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Additional Reference


Suggested Videos

Available from the Centre for Applied Learning, Adelaide TAFE, S.A.
Ph: 08-8207 8500 Fax: 08-8207 8554

- Charging Restrictor System, No. 86-072, 11 minutes
  Describes how to charge a capillary System
Introduction

This resource manual contains learning exercises, review questions and sample assessment instruments. It is designed to assist students achieve the outcomes and purpose described in the National Module Descriptor NR29 and is an example of the depth and breadth of learning expected.

The topics listed in the content are arranged in the preferred learning sequence. It is recognised that this is not the only sequence in which the material could be learnt. Assessment arrangements and sample assessment instruments are based on the sequence of topics listed above. A teacher may decide that for a particular student or group of students it is more effective to present the topics in a different sequence. In this case the students must be informed in writing of the resulting changes in the assessment events before starting the module.

NR29 aims to provide you with the knowledge and skills to select, install charge and commission refrigeration and air conditioning systems that utilise a capillary tube as a metering device in accordance with the Code of Good Practice.

On successful completion of this module, you will be provided with the knowledge and skills to:

- identify the different capillary tubes available and describe their function in domestic refrigerators and freezers
- select the correct replacement capillary tube for a given application
- identify the dangers and observe safety procedures in the installation and repairs of a capillary tube system
- service a capillary system.

Learning plan

The following topic weighting will help you plan and allocated the effort needed to achieve the purpose and outcomes of the module.

1. Functions and applications of a capillary tube 25%
2. Capillary tube selection 10%
3. Installation, repair and safety procedures 45%
4. Servicing capillary tube systems 20%
1. Functions and Applications of a Capillary Tube

Purpose

In this topic you will learn about the operation and function of a capillary tube in a refrigeration system.

Objectives

At the end of this topic you should be able to:

• describe the function of a capillary tube in a system
• list the types and applications of capillary tube systems
• identify the diameter of capillary tube using an appropriate gauge
• describe the function of each major component in a capillary system
• describe the operating characteristics of a capillary system
• describe the terms critical charge and critical length
• determine the correct operating pressures for an operating capillary system

Content

• Function of a Capillary Tube
• Types of Capillary Tube
• Applications of Capillary Tube
• Size Identification of Capillary Tubes
• Major Component Functions
  - Compressor
  - Condenser
  - Filter/drier
  - The Capillary Tube
  - Suction Accumulator
• Operating Characteristics
• System Unloading
• Critical Length/Bore of Capillary Tube
• Critical Refrigerant Charge
• Operating Pressures

References

ARAC, pages 5.24-31 - What is a capillary tube, how it works, sizing and advantages.
Capillary tubes

Function

The capillary tube is an extremely simple device, and its use allows considerable simplification and cost reduction in small hermetic refrigeration systems. It allows the use of low cost hermetic type compressors and eliminates the expansion valve and the liquid receiver. This helps reduce cost and service problems.

It consists of a set length of small inside diameter tubing. It is installed between the condenser outlet and the evaporator inlet, (it takes the place of the liquid line).

The primary function of the capillary tube is to supply liquid refrigerant to the evaporator. It also, because of the high frictional resistance to liquid flow through the capillary tube, meters the refrigerant flow enough to maintain the required pressure difference between the high and low sides of the system.

Types of capillary tubes

Most systems that use a capillary tube as a metering device use a single capillary tube. The exception is with larger domestic air conditioning systems that use multiple tubes to obtain the required pressure drop. This is done to avoid the capillary tube having ridiculous proportions.
Capillary tubes are generally made from drawn copper tube to a set standard of sizes, although for special applications they have been made of other materials, eg stainless steel.

Applications

Capillary tubes should only be used on systems especially designed to use a capillary tube. They are best suited to close connected packaged systems that use hermetic compressors and have relatively constant loads.

Open drive compressors are not normally used with capillary systems as the slightest leak may make the whole system malfunction. This is because capillary tube systems need to have a very exact refrigerant charge.

The most common uses of a capillary tube as a metering device are:

- household refrigerators and freezers
- residential air conditioners
- drinking water coolers
- bottle cabinets
- very low temperature systems.

The capillary tube is most commonly used in domestic refrigerators, freezers and air conditioning units. It has found great use in this market due to its:

- low cost
- simplicity
- lack of maintenance
- need for a smaller refrigerant charge in the system.

Regardless of the application, the capillary tube is best suited to a system that has a constant load. This is because the capillary tube is most efficient at the intended set of design conditions.

Size identification of capillary tubes

There are two generally accepted methods of determining the internal diameter of a sample of capillary tube:

1. Use a dedicated gauge. These are very similar to a set of oxy/acetylene tip cleaners except that they have the size of the test pin stamped on the body.
2. Use a numbers drill set. These drills are graduated in small steps and the normal procedure is to find a drill that just fits in the end of the capillary tube, (check that there are no burrs in the end). Measure the drill with a micrometer or determine the size from the drill stand. This is the size of the capillary tube.

It is important to measure the length of the capillary tube as accurately as possible.

**Major component functions**

A capillary tube system has similar major components to most other refrigeration systems, ie,

- a compressor
- a condenser
- a filter/drier
- a refrigerant metering device, in this case a capillary tube
- an evaporator
- a suction accumulator, probably the major difference.

**Compressor**

Like every vapour compression refrigeration system, the compressor pumps refrigerant around the system, as well as raising the pressure and temperature of the refrigerant so it is above the ambient condensing temperatures.

**Condenser**

A heat rejection device. Refrigerant changes state from a vapour to a liquid in the condenser.

**Filter/drier**

A critical component with a capillary system. The filter drier must be capable of keeping the capillary tube clean and free flowing. The drier should be sized to suit the system as it can act as a receiver for liquid refrigerant, not a good feature for a critical charge system.

**Refrigerant metering device, the capillary tube**

A fixed pressure drop metering device. It causes a drop in pressure due to friction between the tube walls and the refrigerant as the refrigerant is pushed through the capillary tube.
Evaporator
Like all other evaporators, a heat exchange device. Refrigerant boils off from a liquid to a vapour in the evaporator.

Suction accumulator
Basically just a vessel where any excess liquid refrigerant can accumulate but only refrigerant vapour can be drawn off by the compressor. Its volume is carefully calculated to ensure it can hold the refrigerant that migrates to the evaporator on the off cycle.

Operating characteristics
The characteristics of the capillary tube are:

- Simple and cheap.
- No moving parts, so it won’t wear out.
- No liquid receiver needed.
- On the “off” cycle the system pressures (condenser and evaporator) balance out, that is, they even out to the same value. This is required, so the compressor can start against zero pressure difference between the high side and the low side.
- This low starting load allows the use of simple and cheap compressors, drive motors and starters.
- Only a small refrigerant charge is needed. The refrigerant charge cannot be less than the volume of the evaporator tubing or greater than the volume of the evaporator tubing plus the volume of the accumulator. This small charge is not only economical but limits the amount of refrigerant used thus helping the environment.
- The evaporator cannot fill with oil because it fills with liquid refrigerant on the “off” cycle.
- There is no risk of getting liquid refrigerant back to the compressor. The accumulator design helps ensure that only vapour goes back down the suction line.
- The length of a capillary tube depends a lot on the bore of the tube but as a general rule, a tube with a length between 2 metres and 5 meters will provide the best results. It cannot be stressed enough that this is only a STARTING point, length/bore selection must be based on actual field results even though the initial selection was made carefully from the manufacturers data.
The capillary tube system is an exact charge system, that is the refrigerant charge must be correct. The charge is usually measured into the system with either a charging station or an accurate set of scales.

The capillary system always starts unloaded as there is no way to shut off the capillary tube on the off cycle, so the pressures equalise on the off cycle. This has the benefit of allowing a simple starting system to be used for the compressor drive motor along with a lower starting torque motor.

**System unloading**

As mentioned before, when the compressor on a capillary tube system stops, the capillary tube continues to feed the evaporator with liquid refrigerant. This fact is both an advantage and a disadvantage.

- An advantage because the refrigerant pressures in both the high side and the low side reach a balanced condition. The compressor start with equal pressures on both the suction and discharge sides. This allows the compressor to start using the minimum amount of torque and hence power. Motors therefore that drive the compressors in capillary tube systems can be relatively low in starting torque and motor power. Because of this, they are cheaper to make and run.
- A disadvantage is that all the refrigerant goes to the evaporator on the off cycle. This can cause flood back on start up.

