, while the colder and denser mass of fluid goes down (the low-kinetic-energy molecules displace the molecules in high-kinetic-energy states). Through this process, the molecules of the hot fluid transfer heat continuously toward the volumes of the colder fluid.

For example, when heating up water on a stove, the volume of water at the bottom of the pot will be warmed up by conduction from the metallic bottom of the pot and its density decreases. Given that it gets lesser dense, it shifts upwards up to the surface of the volume of water and displaces the upper -colder and denser- mass of water downwards, to the bottom of the pot.

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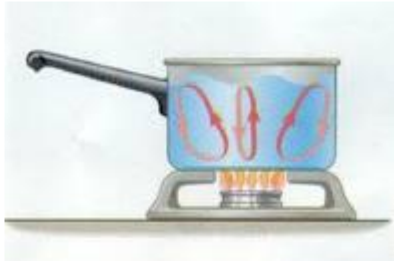


***Heat convection***

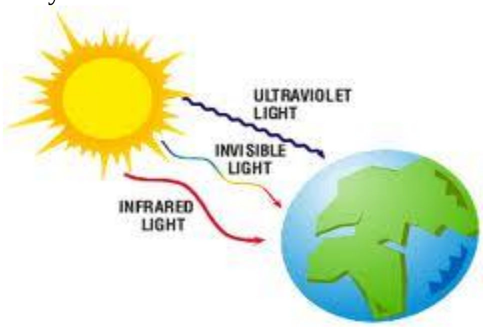
***Formula of Convection:***

**q = hA (Ts - T ∞)**

Where h is for convective heat transfer coefficient, A is the area implied in the heat transfer process, Ts is for the temperature of the system and T ∞ is a reference temperature.

***Radiation***

It is heat transfer by electromagnetic waves or photons. It does not need a propagating medium. The energy transferred by radiation moves at the speed of light. The heat radiated by the Sun can be exchanged between the solar surface and the Earth's surface without heating the transitional space.For example, if I place an object (such as a coin, a car, or myself) under the direct sunbeams, I will note in a little while that the object will be heated. The exchange of heat between the Sun and the object occurs by radiation.

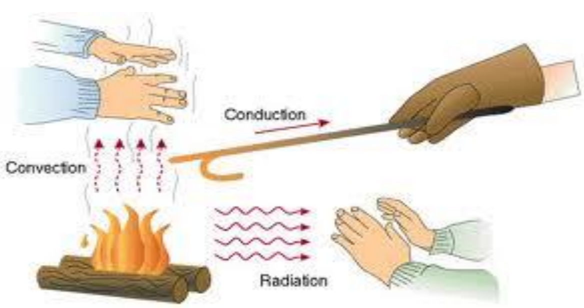


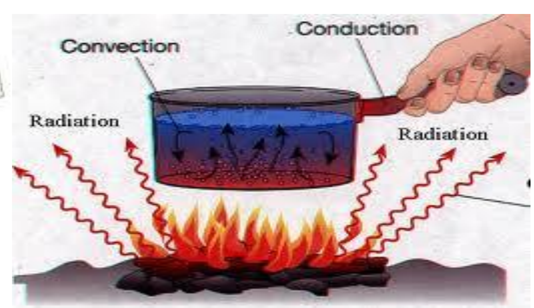

***Heat Radiation***

The formula to know the amount of heat transferred by radiation is:

**$q = e \sigma A [(\Delta T)^4]$**

Where q is the heat transferred by radiation, E is the emissivity of the system, σ is the constant of Stephan-Boltzmann ($5.6697 \times 10^{-8}$ $W/m^2.K^4$), A is the area involved in the heat transfer by radiation, and $(\Delta T)^4$ is the difference of temperature between two systems to the fourth or higher power.

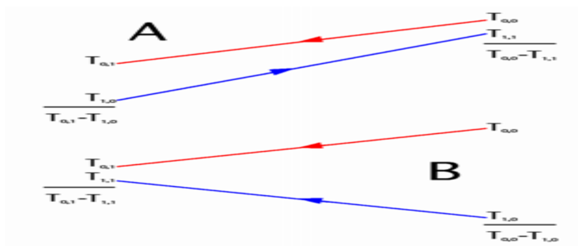


## HEAT EXCHANGERS

**Introduction:**

A heat exchanger is a piece of equipment built for efficient heat transfer from one medium to another. The media may be separated by a solid wall, so that they never mix, or they may be in direct contact. They are widely used in space heating, refrigeration, air conditioning, power plants, chemical plants, petrochemical plants, petroleum refineries, natural gas processing, and sewage treatment. One common example of a heat exchanger is the radiator in a car, in which the heat source, being a hot engine-cooling fluid, water, transfers heat to air flowing through the radiator (i.e. the heat transfer medium).




