REFRIGERATION / AIR CONDITIONING

FUNDAMENTALS & BASIC COMPONENTS

Package No: NR 145

Nominal Student Hours: Flexible.

Delivery: Competence in this training program can be achieved through either a formal education setting or in the workplace environment.

Recognition of Prior Learning: The student / candidate may be granted recognition of prior learning if the evidence presented is authentic and valid which covers the content as laid out in this package.

Package Purpose: In this program students will study the principles of Refrigeration as applied to the vapour Compression Cycle. Identify, list and describe the function and operation of the Major Components and Flow Controls as utilised in the Vapour Compression System. Additionally, students are introduced to the basic Fundamentals of Air Conditioning and associated processes.


Assessment Strategy: The assessment of this package is holistic in nature and requires the demonstration of the knowledge and skills identified in the package content. To be successful in this package the student must show evidence of achievement in accordance with the package purpose.
**Additional Resources:**


Refrigeration and Air Conditioning, Third Edition; Air Conditioning and Refrigeration Institute. Library Reference 621.56REFR

**Videos:**

*History of Refrigeration; TAFE SA Cat No 88.017 9 mins (SIT No. 92)*

*Jobs in Air Conditioning; AMCA 11 min 29 sec (SIT No 67)*

*History of the Refrigerator (SIT No 75)*

*Heat & Pressure; TAFE SA Cat No 85.022 16 mins (SIT No A1)*

*Basic Refrigeration Cycle; TAFE SA Cat No 85.050 9 mins (SIT No A2)*

*Reciprocating Compressors: TAFE SA Cat No 86.040 7 mins (SIT NoG1)*
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Assessment:

Grade Code: 72

<table>
<thead>
<tr>
<th>GRADE</th>
<th>CLASS MARK (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DISTINCTION</td>
<td>&gt;=83</td>
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<tr>
<td>CREDIT</td>
<td>&gt;=70</td>
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<td>PASS</td>
<td>&gt;=50</td>
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</table>

Assessment Events:

1. Assignment 18/72 10%
2. Theory Test 1 36/72 40%
3. Theory Test 2 54/72 30%
4. Theory Test 3 72/72 20%

Assignment: Written report of 1000 words covering the classifications of the six main areas of the Refrigeration and Air Conditioning industry.

Theory Test 1: Short answer questions, multiple choice questions, diagrams and calculations. This assessment covers contents from 1 to 9 in the content summary.

Theory Test 2: Short answer questions, multiple choice questions, diagrams and calculations. This assessment covers contents from 10 to 11 in the content summary.
Refrigeration Fundamentals:

1. History of Refrigeration

Purpose:
The purpose of this section is to provide you with an insight into the development of refrigeration systems from the discovery of ice as a means of preserving foods through the technological advances of modern day.

Recommended videos:
History of Refrigeration; TAFE SA Cat No 88.017 9 mins (SIT No. 92)
History of the Refrigerator (SIT No 75)

Primitive man discovered that coldness slowed down the rate of deterioration of meat and other organic substances. It was eventually realised that this was due to the lower ambient temperature.

Most evidence indicates that the Chinese were the first to store natural ice and snow to cool wine and other delicacies. Evidence has been found that ice cellars were used as early as 1000B.C. in China. Early Greeks and Romans also used underground pits to store ice, which they covered with straw, weeds, and other materials to provide insulation and preserve it over a long period.

Ancient people of Egypt and India cooled liquids in porous earthen jars. These jars were set in the dry night air, and the liquids seeping through the porous walls evaporated to provide the cooling.

Other examples of early refrigeration used in ancient times were:

- In 356 B.C. Alexander the Great supplied his army with refrigerated wine by utilising the use of natural ice.
- The emperor Nero in 68 A.D. used ice to cool and control the room temperature.
- In the Gironde region of France a particularly cold cave was discovered which was used as a refrigerated store 3000B.C.
- The Roman Catacombs, originally quarries, were used as food stores.

In the 18\textsuperscript{th} and 19\textsuperscript{th} centuries, blocks of natural ice were cut from lakes and ponds in winter and stored underground for use in the warmer months. During the 19\textsuperscript{th} century, blocks of ice were distributed for use in purpose built containers called iceboxes. At the time, iceboxes were sufficient for the keeping of foodstuffs but towards the end of the 19\textsuperscript{th} century new inventions were being developed for the storage of food.
The development of mechanical refrigeration had to await progress in the physical sciences. This included a clear concept of the nature of gases and liquids, the relationship between heat and other forms of energy, the behaviour of vapours, etc.

The branch of physics that forms the scientific basis of modern refrigeration is thermodynamics.

Thermodynamics is the science of the mechanics of heat.

**The first law of thermodynamics:**
- Heat and mechanical work were equivalent and stood in a fixed relationship to each other.

The first law of thermodynamics in refrigeration is attributed to Robert Mayer, a German and Joule, an Englishman.

**The second law of thermodynamics:**
- Wherever there is a temperature difference, a moving force can be generated.

The second law of thermodynamics in refrigeration is attributed to Sadi Carnot, a Frenchman (who first introduced the term entropy) and Rudolph Clausius, a German.

**Gas laws:**
- An understanding of the behaviour of what we call refrigerants is equally as important. i.e. the behaviour of the gas laws can be applied to refrigerants.

**Historical dates for the development of the refrigeration industry:**

1662 – 1802  Boyle, Gay-Lussac, Dalton, Charles and Mariotte were credited with formulating the Gas Laws. They showed the exact way in which volume, pressure and temperature are connected in behaviour in ideal gases.

1895  Richard Molliér calculated the first exact vapour tables for CO$_2$ and introduced a graphic representation of the properties of steam, air and refrigerants, which still bear his name.

1823  Michael Faraday discovered that certain gases under constant pressure will condense when the cool.

1834  Jacob Perkins filed a patent for a closed refrigeration system using liquid expansion and then compression to produce cooling.

1848  James Harrison sets up the world’s first ice manufacturing plant in Geelong, Victoria and secured patents to cover his invention. His system used Ether which is dangerous due to its flammability.
1861 Ferdinand Carre, a Frenchman, developed a mechanical refrigerator using liquid ammonia. His machine was used to make ice at a rate of 250kgs per hour.

1895 Richard Mollier introduces a graphic representation of vapour tables for CO$_2$, steam and refrigerant.
1902 Willis Carrier designed a humidity control to accompany a new air cooling system. He also originated the Carrier equation upon which the psychrometric chart and all air conditioning is based.

1925 First industrial use of dry ice.

1931 Refrigerant R12 was developed by Thomas Midgely and C. f. Kettering.

1933 The introduction of the ‘Freon’ group of refrigerants that was to revolutionise the refrigeration and air conditioning industry.

1939 Copeland introduces the first successful semi-hermetic (Coplematic) field serviceable compressor.

Only a half century ago, the iceman was a regular figure in most neighbourhoods, delivering blocks of ice to keep food cold.

1974 Professors Rowland and Molina presented the “ozone theory” that CFCs were depleting the ozone layer.

1985 Stratospheric ozone hole discovered.
1987  Industrialised countries including Australia sign the Montreal Protocol for the reduction of CFC refrigerants.

1990  London Amendments to re-evaluate the world’s production of CFC’s.

1990  Introduction of new HCFC refrigerants R123 & R134a into the industry.


1992  Copenhagen Amendments to increase the percentage of phase out of the CFC’s.

1997  Kyoto Protocol intended to reduce worldwide global warming gas emissions. The greenhouse effect, or global warming, had become a major environmental issue.

1998 – 2005  R410A, an efficient and environmentally friendly HFC based refrigerant blend for residential and light commercial air conditioning applications is used with the scroll compressor for greater efficiencies.

2005  The industry is so diverse and technologically advanced that it is uncommon for the modern technician to be conversant in all areas of the industry. It has become necessary to “specialise” in one of the many sectors whether it be installation, commissioning, or service. It is then to be further decided whether to perform this specialisation in the domestic, industrial, commercial or transport area of either refrigeration or air conditioning.
2. Six Main Classifications of the Industry:

**Purpose:**
The purpose of this section is to provide the underpinning knowledge and skills to identify the various applications within the Refrigeration and Air Conditioning Industry.

**Recommended videos:**
*Jobs in Air Conditioning; AMCA 11 min 29 sec (SIT No 67)*

The six main classifications of the industry are:
- Appliance Servicing / Domestic Refrigeration
- Commercial Refrigeration / Beverage Cooling and Commercial Cabinets
- Industrial Refrigeration / Industrial Freezing and Equipment
- Transport and Marine
- Comfort Air Conditioning / Package and Central Air Conditioning Equipment
- Process Air Conditioning / Industrial Air Conditioning / Specialised Air Conditioning Equipment

**Summary:**
- The three main areas of the industry are appliance servicing, refrigeration and air conditioning.
- The appliance industry covers domestic refrigerators and freezers, and air conditioning systems.
- The refrigeration industry covers commercial and industrial applications, for example merchandising cabinets, coolroom, freezer room, icemakers, beverage coolers etc.
- The air conditioning industry covers residential, mechanical services in office buildings, shopping centres, hospitals, as well as industrial processes such as printing, textile and drug manufacturing.
- Air conditioning is the simultaneous year-round control of temperature, humidity, air purity, air movement and noise, within an enclosed space.
- For short-term storage of food, the temperature is 3°C and the freezer temperature -18°C.
- Air-conditioned space for human comfort should be approximately 23°C and 50 to 55% relative humidity (RH).
The Refrigeration & Air Conditioning Industry

3 Main Fields of the Industry

Appliance Servicing
- Domestic Refrigeration
- Commercial
- Industrial
- Transport / Marine

Refrigeration
- Domestic Refrigeration
- Commercial
- Industrial
- Transport / Marine

Air Conditioning
- Comfort
- Process

Domestic Refrigeration
- Refrigerators
- Freezers

Cabinets, Coldrooms
Beverage Cooling, Cold Plates
Freezer Rooms, Ice Making
Soft Serve

Food Processing
- Food Storage
- Specialised Equipment

Industrial Ice making

Fishing Boats
- Containers
- Trucks
- Rail Cars

Home A / C
- Small, Medium Unit
- Large Buildings

Meat Processing Rooms
- Switchrooms
- Computer Rooms
- Laboratories

Domestic Refrigeration
- Refrigerators
- Freezers

Beverage Cooling (4°C)
- Water Coolers
- Temptrites
- Dispensers

Cold Plates
- Butcher Shops
- Salad Bars

Freezer Rooms (Small)
- -20°C to -40°C

Ice Making
- Flaked
- Crushed
- Cubed

Soft Serve
- Ice Cream
- Slush machines

Food Processing
- Ice Creameries
- Blast Freezers
- Breweries
- Wineries

Food Storage
- Long term freezers

Specialised Equipment
- Chemical manufacture
- Petro / Chemical

Industrial
- Ice making
- Block ice
- Crushed ice
- Dry ice

Fishing Boats
- Trawlers
- Mother ships

Containers
- Trucks
- Rail
- Ships

Trucks / Rail
- Semis
- Van
- Refrigerated Rail Car
- Planes
- Boats
- Trains
- Buses
- Car

Home A / C
- Room Air Conditioner (RAC)
- Split Systems
- Evaporative

Large Buildings
- Central Plant
- Hospitals
- Office Blocks
- Departmental Stores

Small / Medium
- Units
- Homes
- Small Offices
- Small Shops

Meat Processing Rooms
- Butcheries
- Switchboards
- Lift Rooms
- PABX Rooms
- Computer Room
- Banking
- Offices
- Laboratories
- Bacteria Growth
Assignment: Classifications of the Refrigeration and Air Conditioning Industry.

