Refrigeration / Air Conditioning Controls & Circuits

Package No: NRE12/15.

Nominal Student Hours: 40 Hours.

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: This package provides the student with the underpinning knowledge and skills to construct electrical circuit diagrams using standard symbols. The student should be able to identify the application, operational characteristics and adjustment of reduced voltage starters as well as various pressure, temperature, flow, defrost and humidity controls.

Suggested Resources: Australian Refrigeration and Air Conditioning Vol 1&2. Electrical Principles for the Electrical Trades, J.R. Jenneson

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

Competence: This package should be supported by workplace exposure in regards to the operational characteristics of electrical, electronic and pneumatic controls and their electrical circuit configurations for various refrigeration / air conditioning systems under the guidance of a licensed mentor.

Completion: On completion of this package you will obtain results in the National Refrigeration Module No: NR08.

Assessment:
Grade Code: 72

GRADE	CLASS MARK (%)
DISTINCTION	>=83
CREDIT	>=70
PASS	>=50

Assessment Events:

1.	Theory Test	40/40	60%
2.	Electrical Drawings	40/40	20%
3.	Practical Test	20/40	20%
			Total: 100%

Theory Test: Short answer Questions, multiple choice questions. This assessment covers the contents from sections 2 to 8 in the student resource package.

Drawings: This assessment covers the contents from sections 1 to 7 in the student resource package.

Practical Test: Practical: setting of various controls (example thermostats and pressure controls).

Content Summary: Page No

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Refrigeration / Air Conditioning Controls & Circuit NRE12.

Refrigeration / Air Conditioning Drawing Symbols & Layout.

Section No: 1

Purpose: The aim of this section is to provide you with the underpinning knowledge and skills to construct various electrical circuit diagrams from specific drawing symbols and page layouts.

Electrical circuits and symbols: (ARAC 29.10 – 23)
Electrical circuit diagrams can be constructed in a number of ways. Some may contain the control circuit while others will contain both power and control circuit.

The power circuit shows the mains voltage containing electric motors, heaters, motor contactors, main fuses and or circuit breakers etc.

The control circuit contains relays, thermostats, pressure controls, auxiliary contacts etc. The control circuit is not load bearing in that the current flow is very low and its function is to provide automatic cycling and safety control for the plant and equipment. Note: control circuits can either have 240 volts or 24 volts and in some cases 415 volts has been used.

Switching arrangements:
Cycling controls or safety switches can be either normally opened (NO) or normally closed. (NC)

Example:

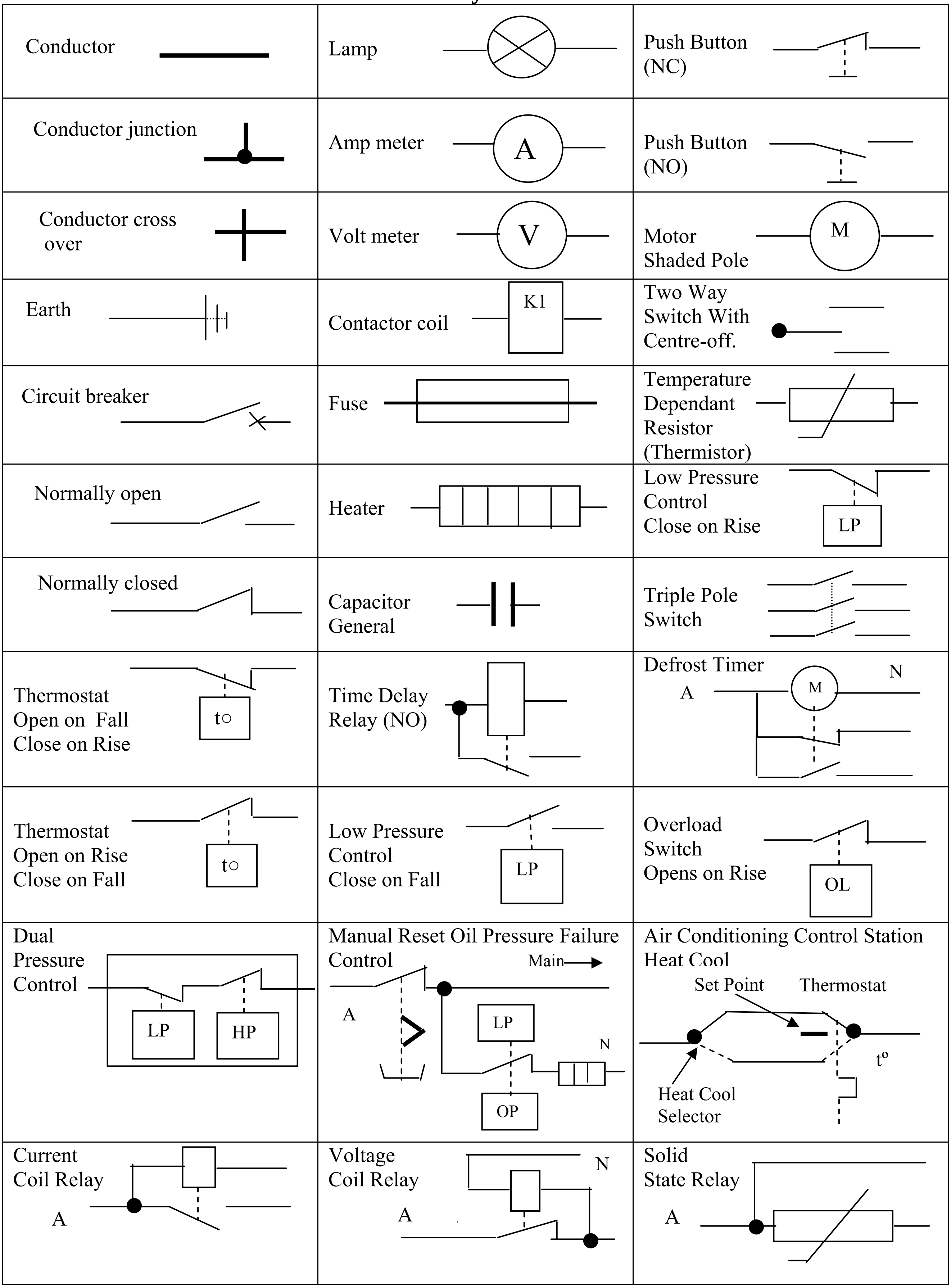
NO NC

Thermostats and pressure controls can either close on rise or open on rise:

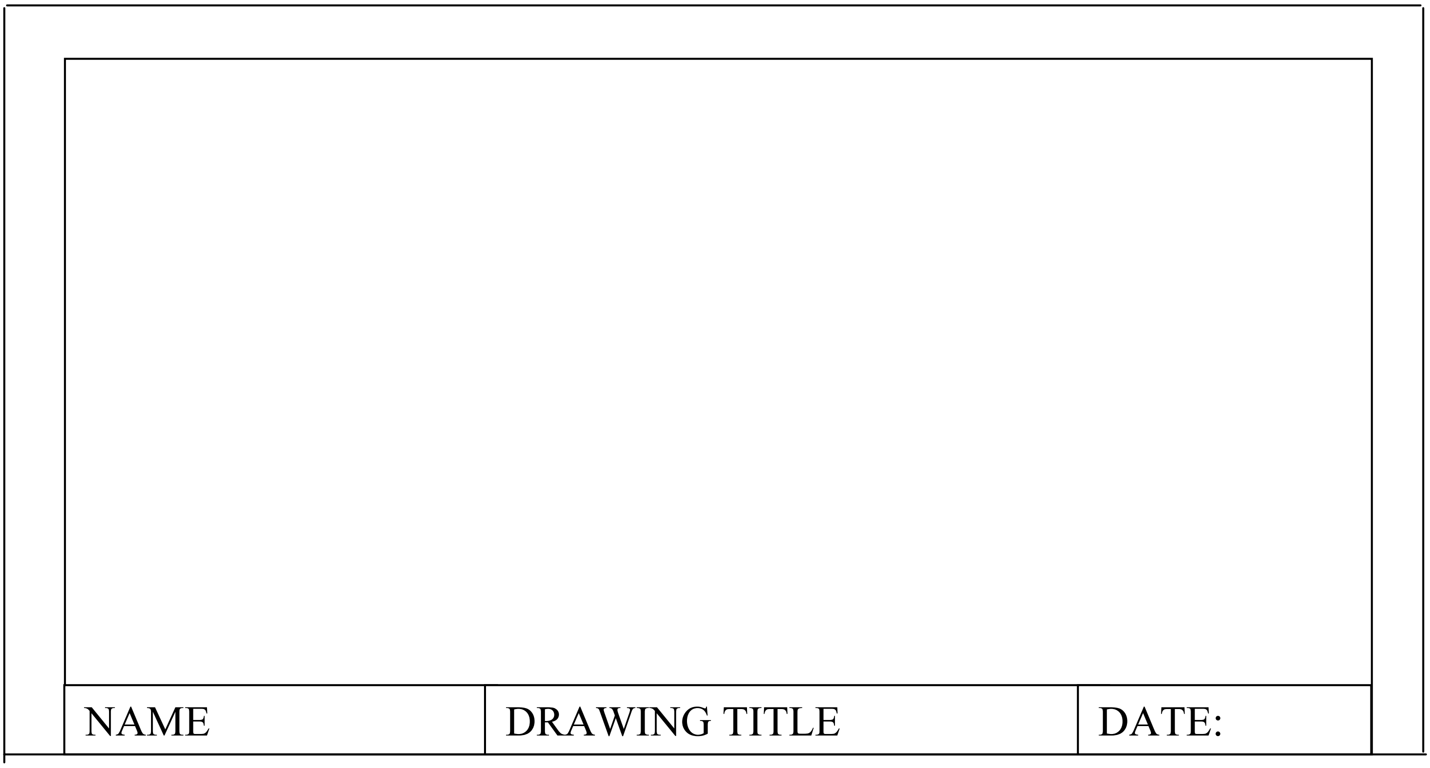
Close on rise N/O Open on rise N/C

Note: automatic controls cycle as required for example: an air conditioning system cycling on room temperature. The same system may have a manual reset high pressure control with a manual reset button which can only be reset when the fault has been rectified.

Electrical Symbol Sheet



Sample of A4 Drawing Layout



Details:

- 10mm boarder
- 12 mm name, title and name blocks

Colours:

- Red for active
- Blue for neutral
- Black for components.

Drawing Exercise No: 1

Purpose: To construct an electrical power and control circuit diagram for a medium temperature refrigerated cool room in accordance with the following details:

Details:

- 415 volt power supply
- Main isolating switch
- HRC fuses
- Three phase motor compressor
- Direct On Line (D.O.L.) contactor
- Permanent split capacitor condenser fan motor
- Two permanent split capacitor evaporator fan motors
- Liquid line solenoid valve
- Low pressure and High pressure safety controls
- Thermostat to cycle LLSV on room temperature
- Room light and switch.

Resources required:

- A4 Project Book
- Ruler
- Circular Templates
- Pens
    - Red
    - Black
    - Blue
    - Green.

Procedure: Using your A4 project book set out the boarder and title block as indicated in this package. Before commencing your final drawing, sketch a rough copy on a piece of paper and check for accuracy with your teacher or workplace mentor.

Note: Red for all active conductors and switch contacts.
Blue for neutral conductors and black for all components.
Green for all earthing..

Refrigeration / Air Conditioning Controls & Circuit NRE12.

Reduced Voltage Three Phase Motor Starting Methods Section No: 2

Purpose: The aim of this section is to provide you with the underpinning knowledge and skills in regards to reduced voltage three phase motor contactors and their associated circuits. In addition the development of electrical power and control circuit diagrams and describe the sequence of operation.

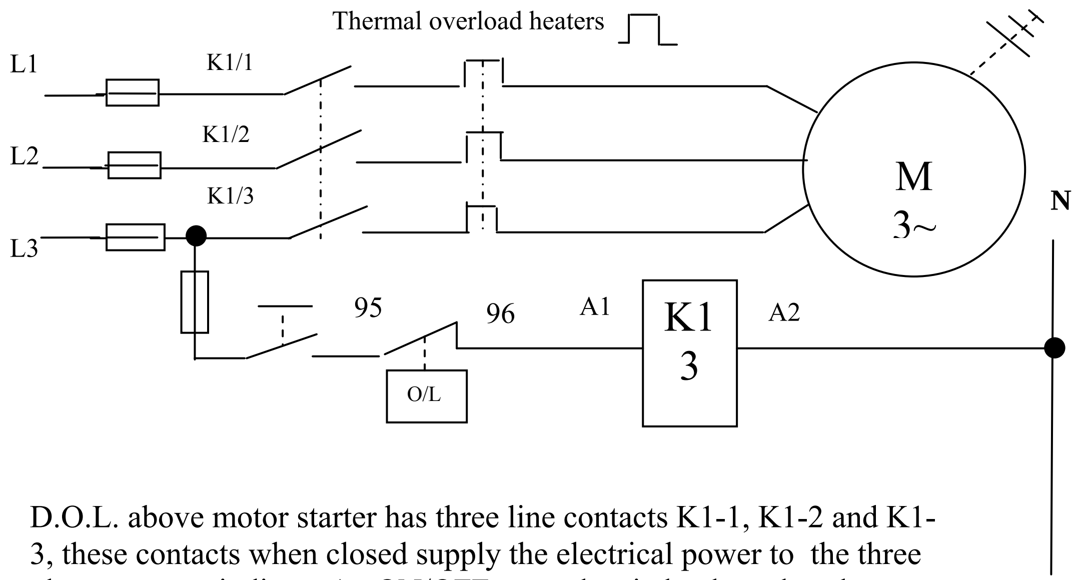
Types of motor starters (contactors) (ARAC, page 14.13)

1. Direct - On – Line (D.O.L.)
2. Reduced Voltage Starters, including
   - Star / Delta
   - Primary Resistor
   - Part Winding
   - Auto – Transformer
   - Solid State (electronic soft starter)

Direct - On – Line (D.O.L.)

Essentially a three phase switch operated by an electromagnetic coil. The voltage of the coil can either be 24, 240 or 415 volts depending on the application. This type of device is a contactor fitted with a thermal overload to protect the motor from drawing excessive current and should act to the motors Full Load Amperes (FLA).

Note: Direct on Line contactor and associated circuit Fig.1.



D.O.L. above motor starter has three line contacts K1-1, K1-2 and K1-3, these contacts when closed supply the electrical power to the three phase motor windings. An ON/OFF control switch when closed energises the contactor coil KI through the overload and thus creating an electromagnet causing the three contacts close.

Note: No: 95 & 96 normally closed A1 and A2 are the electrical terminals for the overload and contactor coil respectively for the majority of three phase contactors.

Fig.1

Star / Delta Contactor (ARAC, pages 14.14 – 14.15

The starting current of a star delta contactor is reduced from approximately 7 times full load current to approximately 2.5 times and the starting torque is reduced from approximately 1.5 times to 0.5 times the full load torque. It should be noted that reduced voltage starting is used only on motors that can be started unloaded. Unloaded means the motor only has to produce enough power to turn its self.

Example:

- A three phase delta connected motor has a full load current of ten amperes.
  Starting current = 10 x 7 = 70 amperes.

- The same motor connected in a star configuration.
  Starting current = 10 x 2.5 = 25 amperes.

Note: the resistance of the motor windings and current flow can be measured with an ohmmeter and a clamp on tong tester respectively.

If the stator winding of a three phase motor is connected in star then the effective voltage across each winding is 240 volts and the current and the torque are reduced by 33% of the values obtained from the same motor connect in delta with a D.O.L. contactor.