**Parallel Flow and Counter Flow Heat Exchanger**

When heat is exchanged between two fluids flowing through a heat exchanger, the rate of heat transferred may be calculated using $Q = UA\Delta tm$

Where

U = overall coefficient of heat transfer from fluid to fluid

A = heat transfer area of the heat exchanger associated with U, m.

Δ□tm = log mean temperature difference (LMTD)

For a heat exchanger with a constant U, the□Δtm is calculated as

$$\Delta t_m = C_f \frac{(T_1 - t_2) - (T_2 - t_1)}{\ln (T_1 - t_2)/(T_2 - t_1)}$$

Where the temperature distribution is as shown in Figure above and $C_f$ is a correction factor (less than 1.0) that is applied to heat exchanger configurations that do not follow a true counter flow design. Figure above illustrates a temperature cross, where the outlet temperature of the heating fluid is less than the outlet temperature of the fluid being heated (T2 < t2). A temperature cross can only be obtained with a heat exchanger that has a 100% true counter flow arrangement. The overall coefficient U is affected by the physical arrangement of the surface area A. For a given load, not all heat exchangers with equal surface areas perform equally. For this reason, load conditions must be defined when selecting a heat exchanger for a specific application.

The load for each fluid stream can be calculated as

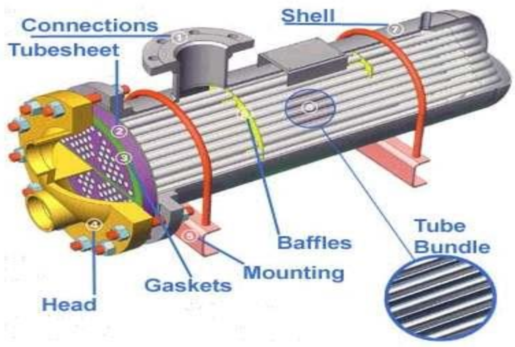
$Q = mc_p\,(t_{in} - t_{out})$

The value of Δtm is an important factor in heat exchanger selection. If the value Δ□tm is high, a relatively small heat exchange surface area is required for a given load. The economic impact is that the heat exchanger must be designed to accommodate the forces and movements associated with large temperature differences. When the approach temperature (the difference between $T_2$ and $t_1$) is small, □Δtm is also small and a relatively large A is required.

**Types of Heat Exchangers:**

***Shell and 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.




***3.2.1 Shell and Tube Heat exchanger***

***3.2.2 Plate heat exchanger:***

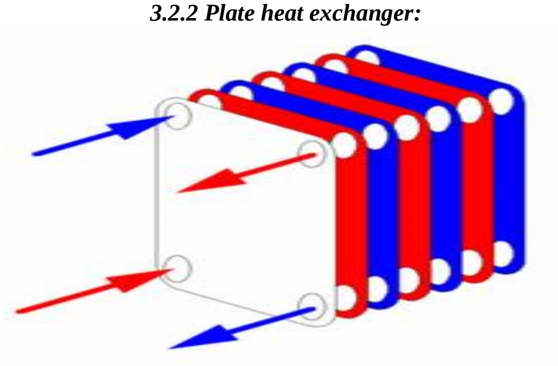


**Plate and frame heat exchanger.**
Another type of heat exchanger is the plate heat exchanger. One is composed of multiple, thin, slightly-separated plates that have very large surface areas and fluid flow passages for heat transfer. This stacked-plate arrangement can be more effective, in a given space, than the shell and tube heat exchanger. Advances in gasket and brazing technology have made the plate-type heat exchanger increasingly practical.

**Single plate heat exchanger**
In HVAC applications, large heat exchangers of this type are called plate-and-frame; when used in open loops, these heat exchangers are normally of the gasket type to allow periodic disassembly, cleaning, and inspection. There are many types of permanently-bonded plate heat exchangers, such as dip-brazed and vacuum-brazed plate varieties, and they are often specified for closed-loop applications such as refrigeration. Plate heat exchangers also differ in the types of plates that are used, and in the configurations of those plates. Some plates may be stamped with "chevron" or other patterns, where others may have machined fins and/or grooves.