Purpose: This assignment is to provide you with the relevant information to differentiate between the different areas of specialisation within the Refrigeration and Air Conditioning Industry.

Task: Compile a written report which covers the following criteria:

- Describe each of the six main classifications of the Refrigeration and Air Conditioning Industry.

- For each classification, select one type of system and report on its construction, operation and conditions which distinguish it from other systems. You will need to include the refrigerant type, operating pressures and the desired operating conditions (temperature and humidity).

Criteria: Your class teacher will advise when the assignment is to be handed in and any penalties which may exist for late submissions.

Pictures and / or diagrams must accompany each classification.

Each classification must be commenced on a new page and be of approximately 200 words.

All pages are to be numbered.

The assignment must be legible; i.e. it may be hand written provided it is neat and easily read.

The assignment is to be presented in a folder. A single plastic sleeve is not considered a folder for presentation.

You will need to include a cover page (which includes your name, class, due date and teachers name), a contents page (listing page numbers for each classification) and a bibliography (last page) acknowledging all references.

Three hours of class time will be allocated for library research and study. (For block release classes this will usually be on a Friday afternoon).
3. Matter:

Purpose:
The purpose of this section is to provide you with the underpinning knowledge and skills to identify basic structures such as matter, atoms, molecules that are essential in the formation of solids, liquids and gases. To understand how ‘heat’ will flow.

Matter
Matter is anything that has mass and occupies space. It can exist as a solid, liquid or vapour / gas. The smallest particle of a piece of matter is an atom.

The Atom
The atom consists of a nucleus at its centre, made up of protons (+ charge) and neutrons (no charge) with electrons (- charge) orbiting the nucleus in much the same way as the planets orbit the sun. The electrons orbit forms ‘shells’. The inner shells are held in orbit tightly, while the outer shells are not held as tightly.

Molecules
- Molecules are formed from the bonding of atoms into groups.
- Molecules with the same types of atoms are called ELEMENTS.
- Molecules with two or more different types of atoms are called COMPOUNDS.
- Molecules of all matter vibrate. The rate at which they vibrate (their KINETIC ENERGY) depends on how much heat energy is added to or removed from the matter and how much matter there is in a body …… or it’s MASS.
- In gases, the molecules are comparatively far apart and can move freely within the space they occupy and they need to be contained.

- In liquids, the liquids are more closely crowded together; they can not move so freely and collide more often. Liquids are held in the shape of the space they occupy and must be support at the sides and at the bottom.

- In solids, the molecules occupy fixed positions but still vibrate. Solids need to be supported from the bottom only.

The force exerted by a:

- **Solid** is downward

- **Liquid** is downward and sideways

- **Gas** is in all directions
Review Questions:

1. What three components make up an atom?

________________________________________________________________________
________________________________________________________________________

2. What is the “charge” of:

An electron? _____________________________________________________________

A neutron? ______________________________________________________________

A proton? ______________________________________________________________

3. In what direction is force exerted on:

A solid? ________________________________________________________________

A liquid? ________________________________________________________________

A vapour or gas? _________________________________________________________

4. What is an element?

________________________________________________________________________
________________________________________________________________________

5. What is a compound?

________________________________________________________________________
________________________________________________________________________

6. What is matter?

________________________________________________________________________
________________________________________________________________________
4. Heat / Temperature:

Recommended videos:
Heat & Pressure; TAFE SA Cat No 85.022 16 mins (SIT No A1)

Purpose:
The purpose of this section is to provide you with a complete understanding of various forms of heat, temperature, heat transfer energy and how heat is transferred from one source to another.

Heat:
Heat is a form of energy. Energy is the ability to do work. Heat can be converted into other forms of energy and other forms of energy can be converted into heat.

Heat transfer laws.
Heat can only transfer from a hot ‘body’ to a cold ‘body’. The greater the heat difference, the faster the transfer will be between the two bodies. Where there is no heat difference there can be no transfer.

The three methods of heat transfer are:
- **Conduction:** by physical contact by two objects at different temperatures.

- **Convection:** by currents flowing in fluids (liquid and gas / vapour) caused by changes in pressure and temperature. Warmer / lighter fluid rises whilst heavier / colder fluid “falls”.

![Conduction Diagram]

![Convection Diagram]
- **Radiation:** *by heat rays / electromagnetic waves through a vacuum or gas. The most common method of radiation is the heat received from the sun.*

The main types of energy are potential and kinetic:

- **Potential** – energy in waiting, e.g. a battery or chemical.
- **Kinetic** – energy in motion or the energy of change, e.g. electric to mechanical energy (an electric motor).

Other types of energy:

- **Mechanical** – an electric motor.
- **Electrical** – delivered by a generator or battery.
- **Light** – lamp / luminare or television screen.
- **Chemical** – petrol, gun powder.

**SI Units:**
The SI unit for work and energy is the ‘Joule’ however; we more commonly refer to the kilojoule (kJ).

Power is the rate at which work is done or energy expended. Work over time is power, hence Joules per second equates to Watts (W) or kilowatts (kW).

Temperature difference (td) is the difference between two different objects and is measured in Kelvin (K).

Temperature change (Δt) is the change in temperature when heat is added or removed. Again, it is measured in Kelvin (K).

**Temperature:**
Temperature is the measure of the heat intensity or heat level of a substance. Temperature alone does not give the amount of heat in a substance.

The temperature of an object is directly related to the thermal kinetic energy of its molecules. Temperature therefore is related to heat. Temperature however does not indicate how much heat is contained in a substance: for example, a lighted match may
be hot enough to burn, but does not contain enough heat energy to boil a kettle of water.

**Temperature Measurement:**
Temperature is measured with a thermometer; a) through uniform expansion of a liquid in a sealed glass tube. There is a bulb at the bottom of the tube and a quantity of liquid (mercury or alcohol) inside; b) the expansion and contraction of metal to measure temperature; c) by measuring a small electric voltage generated in a thermocouple; d) thermistors are the most common method of measuring temperature. A constant voltage is applied to a component which changes its resistance if heat is applied or removed.

The temperature scale in common use today is the Celsius scale. The point at which water freezes under standard atmospheric pressure is taken as the zero point, and the point at which water boils under standard atmospheric pressure is designated at 100. The scale is divided into 100 equal units called degrees.

The Kelvin scale is a scale using the same divisions as the Celsius scale, but setting the zero of the scale at the temperature at which all molecular movement ceases; that is, where no more heat exists in the body and the temperature cannot be lowered any further. This temperature is believed to correspond to -273 degrees on the Celsius scale; that is, absolute zero is 273 degrees below the standard zero on the Celsius scale.

The Fahrenheit scale was used in Australia prior to the introduction of SI (metric) units. Using this scale, water boils at 212°F and water will freeze at 42°F.

**Temperature Conversions**
\[ K = \degree C + 273 \]
\[ \degree C = K - 273 \]

**Testing the Accuracy of a Thermometer in the Field:**
We know that water freezes and ice melts at $0^\circ C$ and that water boils at $100^\circ C$. Consequently, there are two methods for testing the accuracy of a thermometer in the field.

The first method is the freezing method. This requires placing the thermometer in a solution of ice and water. The solution should consist of 30% water and 70% ice. In this solution the thermometer should indicate $0^\circ C$ on the scale.

The second method is to place the thermometer into a container of boiling water. The thermometer should indicate $100^\circ C$.

Both of the above methods will only be accurate at atmospheric sea level.
Review Questions:

1. What is heat?

2. Heat can flow between two bodies. What is required for the flow of heat?

3. Describe the following methods of heat flow:
   - Convection
   - Conduction
   - Radiation

4. List the two main types of energy and give an example of each:

5. List the SI unit and symbol for:
   - Energy
   - Temperature measurement
   - Power
   - Temperature difference

6. What is temperature?
7. 0°C on the Celsius is equal to what temperature on the Kelvin scale?

8. Absolute zero is equivalent to:

9. Describe the two methods for field testing of thermometers:

10. Under what conditions will these field tests be considered accurate?
5. Sensible & Latent Heat:

**Purpose:**
The purpose of this section is to provide you with the underpinning knowledge and skills to identify the various types of heat, their measurement and to apply ‘heat’ theory to a refrigeration system.

**Heat Measurement:**
The SI unit of heat is called the joule (J). However in refrigeration and air conditioning systems the kilojoule (kJ), 1000 joules is used.

The amount of heat required to raise the temperature of 1kg of water by 1K is equal to 4.187kJ. Similarly, the amount of heat removed to lower the temperature of 1kg of water by 1K is also 4.187kJ.

**Sensible Heat:**
Sensible heat is defined as heat which causes a change in temperature of a substance. The term sensible is applied to this particular heat because the changes in temperature it causes can be detected with the sense of touch and can be measured with a thermometer.

**Specific Heat:**
The specific heat capacity of a substance is the amount of heat that must be added or released to change the temperature of one kilogram of the substance one degree Kelvin (K).

The sensible heat required to cause a temperature change in substances varies with the kind and amount of substance. Different substances require different amounts of heat per unit mass to effect these changes of temperature above and below freezing. This is called specific heat.