Note: Star Delta Contactor Circuit Fig.2.

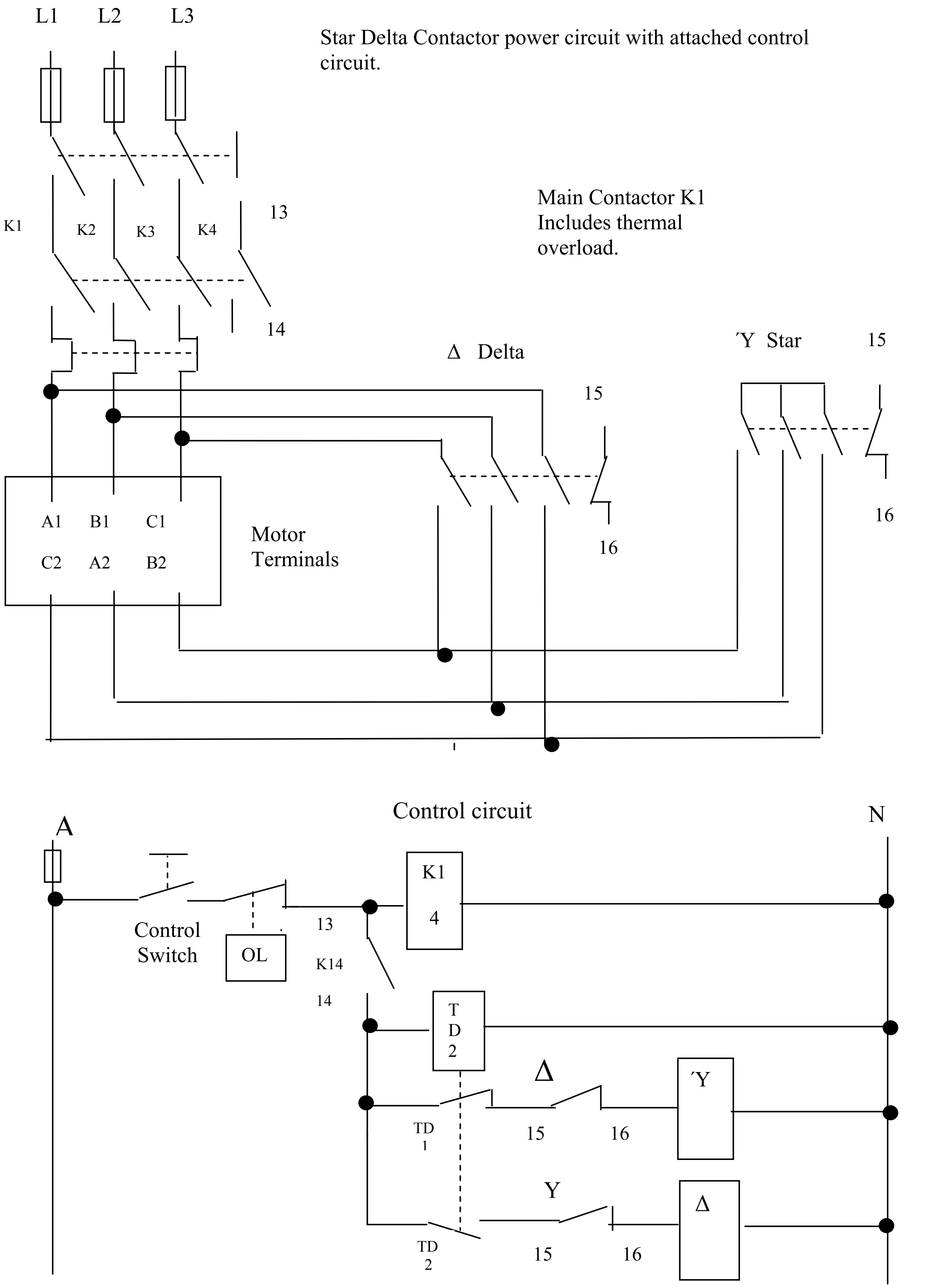

L1 L2 L3
Star Delta Contactor power circuit with attached control circuit.
K1 K2 K3 K4
13
14
Main Contactor K1 Includes thermal overload.
Δ Delta
15
16
΄Y Star
15
16
A1 B1 C1
C2 A2 B2
Motor Terminals
Control circuit
A
N
Control Switch
OL
13
K14
14
K1
4
T D 2
Δ
TD 1
15
16
΄Y
Y
TD 2
15
16
Δ

Fig. 2

Operation:

- When the control switch is closed current flows through the overload (OL) and onto to K1/3 main contactor coil.
- The main contactor K1 supplies power to A1, B1 and C1.
- At the same time current flows to the time delay relay coil TD/2 and to its n/c set of contacts, then on to n/c auxiliary contacts of the delta relay and onto the star relay coil.
- With both the main contactor and star relay coil now energised the motor starts in star. That is the voltage across each phase winding is 240 volts.
- After a pre - determined time period the delay timer switches from TD/1 to TD/2 and then through the n/c star contacts and onto the delta contactor coil.
  Note: TD/1 opens and TD/2 closes.
- With both the main contactor and delta relay energised the motor now operates in delta. That is the voltage across each phase winding is now 415 volts.
- When the control switch is switched to the off position the Time Delay Relay TD/2 returns to its normal position with TD/1 closed.

Primary Resistance Contactor

The primary resistance contactor consists of three resistors and two contactors. On start up one of the contactors (K1) is energised allowing current to flow through the three resistors which are connected in series with each phase winding. These resistors limit the amount of starting current. After a pre-determined period of time as the motor comes up to speed the second contactor is energised through time delay relay this then allows the current to bypass the resistors and providing direct on line current to the phase windings.

Note: Primary Resistance Contactor Circuit Fig. 3 a & b.

Primary Resistance Contactor & power circuit with attached control circuit

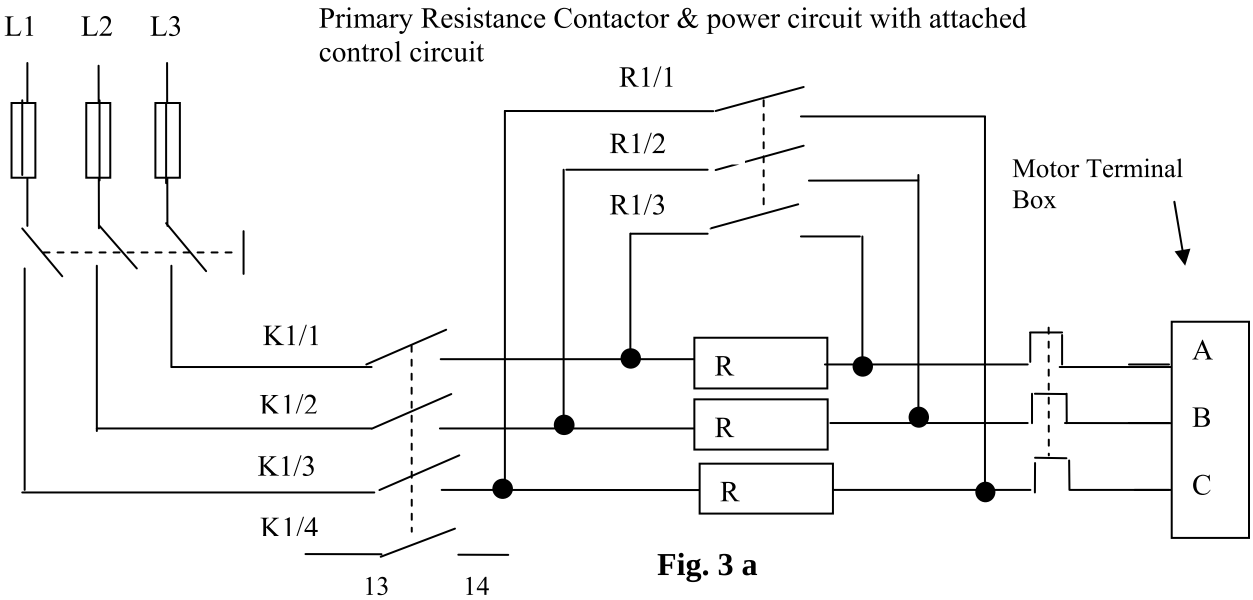


Fig. 3 a

Primary Resistance Control Circuit

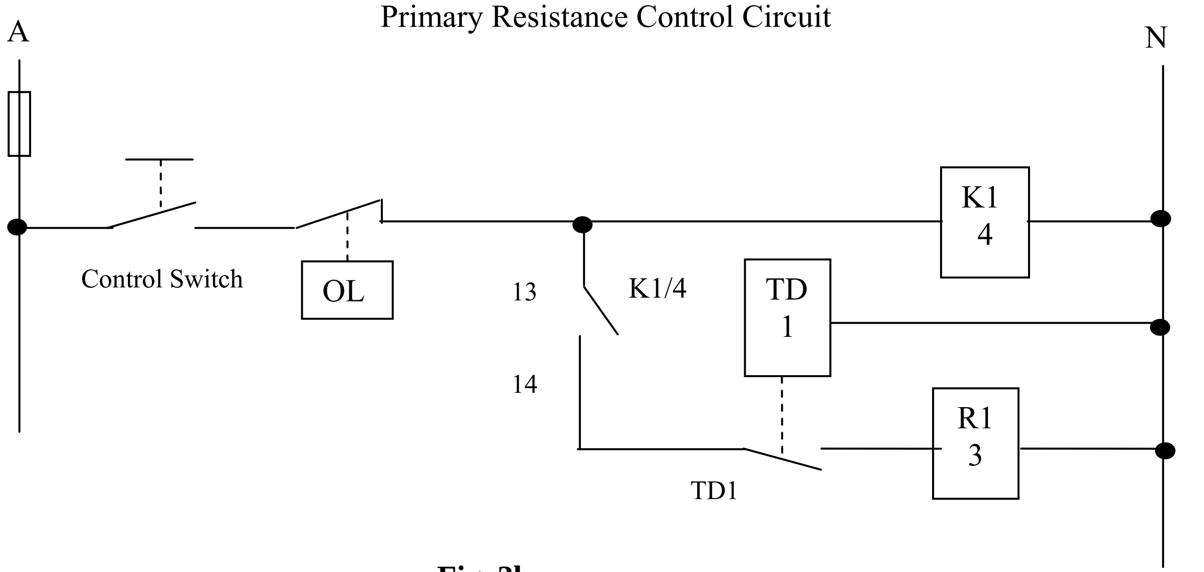


Fig. 3b

Part Winding Contactor:

The part winding motor requires two contactors and a motor that has two windings divided into two halves with each winding having 50% of the motors output power. On motor start up the locked rotor current and starting torque will be halve that of a three phase induction motor operating with a Direct On Line (D.O.L.) contactor.

The windings are designed to provide balanced starting torque when one of the windings is energised and in the run condition both the windings are energised.

Operation:

When the control circuit is energised the starting contactor closes and energises the first winding (Start), after a period of time around 2 – 3 seconds the running contactor is energised through a timer and at this stage both windings are in circuit.

Note: power and control circuits Fig. 4 a & b.

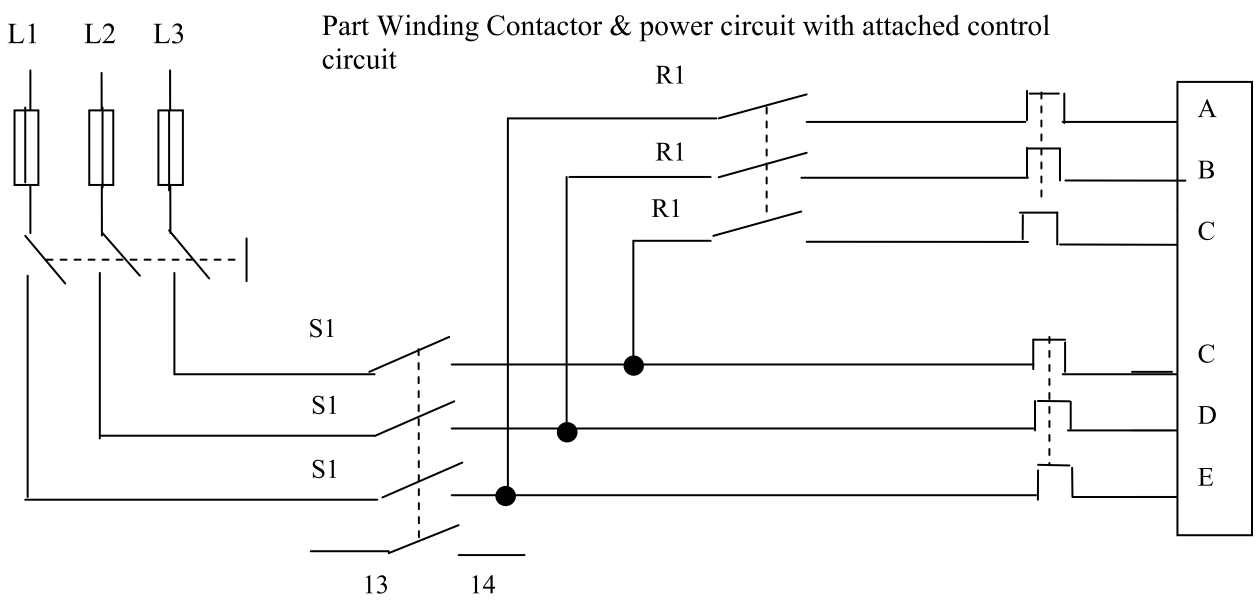


Fig. 4 a

Applications:

The part winding method is used mainly on accessible hermetic compressor motors with the motor windings designed to meet the compressor requirements and not necessarily evenly split.

Part Winding Control Circuit

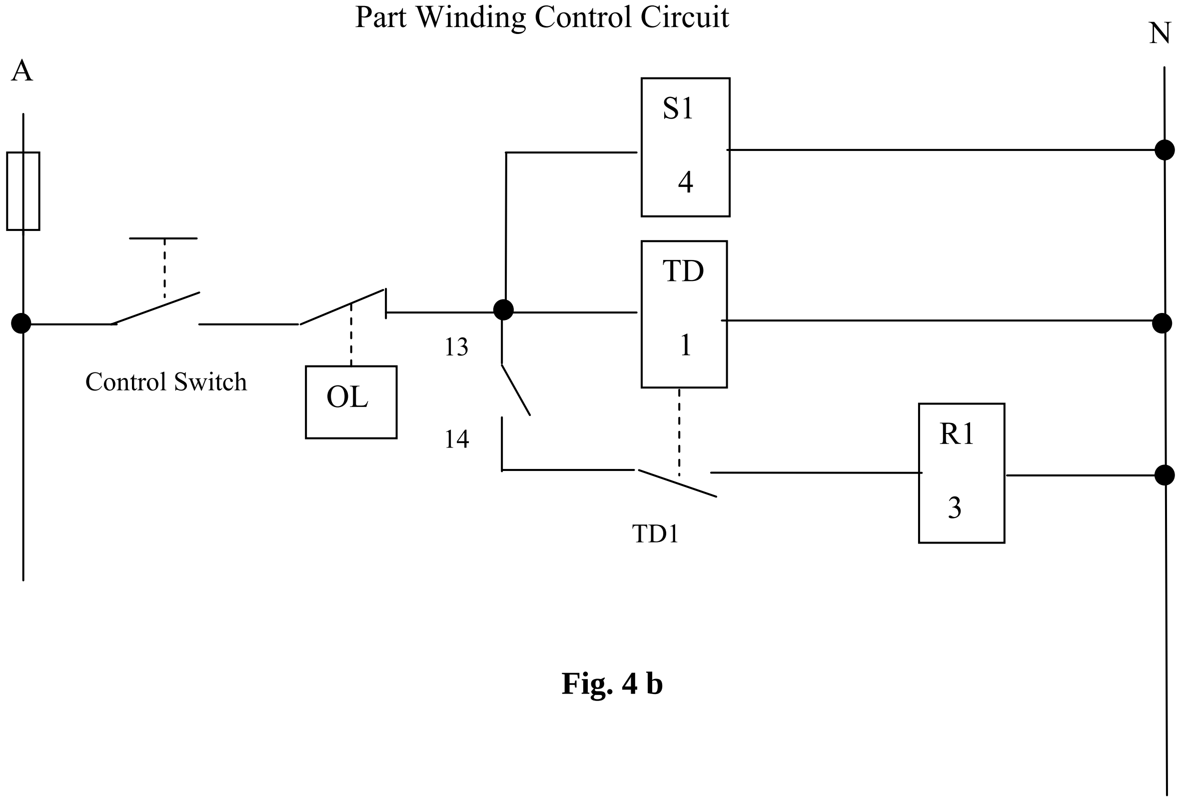


Fig. 4 b

Auto-Transformer Contactor: (ARAC, page 14. 18)

The auto- transformer contactor requires a transformer that has a number of tapping points which provide lower voltages on start up. Common tappings provided are as follows: 40%, 50%, 60%, 70% and 80% of the full line voltage. The auto-transformer has a much greater reduction in starting current in comparison to the star delta contactor.