**Critical length / bore of Capillary Tubes** (ARAC Vol. 1, p.5.29)

The capillary tube and the compressor are piped in series in the system, that means there is only one path for the refrigerant to flow. Because of this, to handle the refrigerant flow, the capacity of the capillary tube must be equal to the pumping capacity of the compressor.

Because capillary tubes are only a set length of small bore tube, we can compare them to a garden hose, the longer the hose the less the water pressure available at the nozzle.

Also, the bigger the hose diameter, the more water flows through it, (that’s why fire fighters use large diameter water hoses), the higher the water pressure at the tap, the greater the amount of water that flows out of the nozzle at the end of the hose.

**Factors that control length/bore of capillary tubes**

- Refrigerant Type.

All refrigerants have different densities and latent heat capacities.
Compressor Pumping Capacity.

The more vapour the compressor pumps, the more liquid refrigerant must go through the capillary tube.

More vapour volume = Less capillary resistance.

Pressure Differences between Condenser and Evaporator.

Liquid flow varies with pressure difference between condenser and evaporator. The bigger the pressure difference, the bigger restriction needed to keep the same flow rate.

Critical refrigerant charge

As previously mentioned the refrigerant charge must be able to be contained in the evaporator and suction accumulator on the "off" cycle.

This fact determines the exact amount of refrigerant that must be charged into a capillary system. Usually this ranges from 75 grams for a small domestic refrigerator up to several kilograms for an air conditioning system.

This exact amount is called a critical charge and you are often only allowed to be plus or minus 2 grams of liquid refrigerant either side of the prescribed charge.

Operating pressures

The diagram above is a graph of the pressure relationship between the high and low sides of a capillary system during a typical operating cycle.
During the running period the high side and the low side pressure are dictated by the operating temperatures surrounding the system, the high side being at a relatively high pressure compared to the low side. In this part of the operating cycle the pressures are similar to those found in expansion valve systems under similar conditions.

Following through the diagram, it is easy to see the difference between the high side and the low side pressure on the "run" cycle. When the system is "off" the high side pressure falls, the low side pressure rises to "balance" the pressures in the system.

Pressures in the system will vary depending on the application. An air conditioning system will have higher suction and discharge pressures than a domestic refrigerator. A domestic refrigerator may have higher pressures than a domestic freezer. This is because the required saturated suction pressures in an air conditioning system are higher than either a refrigerator or a freezer.

The refrigerant used in the system will also have a large effect on the system pressures.

To determine the operating pressure for a capillary system, you will need:

- to know the design evaporator temperature
- to make an educated guess at the design temperature difference of the coil
- a pressure / temperature chart for the system refrigerant

For example,

A domestic freezer has a design temperature of -20°C.

The temperature difference is estimated to be 6K

The refrigerant is R134a.

1. Add the temperature difference to the design temperature

   \[-20°C + 6K = -26°C\] (because the saturated temperature of the coil is lower than the space temperature)

2. Look on the pressure / temperature chart to find the equivalent pressure for -26°C on the R134a scale and the value should be close to the expected suction pressure at SATISFIEV EVAPORATOR CONDITIONS.

As the suction line is usually short, for the purpose of this exercise we can ignore the pressure drop in the suction line, so the satisfied evaporator pressure is very close to the suction pressure at the compressor.

Our expected suction pressure would be approximately 10 kPa.
REMEMBER, the suction pressure will depend not only on the satisfied evaporator conditions but also on the:

- ambient temperature, which may vary from system to system
- load on the system
- condition of the compressor
- condition of the system, eg, if the condenser is clean or dirty
- level of frost build up on the evaporator.

Correct operating pressures are difficult to calculate with any accuracy but with practice it is not too hard to estimate the pressures needed to correctly service capillary tube systems.
Practical exercise 1 - Operating conditions of capillary systems

Task

- Identify at least four (4) different systems that use a capillary tube as the refrigerant metering device.
- Measure the temperature of the cabinet and allowing a suitable temperature difference calculate the estimated suction pressure for each system.

Equipment

- 1 x Refrigeration hand tools
- 1 x Set of refrigeration gauges and appropriate charging adaptors.
- 1 x Digital thermometer
- 1 x Pressure/temperature chart.
- 4 x Capillary systems

Remember Safety First!

- Systems may start automatically so make sure you keep fingers, tools, hair, clothing, etc. away from rotating machinery.
- Take care when fitting and removing gauges, refrigerants burn as well as being unfriendly to the environment.
- Wear safety glasses to avoid the potential of getting refrigerant in your eye.

Procedure

1. Locate the units specified by the teacher for this exercise.
2. Take the temperature of the cabinet.
3. Apply the appropriate temperature difference for the system.
4. Calculate the estimated suction pressure.
5. Check the actual running suction pressure and compare with your estimate.
6. Justify the difference in suction pressures (if any).
System 1

Application ....................................................
Cabinet temperature ............................................
Temperature difference ........................................
Estimated suction temperature ..............................
Estimated suction pressure ...................................
Actual suction pressure ........................................
Justification for difference ....................................
..............................................................................
..............................................................................
..............................................................................
..............................................................................

System 2

Application ....................................................
Cabinet temperature ............................................
Temperature difference ........................................
Estimated suction temperature ..............................
Estimated suction pressure ...................................
Actual suction pressure ........................................
Justification for difference ....................................
..............................................................................
..............................................................................
..............................................................................
..............................................................................
System 3
Application ________________________________________
Cabinet temperature ________________________________
Temperature difference ____________________________
Estimated suction temperature ______________________
Estimated suction pressure __________________________
Actual suction pressure ____________________________
Justification for difference _________________________

System 4
Application ________________________________________
Cabinet temperature ________________________________
Temperature difference ____________________________
Estimated suction temperature ______________________
Estimated suction pressure __________________________
Actual suction pressure ____________________________
Justification for difference _________________________

NR29 Capillary Systems
Module Resource Manual
December 1999
Conclusions
Practical exercise 2 - Identifying and cutting capillary tubes

Task

- You are to determine the sizes of the nominated capillary samples using either of the two sizing methods in the notes.
- You are to cut various pieces of capillary tube and ensure that the ends are cut cleanly with no burrs or distortion.

Equipment

- Capillary tube samples
- Sizing gauge
- Drill set and micrometer
- Three cornered file
- Steel tape/rule
- Capillary tube cutter

Procedure

1. Using the capillary sizing gauge, find a pin that just fits inside the sample of capillary.
2. Note the size from the gauge. It could be an imperial or a metric size. Capillary tube comes in both sizes.
3. Using the number drills find a drill shank that just fits, like the gauge pin, and then measure the shank diameter with the micrometer to find the size.
4. Using the three cornered file carefully file a groove around the capillary and then break the capillary tube through to give a clean edge.
   NB. When cutting the capillary samples try to be exact in your measurement of the specified length to a tolerance of + or - 1/2 mm. (This allows a maximum error of 1 mm).
5. Using the capillary tube cutter, repeat the cutting procedure and compare the difference in the cut edges.
   NB. If you have any questions, don’t hesitate to ASK!. The teacher is there to help you.
### Results

**Capillary tube**

A. Capillary tube gauge size __________________________
   Drill size or number __________________________
   Micrometer reading __________________________
   Compare result above __________________________

B. Capillary tube gauge size __________________________
   Drill size or number __________________________
   Micrometer reading __________________________
   Compare result above __________________________

C. Capillary tube gauge size __________________________
   Drill size or number __________________________
   Micrometer reading __________________________
   Compare result above __________________________

D. Capillary tube gauge size __________________________
   Drill size or number __________________________
   Micrometer reading __________________________
   Compare result above __________________________

### Conclusions

________________________________________________________________________________________

________________________________________________________________________________________

________________________________________________________________________________________

________________________________________________________________________________________

________________________________________________________________________________________
Review questions

These questions will help you revise what you have learnt in this topic.

1. What purpose does the capillary tube have in a refrigeration system?

2. How does the capillary tube create a pressure drop in a system?

3. Which component of a system does the capillary tube replace?

4. List two types of systems that use a capillary tube metering device.
   -
   -

5. Why does the capillary tube metering device allow a system to start in an unloaded condition?
Review questions

6. Why do capillary tube systems have to have a suction line accumulator fitted?

7. What are two benefits of a capillary tube system?

   

   

8. What type of compressor is used with a capillary tube?


9. Briefly describe a capillary tube.
Review questions

10. Complete the following sentence.
   Capillary tubes not only supply liquid but ..........

11. The length and bore of a capillary tube changes with:
   •........................................
   •........................................
   •........................................
   •........................................
   •........................................