<table>
<thead>
<tr>
<th>Material</th>
<th>Specific heat capacity (kJ/kg K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood</td>
<td>1.369</td>
</tr>
<tr>
<td>Water</td>
<td>4.187</td>
</tr>
<tr>
<td>Ice</td>
<td>2.110</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.138</td>
</tr>
<tr>
<td>Alcohol</td>
<td>2.575</td>
</tr>
<tr>
<td>Copper</td>
<td>0.397</td>
</tr>
<tr>
<td>Sulphur</td>
<td>0.741</td>
</tr>
<tr>
<td>Glass</td>
<td>0.494</td>
</tr>
<tr>
<td>Brick</td>
<td>0.837</td>
</tr>
<tr>
<td>Glycerine</td>
<td>2.411</td>
</tr>
<tr>
<td>Liquid ammonia at -15°C (258K)</td>
<td>4.605</td>
</tr>
<tr>
<td>Carbon dioxide at -15°C (258K)</td>
<td>2.512</td>
</tr>
<tr>
<td>R22 at -15°C (258K)</td>
<td>1.088</td>
</tr>
</tbody>
</table>

**Latent Heat:**
Latent heat is defined as heat which brings about a change of state with no change in temperature. This refers to a change from a solid to a liquid, or a liquid to a vapour.

**Latent heat of fusion** is the amount of heat required to be added to change a solid to a liquid OR the amount of heat required to be removed to change a liquid to a solid. Example: ice to water

**Latent heat of vaporisation** is the amount of heat required to change liquid to vapour (gas). This is also known as the saturation point. Example boiling water to steam

**Latent heat of condensation** is the amount of heat required to be removed to change a vapour (gas) to a liquid. Example Steam to water

**Sublimation** is the amount of heat required to change the state of a substance from a solid to a vapour without passing through the liquid state, e.g. Dry ice to CO$_2$.

The heat energy required to make a substance change state is much greater than that required for a sensible heat change. It requires as much heat to change 1kg of water to ice as it does to raise the temperature of that same 1kg of water to 80°C.

In the above diagram, identify the area of sensible and latent heat for each state of matter.
## Product Storage Data Sheet

<table>
<thead>
<tr>
<th>Product</th>
<th>Quick freeze temp °C</th>
<th>°C Storage humidity % RH</th>
<th>kJ/kg K Specific heat</th>
<th>Resp. kJ/kg per day @ storage temp</th>
<th>°C freezing point</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Long</td>
<td>Short</td>
<td>Above freezing</td>
<td>Below freezing</td>
<td></td>
</tr>
<tr>
<td>Apples</td>
<td>-1 - 0</td>
<td>3 - 6</td>
<td>85 - 88</td>
<td>3.60</td>
<td>1.88</td>
</tr>
<tr>
<td>Bacon</td>
<td>-2</td>
<td>-1</td>
<td>2 - 4</td>
<td>80</td>
<td>2.1</td>
</tr>
<tr>
<td>Bananas</td>
<td>5</td>
<td>13 - 22</td>
<td>85 - 95</td>
<td>3.35</td>
<td>1.76</td>
</tr>
<tr>
<td>Beans (green)</td>
<td>13 - 22</td>
<td>4 - 7</td>
<td>85 - 90</td>
<td>3.8</td>
<td>2.00</td>
</tr>
<tr>
<td>Beef, fresh lean</td>
<td>-25</td>
<td>0 - 1</td>
<td>7</td>
<td>85</td>
<td>3.22</td>
</tr>
<tr>
<td>Butter</td>
<td>-10</td>
<td>-1 - 0</td>
<td>4 - 7</td>
<td>85</td>
<td>2.68</td>
</tr>
<tr>
<td>Cabbage</td>
<td></td>
<td></td>
<td>4 - 7</td>
<td>90 - 95</td>
<td>3.94</td>
</tr>
<tr>
<td>Cheese</td>
<td>-10</td>
<td>0</td>
<td>3 - 7</td>
<td>85</td>
<td>2.68</td>
</tr>
<tr>
<td>Cream</td>
<td>0 - 4</td>
<td>-4 - 1</td>
<td>85 - 90</td>
<td>3.56</td>
<td>1.67</td>
</tr>
<tr>
<td>Eggs, fresh</td>
<td>-23</td>
<td>1</td>
<td>85 - 90</td>
<td>3.18</td>
<td>1.67</td>
</tr>
<tr>
<td>Fish, fresh iced</td>
<td>-25</td>
<td>-1</td>
<td>2 - 4</td>
<td>85</td>
<td>3.26</td>
</tr>
<tr>
<td>Flowers</td>
<td>-4</td>
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<td></td>
<td></td>
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<td>80</td>
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<td>Lamb</td>
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<td>82</td>
<td>2.81</td>
<td>1.26</td>
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<td>7</td>
<td>90 - 95</td>
<td>4.02</td>
<td>2.01</td>
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<td>2 - 4</td>
<td>85 - 90</td>
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<td>Milk</td>
<td>-4</td>
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<td>85 - 90</td>
<td></td>
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<td>Mushrooms</td>
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<td>12 - 16</td>
<td>80 - 85</td>
<td>7.9</td>
<td>2.0</td>
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<td>10 - 15</td>
<td>70 - 75</td>
<td>3.81</td>
<td>1.93</td>
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<td>85 - 90</td>
<td>3.77</td>
<td>1.93</td>
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<tr>
<td>Peaches, fresh</td>
<td>0 - 1</td>
<td>10</td>
<td>85 - 90</td>
<td>3.77</td>
<td>1.93</td>
</tr>
<tr>
<td>Pears, fresh</td>
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<td>4</td>
<td>85 - 90</td>
<td>3.77</td>
<td>1.93</td>
</tr>
<tr>
<td>Peas</td>
<td>-1 - 0</td>
<td>4 - 7</td>
<td>85 - 90</td>
<td>3.3</td>
<td>1.8</td>
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<td>80 - 85</td>
<td>3.68</td>
<td>1.88</td>
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<tr>
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<td>85 - 90</td>
<td></td>
<td></td>
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<td>-1</td>
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<td>85 - 90</td>
<td>3.43</td>
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<td>3.31</td>
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<td>0.5 - 1</td>
<td>80 - 85</td>
<td>3.85</td>
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<td>0.5 - 1</td>
<td>2 - 4</td>
<td>85 - 90</td>
<td>3.77</td>
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<tr>
<td>Vegetables, mixed</td>
<td>-2 -1</td>
<td>4 - 7</td>
<td>90 - 95</td>
<td>3.77</td>
<td>1.88</td>
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<td></td>
<td></td>
<td>4.187</td>
<td>2.110</td>
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</table>
Calculations:

The amount of heat added to or removed from a body cannot be measured, it must be calculated.

For the following calculations, it will be necessary to refer to the Product Storage Data sheet provided on the previous page.

Sensible heat calculations:

To calculate sensible heat it is necessary to have the following information available:

- The mass of the matter
- The ‘specific heat capacity’ for the matter
- Temperature change of the matter.

The formula used to determine sensible heat is: \( Q = mc\Delta t \)

Where

- \( Q \) = Quantity of heat in kilojoules (kJ)
- \( m \) = mass in kilograms (kg)
- \( c \) = specific heat capacity in kilojoules per kilogram Kelvin (kJ/kgK)
- \( \Delta t \) = change in temperature of the mass in Kelvin (K)

Example:

What is the sensible heat removed to reduce the temperature of 10kg of water from 20°C to 5°C?

From the product storage data sheet it is determine that the specific heat capacity of water is 4.187kJ/kgK.

The temperature difference is \( 20°C - 5°C = 15K \)

Using the formula \( Q = mc\Delta t \) we can determine the heat quantity as follows:

\[
Q = 10\text{kg} \times 4.187\text{kJ/kgK} \times 15\text{K}
\]

\[
= 628.05\text{kJ}
\]
**Latent heat calculations:**

Latent heat calculations require the following information:

- The mass of the matter
- The latent heat value

The formula for calculating latent heat is: $$Q = mLH$$

Where

- $Q =$ Quantity of heat in kilojoules (kJ)
- $m =$ mass in kilograms (kg)
- $LH =$ latent heat value in kilojoules per kilogram (kJ/kg)

**Example:**

Using the information as per the example sensible heat calculation and the product storage data sheet we can calculate the latent heat quantity as follows:

From the product storage data sheet we have determined that the latent heat of water is $335\text{kJ/kg}$.

Using the formula $Q = mLH$ we can determine the latent heat quantity.

$$Q = 10\text{kg} \times 335\text{kJ/kg}$$

$$= 3350\text{kJ}$$

**Total heat calculations:**

When calculating heat quantities when we have a change in temperature and in state, we need to calculate the amount of sensible heat above the matters freezing point, the amount of latent heat and the amount of sensible heat below the matters freezing point.

Using the examples above and changing the $20^\circ\text{C}$ water to $-5^\circ\text{C}$ ice we need to perform the following calculations:

1. Determine the sensible heat removed from the water at $20^\circ\text{C}$ to its freezing point of $0^\circ\text{C}$.

   $$Q_1 = mc\Delta t$$
   $$= 10\text{kg} \times 4.187\text{kJ/kgK} \times 20\text{K}$$
   $$= 837.4\text{kJ}$$
2. Determine the latent heat removed.

\[ Q_2 = mLH \]
\[ = 10\text{kg} \times 335\text{kJ/kg} \]
\[ = 3350\text{kJ} \]

3. Determine the sensible heat removed below freezing point to \(-5^\circ\text{C}\).

\[ Q_3 = mc\Delta t \]
\[ = 10\text{kg} \times 2.11\text{kJ/kgK} \times 5\text{K} \]
\[ = 105.5\text{kJ} \]

4. Add all of the above to achieve a total heat quantity.

\[ Q_T = Q_1 + Q_2 + Q_3 \]
\[ = 837.4\text{kJ} + 3350\text{kJ} + 105.5\text{kJ} \]
\[ = 4292.9\text{kJ} \]

5. To calculate the system capacity in kilowatts, the total amount of heat removed from the product can be divided by the number of seconds allowed to removed the heat.