Solid State (electronic soft starter) (ARAC, page 14. 21)

The solid state contactors are designed to regulate the motors starting current electronically to provide smooth and step less acceleration of the motor. This type of motor starter controls the voltage applied to the motor terminals via the use of semi conductor devices (S.C.R.s).

The minimum voltage can be adjusted to suit the load requirements and the rate of acceleration is adjusted to meet the required run – up time.

Review Questions Section No:2

Q.1 A direct on line (DOL) contactor when connected to a three phase motor:

(a) Supplies full line voltage
(b) Limits the voltage
(c) Limits the current
(d) Supplies excessive current ( )

Q.2 The thermal elements of a three phase overload for a DOL contactor are connected in:

(a) Series with the contactor coil
(b) Series with the overload
(c) Series with the motor windings
(d) Parallel with each phase ( )

Q.3 A tong tester is clamped:

(a) Around the active and neutral
(b) Between the phases
(c) Between any phase and earth
(d) Around the active conductor ( )

Q.4 An ohmmeter is used to determine the:

(a) Current
(b) Resistance
(c) Voltage
(d) Impedance ( )

Q.5 The purpose of a reduced voltage starter contactor is to:

(a) Reduce the circuits impedance
(b) Reduce the motors speed
(c) Reduce the line current on start
(d) Produce a greater kW output capacity. ( )

Q.6 Describe the operation of a thermal overload when used in conjunction with a DOL contactor in protecting the motor windings from burn out_________________________

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Q.7 List four reduced voltage contactors that are used within the refrigeration and air conditioning industries:____

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Q.8 What is the main purpose of the three phase resistors in a primary resistance motor contactor?____

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Q.9 Describe in your own words the operation of a part winding contactor when used on a semi hermetic compressor:____

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Q.10 A star delta contactor is used to start a 30 kW drive motor for a refrigeration storage room. Describe the sequence of operation of the contactor from start to run:__________________

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Drawing Exercise No: 2

Purpose: To construct an electrical power and control circuit diagram for a, ventilation system in an air conditioning plant room in accordance with the following details:

Details:

- 415 volt power supply
- Main isolating switch
- HRC fuses
- Three phase motor
- Primary resistance contactor
- 24 hour seven day time clock
- Control switch
- Over ride time clock control switch
- Overload protection for motor.

Resources required:

- A4 Project Book
- Ruler
- Circular Templates
- Pens
  - Red
  - Black
  - Blue
  - Green.

Procedure: Using your A4 project book set out the boarder and title block as indicated in this package. Before commencing your final drawing, sketch a rough copy on a piece of paper and check for accuracy with your teacher or workplace mentor.

Note: ***Red for all active conductors and switch contacts***
Blue for all neutral conductors and black for components
Green for all earthing.

Refrigeration / Air Conditioning Controls & Circuit NRE12.

Control Fundamentals
Section No: 3

Purpose: The purpose of this section is to provide you with the basic underpinning knowledge and skills in the function, control variables, operation and application of automatic cycling and safety controls which are associated with various refrigeration and air conditioning systems.

Basic functions of an automatic control circuit:

The three necessary elements of a control system are:

- Sensor or device which senses a change in the “Controlled Variable” (that is the liquid or space temperature being controlled) and acts by changing one of its characteristics such as electrical resistance, volume, shape or length etc.
  Note: temperature sensors can be either bi-metal, bellows, bellows with bulb, thermistor and thermocouple

- Controllers that change in response to the sensor when ever the condition being “sensed” or measured changes from the “Set Point” or “Desired Value” by directing the “Controlled Device” to carry out the corrective action. Thermostatic controllers may respond to a rise in temperature of the sensor by closing the electrical contacts and direct current to a “controlled device” such as a compressor motor.

- Controlled devices operate at the direction of the “controller” to carry out “corrective action” to restore temperatures or pressures to desired values. These electrically controlled devices include fans, reversing valves, solenoids, compressors, damper and water valve motors etc.

Control Variables:

- Temperature ______ Thermostat control
- Pressure ___________ Low / High Safety and Cycling Controls
- Pressure Air ________ Pressure Differential and Oil Pressure Controls
- Humidity __________ Humidistat
- Flow ______________Air Flow “Sail Switch” and Water Flow Switches.

Control purpose:

Controls are used within refrigeration and air conditioning systems to:

1. Cycle plant and equipment on and off to maintain the desired conditions (Cycle controls).

2. Protect plant and equipment from damage and protect the general public from injury (Safety controls).

Cycling controls *must be automatic reset to allow plant and equipment to operate automatically.*

Safety controls *should have wherever possible manual reset .The manual reset function will stop the plant and equipment from operating until the control reset button is reset.*

Six basic functions of automatic control systems:

The previous three elements perform the following six functions:

- Sensing element measures changes in pressure temperature or humidity,

- Control mechanism translates these changes into energy which can be used by motors, valves etc.

- The connecting electrical wiring, mechanical linkages or pneumatic piping transmits the energy to the motor valve or device which carries out "Corrective Action"

- The controlled devices (motors and valves) use energy to operate the corrective action which may directly operate cooling / heating equipment or regulate liquid / air flow.

- The sensing element in the control detects a change in conditions that results from the corrective action and signals the control mechanism.

- The controlled mechanism stops the motor or valve and terminates the call for corrective action to prevent over correction.

Control mechanism:

All cycling and safety controls have built in them a snap open and close action to avoid arching of their contacts and any further damage that arching can cause.

There are three main types of snap action methods used and they are:

- Magnetism
- Spring
- Mercury tilt.

Direct and indirect electrical control:

Electrical controls switch on and off refrigeration and air conditioning systems and their associated equipment such as reversing valves, heater elements, compressor motors and water pumps etc.

Direct electrical control:

Switch single phase loads by directly controlling the load.
Example: a thermostat on a commercial drink cabinet has direct control over the motor compressor.

Indirect electrical control:

Where the load or loads being switched by a control draws high current that is the control cannot directly switch the load without causing damage. These loads use a relay or contactor to transfer the high voltage to the load.

Example: Three phase motor controlled by a stop start switch using a three phase contactor to carry the line voltage to the motor.

Control settings:

1. Cut-in is the condition at which the control closes the circuit, to turn equipment on.

2. Cut-out is the condition at which the control opens the circuit, to turn equipment off.

3. Differential is the difference between the controls cut-in and cut-out points.

Review Questions Section No:3

Q.1 Describe the purpose of the control circuit:______________________________________

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Q.2 Refrigeration / air conditioning controls have a number of control variables, what are they?

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Q.3 List the two cycling methods used on various controls and give an example:___________

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Q.4 Describe what is meant by the terms direct and indirect electrical control:_____________

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Q.5 All electrical controls have a built in snap action. What is its purpose?________________

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Q.6 What is the purpose of the:

- Sensor:____

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- Controller:____

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- Controlled device:____

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Q.7 Describe what is meant by the following terms:

- Cut in:____

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- Cut out:____

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- Differential:____

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Q.8 List the three main types of snap action control methods used:________________________

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Drawing Exercise No:3

Reverse Cycle Ducted AC System

Purpose: To construct an electrical power and control circuit diagram for a split ducted air conditioning system accordance with the following details:

Details:

- 415 volt power supply
- Main isolating switch
- HRC fuses
- Three phase motor
- D.O.L. compressor contactor
- Two permanent split capacitor condenser fan motors
- One permanent split capacitor evaporator fan motor (LMH speeds)
- Reversing valve coil
- Control switch
- Heat cool selector switch
- Thermostat to control space temperature.
- De-ice thermostat.

Resources required:

- A4 Project Book
- Ruler
- Circular Templates
- Pens
  - Red
  - Black
  - Blue
  - Green.

Procedure: Using your A4 project book set out the boarder and title block as indicated in this package. Before commencing your final drawing, sketch a rough copy on a piece of paper and check for accuracy with your teacher or workplace mentor.

Note: ***Red for all active conductors and switch contacts***
Blue for all neutral conductors and black components
Green for all earthing.

Refrigeration / Air Conditioning Controls & Circuit NRE12.

Thermostats
Section No: 4

Purpose: The aim of this section is to provide you with the underpinning knowledge and skills to remove test and adjust various types of temperature cycling and safety controls.

Definition:

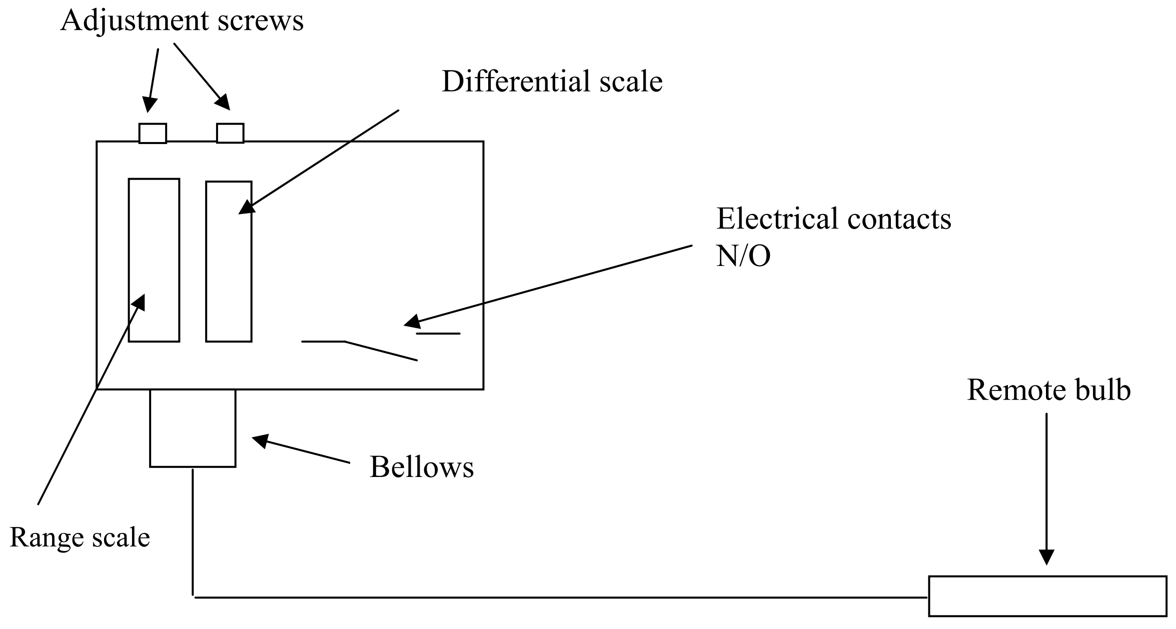
The thermostat is a control that responds to temperature change. (ARAC, 12. 8).

Thermostat components:

The main components of a thermostat are:

- Bellows
- Sensing bulb
- Electrical contacts
- Adjustment screws

Note: attached Fig. 1.



Typical bellows and bulb thermostat component layout.

Operation:

The sensing bulb senses a rise or fall in temperature and expands or contracts the bellows which causes a movement in the cross member and opens or closes the contacts as required.

Setting terms:

1. Cut –in point:
   The cut-in point of a thermostat is adjusted by turning the range adjustment knob.

2. Cut-out point:
   The cut out point is adjusted by altering the differential screw.

   Example: Cut-out = cut - in - differential

3. Differential
   The differential is the difference between the cut-in and cut-out points.

   Example: Differential = cut - in – cut - out.

4. Range:
   The range setting can be changed to cut-in and cut-out at a lower or higher temperature without changing the differential.

   Example: A thermostat set to cut in a 4°C and cut – out at 0ºC has a differential of 4K.

   If the range setting was re-adjusted to cut in at 6°C then the cut out would be 2°C and thus leaving the differential at 4K.

Other terms:

- Set point is the value at which the control scale indicator is set.
- Control point is the value of the temperature maintained in the conditioned space.
- Deviation is the difference between the set point and the control point. For example, if the set point is 22°C and control point is 24°C than the deviation is 2K.

Determining thermostat settings:

When determining the control setting for an air or liquid temperature sensing control (thermostat), you should decide on the average temperature and the maximum and minimum allowable temperatures.

Example 1: Medium temperature coolroom with an average air temperature of 3°C.

- Cut-in temperature = 4°C.
- Cut-out temperature = 2 °C.
- The thermostat is set with a range of 4°C with a differential of 2K.
- This provides an average room temperature of 3°C.

Example 2 A refrigerated cabinet has its thermostat bulb clamped to a forced draught evaporator (FDC) in accordance with the following details:

- Refrigerated space temperature 3°C + / - 1K
- Evaporator TD 6K
- Off cycle defrost.

Thermostat settings: Cut - in = 3°C + 1K = 4°C
Cut – out = 3°C – 1K – 6K = - 4°C.

Therefore the range setting is 4°C with a differential of 8K

Note: Various evaporator Tds are listed in (ARAC, 4.30-31).

Refrigeration pump down cycle:

The majority of medium temperature coolrooms utilise a pump down cycle to maintain the temperature of the room and an off cycle defrost. This arrangement is an effective way of keeping liquid refrigerant out of the compressor crankcase during the off cycle

Operation:

- Thermostat opens at desired room temperature and de-energises a liquid line solenoid valve.
- The LLSV then close shutting of the flow of refrigerant to the evaporator.
- The compressor keeps running until the refrigerant pressure reaches the cut-out point of the low pressure control (just above 0kPa).
- Evaporator fans operate continuously.
- When the room temperature rises the thermostat closes and energises the LLSV.
- Saturated liquid refrigerant enters the evaporator.
- As saturated refrigerant temperature rises to around 447kPa (3°C) the low pressure control closes. (At this point the evaporator coil temperature is 3°C and defrosted).
- The compressor re-starts

Example: Medium temperature coolroom has an average room temperature of 3°C with an evaporator Td of 6K.

Note: at the desired room temperature the evaporator coil temperature would be -3°C and therefore will have some ice build up on the coil.