12. When the compressor in a capillary tube system stops, explain what happens to the flow of refrigerant through the capillary tube

13. Why is the capillary tube soft soldered to the suction line in domestic refrigerators and freezers?
Review questions

14. Explain why a filter drier is necessary on a capillary tube refrigeration system?

15. Should a capillary tube be used on a system that has a widely varying load? Briefly explain your answer.

16. Can open drive compressors be used on capillary tube systems? Explain your answer.

17. Explain how the volume of refrigerant in a capillary tube system is calculated.
18. When the compressors stops does the capillary tube "shut off"? Briefly explain your answer.
2. Capillary Tube Selection

Purpose

In this topic you will learn how to select the correct replacement capillary tube for a given application, from manufacturers catalogues.

Objectives

At the end of this topic you should be able to:

• describe the factors that effect the capacity and selection of a capillary tube
• select a capillary tube from manufacturers data for various applications
• select alternate size capillary tubes from given data
• describe the effects of an incorrectly selected capillary tube on the operation of a system, ie, oversized and undersized.

Content

• Factors Capacity and Selection
• Selection of Capillary Tubes from Manufacturers Data
• Capillary Tube Selection Using Application Charts
  - Domestic Applications
  - Commercial Applications
  - Air Conditioning Applications
• Effects of Incorrect Selection of Capillary Tubes.

References

• ARAC, pages 5.30-31 - Selection of capillary tube
• ARAC, page 24.21 - Selection of capillary tube
• ARAC, pages 5.26-28 - Incorrect selection of capillary tube.
Factors affecting capacity and selection

Due to the number of variables that change with each particular application or selection, it should always be remembered that any selection made should only be considered as a compromise over the systems operating range.

The basis of selection is the known liquid refrigerant flow rate through the tube, as well as the net refrigerating effect in kJ/kg at the appropriate saturated evaporating temperature and liquid entering temperature, given that:

- the flow rate is based on the pressure corresponding to 50°C condensing temperature and 100% liquid flow through the tube
- liquid entering the capillary tube is subcooled by 5K and 60% of the length is made into a suction to liquid line heat exchanger
- the tube should be between 2m and 5m in length as this will give the most stable flow pattern, although this will vary for special applications
- where multiple tubes are required these must be identical in length, configuration and used with multicircuit evaporators.

Selection of capillary tubes from manufacturers data


All capillary tube system manufacturers spend a lot of time and money in optimising the capillary tube with respect to the system that it is designed for. If there is a need to select a replacement capillary tube, the manufacturers catalogue should be used to find the correct part number.

The need often arises where a replacement capillary tube must be selected for a system that has been engineered in the field, or the replacement capillary is of a size that is now no longer made. The mechanic must turn to the replacement charts or graphs that are included in spare parts wholesaler’s handbooks.

These selection tables are designed to use the standard sizes of capillary tube that is readily available. This is not only cost saving for the customer but time saving for the mechanic.

Capillary tube selection using application charts

The following charts and selection data are taken from the Actrol Parts catalogue.

Thank you to Actrol Parts for their assistance in this work.
1. Domestic Applications

Below is an example of how to select a capillary tube for a domestic refrigeration system. It is a single door refrigerator, with a 1/8 HP, R12 compressor fitted with a static condenser.

**Domestic Application**

<table>
<thead>
<tr>
<th>Unit HP</th>
<th>Refrigerant</th>
<th>Condenser Type</th>
<th>Cooling</th>
<th>Application*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/20</td>
<td>R12</td>
<td>Static or Fan</td>
<td>1/8</td>
<td>2, 3, 4, 7, 8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1, 5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5, 6, 9</td>
</tr>
<tr>
<td>1/10</td>
<td>R12</td>
<td>Static or Fan</td>
<td>1/9</td>
<td>9</td>
</tr>
<tr>
<td>1/8</td>
<td>R12</td>
<td>Static or Fan</td>
<td>1/8</td>
<td>SP-1</td>
</tr>
<tr>
<td>1/6</td>
<td>R12</td>
<td>Static or Fan</td>
<td>1/6</td>
<td>SP-2</td>
</tr>
<tr>
<td>1/5</td>
<td>R12</td>
<td>Static or Fan</td>
<td>1/5</td>
<td>SP-3</td>
</tr>
<tr>
<td>1/4</td>
<td>R12</td>
<td>Static or Fan</td>
<td>1/4</td>
<td>SP-4</td>
</tr>
<tr>
<td>1/3</td>
<td>R12</td>
<td>Static or Fan</td>
<td>1/3</td>
<td>SP-5</td>
</tr>
</tbody>
</table>

* Generally, Domestic Applications detailed apply as listed in the Chart.

The following chart will give you the details on the part numbers quoted in the charts used in this section. Capillary tube supplied in service packs will require to be cut to the exact length for each specific application using the methods discussed earlier in this module workbook.

**Procedure**

1. Select the unit H.P. \( \frac{1}{8} \)
2. Select refrigerant type. (R12)
3. Select condenser type. (Static)
4. Select domestic application number - refer to bottom of chart for application number (In this instance – Application 1)

**Answer**

Capillary size required - SP2 and the length is 3050 mm.
Service Packs

<table>
<thead>
<tr>
<th>Part No.</th>
<th>Inside Diameter</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mm</td>
<td>inch</td>
</tr>
<tr>
<td>SP-1</td>
<td>0.66</td>
<td>0.026</td>
</tr>
<tr>
<td>SP-2</td>
<td>0.8</td>
<td>0.0315</td>
</tr>
<tr>
<td>SP-3</td>
<td>0.9</td>
<td>0.0335</td>
</tr>
<tr>
<td>SP-4</td>
<td>1.1</td>
<td>0.0455</td>
</tr>
<tr>
<td>SP-5</td>
<td>1.3</td>
<td>0.051</td>
</tr>
<tr>
<td>SP-6</td>
<td>1.4</td>
<td>0.055</td>
</tr>
<tr>
<td>SP-7</td>
<td>1.62</td>
<td>0.064</td>
</tr>
<tr>
<td>SP-8</td>
<td>1.78</td>
<td>0.07</td>
</tr>
<tr>
<td>SP-9</td>
<td>1.9</td>
<td>0.075</td>
</tr>
<tr>
<td>SP-10</td>
<td>2.04</td>
<td>0.08</td>
</tr>
<tr>
<td>SP-11</td>
<td>2.24</td>
<td>0.088</td>
</tr>
</tbody>
</table>

(Reproduced by Actrol Catalogue and Technical Manual, with kind permission of Actrol Parts)

Complete this sample question

Select the capillary required for an R22 Vertical Freezer, with a static condenser and a 1/3 HP compressor.

1. Unit H.P. __________________________
2. Refrigerant type __________________________
3. Condenser type __________________________
4. Application number __________________________
5. Capillary size required: __________________________

2. Commercial Unit Applications

Below is an example of how to select a capillary tube for a commercial refrigeration system. The system is a 1 HP, Low Temperature Freezer, running on R502 with an evaporator temperature of -22°C.
Procedure

1. Select unit H.P. (1 HP)
2. Select refrigerant type (R502)
3. Select evaporator temperature (-22°C)

Answer

Capillary size required is - SP6 and the length is 2400 mm.

Refer back to the previous chart to determine the details of the required service packs needed. Remember that you will need to cut the capillary tube to length to suit each application.

Complete this sample question

Select the capillary required for a commercial R12 low temperature system, with a 2 HP compressor and a -23°C to -15°C evaporator temperature.

1. Unit H.P.
2. Refrigerant type
3. Evaporator temperature
4. Capillary size required:

3. Air conditioning applications

Here is an example of how to select a capillary tube for an air conditioning system. The system is an R.A.C. with a 3 kW capacity.