Example:

If the amount of heat removed in the above examples was done in one hour, the system capacity can be calculated as follows:

\[
\text{Capacity} = \frac{\text{TotalHeat}}{\text{Time}}
\]
\[
= \frac{4292.9\text{kJ}}{3600\text{s}}
\]

Note: 3600s is the number of seconds in one hour (60 minutes x 60 seconds)

\[ = 1.192\text{kJ/s} \text{ or } 1.192\text{kW} \]
**Review Questions:**

1. How much specific heat is required to change the temperature of 1kg of water 1K?

2. How much specific heat is required to change the temperature of 1kg of ice 1K?

3. What is meant by the following terms?
   Specific heat capacity
   Sensible heat
   Latent heat

4. Describe each of the following terms:
   Sublimation
   Latent heat of fusion
   Latent heat of vaporisation
   Latent heat of condensation
6. Pressure:

Recommended videos:
Heat & Pressure; TAFE SA Cat No 85.022 16 mins (SIT No A1)

Purpose:
The purpose of this section is to provide you with the underpinning knowledge and skills required to identify the various means of measuring pressure, the effects of altitude on pressure and how pressure is applied to cause heat to move.

Pressure:
Pressure is defined as the force exerted per unit of area, \( P = \frac{\text{force}}{\text{area}} \) and it is expressed in Pascals (Pa). The normal pressure of air on the human body at sea level (atmospheric pressure) is approximately 101,300 Pascals or 101.3 kilopascals (kPa).

Note: 1 Pascal equals 1 Newton per square metre, i.e. 1 Pa = 1 N/m\(^2\). A Newton is the SI unit of force. One Newton is equal to the mass of 1 kilogram being accelerated at a rate of 1 metre per second.

Substances always exert a pressure upon the surfaces supporting them. That is, a refrigerator (a solid) exerts a pressure on its legs because if they were removed the box would fall; a liquid always exerts a pressure on the sides and bottom of a container, such as a balloon.

A liquid in a container maintains an increasing pressure on the sides and bottom of the container as the depth of the liquid increases. Gases however, do not always exert a constant pressure on the container because the pressure is determined by the temperature and the quantity in the container.

There are two scales for measuring pressure in the SI system:
- Gauge Scale
- Absolute Scale

Gauge Scale:
Gauges used in refrigeration are calibrated to read 0kPa at atmospheric pressure. This is referred to as gauge pressure and it does not take into account atmospheric pressure which is present at all times. (kPa G)

Pressures below atmospheric are usually shown as negative kilopascals (-kPa). They can also be shown as millimetres of mercury (mm Hg) or (microns).

Absolute Scale:
When we require the total pressure reading we add 101.3 kPa (frequently this figure is rounded off to 100 kPa) to the gauge pressure and call this reading the absolute pressure, i.e. gauge pressure + 100 kPa = absolute pressure. (kPa A)
Zero on the absolute scale is at no pressure at all (a perfect vacuum). A container at zero absolute pressure contains no gas molecules. Absolute values for temperature and pressure are used for gas law calculations etc.

**Types of Pressure Measuring Devices:**
Pressure can be measured by using the following types of instruments:

- **Gauges:** Bourdon Tube; Pressure (measures pressure above 0 kPa G & Compound (measures pressure above and below 0 kPa G).
- **Manometers & magnehelic gauge:**
  - U tube & Inclined; used to measure pressure drop or variation across air conditioning filters or duct pressures.
- **Vacuum gauges:**
  - are used to measure very low pressure below 0 kPa G and use the following scales:
    - Microns
    - Torr
    - Millimetres of Mercury
    - Pascals or Kilopascals
- **Barometers:** used to measure atmospheric pressure

General Gas Laws relate to Pressure – Temperature – Volume. All gas laws are based on “absolute” values.

**Charles’ Law:** Gases behave consistently with temperature changes. This is stated in Charles’ Law. ‘At a constant pressure the volume of gas varies directly as the absolute temperature; and at a constant volume, the pressure varies directly as the absolute temperature.’

**Boyle’s Law:** This expresses a very interesting relation between the pressure and the volume of a gas. It is stated as follows:
  ‘The volume of a gas varies inversely as the pressure, provided the temperature remains constant.’

**Dalton’s Law:** Dalton’s Law of partial pressures is the foundation of the principal operation of the absorption type of refrigerators. The law may be stated as follows:

- The total pressure of a mixture of gases is the sum of the partial pressures of each of the gases in the mixture’, e.g. mix two gases and the total pressure will equal the sum of their individual pressures.
- The total pressure of the air is the sum of the oxygen, the nitrogen, the carbon dioxide and the water vapour pressure.
- ‘A liquid will vaporise regardless of the total pressure, provided that the pressure of its own vapour is low enough’, i.e. water will evaporate without boiling.
**Review Questions:**

1. What is pressure?

2. Air pressure at sea level is known as?

3. How much pressure is exerted on the human body at sea level?

4. At altitudes above sea level, what will happen to the pressure being exerted?

5. List and define the two SI scales used for measuring pressure?

6. List four different types of instruments used to measure pressure.
7. The gas laws relate to:

________________________________________________________________________

________________________________________________________________________

8. Briefly explain each of the following gas laws:

Charles’ Law ______________________________________________________________

________________________________________________________________________

________________________________________________________________________

Boyle’s Law ______________________________________________________________

________________________________________________________________________

________________________________________________________________________

Dalton’s Law ______________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
7. Refrigerant Conditions:

Purpose:
The purpose of this section is to provide the underpinning knowledge and skills to identify the different states of a refrigerant within a vapour compression system and how a refrigerant will absorb and reject heat.

Saturated Temperature
The saturated temperature of a refrigerant is the temperature at which a liquid will boil or a vapour will condense. It is the point at which a change of state will occur for a liquid or vapour.

In its saturated state the refrigerant has a relationship between pressure and temperature.

Saturated Liquid
A saturated liquid is a liquid at its boiling point and the addition of any heat will cause the liquid to change state into a vapour (latent heat).

If additional heat is added to a liquid at saturation condition it will cause the liquid to vaporise.

In an operational system, saturated liquid is present in the evaporator and the condenser.

Saturated Vapour
A saturated vapour is a vapour at its condensing point and if any heat is removed it will cause the vapour to change state into a liquid (latent heat). A vapour can only be saturated when it is in contact with its liquid.

If heat is removed from the vapour at saturation it will cause the vapour to condense into a liquid.

In an operational system, saturated vapour is present in the evaporator and the condenser.

Superheated Vapour
A vapour at any temperature above its saturation temperature is a superheated vapour (sensible heat).

A superheated vapour is produced if any additional heat is added to a saturated vapour without a change of pressure occurring.

If, after vaporisation, a vapour is heated so that its temperature is raised above that of the vaporising liquid, the vapour is said to be superheated. In order to superheat a vapour it is necessary to separate the vapour from the vaporising liquid. As long as the vapour remains in contact with the liquid it will be saturated. This is because any heat
added to a liquid vapour mixture will result in latent heat vaporising more liquid and no superheating will occur. Superheated vapour is usually found in the end of the evaporator, in the suction line, compressor, and discharge line and at the start of the condenser.

Before a superheated vapour can be condensed, the vapour must be de-superheated, that is, the vapour must first be cooled to its saturation temperature. Heat removed from a superheated vapour will cause the temperature of the vapour to decrease until the saturation temperature is reached. At this point, any further removal of heat will cause a part of the vapour to condense (latent heat).

Any vapour heated above its saturation temperature is said to be superheated.

A vapour entering the compressor is superheated.

Sensible heat is added to a vapour to raise its superheated temperature.

**Subcooled Liquid**
If, after condensing, a liquid is cooled so that its temperature is reduced below the saturation temperature, the liquid is said to be subcooled.

In an operational system, subcooled liquid is present in the end of the condenser, the liquid receiver (if fitted) and in the liquid line.

*It should be noted that the refrigerant within the liquid receiver may also be in a saturated vapour state as the receiver is not completely filled with liquid.*

**Flash Gas**
Flash gas is the gas resulting from the instantaneous evaporation of refrigerant in a pressure reducing device (Refrigerant Metering Device – RMD) to cool the refrigerant to the evaporation temperature obtained at the reduced pressure.
**Review Questions:**

1. What is meant by the following terms?
   - Saturated temperature
     _____________________________________________________________
     _____________________________________________________________
     _____________________________________________________________
   - Saturated liquid
     _____________________________________________________________
     _____________________________________________________________
     _____________________________________________________________
   - Saturated vapour
     _____________________________________________________________
     _____________________________________________________________
     _____________________________________________________________
   - Superheated vapour
     _____________________________________________________________
     _____________________________________________________________
     _____________________________________________________________
   - Sub cooled liquid
     _____________________________________________________________
     _____________________________________________________________
     _____________________________________________________________

2. What is the refrigerant state in the liquid receiver?
   _____________________________________________________________
   _____________________________________________________________
3. Where in the system can we find:

Superheated vapour? __________________________________________

Saturated vapour? ____________________________________________

Saturated liquid? _____________________________________________

Sub cooled liquid? ____________________________________________

4. What is the condition of the refrigerant as it leaves the RMD / flow control?

________________________________________________________________

________________________________________________________________
8. Refrigerant Relationships:

Purpose:
The purpose of this section is to provide the underpinning knowledge and skills to determine the relationship between pressure and temperature, the use of a pressure / temperature chart and how to determine the temperatures within the system.

Introduction
The Refrigeration and Air Conditioning Industry is made up of many different applications that operate at vastly different temperature ranges.

By using different refrigerants we can achieve these temperature ranges and still permit each of the systems to operate within an acceptable pressure range. This occurs because each refrigerant has a unique pressure / temperature relationship.

Pressure / Temperature Relationship
The boiling point of any liquid is governed by the amount of pressure placed upon its surface.
If the pressure exerted on the liquid refrigerant is increased, then the boiling temperature will also increase.
If the pressure exerted on the liquid refrigerant is decreased, then the boiling temperature will also decrease.
By reducing the pressure to a sufficiently low enough value it is possible to drop the boiling temperature to a value that is cooler than the surrounding ambient air temperature, thus resulting in the process known as refrigeration.

One of the common refrigerants used in medium temperature applications is R134a. It has a boiling temperature of -26°C at atmospheric pressure but this will drop to -40°C if its pressure is reduced to 50 kPa (absolute) (-51 kPa G).

From this it follows that an R134a refrigerator, maintaining a pressure of 50 kPa (absolute) in its evaporator, will eventually reduce the temperature to -40°C.