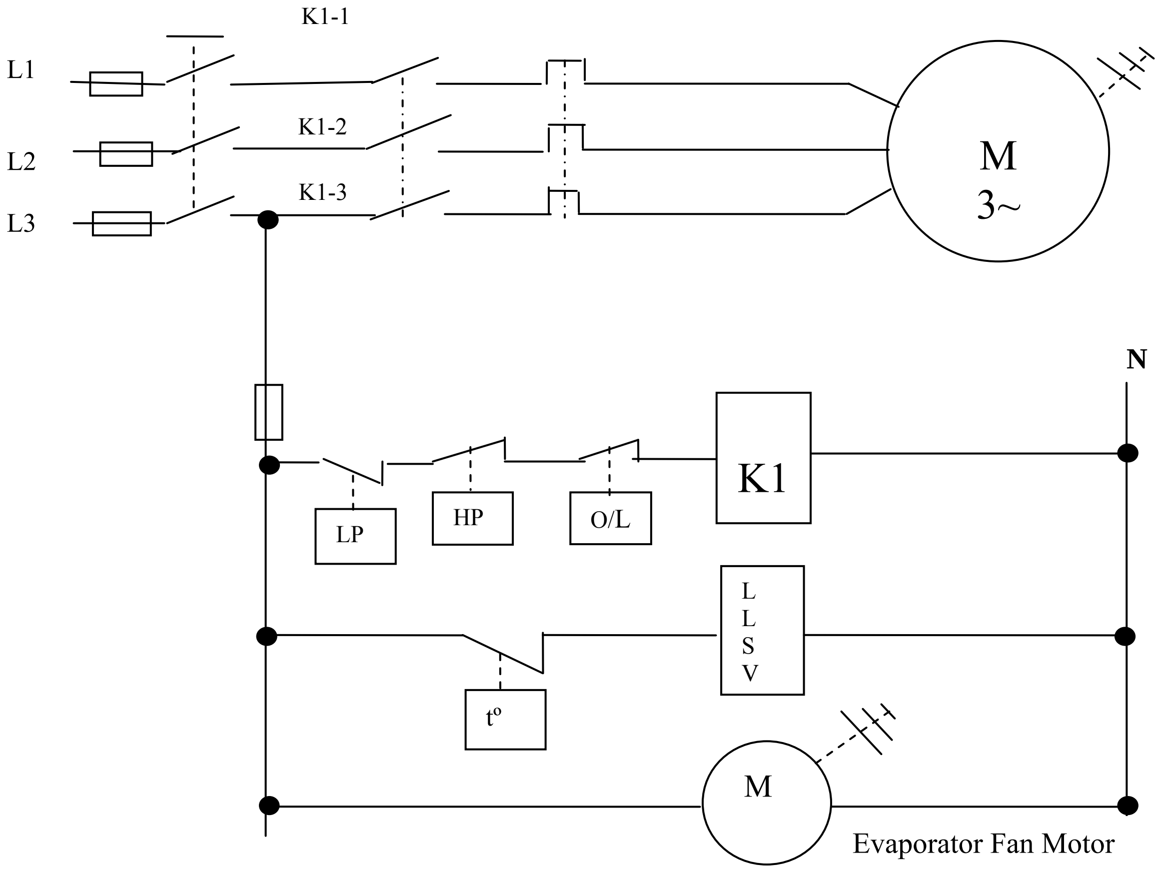
- Average room temperature of 3°C
- Pump down cycle
- Refrigerant 22
- Evaporator Td of 6K
- Evaporator fans operate continuously.

It should be noted that the sensing bulb of a room thermostat should be place in the return air stream of the evaporator.

Control settings:

• Thermostat:	Cut-in = 4°C	Cut-out = 2°C
• Low pressure control:	Cut-out = 10kPa	Cut-in = 447kPa.

Pump down electrical circuit diagram:



Medium temperature coolroom (3°C) incorporating a pump down cycle. Note: belt driven compressor.

Types of thermostats:

Thermostats can be used as cycling or safety controls

Cycling thermostats can either:

- close on rise
- open on rise
- open on fall
- close on fall

Example:1 Air conditioning thermostat on:

- Heating closes on fall and opens on rise in temperature
- Cooling opens on fall and closes on rise in temperature.

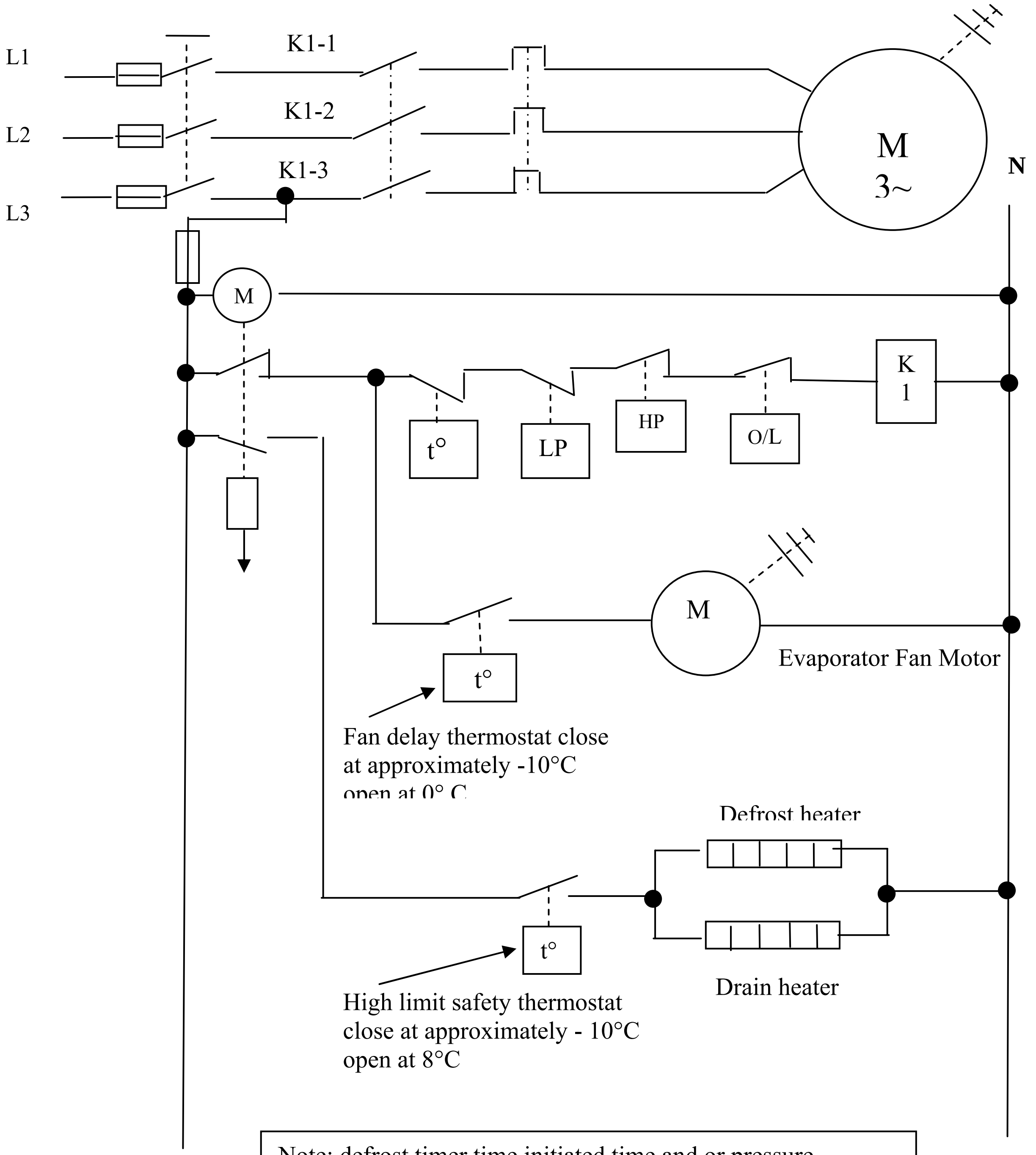
Safety thermostats can either open on rise or on fall with automatic or manual reset.

Example:2 Central air conditioning plant.

- High limit safety thermostat (resistance heater protection) opens on rise and manual reset.

- Ant-freeze safety thermostat (shell & tube evaporator) opens on fall and manual reset.

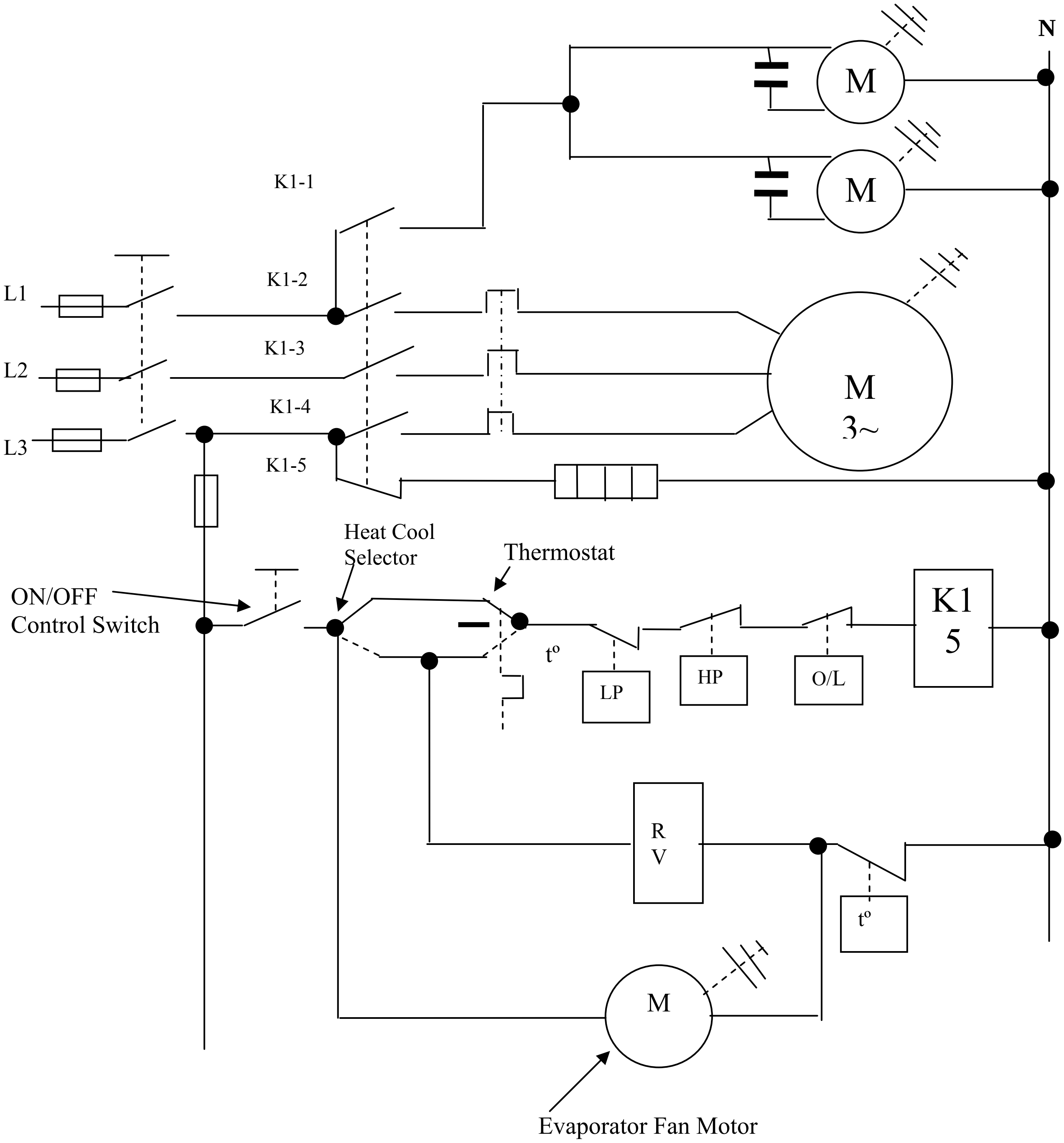
Electrical Wiring Diagram Low Temperature Freezer Room (-20°C)



Note: defrost timer time initiated time and or pressure termination.
The following details defrost timer settings for a low temperature room (freezer room) :

- Four defrosts per day at 40 minutes duration.
- Pressure override set at 6°C saturated evaporator refrigerant pressure temperature.
- Pressure override setting will depend on the type of refrigerant used.

Electrical Wiring Diagram Reverse Cycle Air Conditioning System



Review Questions Section No:4

Q.1 List the main components of a coolroom thermostat:________________________________

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Q.2 Where should the thermostat bulb be located in a freezer room?______________________

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Q.3 What is meant by the following terms in relation to thermostats?

- Cut-in point:____

  ____

- Cut-out point:____

  ____

- Differential:____

  ____

  ____

Q.4 Determine what the thermostat settings would be for a medium temperature coolroom if the average room temperature is 2ºC with an evaporator Td of 8K:

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Q.5 Describe in your own words the operation of a bellows and bulb thermostat:____________

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Q.6 Construct in the space provided a typical electrical control circuit diagram for a medium temperature coolroom incorporating a pump down cycle.

Drawing Exercise No:4

Medium Temperature Cold Storage System
Pump Down Cycle

Purpose: To construct an electrical power and control circuit diagram for a refrigerated cold storage system to maintain an average room temperature of 3º C in accordance with the following details:

Details:

- 415 volt power supply
- Main isolating switch
- HRC fuses
- Star delta compressor contactor
- Two three phase star connected condenser fan motors (DOL)
- One three phase star connected evaporator fan motor (DOL)
- Liquid line solenoid valve
- Thermostat to control space temperature via LLSV
- LP / HP controls
- Limited start timer (to prevent condensing unit from short cycling)
- Crankcase heater.
- HP cycling control on one of the condenser fan motors.

Resources required:

- A4 Project Book
- Ruler
- Circular Templates
- Pens
  - Red
  - Black
  - Blue
  - Green.

Procedure: Using your A4 project book set out the boarder and title block as indicated in this package. Before commencing your final drawing, sketch a rough copy on a piece of paper and check for accuracy with your teacher or workplace mentor.

Note: ***Red for all active conductors and switch contacts***
Blue for all neutral conductors and black for all components
Green for all earthing.

Refrigeration / Air Conditioning Controls & Circuit NRE12.

Pressure Controls
Section No: 5

Purpose: The aim of this section is to provide you with the underpinning knowledge and skills to install, remove, test and adjust pressure controls on an operating refrigeration or air conditioning system. Due care should directed towards electrical safety and the Codes of Good Practice (HB40).

Definition:

A Pressure control responds to changes in pressure. (ARAC, Vol 1, 12.10 & Vol 2, 26.3).

Types of pressure controls:

- Low Pressure Control
- High Pressure Control
- Dual Pressure Control
- Oil Pressure Failure Switch

Operation:

The refrigeration industry has many applications to monitor both high and low pressure. A pressure switch is very similar in operation to the bulb type thermostat but uses pressure from the operating system to expand the bellows in the control.

A small tube is connected from the system to the controls bellows and senses the pressure. A change in pressure will cause the bellows to expand or contract which will activate an electrical switch. It is necessary for these switches to have an operating differential adjustable over a small range. This differential adjustment prevents the system from short cycling by sensing small changes in pressure.

Note: You should gain on the job experience in installing and adjustment of various pressure controls under to guidance of a workplace mentor.

Low Pressure Control:

This type of control can be used as a safety switch to shut the system down in the event of excessive low operating pressure. The control switching is normally closed and opens on a fall in pressure. These controls can be either automatic or manual reset.