R22 Air Conditioning Application

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>BTU/hr</td>
<td>kW</td>
<td></td>
<td>BTU/hr</td>
<td>kW</td>
<td></td>
<td>BTU/hr</td>
<td>kW</td>
<td></td>
<td>BTU/hr</td>
<td>kW</td>
<td></td>
</tr>
<tr>
<td>4000</td>
<td>1.17</td>
<td>1900</td>
<td>SP-4</td>
<td>6250</td>
<td>1.83</td>
<td>1900</td>
<td>SP-7</td>
<td>8500</td>
<td>2.49</td>
<td>2130</td>
<td>SP-9</td>
</tr>
<tr>
<td>4500</td>
<td>1.32</td>
<td>2400</td>
<td>SP-5</td>
<td>6500</td>
<td>1.91</td>
<td>1850</td>
<td>SP-8</td>
<td>9000</td>
<td>2.64</td>
<td>1800</td>
<td>SP-10</td>
</tr>
<tr>
<td>5000</td>
<td>1.47</td>
<td>2900</td>
<td>SP-6</td>
<td>7000</td>
<td>2.05</td>
<td>2290</td>
<td>SP-9</td>
<td>9250</td>
<td>2.71</td>
<td>1790</td>
<td>SP-11</td>
</tr>
<tr>
<td>5500</td>
<td>1.61</td>
<td>3400</td>
<td>SP-7</td>
<td>7500</td>
<td>2.27</td>
<td>1800</td>
<td>SP-10</td>
<td>9750</td>
<td>2.86</td>
<td>2050</td>
<td>SP-8</td>
</tr>
<tr>
<td>6000</td>
<td>1.76</td>
<td>2400</td>
<td></td>
<td>8000</td>
<td>2.34</td>
<td>1720</td>
<td></td>
<td>10250</td>
<td>3</td>
<td>1800</td>
<td></td>
</tr>
<tr>
<td>6500</td>
<td>1.91</td>
<td>2900</td>
<td></td>
<td>8250</td>
<td>2.42</td>
<td>1650</td>
<td></td>
<td>10500</td>
<td>3.08</td>
<td>1750</td>
<td></td>
</tr>
</tbody>
</table>

Note: For Single Capillary Tube Systems... Read directly from above chart. For Multi-Capillary Tube Systems (Two or more circuits)... Divide the total load by the number of circuits to obtain load for each individual capillary tube. Example: 30,000 BTU/hr (8.79 kW) total with three capillary tubes to evaporator = 10,000 BTU/hr (2.93 kW) each.

From Chart select three SP-10 Capillary Tubes 1900mm long.

(Reproduced by Actrol Catalogue and Technical Manual. with kind permission of Actrol Parts)
Procedure

1. Select capacity. (3000 watts)

Answer

Capillary size required - SP10 and the length is 1830 mm

NB. FOR MULTI-CAPILLARY SYSTEMS READ THE IMPORTANT INFORMATION UNDER THE CHART.

Refer back to the previous chart to determine the details of the required service packs needed. Remember that you will need to cut the capillary tube to length to suit each application.

Complete this sample question

Select a capillary tube for an air conditioning system with a cooling capacity of 1.47 kW.

Capillary size required: _________________________

Effects of incorrect selection of capillary tubes
(ARAC Vol 1, p. 5.26 - 28)

If the selection of the capillary is such that its flow capacity is too little, then the resistance of the tube is too great (ie. the capillary is either too long and/or the bore is too small). The ability of the tube to pass liquid from the condenser to the evaporator will be less than the pumping capacity of the compressor at the same conditions, resulting in the evaporator being starved of refrigerant. The excess liquid will back up in the latter portion of the condenser at the entrance to the capillary.

The back pressure will drop due to the effects of starving, whereas the back up of liquid in the condenser reduces the effective condenser surface area causing an increase in the condensing temperature. This results in an increase in the flow capacity of the tube, while a corresponding decrease in the pumping capacity of the compressor occurs.

Because the pumping capacity of the compressor has decreased, an overall decrease in the system capacity will occur.

Excessive Pressure

(Reproduced from Australian Refrigeration and Air Conditioning, with kind permission of Training Publications of Western Australia)
On the other side of the argument, when the tube does not have enough resistance (tube too short and/or bore too large), the flow capacity of the tube will be greater than the pumping capacity of the compressor at the design conditions. This will result in the overfeeding of the evaporator, possible causing liquid floodback to the compressor.

![Diagram](image)

*High Head Pressure and Low Back Pressure*

(Reproduced from Australian Refrigeration and Air Conditioning, with kind permission of Training Publications of Western Australian)

No liquid seal in the condenser at the entrance to the capillary will exist allowing uncondensed refrigerant to enter the capillary along with the liquid, reducing the system capacity.

Because of the excessive flow rate through the tube the compressor will not be able to reduce the evaporator pressure to the desired level.

A system using a capillary tube will only operate at maximum efficiency at one set of operating conditions. At all other conditions the system operates under capacity.

The capillary is somewhat self-compensating in that with a rise or fall in load, the flow capacity of the tube increases or decreases respectively. This is due to the increase/decrease in condensing pressure, which usually accompanies a change in load. With an increase/decrease in condensing pressure, there is an increase/decrease in the refrigerant flow rate through the tube. It is also partially due to the change in the amount of liquid subcooling taking place in the condenser.
Practical exercise 1 - Refrigeration system faults

Task

- Identify the symptoms and effect of overcharge, undercharge and high ambients conditions on a capillary tube system.

Equipment

- 1 x Refrigeration hand tools
- 1 x Refrigeration service gauges
- 1 x Digital thermometers
- 1 x Pressure/temperature chart
- Normal charged capillary system
- Overcharged capillary system
- Undercharged capillary system

Remember Safety First!

- Systems may start automatically so make sure you keep fingers, tools, hair, clothing etc. away from rotating machinery.
- Take care when fitting and removing gauges, refrigerants burn as well as being unfriendly to the environment.
- Wear safety glasses to avoid the potential of getting refrigerant in your eye.

Procedure

1. Locate the units specified by the teacher for this exercise.
2. On each system fit gauges. Where possible fit both the suction and the discharge gauge.
3. Read the pressures on the gauges and compare them to the expected pressures from the pressure/temperature chart.
4. Take evaporator and cabinet temperatures.
5. Look at the systems and see what other symptoms are visible to show the condition of the system.
6. Repeat these steps on each of the sample systems and note the pressures, temperatures and your observations.
### (a) Overcharged System

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Expected</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharge pressure:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suction pressure:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discharge temperature:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dryer temperature:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suction temperature:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evaporator temperature:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cabinet temperature:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>List symptoms</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### (b) Undercharged System

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Expected</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharge pressure:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suction pressure:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discharge temperature:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dryer temperature:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suction temperature:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evaporator temperature:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cabinet temperature:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>List symptoms</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
(c) High Ambient Temperature System

Discharge pressure: ______________________

Suction pressure: ______________________

Discharge temperature: ______________________

Dryer temperature: ______________________

Suction temperature: ______________________

Evaporator temperature: ______________________

Cabinet temperature: ______________________

List symptoms: ______________________

Conclusions

__________________________

__________________________

__________________________

__________________________

__________________________

__________________________
Practical exercise 2 - Capillary tube selection

Task

To select capillary tubes for various applications.

Equipment

Manufacturers catalogues

Procedures

From the manufacturers catalogues supplied select alternate capillary tubes for the following applications:

Example:

Application: \( All \) refrigerator

Condenser cooling Static
Compressor 1/12 HP
Refrigerant R 12
Evaporating temperature \(-14^\circ C\)

Capillary part number SP - 1
Capillary length 1680 mm

Application 1: \( Vertical \) freezer

Condenser cooling Static
Compressor 1/5 HP
Refrigerant R 12
Evaporating temperature \(-23^\circ C\)

Capillary part number
Capillary length
<table>
<thead>
<tr>
<th>Application 2:</th>
<th>Single door refrigerator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condenser cooling:</td>
<td>Fan</td>
</tr>
<tr>
<td>Compressor</td>
<td>1/3 HP</td>
</tr>
<tr>
<td>Refrigerant</td>
<td>R 12</td>
</tr>
<tr>
<td>Evaporating temperature</td>
<td>- 23° C</td>
</tr>
<tr>
<td>Capillary part number</td>
<td></td>
</tr>
<tr>
<td>Capillary length</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Application 3:</th>
<th>Commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressor</td>
<td>1 HP</td>
</tr>
<tr>
<td>Refrigerant</td>
<td>R 502</td>
</tr>
<tr>
<td>Evaporating temperature</td>
<td>- 23° C</td>
</tr>
<tr>
<td>Capillary part number</td>
<td></td>
</tr>
<tr>
<td>Capillary length</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Application 4:</th>
<th>Juice dispenser</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condenser cooling</td>
<td>Fan</td>
</tr>
<tr>
<td>Compressor</td>
<td>1/4 HP</td>
</tr>
<tr>
<td>Refrigerant</td>
<td>R 22</td>
</tr>
<tr>
<td>Evaporating temperature</td>
<td>- 5° C</td>
</tr>
<tr>
<td>Capillary part number</td>
<td></td>
</tr>
<tr>
<td>Capillary length</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Application 5:</th>
<th>Air conditioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>System capacity</td>
<td>5000 Btu/hr (1.47 kW)</td>
</tr>
<tr>
<td>Capillary part number</td>
<td></td>
</tr>
<tr>
<td>Capillary length</td>
<td></td>
</tr>
</tbody>
</table>
**Application 6:**