The temperature within a refrigerator can be controlled by altering the saturated evaporator pressure / temperature of the refrigerant using the compressor.

Pressure / Temperature Charts
The relationship that exists between temperature and pressure is so consistent that tables have been created that accurately show the boiling point or condensing temperature of the refrigerant for any desired pressure.

Pressure / temperature charts show the saturated pressure / temperature relationship.

The term saturated is used because the temperatures in the left column are the actual boiling or condensing temperatures for the refrigerant pressure listed.
## Saturated Pressure / Temperature Chart for Common Refrigerants

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<th>°C</th>
<th>R12</th>
<th>R134a</th>
<th>R409a</th>
<th>R22</th>
<th>R502</th>
<th>R408a</th>
<th>R404a</th>
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Ver 2.1 (SIT)

HVAC & Refrigeration, Ultimo 2007

Refrigeration Fundamentals Refrigeration & Air Conditioning, and Components
Practical Exercise 1:

**Task:**
To determine the refrigerant type within an unlabelled / unmarked cylinder or container.

**Equipment:**
Unlabelled / unmarked cylinder/s container/s containing refrigerant.
Service manifold gauge set with gauge lines.
Thermometer/s.
Pressure / temperature chart.

**Procedure:**
Connect the service manifold gauge set to the cylinder / container and observe the pressure therein.
Measure the ambient temperature surrounding the cylinder / container.
Referring to the pressure / temperature chart determine the refrigerant type in the cylinder / container. This is performed by referencing the temperature scale and then locating the pressure corresponding to your instrument reading. You can then determine what refrigerant is in the cylinder / container.

**Example:**
Ambient temperature is 22°C and pressure is 1049kPa. By referencing the pressure / temperature chart we can determine that the refrigerant type is R404a.

*Note: this method was useful when there were limited numbers of refrigerants available before the introduction of HCFCs, HCs and PFCs. As there are numerous refrigerants available with very similar characteristics it is recommended that any unidentified refrigerant be returned to a recommended supplier and NOT used in any system as contamination of the system may result.*

**A risk assessment MUST be undertaken before attempting this exercise.**
**Review Questions:**

1. If the pressure exerted on the refrigerant is increased, what will happen to the temperature of the refrigerant?

2. The boiling temperature of any liquid is governed by?

3. Pressure / temperature charts display what refrigerant relationship?

4. Referring to the Pressure / temperature chart, what is the temperature if an R404a system has an operating pressure of 1429kPa?

5. Using a pressure temperature chart determine what refrigerant is in a cylinder if the ambient temperature around the cylinder is 32°C and the pressure is 1165kPa.
9. Introduction to the Basic Vapour Compression System:

Purpose:
The purpose of this section is to provide you with the underpinning knowledge and skills to identify the various components and their function within the Basic Vapour Compression System.

Recommended video:
Basic Refrigeration Cycle; TAFE SA Cat No 85.050 9 mins (SIT No A2)

Refrigeration is the process of removing heat energy from a product or ‘substance’.

A refrigeration system is a machine designed to move heat energy. It does this by transferring heat from the space to be cooled, to the atmosphere.

This is done by causing the refrigerant fluid in the system to change from a liquid to a vapour and back to liquid again in a controlled way by adding and removing heat.

A cycle is a series of events occurring in a specific sequence which enables a continued repetition of the sequence without interference, i.e. a cycle is one complete unit of a series of repetition..

The basic vapour compression system consists of the following major components, interconnecting pipe work and refrigerant:
Compressor: compresses and ‘circulates’ refrigerant vapour.

Condenser: rejects heat to the atmosphere (a heat exchanger).

Liquid Receiver: a vessel designed to store liquid refrigerant.

RMD (Refrigerant Metering Device): regulates flow of refrigerant into the evaporator.

Evaporator: absorbs heat from the medium being cooled (a heat exchanger).

Discharge Line: connects the compressor to the condenser.

Liquid Line: connects the liquid receiver to the RMD.

Suction Line: connects the evaporator to the compressor.

Refrigerant: the ‘fluid’ used to move heat energy.

The High-side of the System is the part of the refrigeration system containing the high pressure refrigerant. It can also refer to the condensing unit which consists of the compressor, condenser and liquid receiver all mounted on the one base.

The Low-side of the System is the part of the refrigeration system containing the low pressure refrigerant.

Basic System Operation:
The basic refrigeration cycle is as follows:

- The compressor increases the pressure and temperature of the refrigerant vapour. During compression, the refrigerant is “superheated”.

- The “superheated” refrigerant then passes via the discharge line into the condenser. As the refrigerant vapour ‘cools’ (rejects heat energy to the atmosphere) it is said to be a “saturated liquid vapour” and as it continues to cool it further changes state into a “subcooled” high pressure, high temperature liquid.

- This “subcooled” high pressure; high temperature liquid then passes through the liquid receiver and via the liquid line to the RMD (Refrigerant Metering Device).

- As the liquid passes through the RMD (Refrigerant Metering Device) it becomes a low pressure, low temperature liquid which then flows into the evaporator. This is where flash gas is found in the system.
• The low pressure, low temperature liquid passes through the evaporator absorbing heat from the surrounding atmosphere / product and changes state to a low pressure, low temperature “saturated vapour” as it absorbs heat energy.

• The low pressure, low temperature “saturated vapour” then returns to the compressor via the suction line and continues to absorb heat. This additional heat absorption changes the “saturated vapour” into a low pressure, low temperature “superheated vapour”. The compressor’s pumping capacity will determine the Saturated Suction Temperature, SST.

• The refrigerant having returned to the compressor then enables the “vapour compression cycle” to continue.
Review Questions:

1. List the 5 major components of a basic vapour compression system.

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2. What is meant by the term refrigeration?

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3. In the vapour compression system, the refrigerant changes from one state to another and back again. What are these changes in state?

______________________________________________________________

4. What does the term RMD stand for? What is the purpose of an RMD?

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5. Describe what is meant by the term ‘cycle’.

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6. What are the three terms used to describe the various conditions of the refrigerant throughout the system?

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10. Major Components

The Major Components of the Vapour Compression System:

Purpose:
As previously stated the purpose of this section is to provide you with the underpinning knowledge and skills to identify the various components, their construction and their function within the Vapour Compression System.

Recommended video:
Reciprocating Compressors: TAFE SA Cat No 86.040 7 mins (SIT No G1)

Compressors:
A compressor enables refrigerant to circulate throughout the system by creating a pressure difference between the high and the low sides of the system. It supplies the forces necessary to keep the system operating.

Without the operation of the compressor there can be no refrigeration generated by this type of system. The compressor as such can be likened to being the ‘heart’ of the system.

Compressors fall into the following categories:
- Open Drive – direct or belt driven.
  - Semi Hermetic or semi sealed.
  - Hermetic or fully sealed.

Open drive compressors:
Here the motor is separate from the compressor. The compressor and the motor may be connected by means of belts or by direct drive couplings.

They are readily serviceable and do not have the potential for system contamination due to electrical burn out.

One of the main concerns with an open drive compressor is the shaft seal. Wear of the shaft seal can cause refrigerant leakage and the ingress of air and contaminants. Misalignment of drive couplings and pulleys put undue strain on the seal and bearings causing undue wear and shortened life. Belt slip due to stretching or wear can reduce the compressor output and efficiency.
Open drive, reciprocating compressor.

Semi hermetic compressors:
These incorporate the electric motor and the compressor in the one unit and are field serviceable; i.e. the motor and compressor are housed in one common body and can be dismantled on site.
Hermetic or fully sealed compressors:
Have all of their components sealed into a housing that does not allow field serviceability. Being built to exacting standards, these are reliable, long life compressors that require little or no maintenance or service. The motor and compressor are totally sealed in the one housing which is welded together rending it unserviceable as it cannot be dismantled.

Methods of compression:
The mechanical action of the compressor parts determines its classification, however, regardless of the type of compressor the effect on the refrigerant and the system is identical.

There are 5 types of compressor commonly used in the refrigeration and air conditioning industry, they are:

- **Reciprocating:** a piston travels back and forth (reciprocates) within a cylinder.

This is the most widely used compressor in the refrigeration and air conditioning industry. Reciprocating compressors range in size from small single cylinder hermetic...
units up to large industrial multi cylinder compressors. They are of relatively high efficiency but they are not designed to pump liquid.

- **Rotary:** an eccentric rotates within a cylinder and because of the vane seal they have no need for suction valves but they do require a discharge valve.

  ![Rotary Compressor](image)

  Rotary compressors are very quiet, mechanically and electrically efficient and they have the ability to pump small amounts of liquid.

  There are two types of rotary compressor:
  - Rotating Blade (or vane):
    The eccentric has a blade or vane fitted, this enables the separation of the high and low sides of the system.
  - Stationary Blade (or vane):
    The blade or vane is fitted to the compressor housing and is spring operated maintaining contact of the blade and eccentric whilst separating the high and low sides of the compressor.

- **Scroll:** the vapour is compressed between two identical involute spiral scrolls. One scroll is fixed and the other rotates, compressing the vapour as it is pushed from the periphery to the centre of the spiral as it discharges.
Scroll compressors are efficient, quiet, lightweight and smaller than reciprocating compressors.

- **Screw (also known as a Helical Rotary):**
The vapour is compressed between two rotating screws which intermesh and compress the vapour trapped between the lobes or threads as they turn and push the vapour to the discharge port. Refrigerant flow is smooth, there is no ‘piston pulse’.

Screw compressors are noisy in operation but this is offset by their high efficiency and capacity range (20% to 100%). They can pump small amounts of liquid and are generally used in industrial refrigeration due to their large capacity.
- **Centrifugal:** a rotor (or impeller) with many blades rotating in a housing, draws in vapour and discharges it at a high velocity by centrifugal force.

![Centrifugal Compressor Image]

Centrifugals are popular in the air conditioning of large buildings due to their low noise levels. They have a large capacity range (15% to 100%) and are efficient.

**Lubrication:**
Compressor lubrication is provided by one of two means:

- **Splash Method**
- **Force Feed**

**The Splash Method:**
Is generally attributed to the reciprocating compressor and refers to the ‘dipping’ of the crankthrow (eccentric) into the oil in the compressor sump causing the oil to ‘splash’ to where lubrication is required.

**Force Feed:**
An oil pump circulates the oil from the compressor sump to the components requiring lubrication by means of oil lines.