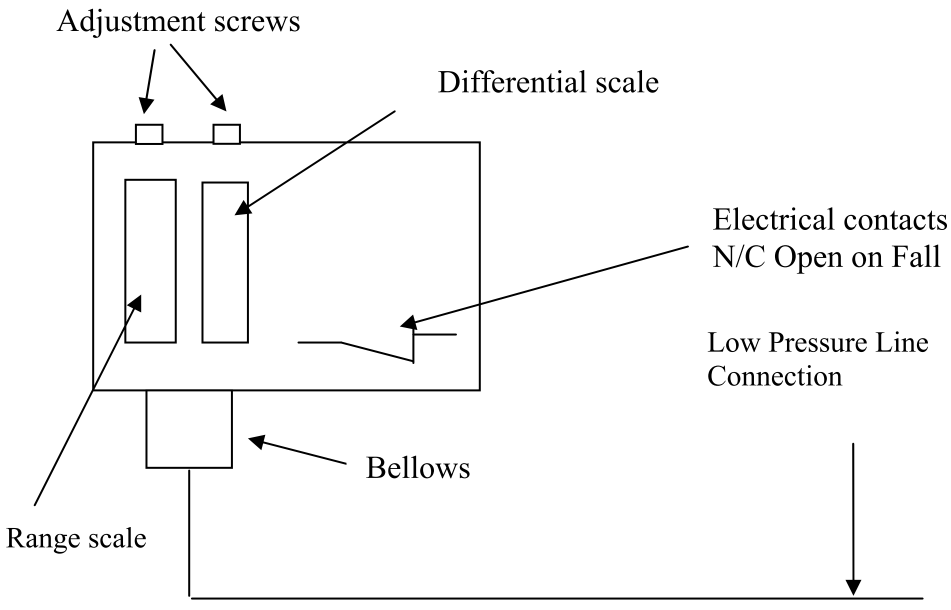
The low pressure control can also be used as a cycling control, for example

- Cycling the refrigeration system on or off by utilising a pressure temperature relationship (eliminating the use of a thermostat).

- In a pump down cycle in refrigeration and air conditioning systems to eliminate liquid flood back on start up.

- Evaporator fan delay (reverse acting) after defrost cycle on a low temperature system (-20°C). In this example the electrical contacts are normally open and close on fall in evaporator pressure. This prevents hot air and water from the defrost cycle being blown into the room or onto the product

  Evaporator fan delay after defrost.
  (R22 : Close contacts at 253kPa = -10ºC and open at 396 kPa = 0ºC).



Typical Low Pressure Control.

Low Pressure (LP) Control Setting Procedure

1. With the system running, set the ***Cut In*** to a higher value than required

2. Close the suction service valve to cause the compressor to cut out on the LP control (The ***Differential*** value may have to be reset to a lower value to cause this to happen).

3. Crack open the suction service valve and allow the pressure in the compressor to build up to a pressure equal to the ***Cut In*** value.

4. Lower the ***Range*** or ***Cut In*** value on the control until the compressor starts.

5. Open the suction service valve to keep the compressor running.

6. Gradually close the suction service valve to restrict the suction vapour flow until the compressor is running at a pressure equal to the ***Cut Out*** value.

7. Reduce the value of the ***Differential*** setting until the LP control stops the compressor.

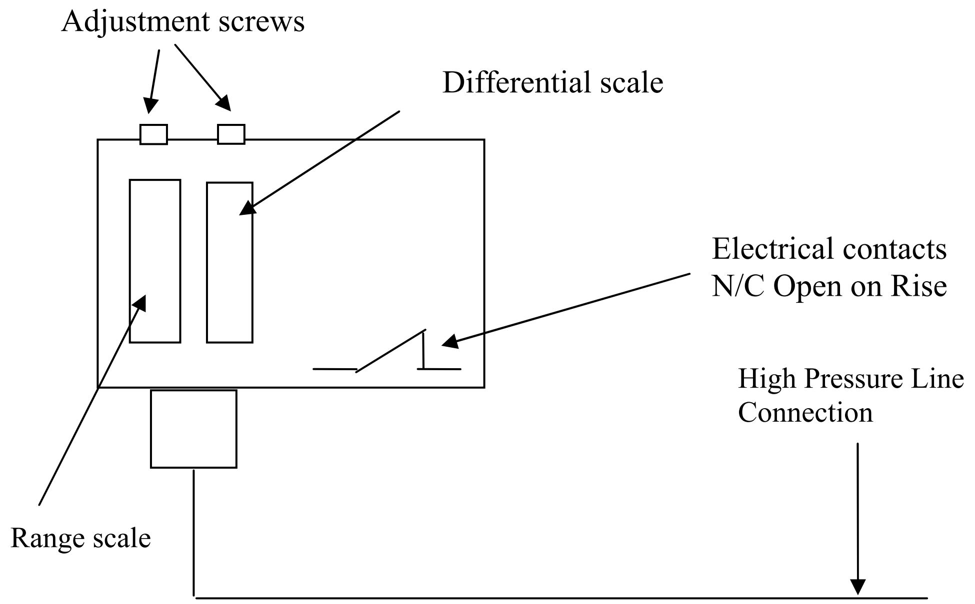
8. The control is now set. Repeat the procedure to check the settings and the reliability of the control.

High Pressure Control

If the discharge pressure becomes too high a high pressure (HP) control can be used to stop the compressor. To stop the compressor by using a HP control in the event of the discharge pressure becoming excessive its switching mechanism must open the compressor circuit on a rise in pressure.

Note: high pressure safety controls should be manual reset

High pressure controls can also be used to cycle extra condenser fan motor / motors on and off to control the high side pressure in a refrigeration system. To use the HP control to cycle extra condenser fan motor / motors on and off, its switch mechanism must close on rise in pressure.



Typical High Pressure Control.

High Pressure Control Setting Procedure

1. With the system running, set the ***Cut Out*** to a higher value than required.

2. Restrict coolant flow to the condenser.

3. When the compressor is running with the discharge pressure equal to the ***Cut Out*** value, lower the control ***Range*** or ***Cut Out*** setting until the control stops the compressor.

4. If the control has an adjustable ***Differential***, allow the discharge pressure to drop to the ***Cut In*** value and adjust the ***Differential*** until the compressor restarts.

5. The control is now set. Repeat the procedure to check the settings and the reliability of the control.

Note: ***When setting high pressure controls the design ambient temperature plus the condenser Td and plus a safety of 5K***

- ***Air cooled condenser Td = 15K***
- ***Water cooled condenser Td = 10K***

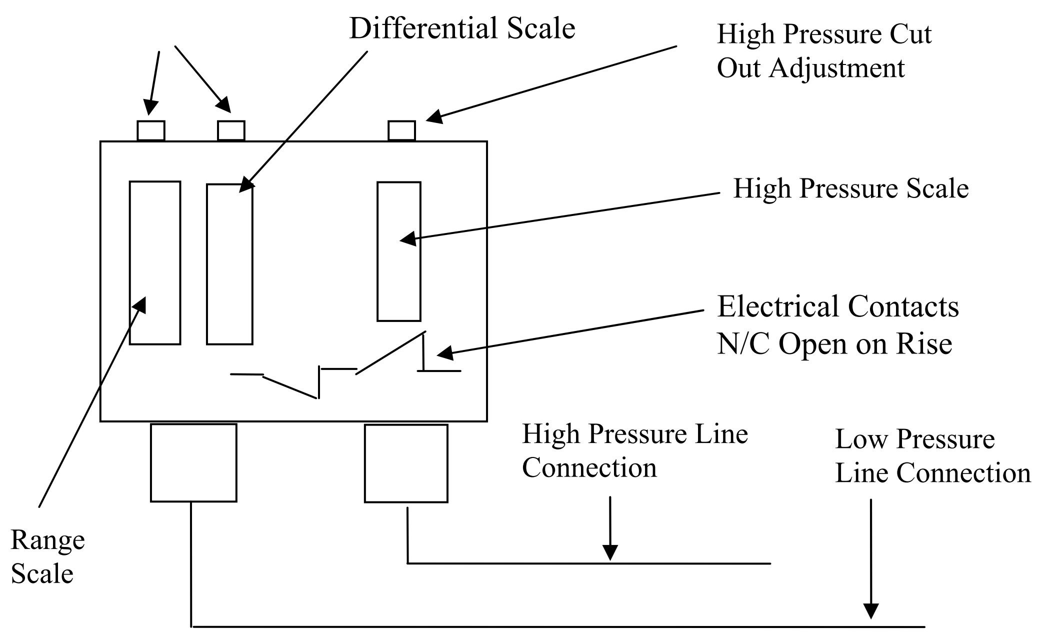
Example: ***An air cooled condenser operating on R22 has a 15 K Td and a design ambient temperature of 36 °C. Determine the high pressure safety cut out pressure.***
36 + 15+ 5 = 56°C = 2120kPa

Example: ***A water cooled condenser operating on R22 has a 10 K Td and a design ambient temperature of 36 °C. Determine the high pressure safety cut out pressure.***
36 + 10 +5 = 51°C = 1885kPa

Dual Pressure Control

This type control replaces individual LP and HP controls. The control consists of two bellows, one for the low pressure side and the other for the high pressure side of the system and a single or two switches in series.

Some may be automatic reset on LP with manual reset on HP where two switches are used.



Typical Dual Pressure Control.

Oil Pressure Failure Control

An oil pressure failure control is a differential pressure control that will stop the compressor if:

- Oil pressure fails to reach an acceptable pressure within a set time period on compressor start up.

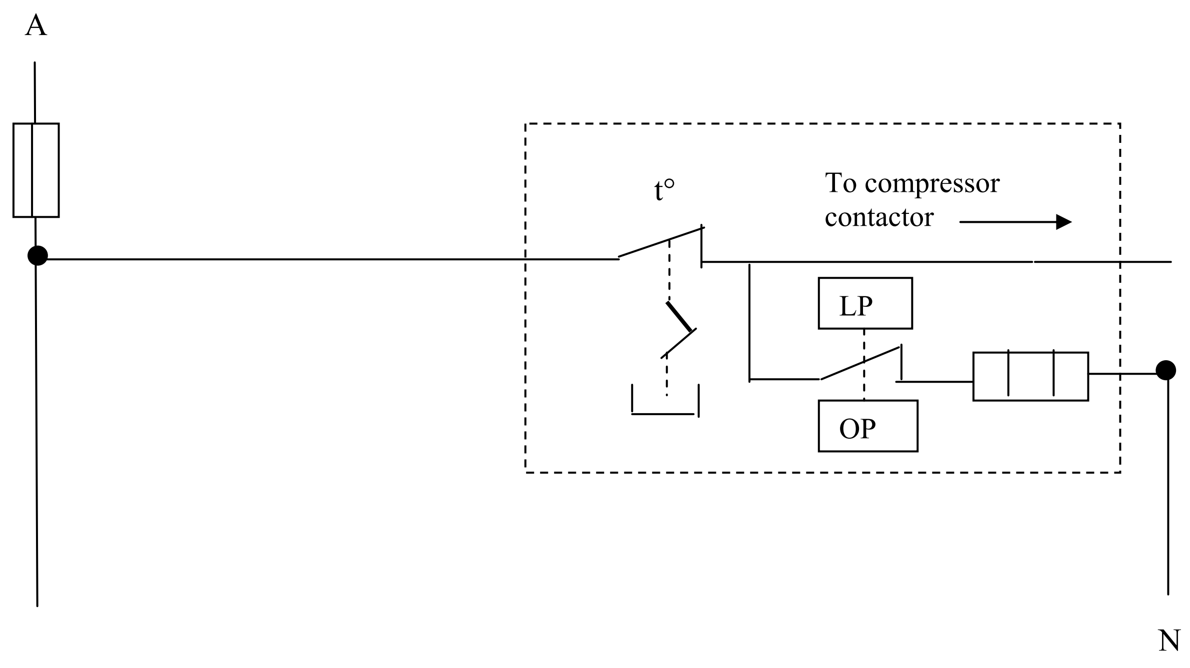
- The oil pressure drops below a minimum acceptable level during running for the same period of time.

The oil pressure failure control senses the compressors crankcase pressure and the outlet pressure from its oil pump and is connected between these two points. The compressors oil pressure is the difference between these two pressures.

The time delay period of an oil pressure failure control is usually between one to two minutes.

OPFC Failure:
The following are typical faults that may cause the OPFC to open the compressor contactor coil.

- Low oil level
- Block oil strainer
- Faulty oil pump
- Incorrect setting of OPFC.



Practical Exercise

Control Settings

Aim: To adjust the cut in and cut out settings on low pressure /high pressure controls on a refrigeration system from the information supplied by your teacher.

Procedure: Determine the control settings from the given information and record and record in attached table.

Determined control settings table (R22)

Low Pressure Control	Cut-in	Cut-out	Differential
High Pressure Control	Cut–in	Cut-out	Differential

Conclusion: Explain why you used these particular settings and show all the required calculations and steps required in obtaining your results.

Note: You should ensure that your results and work carried out complies with the Codes of Good Practice and all Relevant Legislative Requirements.

Review Questions Section No: 5

Q.1 Dual pressure controls are connected to two points in a refrigeration system, these are:

(a) oil pump and suction line
(b) low side
(c) high side
(d) suction and discharge

Q.2 The manual reset feature of an oil failure control is used for the purpose of:

(a) operating a defrost cycle
(b) protecting the system
(c) indicating a malfunction
(d) stopping the compressor on low oil pressure.

Q.3 When adjusting a low pressure control, altering the range setting will:

(a) improve the range control
(b) raise / lower both cut-in and cut-out
(c) raise / lower the cut–out setting only
(d) improve the range of the control

Q.4 When installing a low pressure control, it must be connected to the:

(a) oil pump and suction
(b) high side of the system
(c) Low side of the system
(d) Suction and discharge.

Q.5 High pressure controls are installed to protect the:

(a) product
(b) compressor
(c) condenser
(d) iquid receiver.

Q.6 List four faults that could cause the compressor to cut out on O.P.F.C.

____

____

____

Q.7 Why is it necessary to have a manual reset on an oil pressure failure control?

____

____

Q.8 Describe the main purpose of an oil pressure failure control:

____

____

____

Q.9 Can a high pressure control be used as a cycling control and if so give an example?

____

____

____

Q.10 From the following details list the control settings for a medium temperature cool room that utilisers a pump down cycle: ***(Note: show all working in the space provided.)***

- Average room temperature = 3°C
- Evaporator Td of 6K
- Refrigerant R134a
- Design Ambient Temperature = 35°C

Thermostat:

Low Pressure Control:

High Pressure Control

Drawing Exercise No: 5

Air Conditioning System

Purpose: To construct an electrical power and control circuit diagram for a package air conditioning system in accordance with the following details:

Details:

- 415 volt power supply
- Main isolating switch
- HRC fuses
- D.O.L compressor contactor
- Two three phase star connected condenser fan motors (DOL)
- One three phase star connected evaporator fan motor (DOL)
- Resistance heaters 3 x 4kW (three phase star connected)
- D.O.L. contactor for resistance heaters
- On / off control switch
- Thermostat to control space temperature (Heat- Cool)
- High limit safety thermostat for resistance heaters
- Air pressure failure control for resistance heaters
- LP / HP controls
- Oil pressure failure control
- Limited start timer (to prevent condensing unit from short cycling)
- Crankcase heater.

Resources required:

- A4 Project Book
- Ruler
- Circular Templates
- Pens
  - Red
  - Black
  - Blue
  - Green.