<table>
<thead>
<tr>
<th>System capacity</th>
<th>25,000 Btu’s</th>
</tr>
</thead>
<tbody>
<tr>
<td>No of capillary tube circuits</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>No of kilowatts for 25,000 Btu’s</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>kilowatts per capillary</td>
<td></td>
</tr>
<tr>
<td>Btu’s per capillary</td>
<td></td>
</tr>
<tr>
<td>Capillary part number</td>
<td></td>
</tr>
<tr>
<td>Capillary length</td>
<td></td>
</tr>
</tbody>
</table>

**Application 7:**

<table>
<thead>
<tr>
<th>System capacity</th>
<th>5.86 kilowatts</th>
</tr>
</thead>
<tbody>
<tr>
<td>No of capillary tube circuits</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>kilowatts per capillary</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Capillary part number</td>
<td></td>
</tr>
<tr>
<td>Capillary length</td>
<td></td>
</tr>
</tbody>
</table>

**Application 8:**

<table>
<thead>
<tr>
<th>System capacity</th>
<th>2.7 kilowatts</th>
</tr>
</thead>
<tbody>
<tr>
<td>No of Btu’s for 2.7 kilowatts</td>
<td></td>
</tr>
<tr>
<td>Capillary part number</td>
<td></td>
</tr>
<tr>
<td>Capillary length</td>
<td></td>
</tr>
<tr>
<td>System</td>
<td></td>
</tr>
</tbody>
</table>
**Application 9:**

- **Air conditioning, Multi capillary tubes**
- System capacity: 38,000 Btu's
- No of capillary tube circuits: 4

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No of kilowatts for 38,000 Btu’s</td>
<td></td>
</tr>
<tr>
<td>Kilowatts per capillary</td>
<td></td>
</tr>
<tr>
<td>Btu's per capillary</td>
<td></td>
</tr>
<tr>
<td>Capillary part number</td>
<td></td>
</tr>
<tr>
<td>Capillary length</td>
<td></td>
</tr>
</tbody>
</table>
Practical exercise 3 - Effects of an incorrectly sized capillary

Task

Determine the operating pressures and temperatures of capillary tube systems with normal, oversized and undersized capillary tubes fitted.

Equipment

- 1 x Refrigeration hand tools
- 1 x Refrigeration service gauges and appropriate charging adaptors
- 1 x Digital thermometer
- 1 x Pressure/temperature chart
- 1 x capillary system with a correctly sized capillary
- 1 x capillary system with an oversized capillary
- 1 x capillary system with an undersized capillary

Remember Safety First!

- Systems may start automatically so make sure you keep fingers, tools, hair, clothing etc. away from rotating machinery.
- Take care when fitting and removing gauges, refrigerants burn as well as being unfriendly to the environment.
- Wear safety glasses at all times.

Procedure

1. Locate the unit specified by the teacher for this exercise.
2. On each system fit gauges. Where possible fit both the suction and the discharge gauge.
3. Read the pressures on the gauges and write them into the following table.
4. Take the suction temperature, capillary tube inlet temperature and evaporator temperature. Again write them into the following table.
5. Repeat these steps on each of the sample systems and note the pressure and temperatures and your observations.
<table>
<thead>
<tr>
<th>Normal sized tube</th>
<th>Oversized tube</th>
<th>Undersized tube</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suction pressure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discharge pressure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suction temperature</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cap. tube inlet temp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evaporator temp.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. List at least 4 symptoms of a capillary system operating with
   (a) Undersized capillary

   __________________________________________________________________________
   __________________________________________________________________________
   __________________________________________________________________________
   __________________________________________________________________________

   (b) Oversized capillary

   __________________________________________________________________________
   __________________________________________________________________________
   __________________________________________________________________________
   __________________________________________________________________________
Review questions

*These questions will help you revise what you have learnt in this topic.*

1. What length of capillary tube will give the most stable flow conditions as a general rule?

2. List three special considerations which must be observed when using multiple capillary tubes.

   - 
   - 
   - 

3. From the charts in the module, select a replacement capillary for the following application:
   Two door side by side refrigerator/freezer
   Compressor 1/5 HP, with a fan cooled condenser, and the refrigerant is R12.
   Capillary length ____________________________
   Capillary part number ____________________________

4. If the flow through a capillary tube is too little, list two factors that could cause this.

   - 
   - 

5. Will uncondensed refrigerant flowing into the capillary along with condensed liquid refrigerant cause a capacity increase or decrease? Explain your answer.

   ____________________________
   ____________________________
Review questions

6. Can a capillary tube system operate at varying conditions? Explain your answer.

7. From your observations of Practical task 2 what effect on the system operation does:
   (a) an oversized capillary tube have.

   (b) an undersized capillary tube have.
3. Installation Repair and Safety Procedures

Purpose

In this topic you will learn to install and repair of a capillary tube system, in accordance with Codes of Practice, Regulations and OH&S requirements.

Objectives

At the end of this topic you should be able to:

- identify electrical hazards
- identify system refrigerant
- list the correct procedures to remove/store refrigerant from a system in accordance with the Code of Good Practice
- identify current local and national regulations relating to refrigerants and systems
- remove the refrigerant from the system in accordance with the Code of Good Practice
- remove the existing capillary tube
- select and cut to length the replacement capillary tube
- install the replacement capillary tube
- pressure test the system
- evacuate and recharge the system
- return the system to normal operation.

Content

- Identification of Electrical Hazards
- Identification of the System Refrigerant
- Procedures to Remove/Store Refrigerant
- Removal of the Existing Capillary Tube
- Selecting and Cutting the Capillary Tube
- Installation of the Capillary Tube
• Pressure Testing
• Evacuation and Recharging
• Return the System to Normal Operation

Reference

Identification of electrical hazards

A large number of capillary tube systems will be found to be plug in appliances. While these are relatively simple to make electrically safe it is essential to be able to carry out this procedure as an automatic function.

- Where possible NEVER test live.
- Try to work in a situation where there are other people around.
- Always use test equipment that is:
  - safe
  - reliable
  - as simple as possible to use
  - acts on as many of your senses as possible eg, lights light and a buzzer buzzes at the same time if power is detected.
- If you have to work live concentrate fully on the job in hand.
- Test, then retest before you touch any components.
- Maintain your test equipment yourself.
- Never trust anybody to test equipment for you, always test your self.
- Convince yourself that everybody else out there is there to try to injure you.
- If in doubt, don’t touch.
- If you remove a fuse link from a circuit, replace it with a “dead” fuse link and take the good one with you in your pocket.
- If a lockable isolation switch is provided, lock it with your own lock and keep the key in your pocket.
- If necessary make up a lockable box to lock up the three pin plug and keep the only key in your pocket.

While the above safety pointers may be considered extreme by some people in the industry, remember that you, and you alone are the last line of protection for yourself. By all means look out for the safety of other people, but trust your own safety to one person, YOU.

Identification of the system refrigerant

For a review of this topic you should refer back to your NR03 module and class notes.
Briefly, system refrigerant identification is performed by:

- Looking for either the chemical name or the formula on the unit data plate.
- Checking on the system for identification, either by name tag data or colour coding. As you can remember each refrigerant has its own colour code.
- By letting the system stand and then when it has reached ambient temperature take a pressure reading. By referring to a pressure temperature chart, find the ambient temperature, go across the chart until you find the measured pressure value, then follow the column up to the top and read off the refrigerant.
- It is very difficult, if not impossible to identify a refrigerant by taking a gauge reading only.

**Procedures to remove/store refrigerant**

Whenever it is necessary to remove refrigerant from a capillary refrigeration system it is necessary to remove the complete refrigerant charge. Usually the amount of refrigerant in question is only small, typically up to 500 grams, so it is usually accepted that removal of this small amount of refrigerant with a reclaim/recovery unit would add unnecessarily to the cost and difficulty of service. For this reason the accepted method of refrigerant recovery is to use the flexible bag method. The bag must comply with Australian Standard AS 4211.3 – 1996.

In this method the system is isolated from the electrical supply and the pressure in the system is allowed to balance out. The flexible bag is then connected to the system, often through a temporary line piercing fitting, and the refrigerant is allowed to transfer into the flexible bag. It will help if the bag is kept as cool as possible (wrap a wet towel around the bag and blow the air from a fan over the bag). The system should be as warm as possible (defrost the system if possible) as this will ensure that as much refrigerant as possible flows into the bag.