**Condensers:**
The condenser is a heat exchange device which rejects heat, both sensible and latent, from the system.

The entering high temperature high pressure refrigerant vapour de-superheats and cools to its saturation temperature at which point it begins to condense, a process
which continues as it passes through the condenser. Towards the end of the condenser it cools to a temperature below its saturation temperature and in so doing becomes a sub-cooled liquid.

**There are three groupings of condenser:**
- Air cooled
  - Water cooled
  - Evaporative

**Air Cooled:**
Air cooled condensers fall into two categories:
- Forced/Induced draft
  - Natural draft

*Forced / Induced draft condensers* use a fan to provide air circulation.

They can be remotely mounted away from the remainder of the system and can include the compressor. When in this combination they are referred to as the condensing unit.

*Natural draft or static condensers* are usually limited to domestic applications. They rely on natural air movement or convection currents.
Construction is generally of bare pipe but to increase their surface area, wire fins or plates may be added.

**Water Cooled:**
Water cooled condensers use water as their cooling medium. They are more efficient than air cooled condensers but they need a supply of cool water, i.e. from a cooling tower. Water flow in general is in the opposing direction (counter flow) to the refrigerant flow.

They fall into three basic styles:

- **Tube in tube:** have a small tube inside a larger tube. The water flows through the smaller tube whilst the refrigerant flows in the outer / larger tube. Some heat rejection will be to the surrounding air. They need to be cleaned chemically.

![Tube in Tube Condenser Diagram](image)

- **Shell and coil:** generally have a coil of tube fitted inside a casing/shell. The water flows through the coil whilst the refrigerant is contained in the casing/shell. This type of condenser can act as a liquid receiver. They need to be cleaned chemically.
- Shell and tube: have straight lengths of tubing running the full length of the shell. The tubes are fastened to the shell end plates and “water boxes” are then fitted to the ends of the shell. Water flows through the tubes and the refrigerant is contained in the shell. As with the shell and coil condenser, this type of condenser acts as a liquid receiver. This type of condenser requires dismantling to enable manual cleaning.

**Evaporative Condensers:**
Evaporative condensers use both air and water as the cooling medium and are a very efficient form of condenser.

The condenser is housed within a tower arrangement and can easily be confused with a cooling tower.
Water is constantly pumped from the sump/basin/reservoir of the tower to the distributor heads where it is sprayed evenly over the condenser pipes. Forced air flows in the opposing direction to the water flow increases the cooling effect and efficiency by replacing moist air with dry air.

The need for bacteria control is mandatory to comply with the Public Health Act and must be done to AS / NZS 3666 Parts 2 and 3.

Cooling Towers:
Cooling towers are devices which enable air movement over the water to remove the system heat from the water. They are needed when water cooled condensers are installed.

Cooling towers may be considered as water conservation devices as it is illegal to run fresh water through a condenser once and then to waste. (Water Conservation Act).

Strict guidelines are in force for the maintenance of cooling towers and the control of bacteria. These guidelines are known as AS3666 Part 2.

There are two main types of cooling tower:
- **Natural draft**: rely on natural wind movement and convection currents to provide air circulation. They are not commonly used for air conditioning.
- **Forced draft (either forced or induced draft)**: depend on fans to provide the air circulation. forced – cross flow. induced – counter flow.
Cooling Tower Operation:
Water is drawn from the sump/basin/reservoir of the cooling tower and circulated throughout the condenser circuitry before returning to the cooling tower distributor. The distributor is located toward the top of the cooling tower and enables the water to be evenly sprayed over the fill which increases the water surface area for the air flow to evaporate and cool the water. The cooled water then collects in the sump/basin/reservoir for recirculation.

As water evaporates, air draws heat from the body of the water. The larger the surface area of the water the more heat can be rejected.

Water Pumps:
Water pumps are mechanical devices, generally centrifugal type, used to circulate water through pipes and equipment such as water cooled condensers, cooling towers evaporative condensers, water chillers, cooling coils, boilers and hot water coils.

Water Treatment:
Water treatment is usually carried out by specialists to comply with the Public Health Act.

Chemical treatment and water filtration are required to reduce/control the build up of bacteria, solids, algae etc. The water must not be acidic or alkaline; i.e. it must be neutralised, to aid in the prevention of system corrosion.
**Water Regulating Valves:**
Water regulating valves were commonly used on waste water systems which are now illegal in most states; however, some old systems may be in existence.

Water regulating valves are commonly used on water cooled condensers to maintain proper condensing conditions and to minimise water usage. Their sensing bulb is connected to the discharge line and operates in response to changes to the system discharge pressure. They are used to regulate the flow of water through the condenser.

The two main forces affecting the operation of the water regulating valve are:
- discharge pressure
- spring pressure

**Liquid Receivers:**
Liquid receivers are used to store the liquid refrigerant after it leaves the condenser. It should be located below the condenser to enable natural flow.
The receiver may be constructed either vertically or horizontally and should have sufficient capacity to hold the entire system’s refrigerant charge. The design should be such that only liquid refrigerant leaves the receiver and enters the liquid line.

![Receiver Diagram]

**RECEIVER**

**Evaporators:**
An evaporator is a heat exchanger which absorbs heat from the product/space to be cooled. This heat absorbing process is accomplished by maintaining the evaporator at a lower temperature than the medium to be cooled. The heat absorbed in the evaporator “boils” the refrigerant creating a change in state from liquid to vapour (latent heat).

There are two groupings of evaporator:
- Dry Expansion
- Flooded

*Dry system evaporators* are fed refrigerant as quickly as is needed to maintain the desired temperature. The evaporator pipes have more vapour than liquid per volume. At the end of the evaporator there is no liquid, i.e. it is dry.

*Flooded system evaporators* are always filled with liquid refrigerant.

The type of refrigerant metering device, RMD, determines the type of evaporator to be used.

There are two broad classifications of evaporator:
- Air cooling, i.e. the evaporator is used to cooled the air which in turn cools the product.
- Liquid cooling, i.e. the evaporator cools a liquid or secondary refrigerant which then cools the product.

Other factors to be considered when classifying evaporators include:
• Type of refrigerant metering device/liquid refrigerant level in the evaporator:

  ▪ Direct or dry expansion (DX):
    in which liquid is introduced at one end of a tube through a restrictor and flows through the tube, evaporating as it goes. Correctly controlled, all liquid will vaporise just before the tube outlet to the suction line. Generally, 25% liquid and 75% vapour.

  ▪ Flooded: in which the evaporator is in the tank (e.g. Temprite) or uses a header plus tubes and the refrigerant control system is designed to maintain a set level of liquid refrigerant. Generally, 75% liquid and 25% vapour.

• Product or material to be cooled
  ▪ Air
  ▪ Liquid
  ▪ Contact cooling/freezing

• Type of construction:
  ▪ Bare tube evaporators:
    normally used for cooling liquids, but sometimes used for air cooling in freezer applications.

  ▪ Plate surface evaporators:
    used for both air and contact cooling in domestic refrigerators and in commercial and industrial plants.
- **Finned evaporators:**
  mainly used for air cooling, either with natural or forced air convection.

- **Shell and tube or shell and coil evaporators:**
  with the refrigerant in a tank like vessel and the liquid to be cooled circulated through straight or coiled tubing inside the vessel.
• Product circulation method:
  ▪ Natural or gravity convection:
    where the circulation of the air or liquid cooled is caused by the increased density of the product when cooled.
  ▪ Forced convection (or forced draft):
    where the movement of the air or liquid is forced or induced over the evaporator surfaces by a fan or pump.

• Amount of ice build up during operation:
  ▪ Frosting: for air cooling, bare pipe, plate or finned coils with wide spacing between fins are used. Regular manual defrosting is required.
  ▪ Defrosting: for air cooling, this type is normally closer finned, allowing less than 1mm of ice to accumulate during the ‘on’ cycle, with controls set to permit full defrost in ‘off’ cycle, or at set intervals.
  ▪ Non-frosting: these are evaporators of any type whose operating temperature is high enough to prevent ice formation. With air cooling evaporators, fins can be very closely spaced, with 300 to 400 fins per meter, as in air conditioners.

• Air cooling applications include:
  ▪ Domestic refrigerators – plate surface, natural convection, frosting, and dry expansion.
  ▪ Coolrooms – finned surface, forced convection, defrosting, and dry expansion.

• Liquid cooling applications:
  ▪ Baudelot cooler – bare tube, natural convection, non-frosting, and flooded evaporator.
- Temprite – shell and coil, forced convection, defrosting, and flooded evaporator.
Temperature Difference of the Condenser and Evaporator:

Relative Humidity:
The relative humidity (RH%) of air is ‘the mount of water vapour contained in the air compared with the amount of water vapour the air can hold at a given temperature and is stated as a percentage’.

The warmer the air, the more water vapour or moisture it can hold. Air at 35°C is capable of holding 36 grams in every kilogram (approximately 1 cubic metre) while air at 23°C can hold only 18 grams/kilogram.

Evaporator temperature difference:
In almost all refrigeration applications, the control of humidity in a space is of utmost importance to keep product quality to a maximum. This is usually achieved by controlling the evaporator temperature difference.

Evaporator temperature difference is the difference in temperature between the refrigerant saturation temperature in the evaporator (the boiling temperature of the refrigerant in the evaporator) and the temperature of the air returning to the evaporator from the refrigerated space (the air coming onto the evaporator).

Condenser temperature difference:
Condenser temperature difference is the difference in temperature between the refrigerant at saturation temperature in the condenser and the temperature of the air on to the condenser.

This is similar to the evaporator temperature difference with the exception that the heat energy has to be rejected into the atmosphere and the temperature of the atmosphere will vary as the prevailing (ambient) conditions vary. This is why ‘head’ pressures are greater on hot days. Water cooled keeps discharge pressure/temperature fairly constant.

The ability to be able to measure the temperature difference of an evaporator or a condenser is a vital part of an air conditioning or refrigeration technician’s job as it is the only accurate way to measure the performance of those parts of the system.
**Secondary Refrigerants:**

When an evaporator cools a product or space, the cooling effect is called direct refrigeration. When an evaporator is used to cool some other fluid, e.g. water or brine and that fluid is then pumped to cool the product or space, this cooling effect is called indirect or secondary cooling.