Refrigeration / Air Conditioning Controls & Circuit NRE12.

Flow and Humidity Controls Section No: 6

Purpose: The aim of this section is to provide you with the underpinning knowledge and skills to install, remove, test and adjust flow and humidity controls on an operating refrigeration or air conditioning system. Due care should directed towards electrical safety and the Codes of Good Practice (HB40).

Flow controls:

A flow control is designed to sense either fluid or air flow that is if the air flow or fluid flow drops below a predetermined level the contacts of the switch will open to stop the system and or equipment.

Applications:

1. Chilled water system:
   A flow control is fitted to the chilled water circuit to stop the refrigeration plant should the water flow drop to such a level that the evaporator may freeze and cause damage. Used; extensively on shell and tube evaporators.
   Possible causes for the flow control to open are as follows:
   - Chilled water pump motor out on overload
   - Chilled water pump inefficient
   - Block chilled water strainer
   - Faulty control setting.

2. Condenser water flow:

   A flow control if fitted to the condenser water piping circuit, so that if the water flow drops to low the compressor will be de-energised.
   Possible causes for the flow control to open are as follows:
   - Condenser water pump motor out on overload
   - Condenser water pump inefficient
   - Block condenser water strainer
   - Faulty control setting.

3. Resistance heaters (installed in duct work):
   Air conditioning resistance heating elements installed in duct work require protection if and when the flow of air falls to a dangerous level. A flow switch is installed after the heaters to sense the air flow.
   - Evaporator fan motor out on overload
   - Block condenser air filters
   - Clogged evaporator coil
   - Faulty control setting.

Humidistat

A control that operates by changing the relative humidity (RH) is called a **Humidistat.**

The sensing material used by a humidistat can be either hair or nylon. These types of materials stretch with an increase in the air's relative humidity and contract when there is a decrease with a decrease in the air's RH.

Operation:

- De- humidification – the switching mechanism closes the circuit on a rise in relative humidity. Achieved in air conditioning applications by cooling to air to below its dew point temperature.

- Humidification – The switching mechanism closes the circuit on a fall in the relative humidity. Humidification in air conditioning systems is achieved by either using water or steam sprays.

Review Questions Section No: 6

Q.1 Describe in your own words the purpose of a flow switch:____________________________

Q.2 Give three examples where flow switches are extensively used:____________________________

Q.3 List four possible causes for a chilled water flow control to open circuit:____________________________

Q.4 The resistance heater flow control on an air conditioning system is open circuit, give at least four possible causes for this problem:____________________________

Q.5 List two common sensing elements used in a humidistat:____________________________

Q.6 In air conditioning applications:

humidification is achieved by;____________________________

de-humidification is achieved by:____________________________

Refrigeration / Air Conditioning Controls & Circuit NRE12.

Timer Controls
Section No: 7

Purpose: The aim of this section is to provide you with the underpinning knowledge and skills to install, remove, test and adjust timer controls on an operating refrigeration or air conditioning system. Due care should directed towards electrical safety and the Codes of Good Practice (HB40).

Function:

The function of control timers in refrigeration and air conditioning systems is to energies and de-energising the control or associated circuits on either: time, temperature, pressure or as a de-ice control.

Types of timer controls:

1. Time Initiated Time Terminated (TITT)

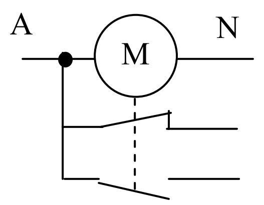
This type of timer can be adjusted to the:

- Current time of day
- Number of defrosts of off cycle time
- Length of defrost or off cycle.

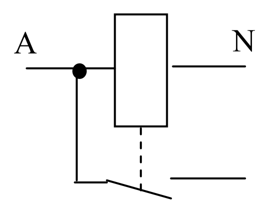
Applications:

- Low temperature freezer rooms defrost cycles.
- Switching large air conditioning systems on and off over a seven day time period.
- Limited starting timer. Prevents large motors from short cycling.

Electrical circuit symbols



Time initiated time terminated timer



Time delay (relay / timer)

2. Time Initiated Temperature Terminated (TITT)

This type of timer can be adjusted to the:

- Current time of day
- Number of defrosts per day
- Length of defrost cycle (in minutes)
- Temperature at which to defrost cycle ends.

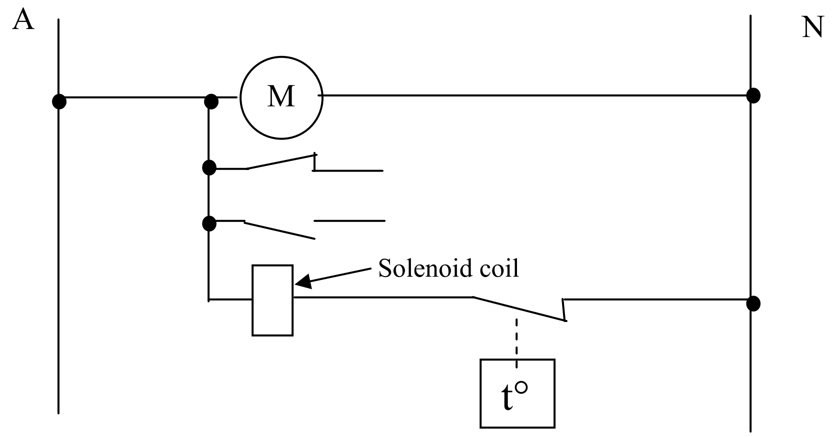
Applications:

- Low temperature freezer rooms defrost cycles
- Reverse cycle air conditioning de-ice cycles.

Electrical circuit symbols

Using a time initiated time terminated defrost timer which has an override solenoid coil utilising a temperature control to sense the evaporators saturated refrigerant pressure / temperature.

Time initiated time or temperature termination



Note: thermostat opens on temperature fall and closes on rise in temperature

3. Time Initiated Pressure Terminated

This type of timer can be adjusted to the:

- Current time of day
- Number of defrosts per day
- Length of defrost cycle (in minutes)
- Pressure at which to defrost cycle ends (saturated evaporator pressure temperature)

Application:

- Low temperature freezer rooms defrost cycles

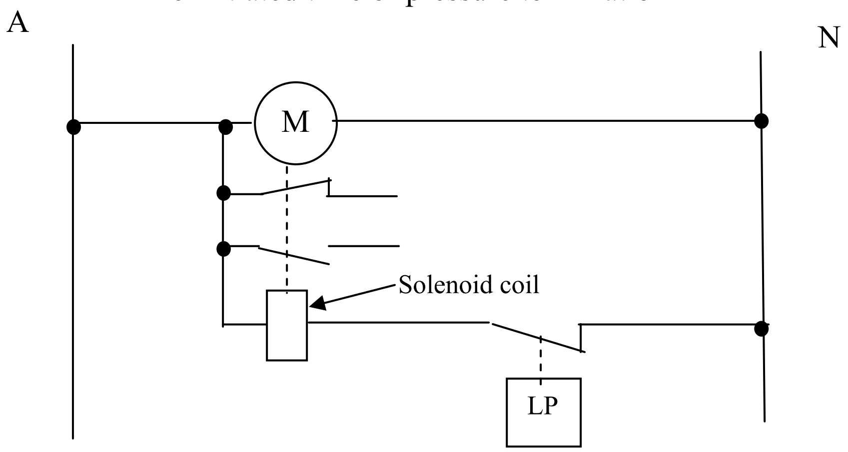
Electrical circuit symbols:

The following electrical circuits indicate two ways in which a time initiated time or pressure defrost timers can be connected.

1 Using a time initiated time terminated defrost timer which has an override solenoid coil utilising a low pressure control to sense the evaporators saturated refrigerant pressure / temperature.

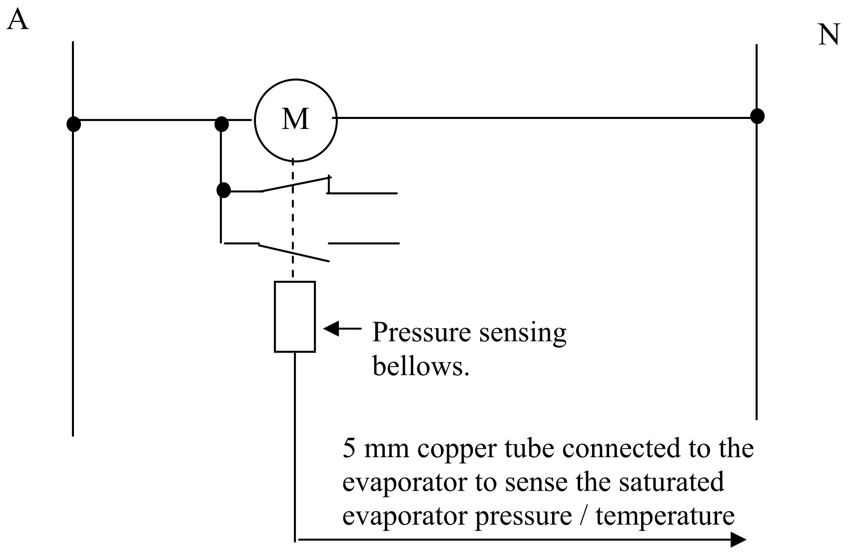
2 Using a time initiated time or pressure terminated defrost timer with a pressure sensing override bellows. This bellows senses the evaporator saturated refrigerant pressure / temperature.

Time initiated time or pressure termination



Note: low pressure opens on temperature fall and closes on rise in temperature

Time initiated time or pressure termination



Defrost timer settings:

Example:

A low temperature freezer room operates on R404A refrigerant with an average room temperature of temperature -20°C, SET of -30°C, SCT of 40°C and an ambient temperature of 35°C. Determine the following control settings. Reference should be made to a pressure temperature chart.

- Room thermostat
- LP / HP controls
- Time initiated time or pressure termination
- Evaporator fan delay thermostat
- High limit safety thermostat, (defrost and drain heaters).

Note: low temperature freezer rooms require 4 defrosts per day with a, duration of approximately 40 minutes.

1. Thermostat: Cut – out = -21°C Cut - in = -19°C
(Maintaining an average room temperature of -20°C).

Cut – in temperature	**-19°C**	↑
Average room temperature	**- 20°C**	↕
Cut – out temperature	**-21°C**	↓

2. LP Control:
The saturated evaporator pressure at -30°C equals 108 kPa and therefore the cut-out should be below 108 and above 0 kPa
Cut – out = 40 kPa
Cut – in = 100 kPa.

- It should be noted that the condensing unit may cut out on LP while the room is being load because of the evaporator fans being isolated. This will cause a drop in the SET and therefore suction pressure.
- The cut – in is set below its normal operating SET to maintain room temperature.
- To prevent any short cycling during this period it may be necessary to install a limited starting relay in the condensing units control circuit.

HP Control
Cut – out = Ambient + Td + 5K safety factor

(note air cooled condensers Td = around 12K and water cooled Td around = 8K)

Cut – out = 35 + 15 + 5 = 52°C = 2349kPa.
Cut – in = automatic reset which has a fixed differential or manual rest.

3. Time initiated time or pressure termination

- Four defrost periods per day with time duration of approximately 40 minutes.
- Pressure over ride set at 653 kPa which equals an SET of 6°C.

4. **Evaporator fan delay thermostat**

The evaporator fan delay thermostat is designed to prevent moisture of hot air from being blown onto the product or into the room.
Cut – in = approximately -10°C (SET)
Cut – out = approximately 0°C (SET).

5. High limit safety thermostat

The high limit safety thermostat is designed to protect the heaters from over heating on a defrost cycle.
Cut – in = approximately -10°C
Cut – out = approximately 8°C

Review Questions Section No: 7

Q.1 Describe what the function of timer controls when used in refrigeration and or air conditioning systems:____

Q.2 Explain why and when time delay relays used in refrigeration and air conditioning systems:

Q.3 What is the purpose a the fan delay thermostat when used on a low temperature coolroom:

Q.4 A high limit thermostat on a low temperature cool room protects? And what would the cut-in and cut-out settings be?

Q.5 List two types of defrost timers and describe their operation:

Drawing Exercise No: 6
Low Temperature Freezer Room

Purpose:

To construct an electrical power and control circuit diagram for a low temperature freezer room to maintain an average room temperature of -18º C in accordance with the following details:

Details:

- 415 volt power supply.
- Main isolating switch.
- HRC fuses.
- Star delta compressor contactor.
- Two permanent split capacitor condenser fan motors.
- Two permanent split capacitor evaporator fan motors
- Defrost timer: time initiated time or temperature termination.
- Defrost heater and drain heaters (consisting of two defrost heaters and drain trough heater each with a 2kW power rating).
- Defrost contactor (DOL).
- High limit safety thermostat to protect heater.
- Thermostat to control room temperature.
- Evaporator fan delay thermostat.
- LP / HP controls.
- Limited start timer (to prevent condensing unit from short cycling).
- Crankcase heater.
- HP cycling control on one of the condenser fan motors.

Resources required:

- A4 Project Book
- Ruler
- Circular Templates
- Pens
  - Red
  - Black
  - Blue
  - Green.

Procedure:

Using your A4 project book set out the boarder and title block as indicated in this package. Before commencing your final drawing, sketch a rough copy on a piece of paper and check for accuracy with your teacher or workplace mentor.

Refrigeration / Air Conditioning Controls & Circuit NRE125

Electronic & Pneumatic Controls
Section No: 8

Purpose: The purpose e of this section is to provide you with a basic understanding of electronic and pneumatic controls. On the job training and by attending manufacturers specific controls courses will enhance your ability to gain a greater understanding within the controls industry.

Note: The HVAC & refrigeration Diploma Course No: 290 covers controls in much greater scope and depth.

Electronic control systems consist of a sensor, controller and the load being driven and most control systems provide for:

- Programming options
- Cooling and heating cycles
- Fans
- Alarm
- Defrost
- Temperature logging
- Humidity
- Graphing of refrigeration / air conditioning cycle.

Temperature sensor:
Electronic sensors can be used to measure temperature, humidity, pressure, pressure difference etc where there is a change in the conditioned being sensed by the sensor. The sensor senses a change and reacts by varying its output to the controller

Various sensor outputs are available from manufacturers and are as follows:

- Resistance (PTC or NTC) PTC = positive temperature coefficient
  NTC = negative temperature coefficient.

- Voltage (mV)
- Amperage (mA).

Controllers:
A controller receives the signal from the sensor and amplifies it into some form of energy that can be used to turn components on and off as well as drive actuators open, closed or some where in between (proportional).

Domestic controllers: will vary in the type of adjustments available and are user friendly in regards to the customer and service technician.

Commercial controllers: these controllers are more complicated in that they have a wide variety of functions available to the service technician and minimum functions available to the customer.