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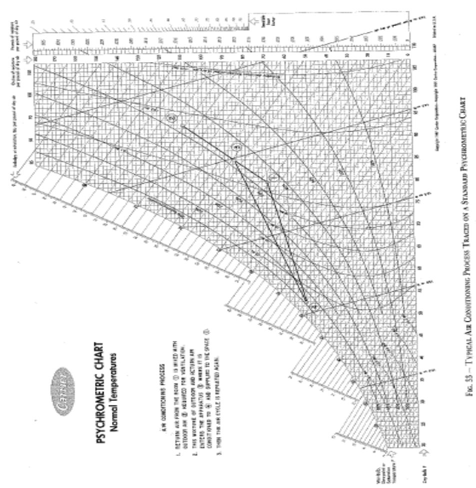
**Plate fin heat exchanger:**
This type of heat exchanger uses "sandwiched" passages containing fins to increase the effectively of the unit. The designs include cross flow and counter flow coupled with various fin configurations such as straight fins, offset fins and wavy fins. Plate and fin heat exchangers are usually made of aluminum alloys which provide higher heat transfer efficiency. The material enables the system to operate at a lower temperature and reduce the weight of the equipment. Plate and fin heat exchangers are mostly used for low temperature services such as natural gas, helium and oxygen liquefaction plants, air separation plants and transport industries such as motor and aircraft engines.

## PSYCHOMETRY
The art of measuring the moisture content of air is termed as Psychometry.The science which investigates the thermal properties of moist air , considers the measurement and control the moisture content of air, and studies the effect of atmospheric moisture on material and human comfort may properly be termed as Psychometrics' device which is used for measuring wet bulb and dry bulb temperatures simultaneously.

**Psychometric chart:**



**Psychometric process:**
***Sensible heating:***
By sensible heating, heat is added to the air which results in temperature rise and there is no change in the moisture content of air. In other words moisture is constant. On the Psychometric chart this process is shown as a straight horizontal line

***Sensible cooling:***
By sensible cooling the temperature will fall without change in moisture content, resulting in removal of heat as such fall in wet bulb temperature.

***Cooling and de-humidification:***
If heat is removed from air its resulting in fall in dry bulb temperature. If the surface temperature of the coil is maintained below the dew point temperature of the air then dehumidification starts with removal of moisture. The dry bulb temperature, the moisture content and the wet bulb temperature decreases showing the removal of heat.

***Heating and humidification:***
If heat and moisture is added or air it will follow the process just opposite to that of cooling and dehumidification. The dry bulb temperature increases showing addition of heat.

***Bypass Factor:***
It is that portion of air passing through the heat exchanger coils / fins completely unaltered from its entering conditions. This could be due to lesser heat transfer area, less coil surface area, wider spacing of the coil/ fins, increase in velocity.

## AIR-CONDITIONING SYSTEM CLASSIFICATION

**Different air-conditioning units commercially available in market:**

a. Split units.
b. Ducted split units.
c. Packaged units.
d. Water cooled split units.
e. Air cooled chillers.
f. Water cooled chillers.

## COOLING LOAD CALCULATION:

The Air-conditioning load is estimated to provide the basis for selecting the conditioning equipment. In this load estimate the heat coming into the conditioned space as well as the heat being generated by the occupants and machines is accounted.

**Load Estimation:**
Estimation of cooling / heating load involves the following variables.

a. Magnitude and direction of wind velocity.
b. Outside Humidity and Temperature.
c. Nature and Material of construction, i.e. Resistance I value.
d. Orientation of the Structure (Building).
e. Type of Windows (single glazed, double glazed) and doors.
f. Periods of Occupancy.
g. Number of Persons in the room
h. Occupant's activities.

**Cooling Load Estimate** :
Room Sensible Heat (RSH)

1. Solar and transmission heat gain thru walls and roof,
2. Solar and transmission heat gain thru glasses,
3. Transmission heat gain thru partition wall, ceiling, floor, etc,
4. Infiltration,
5. Internal heat gain from people, power, lights, appliances, etc,
6. Supply duct heat gain, supply duct leakage loss and fan power,
7. Additional heat gain not accounted above, safety factor.

**Room Latent Heat (RLH):**
A latent heat gain is the heat contained in water vapour. It is the heat that must be removed to condense the moisture out of the air.

1. Infiltration
2. Vapor transmission
3. Internal heat from people, steam, Appliances, etc.,
4. Supply duct leakage loss.
5. Additional heat gain not accounted above, safety factor.

**Heat and water Vapour flow through Structures**:
There is a high chance of flow of water vapour through structures due to the temperature and humidity difference produced in the conditioned space and the outside air.
This process can be controlled by

1 Applying plastic type of paints on the interior and exterior of the walls to close the porosity of the walls.
2 In composite wall structures a poly ethylene sheet id used on both the sides of the insulating material present inside the composite walls so as to prevent the transmission of moisture into the air-conditioned space.

**Building survey/Building Orientation :**
Physical site inspection of the building is a must before starting the HVAC design for that building. The orientation of the building with respect to the four directions N/S/E/W – NE / SE / SW / NW by a compass or by the visual judgment with respect to the sun position.