The fluids used are called secondary refrigerants. There are many fluids that can be used as secondary refrigerants but the three most commonly used are:

- **Water:** a very commonly used secondary refrigerant because of its low cost. It cannot be circulated at temperatures below 0°C (as it turns to ice) and it can cause corrosion.

- **Chloride solutions:** are a mixture of water and salt, usually calcium chloride or sodium chloride (common salt), and can be used at temperatures below 0°C. However, calcium chloride can contaminate food, chloride solutions can cause corrosion and they cannot transfer heat as effectively as water.

- **Glycol solutions:** are an exact mixture of water and anti-freeze agents. The most commonly used glycol solution is propylene glycol. Glycol solutions can be used at temperatures below 0°C and they are non-corrosive. However, glycol solutions are poisonous if swallowed

*Note: There are food grade glycols in use.*
Flow Controls:
Throughout this package we have used the term RMD (Refrigerant Metering Device). We will now use another terminology depicting this same component and that is Flow Control.

The flow control is the component used to reduce the high pressure in the high side of the system to a low pressure in the low side of the system. This drop in pressure can be achieved by various methods of restriction, dependant on the type of flow control.

The flow control governs the flow of liquid refrigerant into the evaporator at the same rate as it is evaporating so that the evaporator maintains its efficiency without overloading the rest of the system.

The operation of any flow control depends on one or all of the following:
- pressure change
- temperature change
- volume or quantity change

There are nine types of liquid flow controls used throughout the refrigeration and air conditioning industry, they are:
- Hand Expansion Valve
  - A manually operated valve which requires the system to be monitored by an operator who then adjusts the valve as required. Typically found in industrial applications where there is Liquid Recirculation.
- Low Side Float
  - Is found in the low pressure side of the system and operates on the level of liquid refrigerant in the evaporator. Most typical application is a Temprite.
- High Side Float
  - Is found in the high pressure side of the system. Found in critical charge systems where the liquid level in the evaporator is controlled by the level of liquid refrigerant in the high side float. Most common application is on air conditioning chillers and industrial systems.
- Automatic Expansion Valve (AXV)
  - Maintains a constant pressure in the evaporator and responds to evaporator pressure and spring pressure. As it does not have a temperature or pressure sensing bulb it cannot adjust to varying loads. Usage is limited but can be found on industrial ammonia
systems and small constant load applications, eg ice-cream holding cabinets.

- **Thermostatic Expansion Valve (TXV)**
  - Regulates the amount of liquid refrigerant flowing into the evaporator proportionately to the rate of vaporisation. It is the most common flow control used in the refrigeration and air conditioning industry. TX valves are commonly used in small air conditioning units through to large industrial applications.

- **Thermal-electric Expansion Valve (TEXV)**
  - The valve is controlled by changes in input voltage that is varied by the sensor. The sensor will vary depending on application. They are used in residential air conditioning systems and some supermarket cabinets.

- **Electronic Expansion Valve**
  - The electronic regulator receives signals from the sensors and adjusts the electrical output to the expansion valve, causing the valve to open or close. Used on multiple evaporator supermarket cabinets.

- **Capillary Tube**
  - The simplest type of refrigerant control used in the industry today. The capillary length and bore are sized to meter refrigerant and create a pressure drop. This type of system requires a critical refrigerant charge and negates the need to use a liquid receiver. Most common applications are domestic refrigerators and air conditioners and small commercial systems.

- **Two Way Flow Control Valve**
  - Also known as Chatleff or Accurator valves. Commonly used in reverse cycle residential and light commercial air conditioning applications and they may be used in small refrigeration equipment such as beverage coolers and ice-makers.

**NOTE:** Flow controls are covered in greater detail in Package No: 9/10/29
Refrigerant Distributors:
Distributors are used to connect the metering device to the evaporator and ensure an even flow of refrigerant liquid/vapour mix to each evaporator circuit. They are used where an evaporator has multiple refrigerant circuits.

The outlet end of the distributor is drilled to accommodate the tubes that join the distributor to the evaporator.

There are four types of distributor in use, they are:

- Venturi
  - Creates a minimum of turbulence in the refrigerant. It has minimal overall pressure loss and can be mounted in any position.

- Pressure drop
  - Creates turbulence in the refrigerant. The nozzle creates a pressure drop but it does increase the velocity which causes the liquid and vapour to mix evenly. The size of the nozzle determines the capacity of the distributor.

- Centrifugal
  - Depends on a high refrigerant entrance velocity. It creates a swirling effect to ensure a thorough mix of liquid and vapour refrigerant.

- Manifold (or Weir)
  - Depends upon a level mounting position and a low refrigerant entrance velocity. It can overfeed circuits directly in front of the inlet and it needs special baffles to ensure even liquid distribution.
Observational Exercise 1.

Task: To identify the major components of the vapour compression system and to observe different styles of components.

Equipment: Different equipment located throughout the college workshops; e.g. demonstration units; coolrooms; merchandising cabinets; various evaporators, condensers, compressors and flow controls (RMDs – Refrigerant Metering Devices); cooling towers and pumps.

Wherever practical, the equipment is to be operated for demonstration of system operation.

Procedure: Conduct a tour of the various workshops and facilities available within the department and identify the equipment and components found therein.

Students are to identify the different system components and refrigerant types used in the various systems.

Discuss the function and operation of the individual components and systems which are being observed.

Demonstration of system operation to be conducted during which observation of operating pressures and temperatures are to be noted.
Practical Exercise 2:

**Service Gauge Manifold Set, Connect To & Disconnect From a Basic Vapour Compression System:**

**Purpose:**
The purpose of this section is to provide you with the underpinning knowledge and skills required to safely connect and disconnect a service gauge manifold set to a Basic Vapour Compression System and to minimise the loss of any refrigerant in the process. Ensuring compliance with HB20.1, HB20.2 & HB20.3 Codes of Good Practice (Parts 1, 2 and 3).

**Fitting Service Gauges to a “Pumped Down” System**

1. Check that the system is electrically isolated.
2. Remove the valve stem caps from the discharge and suction service valves and check the valves are fully back-seated.
3. Check that the manifold hand valves are closed and the centre hose (generally the yellow hose) is sealed/capped.
4. Remove the service port caps and connect the manifold gauge lines, (generally the blue hose) from the compound gauge to suction service valve and (generally the red hose) from the pressure gauge to discharge service valve.
5. Where fitted, slightly loosen the service valve “gland”.
6. “Crack” or slightly front-seat the discharge service valve and slightly purge through the discharge gauge line, the gauge manifold by cracking both hand valves, and the suction gauge line at the suction service valve.
7. Now crack the suction service valve ensuring that the gauge hand manifold valves have been front seated (closed).
8. Switch the system electrics ON.
9. Open the liquid line hand valve. When the low side pressure increases the LP control closes energising the compressor.
10. Monitor the system operation and pressures.
“Pumping Down” the System and Removing the Service Gauges.

1. Fully backseat the discharge service valve.
2. Where fitted, tighten the discharge service valve “gland”.
3. Open the manifold hand valves. This will enable any refrigerant in the gauge lines to flow back to the system via the “low side”.
4. Close the liquid line hand valve. The system will “pump down” i.e. the refrigerant flow to the evaporator has been isolated and as such the system will draw the refrigerant from the low side and pump it into the high side where it will condense and collect in the liquid receiver. When the low side pressure reaches the cut-out setting of the LP control the compressor will switch OFF. Ensure the pressure is no higher than 10kPa and no less than zero by using the pumpdown override switch.
5. In the event of an increase in pressure, use the pumpdown override switch to enable pressure reduction.
6. Electrically isolate the system.
7. Fully backseat the suction service valve.
8. Where fitted, tighten the suction service valve “gland”.
9. Remove the manifold gauge lines and seal/cap them.
10. Refit all valve stem caps and service port caps.
11. Leak test the service valves and ports.

Note: The centre port of the manifold gauge set should be capped or if a gauge line is fitted, the line will be sealed to prevent the loss of refrigerant.
Review Questions:

1: Label the individual components of the reciprocating compressor below.

(1) ____________________________          (6) ____________________________
(2) ____________________________          (7) ____________________________
(3) ____________________________          (8) ____________________________
(4) ____________________________          (9) ____________________________
(5) ____________________________        (10) ____________________________

2. List the three categories of compressors.
3. List each of the five types of compressor and describe the operation of each.

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

4. What are the two main methods of compressor lubrication? Briefly describe each method.

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

5. There are two types of rotary compressor, what are they and how do they differ?

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
6. Screw compressors are known by what other name?

7. Complete this statement: “A condenser is a heat exchange device which……..

8. What happens to the refrigerant as it passes through the condenser?

9. List three main types of condenser.

10. What are the two main styles of air cooled condenser? Describe each style.
11. What are the three basic styles of water cooled condenser? Briefly describe the construction of each.

12. Describe the operation of an evaporative condenser.

13. What is the purpose of a water pump?
14. What is the function of a cooling tower?

_____________________________________________________________________

_____________________________________________________________________

_____________________________________________________________________

15. Describe the operation of a cooling tower.

_____________________________________________________________________

_____________________________________________________________________

_____________________________________________________________________

_____________________________________________________________________

_____________________________________________________________________

_____________________________________________________________________

16. What is the Australian Standard governing the chemical treatment and maintenance of cooling towers?

_____________________________________________________________________

17. What is the purpose of chemical treatment and water filtration?

_____________________________________________________________________

_____________________________________________________________________

_____________________________________________________________________

_____________________________________________________________________

18. What two forces affect the operation of the water regulating valve?
19. How does the water regulating valve operate?

_____________________________________________________________________

_____________________________________________________________________

_____________________________________________________________________

20. What is the function of the liquid receiver?

_____________________________________________________________________

_____________________________________________________________________

_____________________________________________________________________

21. Liquid receivers may be mounted vertically or horizontally, what other design characteristics must also be considered?

_____________________________________________________________________

_____________________________________________________________________

_____________________________________________________________________

22. There are two main types of evaporator, what are they and what are their main characteristics?

_____________________________________________________________________

_____________________________________________________________________

_____________________________________________________________________

_____________________________________________________________________

_____________________________________________________________________

_____________________________________________________________________

23. List the two ‘broad’ classifications of evaporators.
24. List four styles of construction of evaporator.

___________________________________________

___________________________________________

___________________________________________

___________________________________________

25. Give two examples of application for:

Air cooled evaporators: _____________________________

___________________________________________

Liquid cooling evaporators: _____________________________

___________________________________________

26. When a fan is used for circulating air, the air flow may be considered to be:

___________________________________________

___________________________________________

27. Define relative humidity?

___________________________________________

___________________________________________

___________________________________________

___________________________________________

28. What is evaporator temperature difference?

75
29. What is condenser temperature difference?