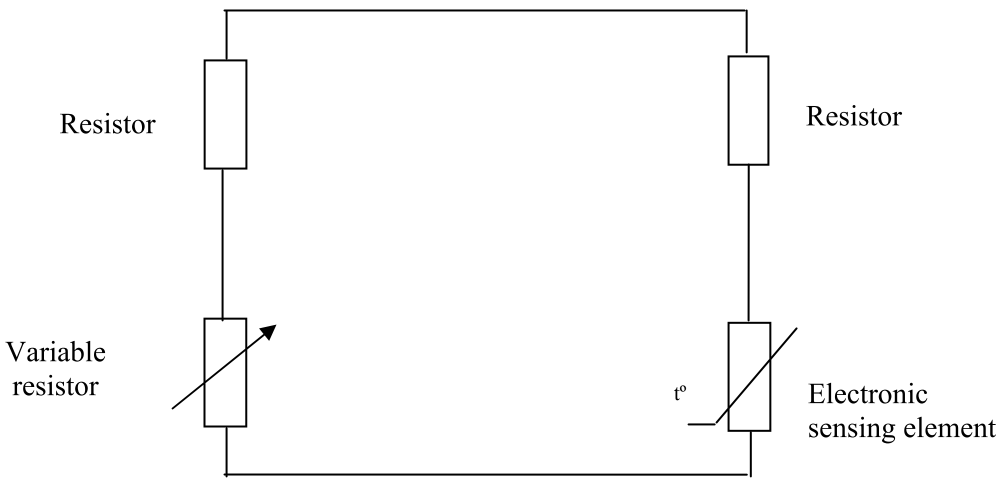
These types of controllers include the following functions:

- Set point: Value that the controller is required to maintain.
- Differential: Difference between the cut out and cut in points.
- Dead band: No corrective action has been taken.
- Proportional: Control point range through which the controlled variable must pass to move the final control element through its full operational range.

Electronic controllers consist of three basic parts and they are:

- The bridge
- The amplifier
- The output circuit.

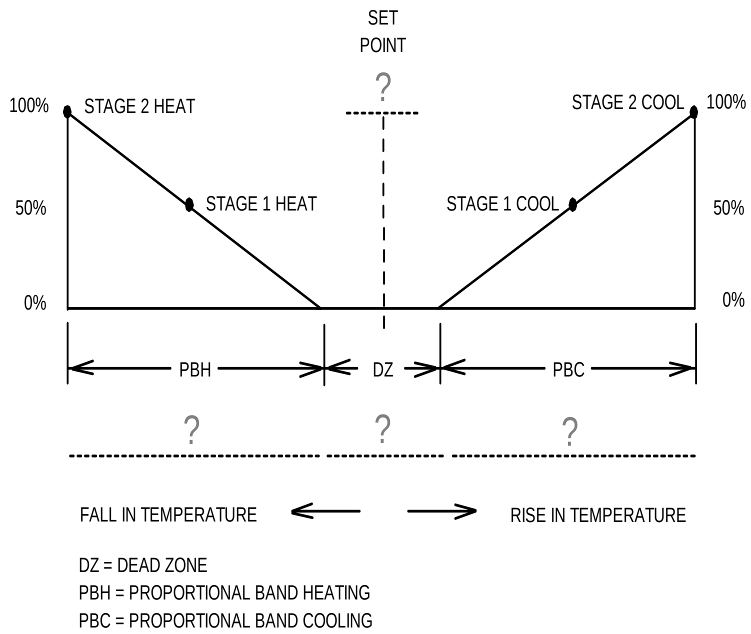
The bridge:
The bridge incorporates the sensing part of the controller and works on the Wheatstone Bridge principle but with the addition of an electronic sensing element and a variable resistor to adjust the set points



The Bridge Circuit

The amplifier
The signal from the bridge is measured in millivolts and must be amplified to an output of between 0-10 volts. The controller will generally have two amplifiers fitted one for direct and one for reverse acting signals.

The output circuit:
The output circuit is where actuators are connected to the controller and in the diagram below reverse acting and direct acting signals are illustrated.



Outputs of an electronic controller

Note: ***For a balance to occur in the bridge, the sensing element and the set point variable resistor must be in balance and when this occurs the output voltage will be zero.***

Temperature fall:
When the temperature drops below the set point the reverse acting output signal will increase proportionally to 10 volts and the direct acting output will be zero.

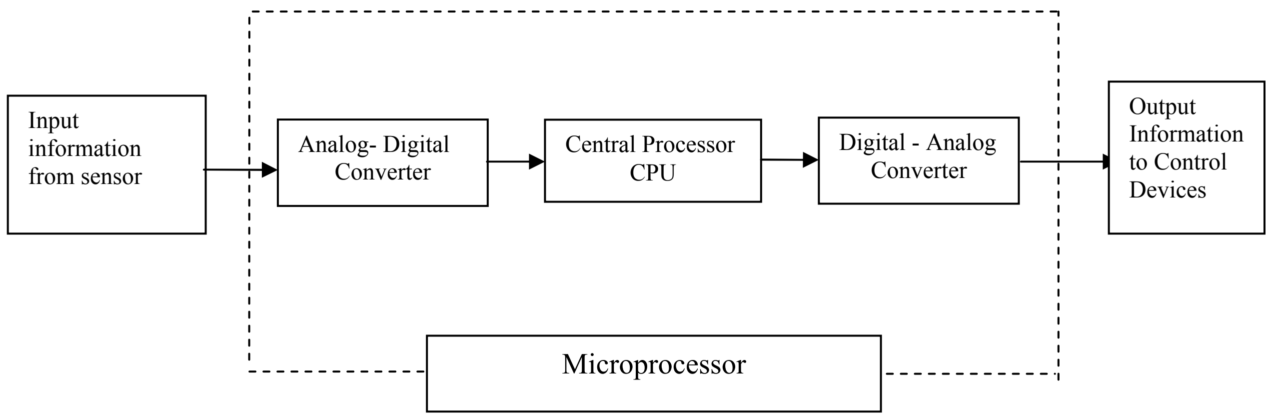
Set point:
At the set point both outputs will be zero.

Temperature rise:
When the temperature increases above the set point the direct acting output signal will increase to its maximum output and the reverse acting output will be zero.

Types of Electronic Controllers:

- ON/Off control (1 – 3 outputs)
- Proportional Control (1 – 3 outputs)
- Step Controllers
- Two and Three in One Controller
  (both temperature and humidity contained in the one controller)

Microprocessors
Microprocessors are a computer based system that can be used to control air conditioning systems. Its main advantage is that it can control more accurately than any other forms of control systems.



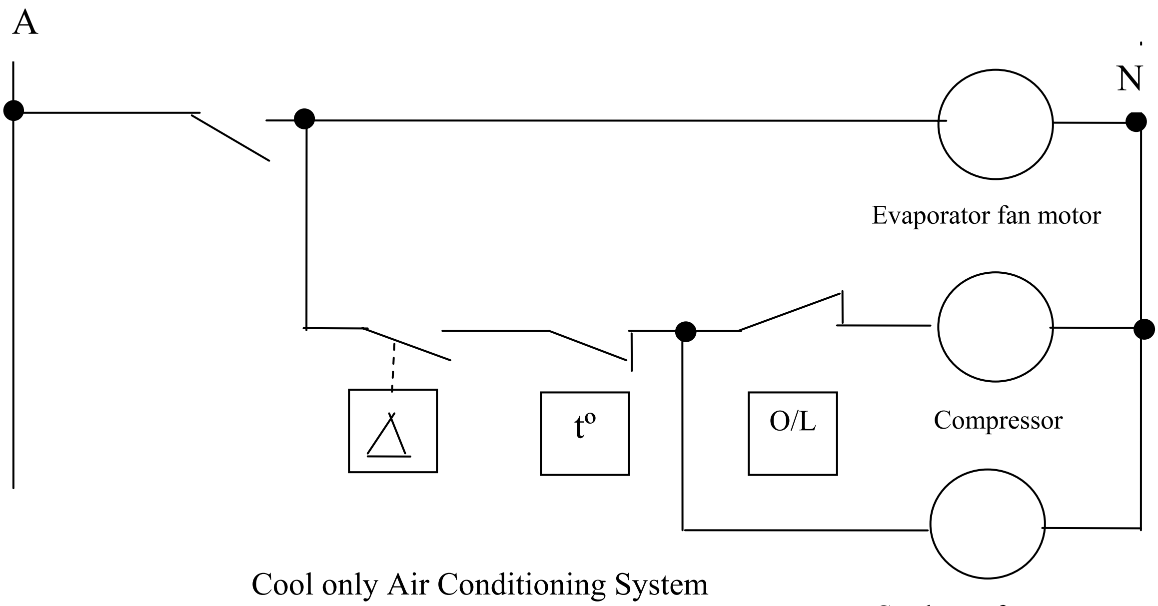
The attached block diagram indicates the basis of how a microprocessor system operates

Programmable Logic Controller (PLC)

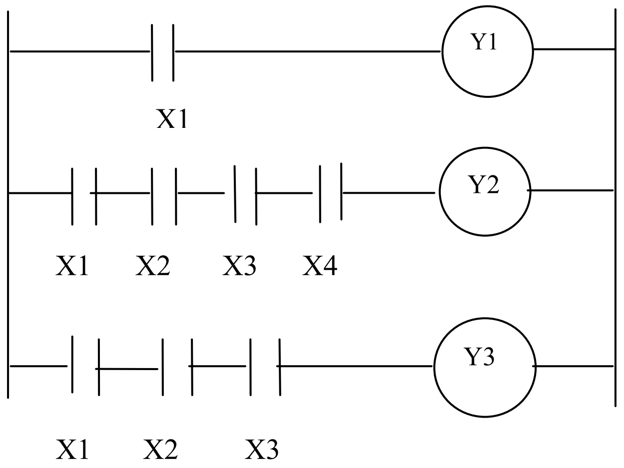
PLC's simplify circuits by having many control circuit components within the microprocessor (the brain of the controller). These components are as follows:

- Inputs
- Outputs
- Internal relays
- Latching relays
- Timers, etc.

PLC Ladder Diagram



Cool only Air Conditioning System



Inputs

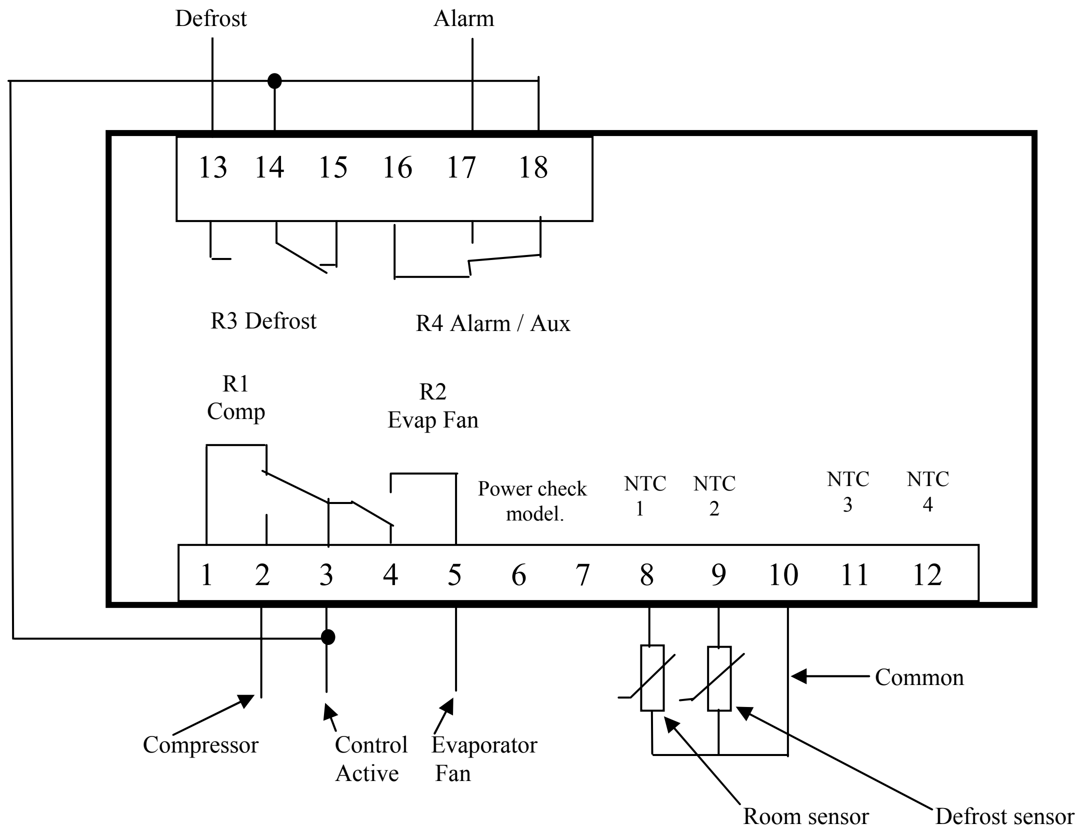
- On/off Switch X1
- Sail Switch X2
- Thermostat X3
- Thermal Overload X4

Outputs

- Evaporator fan Y1
- Compressor Y2
- Condenser fan Y3

Note: ***The difference between the two diagrams and thw key used to identify the inputs and outputs.***

Typical Low Temperature Freezer Room Controller



Note:	***Motors or loads that exceed 1kW must be switched by an external relay or contactor***

Direct Digital Control (DDC)

Direct Digital Controls are computer based microprocessor machines that can be used to maintain set conditions of air conditioning applications. To maintain the required conditions a DDC control must perform the following functions:

- Sense function
- Decision function
- Memory function
- Action function.

Sensing function:
The sensing function senses the control variable and transfers the information to the microprocessor for interpretation. The input can either be On / Off or analog and the sensing inputs can include temperature, humidity and pressure, etc.

Sensing inputs can include one or more of the following:

- Variable resistance signal
- Variable milliamps signal (0 – 20 mA
- Variable DC voltage signal (0-12V).

Decision function:
This function compares the input to the information stored in the memory by making calculations on the deviation. Once the calculations are made a logical decision on the corrective action is taken.

Memory function:
The memory function is the brain and is where the DDC remembers what to do, how to do it and even analyses the result of every completed task. This is done by the use of a program.

Action function:
The action function is where the microprocessor carries out the corrective action by using action units of the DDC. These actions functions are called outputs of the system.

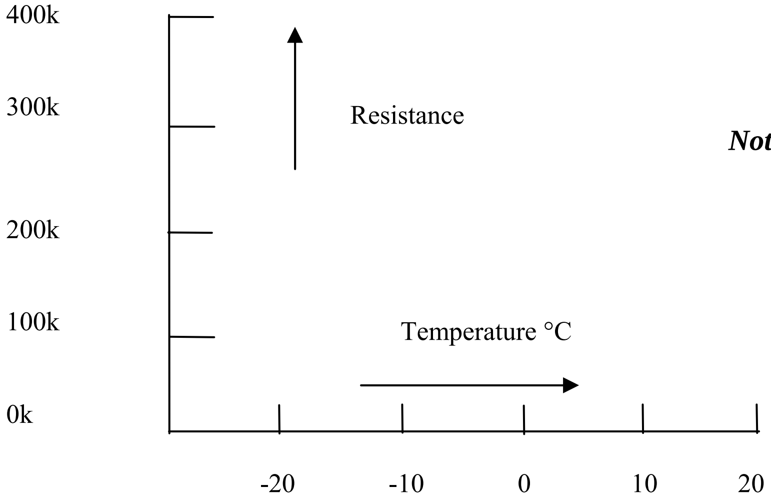
The two types of outputs are On / Off and Analog (variable).

The action unit can be used to turn on and off: supply fans, compressors etc, communicate information to humans and or other computers.

Temperature sensors:

Most temperature sensors are a NTC thermistor and extremely accurate (0.2ºC) with non-linear resistance – temperature. The sensor should be mounted in the return refrigerated air and with at least 160mm of sensor cable in the refrigerated space to ensure accurate temperature sensing.