## VRF-VARIABLE REFRIGERANT FLOW:
Many HVAC professionals are familiar with mini-split systems: an air conditioner or heat pump with more than one factory-made assembly (e.g., one indoor and one outdoor unit). A variation of this product, often referred to as a multi-split or a variable-refrigerant flow (VRF) system, typically consists of:

A condensing section housing compressor(s) and condenser heat exchanger.Multiple indoor direct-expansion (DX) evaporator fan-coil indoor units with electronic expansion devices, temperature sensing capabilities, and a dedicated microprocessor for individual control,A single set of refrigerant piping that interconnects the condensing unit and the evaporator units,A zone temperature control device that may or may not be interlocked with a system controller.VRF multi-split products are fundamentally different from unitary or other types of traditional HVAC systems in that heat is transferred to or from the space directly by circulating refrigerant to evaporators located near or within one conditioned space. In contrast, conventional systems transfer heat from the space to the refrigerant by circulating air (in ducted unitary systems) or water (in chillers) throughout the building. The main advantage of a VRF system is its ability to respond to fluctuations in space load conditions by allowing each individual thermostat to modulate its corresponding electronic expansion valve to maintain its space temperature set point (see Tables 1 and 2 for a comparison of VRF to other systems).

## VRF SYSTEM
A system that provides Climate control & zoning comfort. Effective energy consumption by means of optimized inverter driven scroll compressor & temperature controls, producing highly responsive cooling and/or heating. Outdoor units with single or multiple variable speed DC compressors. Single or multiple indoor units equipped with temperature sensing devices.A factory supplied zone temperature supervisory control, GUI and networking Capabilities.

## CHILLED WATER PIPE DESIGNING AND PUMP SELECTION
Water pipe lines are used in HVAC for the circulation of chilled water from the refrigeration plant to the air-conditioned space / AHU / FCU. Water pipe lines are also used for the circulation of water from the condenser to the cooling tower. The size and length of the pipes and fittings must be designed so as to minimize the frictional losses thereby reducing the initial and recurring cost.

## COMPARISON BETWEEN VRF AND CHILLED WATER SYSTEM:

| Item | Description | Variable Refrigerant Flow | Chilled Water AC System |
|---|---|---|---|
| 1 | Human Comfort | Good –true air conditioning | Not so good air conditioning |
| 2 | Operation at partial load | Good performance and control | Good performance and control |
| 3 | Long distance pipes | No Problem | Up to 100 m is OK, If more then there is a cooling capacity reduction up to 75% |
| 4 | Installation | Easy to install | Difficulty in installation |
| 5 | Customer operation | Easy and simple – Good Very important | Not so clear to customer - Acceptable |
| 6 | Malfunction Possibility | More reliable, just few parts and components | To many parts and components and long pipe lines |
| 7 | Operational life expectation | Up to 25 years - Acceptable | Up to 15 years – Good |
| 8 | Maintenance | No problem ,Good | Depends on the design, access may be a problem |
| 9 | Space Requirement | Require less space | Require more space |

## 11 Cost Estimation Of Vrf And Chilled Water System:

11.1 Cost Estimation Of Vrf:

Ducted Split Unit Air Conditioner Of 4tr Capacity Is = Rs21,000/-

For 6 Units Of 4tr Capacity 6 X 21,000 = Rs1,26,000/-

Installation Charges Is 6 X 1,000 = Rs6,000/-

Outdoor Unit Of (24tr X 1.5) = 36 Tr Is = Rs4,44,000/-

Installation Charges Is = Rs50,000/-

Copper Piping For Room 1 = Rs17,000/-

Room 2 = Rs7,000/-

Room 3 = Rs34,000/-

Installation Charges = Rs1,70,000/-

Total Cost = Rs8,75000/-

11.2 Cost Estimation Of Chilled Water System:

Cost Of Chiller 2 X 3,75,000 = Rs7,50,000/-

Cost Of Pump Of 4hp 2 X 50,000 = Rs1,00000/-

Cost Of Ms Piping = Rs60,000/-

Total Cost = Rs9,10,000/-

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## CONCLUSION

It is concluded that by using air-conditioning system the indoor air quality is maintained, which is free of bad odour, allergic bacteria, fungus, smoke and other air contaminants. The air temperature is also maintained at its level and the occupants are comfortable in the system. The fresh air contains sufficient amount of oxygen so that our occupants can get a hygienic environment in which human body and mind can feel comfort. The criteria of the design of VRF compare to Chilled water system saves at least 40% of cost of installation as well as it gives a quality of air.

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