30. What is a secondary refrigerant?

31. List three types of secondary refrigerant.

32. What is the purpose of a flow control?

33. List all four types of distributors.
34. What is the function of a distributor?

35. There are nine types of flow control used in the air conditioning and refrigeration industry, list all nine.
11. Air Conditioning Fundamentals

Air Conditioning Fundamentals

Air conditioning is the automatic control of:
- Temperature.
- Relative Humidity.
- Air Cleanliness.
- Air Distribution.
- Noise.
- Purity.

Terminology:
Air conditioning maintains internal conditions, under all prevailing external and internal loads.

Metabolic rate is the heat generated by a living body. This is determined by a number of factors, such as the level of activity of the body.

Occupied zone is the area that people occupy within air conditioned space 1.83m above floor level with air movement (velocity) of 0.125m/s.

Comfort air conditioning must satisfy the requirement level of human occupation.

Note: This is not a requirement for critical / industrial mechanical equipment rooms, where machines are being air conditioned for the production of goods and relative humidity is monitored and controlled..

Psychometrics is the study of the properties of air and moisture vapour mixtures.

Standard air is air at a barometric pressure of 1013.25 hPa at 20°C and 50% relative humidity.

Ventilation is the introduction of fresh air into a space to satisfy ventilation code requirements.
Types of Air Conditioning
The main types of air conditioning and their uses are listed below:

**Room air conditioners (RACs)** are used mainly in single rooms in domestic areas or small offices for comfort conditions.

![Diagram of room air conditioner]

**Split system air conditioners** are used in single rooms or groups of rooms, mainly for domestic use to create comfort conditions.

![Diagram of split system air conditioner]
**Chiller set and direct expansion** are used in large commercial office spaces and industrial areas, e.g. operating theatres, chocolate factories, art galleries for *comfort* and *industrial* conditions.

![Diagram of a cooling system](image1)

**Evaporative coolers** are used in areas with low moisture content in the air.

![Diagram of an evaporative cooler](image2)
Comfort Conditions

Radiation – heat in the form of radiation waves is lost from the body to colder surfaces around the body.

Note: Perspiration is a salty fluid secreted by the sweat glands of the skin. It evaporates on the surface of the skin, providing a cooling effect, and assists in cooling the body.

A body continually uses all three methods at once to reject heat. Sometimes one method will be used more than others. For example, if you are dancing you will be losing heat mainly by perspiration.

Age, sex, dress, activity, health of the body and traditional environment also affect how you get rid of heat and stay comfortable.

Note: People feel cold if they lose heat more quickly than their bodies can produce it. They will feel hot if the body produces heat more quickly than it loses it. For example, when the sun goes down, people put on more clothes to slow down heat loss.

Therefore, air conditioning should:

- Produce a condition where heat flows from our body at a rate that suits our activity and where comfortable clothing can be worn and heat can be rejected with least effort.

- Provide an environment people expect, which may vary from country to country.
Low Relative Humidity RH% -
The lower the relative humidity and the higher the air temperature, the greater the quantity of heat lost by perspiration.

No Air Movement –
If there is no air movement around the body, the layer of air closest to the body soon approaches saturation and causes a feeling of stuffiness and discomfort.
High Relative Humidity RH% -
The higher the relative humidity and the lower the temperature, the lower the quantity of heat lost by perspiration.

High humidity is less important than temperature except in special areas.

For example, hospitals require relative humidity below 50% to reduce bacterial growth. Lower temperature and low humidity are preferred when there is a lot of activity.

Air Movement –
If the air movement across the body is high, there is an increased rate of evaporation which makes the body feel cool.

Note: Air moving at a speed over 0.15m/s is a pleasant breeze only if this air is within one or two degrees of the room air.
Basic System Layout

**Major air handling unit components.**

A basic air handling unit comprises:
- Supply air fan
- Cooling coil
- Heating coil
- Filter
- Duct work for:
  - supply air
  - return air
  - outside air
- outlets and grills
- dampers

**Functions of components**

The *supply air fan* circulates air through the conditioned spaces and through the air handling unit.

The *cooling coil* reduces the temperature and relative humidity of air being supplied to the conditioned space.

The *heating coil* increases the temperature of air being supplied to the conditioned space.

The *filter* cleans the air being supplied to the conditioned space.
Duct work is used to direct:
- Return air back to the air handling unit from the conditioned space.
- Outside air to the air handling unit.
- Supply air to the conditioned space.

Outlets and grills distribute air to the conditioned space.

Dampers control air quantities to the conditioned space.

**Packaged air conditioning system**

The packaged air conditioning system is another form or air handling unit.

The main difference is that the packaged air conditioning system incorporates the refrigeration system mechanicals into the same cabinet containing the air handling unit.
Ventilation systems

The word ‘ventilation’ means to remove polluted air from inside a space and replace it. Examples of ventilation requirements are listed below.

<table>
<thead>
<tr>
<th>Occupancy type</th>
<th>Net floor area per person + m²</th>
<th>Minimum outdoor airflow rate</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Education Classrooms</td>
<td>2</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Food and drink services.</td>
<td>1</td>
<td>20</td>
<td>For occupancies where smoking is not permitted 10L/s may be approved.</td>
</tr>
<tr>
<td>Bars</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General areas Dressing rooms</td>
<td>2</td>
<td>10</td>
<td>General requirements (applies to all forms unless separately listed).</td>
</tr>
<tr>
<td>Theatres Auditoriums</td>
<td>0.6</td>
<td>15</td>
<td>For auditoriums where smoking is prohibited the figure of 15 may be reduced to 10, subject to the requirements of the Regulatory Authority.</td>
</tr>
<tr>
<td>Merchandising Arcades</td>
<td>5</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

Example from table: Theatres – Auditoriums

1. Smoking level: with ‘no smoking’ the table recommends 10l/s of outside air per person occupying the space.

2. Minimum requirement per person is 10L/s unless smoking is permitted, when 15L/s are required.

3. If the number of persons is not known then:

   Outside Air quantity = Floor Area x Factors
   
   E.g. If floor area space (10m x 5m) = 50m²
   
   Ventilation rate = 0.6m² / person
   
   = 50m² x 0.6m² / person x 10L/s per person non smoking
   
   =833L/s non smoking
   
   = 1250L/s smoking

Reference: AS 1668.2 – 1991
Forced ventilation system pressurises air supply to all points. Air is released through door grills, windows, etc.
SAA Codes and Regulations

SAA codes and regulations are used to provide a standard set of guidelines which you must follow. The following codes are only a sample of the many codes that outline the standards that must be observed.

Code AS 1668-1991 Part 1
*Fire precautions in buildings with air handling systems.*

This code sets out the requirements for the design, construction, installation and operation of the air conditioning systems related to precautions intended to prevent the spread of fire and smoke through a building by the air conditioning or ventilation systems.

Code AS 1668-1991 Part 11
*Ventilation requirements.*

This code applies to air-handling systems for the mechanical ventilation or air conditioning of indoor enclosures, where such method of control of indoor environment is required by statutory bodies or is an alternative to natural ventilation.

Code AS 1677-1986
*Refrigerating systems.*

This code details the specific requirements for the design, construction, testing and operation of refrigerating systems for all forms of mechanical cooling and air conditioning systems. This does not apply to domestic refrigerators, room air conditioners or any refrigeration equipment containing less than 2.5kg of class 1 refrigerant.

Code AS 3666-2000
*Air handling and water systems of buildings, Microbial control.*

This code outlines the minimum requirements for the design, installation, commissioning, operation and maintenance of air and water systems in buildings.

Its aim is to assist in the control of micro-organism, particularly those associated with Legionnaires Disease etc.
**Review Questions:**

1. What is the name given to the study of the properties of air?
   ________________________________________________________________

2. Define ‘metabolic’ rate.
   ________________________________________________________________

3. Define ‘occupied zone’.
   ________________________________________________________________

4. List the following properties of standard air.
   
   Dry bulb temperature ___________ C  
   Relative humidity ___________ %  
   Barometric pressure ____________ hPa  

5. What is the term given for the introduction of fresh air in an enclosed space?
   ________________________________________________________________

6. Define the term ‘comfort conditions’.
   ________________________________________________________________

7. What is the full name of the following abbreviations?
   
   OA __________________________________________________________
   RA __________________________________________________________
   MA __________________________________________________________
   SA __________________________________________________________

8. In what part of a split system is the supply fan found?
   ________________________________________________________________
9. List three factors that affect human comfort in a conditioned space.
   a) ____________________________________________________________
   b) ____________________________________________________________
   c) ____________________________________________________________

10. Name three methods used to move the air in an enclosed space.
    a) ____________________________________________________________
    b) ____________________________________________________________
    c) ____________________________________________________________

11. What is the name of the refrigeration component that reverses the flow of refrigerant in a reverse cycle system?
    ____________________________________________________________

12. Match each piece of equipment with its correct use by placing the number of the ‘Use’ next to the equipment name. (It is possible for a piece of equipment to have more than one use).

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chiller set</td>
<td>1</td>
</tr>
<tr>
<td>Evaporative cooler</td>
<td>2</td>
</tr>
<tr>
<td>Room air conditioner</td>
<td>3</td>
</tr>
<tr>
<td>Split air conditioner</td>
<td>4</td>
</tr>
<tr>
<td>Packaged air conditioner</td>
<td>5</td>
</tr>
</tbody>
</table>

13. Will solar heat penetrate glass?  
   Yes  □  No  □

14. Why do you feel cold when the temperature is below comfort conditions?
15. List four factors that affect the quantity of heat lost by perspiration.
   a) ____________________________________________________________
   b) ____________________________________________________________
   c) ____________________________________________________________
   d) ____________________________________________________________

16. Why do you feel hot when there is no air movement around you on a hot day?

17. On the following diagram show:
   a) the air movement (by drawing arrow heads on the indicator lines)
   b) the type of air, either OA, RA or SA

   ![Diagram showing air conditioning unit and air movement](image)

18. Which of the Australian Standards covers Microbial Control?

19. What is the aim of Australian Standards?