**WARNING**

Only inflate the bag until it is partially inflated. The bag should be still “squashy”. Overpressurising the bag will cause it to burst. The bag should then be taken to the workshop and the refrigerant contained within should be recovered into a proper reclaim cylinder.

The bag should be destroyed after six (6) uses.

The temporary piercing valve should be removed in the process of the service and replaced with a schraeder valve on both the suction and the discharge sides of the system.

For larger systems, the standard procedure of reclaiming the refrigerant with a proper reclaim machine should be followed.
Removal of the existing capillary tube

This process requires a lot of careful work as the cabinet may have to be cut open, or at the very least the system will have to be disassembled to the point where the evaporator to capillary tube joint will be exposed for service.

Where possible remove the existing tube, either by de-soldering the capillary to suction line soft soldered joint (the heat exchanger), and carefully removing the capillary tube.

Sometimes the capillary tube will be sealed to the suction line with heat paste to act as a heat exchanger, this paste can be removed with a rag soaked in kerosene. Be warned this paste will get everywhere so take care and keep your hands clean and you will not end up with paste all over the customers cabinet.

The capillary tube is often run inside the suction line, especially on domestic units so it will be impossible to remove the capillary, but trim of the accessible parts as best as you can. Solder over the cut ends just to make sure there is no chance of a leak around them.

This process, although sometimes difficult will allow the mechanic to accurately measure the length of the existing capillary tube.

Take care, the old tube may be brittle and break easily, it is a lot easier to measure if it is all in one piece.

Selection and cutting the capillary tube

You have already been through the selection process for tube selection, if you feel a little rusty, look back to Section 2 and review that work.

Remember, when cutting the capillary tube, it is of vital importance that the cut is square and clean with no burrs etc to cause a restriction. Use a three cornered file or a capillary tube cutter to achieve a clean cut.

NB. Measure twice and cut once. Check the diameter as well as the length measurement before you cut the tube.

Installation of the capillary tube

Where possible replace the capillary tube in the same place that the old one came from, eg, soft solder the new tube in the same place the old one was, try to make the bends etc, the same as the old one. This way you won't put any unaccounted for restrictions in the system.

Take care when soldering in the capillary tube to the evaporator and the drier, make sure that the silver solder cannot run back up the capillary tube and block it. Allow enough capillary tube inside the evaporator and the drier but
be careful inside the drier, don’t block the tube with the final screen in the drier, or you will have symptoms of a shortage of refrigerant in the system.

Pressure testing

This topic was covered in the module NR03 Refrigerants, if you’re not sure go back and review the topic in that module.

Briefly, always use dry Nitrogen, not only is it an inert and therefore non ozone damaging gas but being dry it helps to soak up any moisture in the system. Always use a pressure regulator for dry nitrogen. Pressure test to the normal running discharge pressures to start and if no leaks are found take the pressure up to a maximum value of 1000 kPa, whichever is the highest value.

You must always have a positive pressure in the system before you try to leak test. It won’t work if you have a negative pressure in the system.

Evacuation and recharging

The normally accepted practice for capillary tube systems is to use the “deep vacuum” method. This consists of connecting a vacuum pump to the system and letting the vacuum pump run for as long as possible.

In NR03 you were taught that the vacuum should be measured at a point as far away as possible from the source of the vacuum, at the metering device was suggested as a possible point for measuring the vacuum. This assumes the vacuum pump was connected to the suction and discharge service valves on the compressor.

In a capillary system there are usually no service valves (other than system access valves eg, Kirby charging valves etc) so it is very difficult to use this method. It is impossible to connect a vacuum measuring device to the inlet or the evaporator, so the single deep vacuum method is preferred, (evacuating to a vacuum of 500 microns).

The length of time the vacuum pump is left on the system is up to the judgement of the mechanic but I feel that it is not possible to have the vacuum pump on the system for too long a time.

When recharging the system, as the capillary tube system is a balanced or critical charge system, the only really accurate way to recharge is by weighing in the charge. This can be accomplished by either of two methods:

• Calibrated Charging Cylinder.

This method requires the mechanic to know the exact refrigerant charge, this amount of refrigerant is then charged into the system, (usually as a bomb or dump charge, preferably into the discharge side of the system).
• Charging by scales.

This method requires the use of scales. These may be the same scales that were used to accurately weigh the amount of charge recovered from the system. If the refrigerant was recovered into a “bag” the exact charge must be known before attempting to recharge the system.

Probably the charging cylinder method is the easiest but requires that the mechanic must carry the charging cylinder with him.

Regardless of which method is used the refrigerant should be charged into the system with extreme care as damage can result.

Remember:

• Blended refrigerants must be charged as a liquid or the mix of the refrigerants could be incorrect. This will lead to poor system performance.

• All refrigerants will burn your skin or eyes.

• Always use adequate safety precautions, eg, gloves and safety glasses.

Return the system to normal operation

After you have measured in the charge (as a liquid) allow time for the refrigerant to “boil off” in the system before you turn on the system. Allow the system to run until it reaches the required temperatures and then check to see the system is running at or below the accepted compressor amps and the system is running at the correct suction and discharge pressures.

Whenever you work on a capillary tube system where you have the refrigerant out of the system, it is a good tradesman like practice to fit a schraeder valve to the high side of the system (provided there is no other method of accessing the high side of the system). This way you can measure what is happening to the system with a degree of accuracy.
Practical exercise 1 - Capillary tube replacement

Task
Remove and replace the capillary tube in a specified system.

Equipment
- 1 x Refrigeration hand tools
- 1 x Capillary tube
- 1 x Capillary tube gauge
- 1 x Three cornered file or capillary tube cutter
- 1 x Solder in drier
- 1 x Silver solder and flux
- 1 x Oxy acetylene set
- 1 x Oxy acetylene tray
- 1 x Dry nitrogen cylinder with regulator
- 1 x Refrigeration service gauge set
- 1 x Vacuum pump
- 1 x Leak detector
- 1 x Refrigerant Recovery Unit (or bag)

Remember Safety First!
- Systems may start automatically so make sure you keep fingers, tools, hair, clothing etc. away from rotating machinery.
- Take care when fitting and removing gauges, refrigerants burn as well as being unfriendly to the environment.
- Wear safety glasses at all times.

Procedure
In the workshop you are to:

1. Recover the refrigerant in the system, using the approved method.
2. Carefully remove the existing capillary tube, take extreme care when unsoldering the tube from:
   - the drier,
   - the evaporator,
   - the suction line heat exchanger,

   The capillary tube will be very fragile, it will break easily.

   Remove the old filter/drier, but note how it was positioned in the system, the replacement will need to be installed in the same position, otherwise it may hold some of the refrigerant in the drier body and upset the charging process.

3. Measure the existing capillary tube diameter with the capillary tube gauge, then carefully measure the length of the existing tube. You will need both pieces of information to allow you to select a new tube.

4. Select a new length of identical capillary tube or a replacement length of a different diameter/length combination, as directed by your teacher. **Remember**, measure twice and cut once!

   Cut carefully and ensure the ends of the capillary tube are cut cleanly with no burrs or restrictions.

5. Carefully solder the new capillary tube into the evaporator then soft solder the tube to the suction line to act as a heat exchanger. Carefully fit the drier to the condenser outlet (remember different metals, in this case steel to copper, use blue tip silver solder and flux) then solder the drier to the condenser outlet. Fit the capillary tube into the drier body far enough to ensure that solder cannot run up the capillary tube and block the end but not too far so that the capillary tube is pushed into the screen at the end of the desiccant in the drier. Solder in the drier. Remove the flux from the drier to condenser joint.

6. Using dry nitrogen pressure test the system. Start the pressure test at the normal running high side pressure, if OK raise the pressure to 1000 kPa and retest. If still no leaks **great work!**

   If you do have a leak, no worries, just let the nitrogen out, and re-solder the offending joint. Re-test with the dry nitrogen.

7. Evacuate the system to at least 500 microns of vacuum. While this is happening find out the amount of refrigerant that has to be recharged into the system and have the refrigerant waiting in the charging cylinder.

8. After you are satisfied that the system is holding the vacuum (isolate the system from the vacuum pump using the gauges, turn off the vacuum pump and watch to see if the gauge needles move). Carefully charge the refrigerant into the system as a liquid, preferably through the discharge connection.
Allow time for the refrigerant to boil off to a vapour (this should only take 2 or 3 minutes, depending on the amount of charge, and the temperature of the system.)