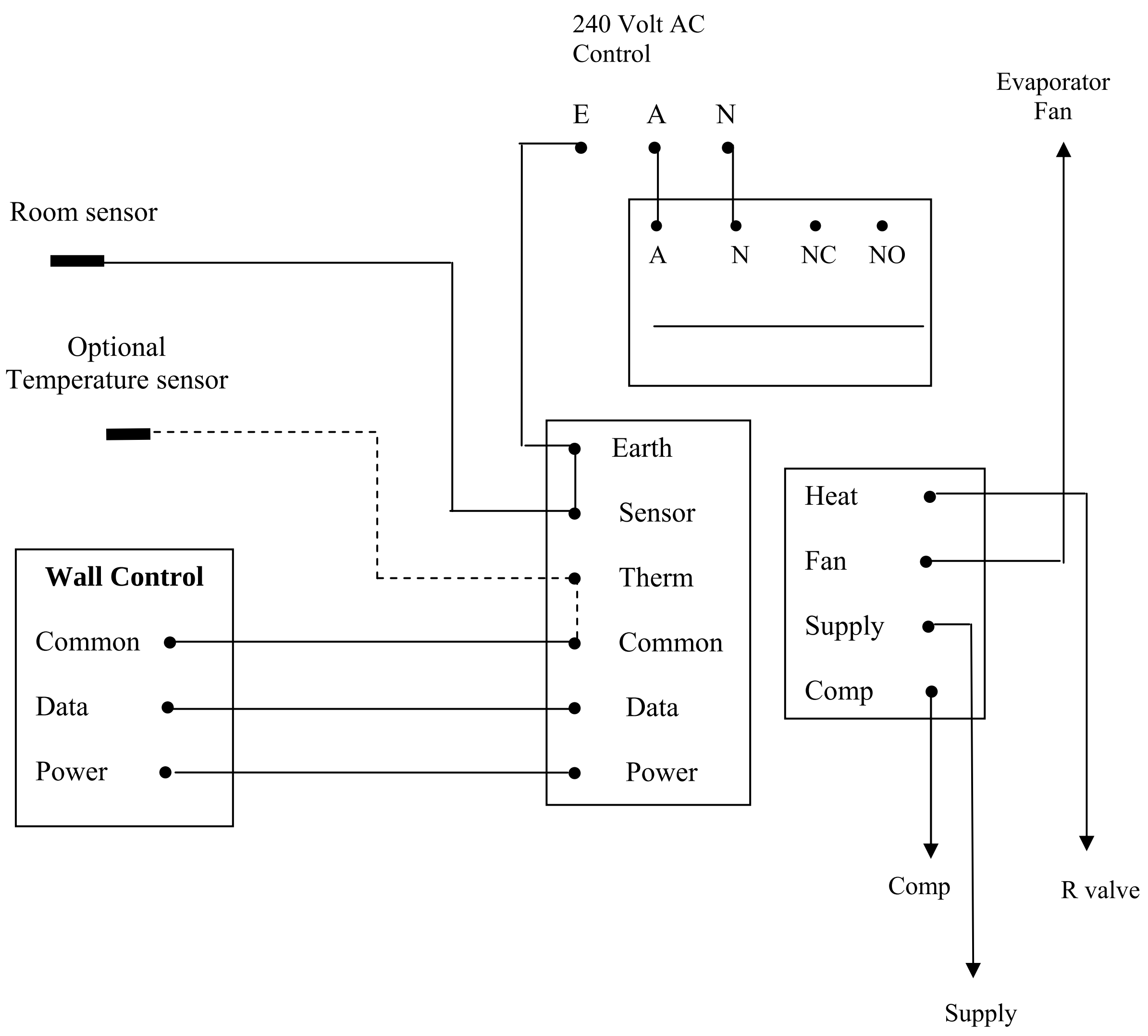
Note: Defrost sensing probes should be mounted centrally within the evaporator coil.



Note: As the resistance increases the temperature of the sensors falls.

Resistance verses Temperature

Air Conditioning Controller



Pneumatic Controls: (ARAC, pages 29.27 – 29.30)

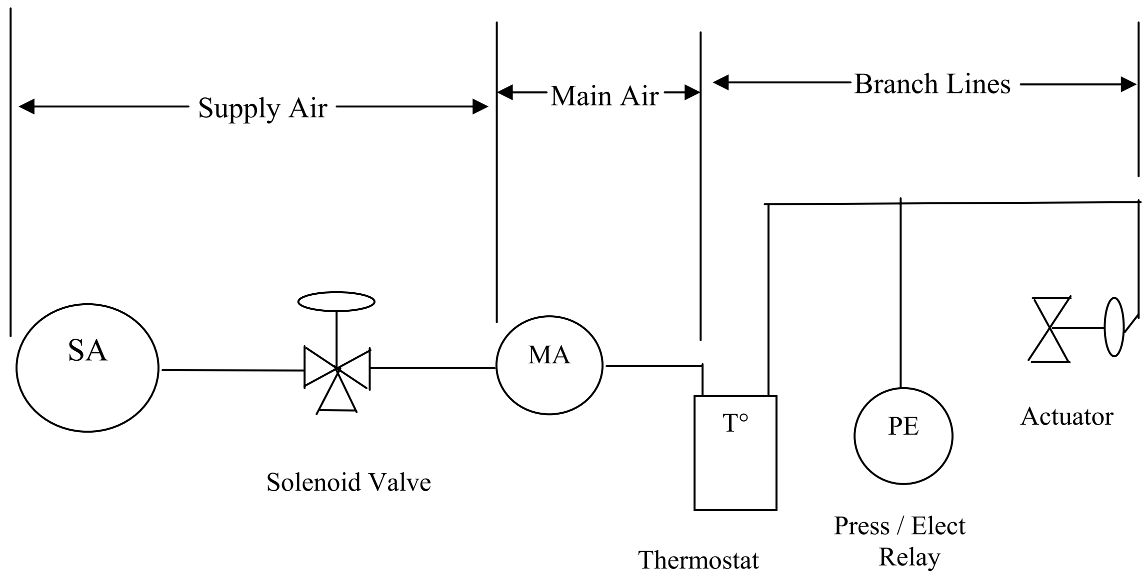
Pneumatic control systems use clean dry air as a power source in place of voltages and currents for the control and operation of air conditioning plant and equipment. An air compressor is used to supply the system with energy instead of mains power supply.

The majority of the control system remains the same (other then the fact that they operate by air). Sensors are required to sense the conditions and the controller responds to the sensor signal and pneumatic control devices are energised to operate the load.

Pneumatic systems can also be coupled with electricity and / or electronics. Equipment like compressors, fan motors and heaters can be controlled by electronics to obtain greater accuracy.

Control equipment such as pneumatic – electrical (PE) relays (switching devices) and electronic – pneumatic transducers and sensing devices can be used to link various systems together.

Pneumatic Operating Circuit



Review Questions Section No: 8

Q.1 What does an electronic control system consist of?________________________________

____

Q.2 Describe in your own words the main purpose of an electronic controller:______________

____

____

Q.3 What are the three basic parts of an electronic controller?___________________________

____

Q.4 Name the two amplifiers used in electronic controllers and what voltage range doe they operate within?____

____

Q.5 What is meant by the following terms?

- Set Point:____
- Differential:____
- Dead Band:____
- Proportional Control:____

Q.6 Describe what a microprocessor is and what its main advantage is?___________________

____

____

Q.7 List the main components of a programmable logic controller (PLC):_________________

____

____

Q.8 List the four main functions of a direct digital controller (DDC):____________________

____

____

Q.9 What is the main purpose of the action function of a DDC controller?________________

____

____

Q.10 Name the energy used by pneumatic control systems and how it is generated?__________

____

____

Q.11 List the following air pressure readings that exist in a pneumatic control system:

- Branch:__________________
- Main Air:________________
- Supply Air:_______________

Q.12 In the space provided draw a basic circuit diagram of a pneumatic control system labelling all major components:

Answers to Review Questions

Section No: 2

Q.1 a
Q.2 c
Q.3 d
Q.4 b
Q.5 c

Q.6 To protect the motor from excessive current and should act to the motors FLA.

Q.7 Star / Delta
Part Winding
Primary Resistance
Auto-Transformer
Solid State (electronic soft start).

Q.8 Limit the amount of starting current.

Q.9

- Control circuit is energised.
- Starting contactor closes and energises the start winding (first winding).
- The timer energises the second winding after 2 – 3 seconds.
- The both windings remain in circuit.

Q.10

- The main contactor is energised through the control circuit.
- The timer energises the star relay through the timer and the delta relay NC auxiliary contacts.
- The motor starts in star (240 volts across each phase).
- After a period of time the timer switches the star relay of and energises the delta relay through the NC contacts of the star relay.
- The motor now runs in delta (415 volts across each phase).

Section No: 3

Q.1 Cycle plant and equipment on and off to maintain the desired conditions (cycling controls).

Protect plant and equipment from damage and general public from injury (safety controls).

Q.2

- Temperature.
- Flow.
- Humidity.
- Pressure.
- Air pressure.

Q.3 **Cycling controls** used for automatic operation of system.

Safety controls used to interrupt the control circuit in the event of a fault condition (low pressure control, refrigerant shortage).

Q.4 **Direct:** Switching single phase loads by directly controlling the load. (ON / OFF Control Switch to control a permanent split phase fan motor).

Indirect: A relay or contactor is used via a control circuit to transfer the high voltage to the load.

Q.5 An opening and closing action that avoids arching of the contacts.

Q.6

- A device that senses a change in the controlled variable.
- The controller responds to the sensor by closing or opening its contacts to a controlled device (compressor motor relay coil).
- Controlled device reacts to the controller to carry out the corrective action.

Q.7

- Cut-in is the condition at which the control closes its contacts.
- Cut-out is the condition at which the control opens it contacts
- Differential is the difference between the controls cut-in and cut-out points.

Q.8 Magnetism, spring and mercury tilt.

Section No: 4

Q.1

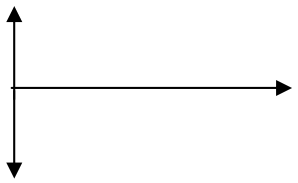
- Sensing bulb.
- Bellows.
- Electrical contacts.
- Adjustment screws.

Q.2 Return air stream onto the evaporator.

Q.3

- Cut-in is the condition at which the control closes its contacts.
- Cut-out is the condition at which the control opens it contacts
- Differential is the difference between the controls cut-in and cut-out points.

Q.4 Cut-in = 3°C

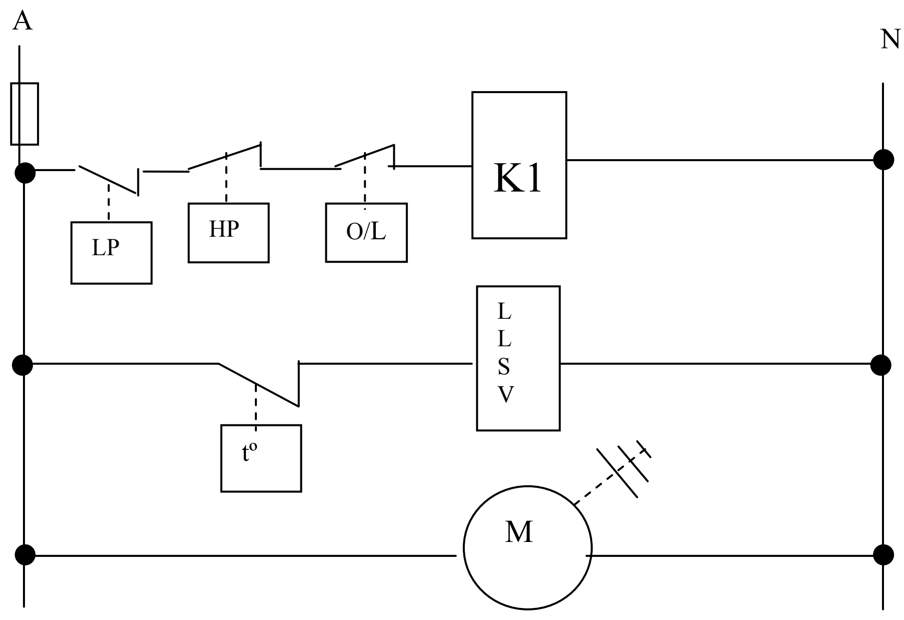


Average Room Temperature = 2°C

Cut-out = 1ºC

Q.5 The sensing bulb senses a rise or fall in temperature and either expands or contracts the bellows which forces the electrical contacts to open or close.

Q.6



Section No: 5

Q.1 d

Q.2 c

Q.3 d

Q.4 c

Q.5 b

Q.6

- Low oil level
- Blocked oil strainer
- Faulty pump-
- Incorrect setting of control.

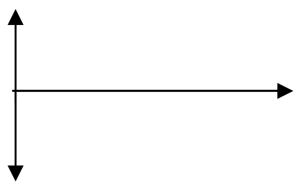
Q.7 It indicates that a fault condition exists.

Q.8 It protects the compressor from mechanical damage.

Q.9 Yes, to maintain a constant head pressure by cycling one of the condenser fans.

Q.10 **Thermostat:**

Cut-out = 2°C



Average Room Temperature = 3°C

Cut-in= 4°C

Low pressure control:

- Saturated evaporator temperature (SET) = 3ºC – 6KTD = -3°C.
- Saturated evaporator pressure = 161 kPa.
- Low pressure cut-out = below 161 kPa and above zero kPa
  Cut-out around 70 kPa.
- Cut-in = 225 kPa = 3ºC evaporator coil temperature.

High pressure control:

- Cut-out = 35 + 15 + 5 = 55°C = 1355 kPa.

Section No: 6

Q.1 It opens the electrical control circuit if there is low or no water / air flow.

Q.2

- Chilled water systems.
- Condenser water flow.
- Resistance duct heaters (air flow).

Q.3

- Condenser water pump motor out on overload.
- Condenser water pump inefficient.
- Blocked condenser water strainer.
- Incorrect control setting.

Q.4

- Evaporator fan motor out on overload.
- Blocked evaporator air filters.
- Clogged evaporator coil.
- Faulty control setting.

Q.5 Air or nylon.

Q.6 Using water or steam sprays.
By cooling the air below its dew point.

Section No:7

Q.1 To energise or de-energise the control or associated circuits on either time, temperature, pressure or as a de-ice control.

Q.2` Used to prevent the compressor motor from short cycling (limited number of starts / hour).

Q.3 To prevent hot air and moisture entering the room after a defrost cycle.

Q.4

- Protects defrost and drain heaters from overheating and thus excess heat from the evaporator coil/
- Cut-out = around 8ºC
- Cut-in = around -10 ºC

Q.5 Time initiated / time or pressure termination.
Time initiated / time or temperature termination.

Section No: 8

Q.1 Sensor, controller and load being driven.

Q.2 The controller: receives a signal from the sensor amplifies into a form of energy that can turn the components on and off.

Q.3 Bridge, amplifier and output circuit.

Q.4 Reverse acting output responds to temperature de-creases below the set point.
Direct acting output responds to a temperature increase above the set point.

Q.5

- The value that the controller is required to maintain.
- The difference between the cut-in and cut-out.
- No corrective action is required.
- Gives a variable signal proportional to the load.

Q.6

- A computer based system that can be used for air conditioning control.
- Its main advantage is that it is very accurate.

Q.7

- Inputs.
- Outputs.
- Internal relays.
- Latching relays.
- Timers.

Q.8

- Sense function.
- Decision function.
- Memory function.
- Action function.

Q.9 Computer based microprocessor that can be used to maintain set conditions of air conditioning systems.

Q.10 Air which is generated from an air compressor.

Q.11

- Branch = 20 – 90 kPa
- Main air = 100 – 120 kPa
- Supply air = 700kPa

Q.12

Pneumatic Operating Circuit