Start the system and check the pressures on both the high and low sides of the system.

9. Allow time for the system to come down in temperature and then check with a thermometer.

Some systems will not have a recorded charge as these systems have been built, or modified “on site”, and so it is impossible to charge to an exact charge by weighing. The normally accepted method of charging these systems is to charge in a small amount of refrigerant with the charging cylinder, run the system and check the condition of the suction line coming back from the evaporator. When the system is correctly charged, the suction line will be cold and wet coming out of the cabinet but should be dry, although still cold, at the compressor.

This method of charging is known as the frost-back method: While it is possible to charge by this method, it can be time consuming. Any excess refrigerant charge in the system will need to be removed with a recovery system or recovery bag. Practice will help you to make a fair guess at how much refrigerant a system will need but the best way is to use the charging cylinder.

10. Record the operating conditions of the system below, when it is down to temperature.

<table>
<thead>
<tr>
<th>Refrigerant type</th>
<th>Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space temperature</td>
<td></td>
</tr>
<tr>
<td>Suction pressure</td>
<td></td>
</tr>
<tr>
<td>Discharge line temperature</td>
<td></td>
</tr>
<tr>
<td>Condenser outlet temperature</td>
<td></td>
</tr>
<tr>
<td>Ambient temperature</td>
<td></td>
</tr>
<tr>
<td>Evaporator temperature</td>
<td></td>
</tr>
<tr>
<td>Frost or sweat line location</td>
<td></td>
</tr>
</tbody>
</table>
Review questions

These questions will help you revise what you have learnt in this topic.

1. List five items relevant to electrical testing.
   - 
   - 
   - 
   - 
   - 

2. List three methods used to identify the refrigerant in the system
   - 
   - 
   - 

3. When using the flexible bag recovery method, how full should the bag be before it is considered too full and another bag used?

4. How many times can a flexible bag be used to recover refrigerant?
Review questions

5. If a piercing valve has to be used to remove the refrigerant from a system, can the piercing valve be left on the system as a permanent fixture?

6. When you have to replace a capillary tube in a system, what two measurements must be taken to allow you to determine which capillary tube is an acceptable replacement?

7. Why is the capillary soft soldered to the suction line?

8. What two methods are used to cut capillary tube cleanly?

9. What is the acceptable maximum test pressure for a capillary tube system?
Review questions

10. What is the acceptable method of evacuation for a capillary tube system? Explain the method briefly.

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

11. List and briefly explain the two methods of charging refrigerant into a capillary tube system.

- _______________________________________________________________________
- _______________________________________________________________________
- _______________________________________________________________________
- _______________________________________________________________________

12. Why should blended refrigerants be charged as a liquid?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
Notes
4. Servicing Capillary Tube Systems

Purpose
In this topic you will learn how to correctly and safely service a capillary tube system.

Objectives
At the end of this topic you should be able to:

- commission a capillary tube system
- identify the “normal” operating characteristics of a capillary system
- determine refrigeration faults within a capillary system given symptoms and observations eg, overcharge and undercharge, and high ambient temperatures
- identify and repair refrigeration type faults in capillary tube systems
- use the appropriate test equipment and test procedures to make safe, isolate/replace and re-energise electrical components
- diagnose faulty components in capillary tube refrigeration systems and select from manufacturers catalogues correct or replacement components

Content
- Commissioning a Capillary Tube System
- Identification of Normal Operating Characteristics of a Capillary System
  - System Design
  - Refrigerant
  - Application
  - Ambient Conditions
  - Intended Use of the System
- Normal Operating Conditions
- Determining Refrigerant Faults
  - Overcharge
- Undercharge
- High Ambient Temperatures

- Typical Complaints Resulting from Improper Capillary Tube Applications
Commissioning a capillary tube system

Due to the basic simplicity of these systems there is not a lot of commissioning needed, other than the standard procedure of test running the system. There is though a case for a general check over before turning on.

This general check over should consist of:

- a check of the electrical connections for possible loose joints
- a check of the refrigeration system, especially the condenser, for damage or obstructions to the free flow of air over the condenser
- a check to ensure that all packing has been removed from around the compressor, and/or the fan(s)
- a check of the refrigerant charge with the system running and whether the evaporator is working across its entire surface
- a check of the condensate drainage arrangements to ensure free flow of condensate away from the unit
- instruction to the customer as to the operating sequence of the unit
- re-assurance to the customer that advice/service is only a phone call away.

Identification of "NORMAL" operating characteristics of a capillary system

As has been said before, the "normal" operating characteristics of a capillary tube system depend on a large number of variables:

- System design
- Refrigerant
- Application of the system
- Ambient conditions
- Intended use of the system

1. System design

The system must be designed for the job/application intended. It is no use designing a system to cope with one set of storage conditions and then when installed expect the system to operate within a different set of conditions.
2. Refrigerant

The capillary tube system is designed to work at optimum conditions as designed and built. It does not take too kindly to change and it is very difficult to determine whether the system is really working 100% efficient in the field without some fairly sophisticated test equipment.

Given this factor it is often considered uneconomic to retrofit capillary tube systems to another refrigerant from the original. The cost of the retrofit along with the problems associated with optimising the performance usually rules out the process.

However, if the system has been specially designed for the application and has a lot of its working life left, it may be worthwhile to consider a retrofit process. Most refrigeration mechanics would probably take the easy way out and opt for a "drop in" refrigerant and hope for the best.

3. Application

Basically, if the system is designed to keep the product at a specific set of conditions, it is useless (and probably fairly stupid) to expect the system to automatically adapt to a different set of conditions.

For example, when I was contracting, I was asked by a customer to change a domestic upright freezer to a beer fridge. His reckoning was that if the unit would run as a freezer on a 18 hour a day running cycle it would run as a refrigerator but on a much shorter run cycle.

I must admit I laughed at him, much to his anger, so he went ahead and found another refrigeration company to change the thermostat and set the freezer up to run at 4° C. I think he froze 48 bottles of his home brew before he rang me and asked what he could do. He was very angry when I laughed at his plight. He solved his own problems when he bought another refrigerator for his beer.

The moral of the story - use the system as it was originally designed.

4. Ambient Conditions

The system is designed to operate in a set of ambient conditions that takes into consideration most of the climatic variables that the manufacturer can possibly foresee. It is easy to find to problem when a system that is designed for an ambient condition of say 30 ° C is used in an ambient of 40 ° C. The system will not maintain its design temperature and will draw much more power to try to run to design.

We tend to accept that when the ambient temperature goes over the designed the system will run much longer. Normally the extended running time is not even noticed by the average customer.

Incorrectly designed ambient conditions usually are shown up when imported systems are run in Australian conditions. The systems all fall down, they can
not keep up with the load imposed on them, try as they might. It is not possible to fit 26 hours running time into a 24 hour day.

The other application you will often find is that the customer has exceeded the design conditions. For example, the refrigerator is sited in the kitchen up tight against the oven. Excellent for the “work triangle” system of kitchen design, but the poor refrigerator is made to work in an ambient condition that is over the original design parameter. To the credit of the refrigerator manufacturer the refrigerator usually does work and continues to do so with a minimum of fuss, although with a shortened life expectancy.

The refrigerator needs the best possible ventilation around it to enable it to rid itself of the heat the system has picked up from the product. Unfortunately this is not always possible due to the design of the kitchen but you as a mechanic must try to convince the customer that the refrigerator needs fresh air too.

5. Intended use of the system

A system that is designed for domestic use should really be used-for domestic use only. While nearly all capillary tube systems will work in any suitable application, running costs are the give away as to whether the unit is running efficiently.

Like many of the facts that have to be explained to the customer, this one is rather difficult. The customer only sees the unit running well but rarely does he consider the actual life of the unit compared to the intended life span designed in by the manufacturer.

Normal operating conditions

- Probably the best indicator of whether a capillary tube system is running under normal conditions is the compressor motor amps. Most capillary systems run on less than full load amps when the system is operating within the designed conditions.

The pressures shown on a set of gauges will also indicate how the system is running although not as accurately as the amperage drawn. The suction line should be cool/cold coming out of the cabinet when the system is running well.

To determine normal operating conditions it is important to look at the surrounding conditions, ie ambient temperature, conditions of use, etc.

Until you become more familiar with these types of systems always take the time to put thermometers in place and check the running temperatures as well as the pressures in the system. Experience will help you in determining the normal operating conditions for each specific system.
Determining refrigeration faults

Overcharge

This is usually an easy fault to determine as the unit is running with a very cold/iced up suction line. In new equipment it is rare as most of these units are charged by a computer controlled charging station, which rarely makes mistakes. Still it is not a difficult fault to determine so look at each unit just to be sure.

On your gauges it is shown by a higher than normal suction pressure while the discharge pressure may be normal.

Undercharge

This fault is not common in new equipment but in older/used equipment it nearly always indicates a leak in the system. This should immediately ring alarm bells in your mind!!!

The Code of Good Practice states that you should not add refrigerant to a system that you are not 100% sure will not leak. If you are not 100% sure - DO NOT ADD REFRIGERANT!!

If you find a system running short of refrigerant you must recover the existing refrigerant, pressure test the system, repair the leak, evacuate and the recharge the system with refrigerant.

On your gauges an undercharge will show up as a very low suction pressure reading, often into a vacuum, little or no refrigeration effect, and a very hot compressor case. BEWARE you can burn yourself badly on the case.

High ambient temperatures

A common fault, often caused by a lack of preventative maintenance on the part of the owner, by letting the condenser become choked with dust, papers, and any other things that live on the floor.

It can also be caused by poor location of the system in relation to heat generating sources, eg, the refrigerator up tight against the oven, or the refrigerator jammed in the cupboard space with no thought to ventilation for the unit. These problems are not easy ones to fix as the customer often does not have room to put the refrigerator somewhere else where the ventilation is better, or can’t improve the ventilation due to the design of the kitchen cupboards.

This type of fault shows up on your gauges as a high to very high discharge pressure with a high suction pressure. The compressor will also be HOT, TAKE CARE.

You will also find that there is not a lot of refrigeration happening also. After improving the ventilation ( if possible ) you should be able to see the pressures on your gauges falling toward the normal levels.
Typical complaints resulting from improper capillary tube application

A. Insufficient Capacity: Unit runs too much or ice cubes freeze too slowly

1. Evaporator only partly frosted and the cabinet is too warm.
   (a) Low on Charge.
      Correction: - Find and repair leak, evacuate and recharge
   (b) Refrigerant being robbed from the evaporator by liquid backing up in the high side as a result of the capillary tube being too long or having too small a bore.
      Correction: - Replace capillary tube with the correct size.

Tests:
(1) Check condenser temperatures. Liquid back-up in the condenser will be indicated by high discharge temperature, and by the condenser outlet being noticeably cooler than the rest of the condenser.
(2) Turn off the unit for a few minutes and allow the liquid refrigerant in the high side to pass through the capillary tube into the evaporator. Turn on the unit and observe the evaporator. If the evaporator is properly charged, or overcharged at the beginning of the cycle, but becomes undercharged as the unit runs, liquid refrigerant is backing-up in the condenser.

2. Evaporator fully frosted or uniformly cold.
   (a) Unit overcharged.
      Correction: - Remove charge accordingly.

Tests:
Check for suction line frost-back, which indicates overcharge.
(b) Insufficient capillary tube.
   Tube is too short or the bore is too large
   Correction: - Replace capillary with correct size.
(c) Air or other non-condensibles in the system.
   Correction: - Recover, evacuate and recharge.

Tests:
(1) Very high inlet discharge temperature, outlet of condenser noticeably cool.
(2) High wattage.
3. **Rapid cycling**

(a) Liquid traps in the highside and evaporates during the compressor off-cycle, adding hot gas to the evaporator and causing rapid cut-in.

Correction: - Arrange highside to achieve good liquid drainage.

Tests:

Excessive unloading time. Also portions of the highside trapping liquid, may cool noticeably during off-cycle.

B. **No refrigeration.**

1. **Unit runs continuously**

(a) Unit has lost its charge.

Correction: - Repair leaks, evacuate, and re-charge

(b) Capillary tube or inlet screen plugged.

Correction: - Replace accordingly

Tests:

Open refrigerant line in highside with temporary piercing valve: liquid refrigerant should be present at valve outlet.

(c) Moisture in system and the capillary tube freezes up.

Correction: - Replace drier, dehydrate system, and recharge.

Tests:

(1) Refrigerating effect will be intermittent as the ice plug warms up, melts and then refreezes.

(2) Also, turn unit off and allow the evaporator to warm up. Refrigeration will be temporarily restored when the unit is re-started.

2. **Unit cycles on overload protector, or will not run at all**

(a) Same as (b) and (c) above under B. If the capillary tube plugs up, pressure will not balance and the motor may not have sufficient torque to start under the unbalanced pressures experienced.

C. **Noisy operation**

1. **Noisy compressor**

(a) May be operating at excessive discharge pressure due to:

(1) Capillary tube being too long or bore is too small.
Correction: Recover charge, correct capillary problem, leak test, evacuate and charge.

(2) Restriction in capillary tube or inlet screen.
Correction: Recover charge, clear restriction and/or replace filter dries, leak test, evacuate and charge.

(3) Noncondensables in system.
Correction: Recover charge, evaluate and charge with clean refrigerant.

(b) Overcharged system.
Correction: Remove charge according to the Code of Good Practice, until the correct level is attained.

2. **Gurgling sound in condenser during “off” cycle**
   (a) Poor liquid drainage resulting in a percolating action.

3. **Noisy evaporator**
   (a) Vibration of capillary tube at evaporator inlet.
   Correction: Dampen vibration of excess capillary tube by winding it in a tight coil and taping or soldering together.
Practical exercise -Fault diagnosis

Task
Diagnose the faults on the nominated capillary tube systems.

Equipment
- 4 x Capillary system fitted with different faults
- Refrigeration hand tools
- Digital thermometer
- Electrical test equipment

Remember Safety First!
- Systems may start automatically so make sure you keep fingers, tools, hair, clothing etc. away from rotating machinery.
- Take care when fitting and removing gauges, refrigerants burn as well as being unfriendly to the environment.
- Wear safety glasses at all times.
- When testing electrical components make sure you are concentrating on the job in hand.
- Always use test equipment that gives a definite answer eg, test lamps or combicheck.

Procedures
1. Your teacher will have installed faults on a number of different capillary systems.
2. You should by now be able to begin the fault finding process without too much guidance from your teacher so the steps in the procedure have purposely been left out.

You may find it helpful to “map” out your method of fault finding on paper, writing down what you have tested and the results you obtained from your tests. For example:

Is the unit safe to plug in? (Meggar test)
Can gauges be fitted to both sides of the system?
Does the unit run?
Does it refrigerate?
Does it make funny noises?
Does it have any obvious refrigerant leaks? (Oil traces)

Are the condenser and evaporator working?

By now you are on your way. Remember test often and test everything until you reach the answer, assume nothing. If you have not tested the component you cannot decide if it is good or bad.

3. Record the step you take, the symptoms and the fault for each system.
4. Ask your teacher to check your results.

Unit 1

(a) Type of systems

(b) Fault finding steps

(c) Symptoms

(d) Fault
Unit 2
(a) Type of systems 
(b) Fault finding steps

(c) Symptoms

(d) Fault

Unit 3
(a) Type of systems
(b) Fault finding steps
(c) Symptoms

(d) Fault

Unit 4

(a) Type of systems

(b) Fault finding steps

(c) Symptoms

(d) Fault
Review questions

*These questions will help you revise what you have learnt in this topic.*

1. List **five** items that you should check when commissioning a capillary tube system.

   - 
   - 
   - 
   - 
   - 

2. List **four** variables that "normal" operation of a capillary tube system depends upon.

   - 
   - 
   - 
   - 

3. Can a capillary tube system run efficiently on a different set of conditions from the set for which it was designed? Briefly explain your answer.

   - 
   - 
   - 
   - 

Review questions

4. Generally, why is it uneconomic to retrofit a capillary tube system?

5. If the ambient conditions are above the designed set of ambient conditions for a capillary tube system, what effect would this have on the running time?

6. Is it a sensible decision on the part of the owner, to expect a capillary tube system that is designed to maintain an evaporator temperature of -5°C to run at an evaporator temperature of -25°C? Briefly explain your answer.

7. What is the standard symptom for an overcharged capillary tube system?
Review questions

8. Bearing in mind the Code of Good Practice, how do remedy the overcharged system problem in the above question?

9. What is the standard symptom for an undercharged capillary tube system?

10. Bearing in mind the Code of Good Practice, how do remedy the undercharged system problem in the above question?

11. What is the common fault that leads to a capillary tube system running in a high ambient set of conditions?
12. If a capillary tube system is running in a high ambient set of conditions why will the compressor be hot?