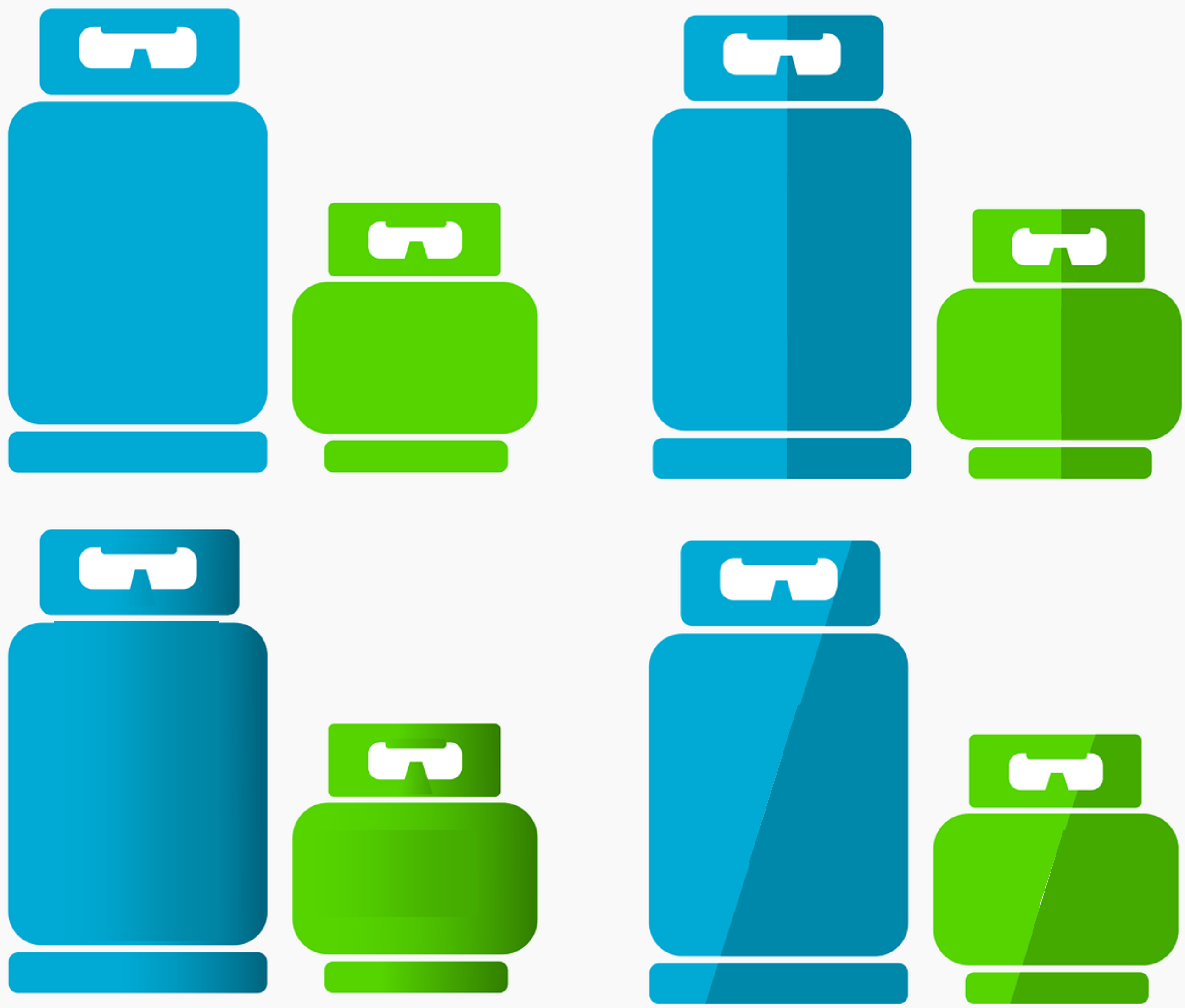

Resource and Study Guide

Refrigerant Management

Partnership of AHRI & UNEP

July 2019

The Refrigerant Management Resource and Study Guide is presented in partnership by the following organizations:

AIR-CONDITIONING, HEATING, & REFRIGERATION INSTITUTE

we make life better®

UN environment

United Nations Environment Programme

About the Resource and Study Guide

RDL Certification

The Refrigerant Driving License: Small Applications certification exam covers best practices for refrigerant management for many different types of refrigerants. This study guide focuses specifically on refrigerant management and should not be treated as the sole source of preparation for the entire RDL: Small Applications certification exam.

The Competency Model

The information contained in this book is based upon a competency model that was developed by a panel of subject matter experts (SMEs) in the HVACR (RAC) profession. These competencies were then validated by a larger pool of professionals from many organizations.

The competency model defines the standards of excellence expected of installation and service technicians in the HVACR (RAC) industry working with refrigerants. Candidates seeking this certification are expected to be experienced HVACR (RAC) technicians, but with limited knowledge of flammable refrigerants. This certification examination is not intended for designers, sales personnel, or engineers.

The experts identified four domains, the major responsibilities of technicians when working with refrigerants:

1. **Fabricating Copper Tubing**
2. **Evacuation & Charging**
3. **Refrigerant Circuit Tools**
4. **Recovery/Recycling Machines**

The tasks associated with successfully carrying out each domain were also identified (see the *Appendix* for the full list of tasks within each domain). Finally, technicians must have knowledge and skills in the following areas to adequately perform the tasks:

- **Codes**
- **Standards**
- **Regulations**
- **Certification and education**
- **Refrigerant types and associated hazards**

- **Life cycle of equipment**

The competency model has its origins in United States (U.S.) regulations, but this study guide and the examination build from the model to address a more global audience. Many of the regulations noted in the competency model have similarities to international rules and standards because the "fundamentals of safe handling practices are based on the science of what will be safe for technicians and building occupants" (McGowan, 2017). While there is no single, international standard on flammable refrigerants, the Montreal Protocol and its Kigali Amendment act as a guiding framework for their introduction as minimally environmentally-harmful refrigerants in 197 participating countries.

Within this guide, various examples of standards and regulations will be provided as illustration where possible. For purposes of examination preparation, candidates should focus on the example that governs their locale. However, because regulations can vary (and change), not only by country, but by different locales within an individual country, the model is not intended to go to the level of detail that may be experienced in day-to-day operations. The examination and resource study guide intend to reflect accepted best practices and the knowledge needed by HVACR (RAC) technicians handling refrigerants regardless of their setting. ***For these reasons, this book should never substitute for manufacturer specific instructions, applicable safety standards, or national, provincial, or local regulations in the actual use of refrigerants.***

While based on the same competency model, this guide and the examination were created independently of each other. That means that while the content of both addresses the same foundation, the content in this guide will not directly teach what is in the test. A certification test measures competence as an experienced professional, not how much information is learned from a single resource. Therefore, this guide is intended neither to teach to the test nor to ensure that someone will pass. It is meant to be a comprehensive study tool that outlines the areas with which technicians should be familiar, reinforces what is already known, and helps test candidates research and learn information with which they may be less familiar. This book should be only one resource used in examination preparation.

The competency model domains are reorganized in the book to facilitate instruction (as are some tasks). The first chapter covers fabricating copper tubing. The second chapter discusses evacuation and charging of refrigerants, followed by chapters covering tools and recovery/recycling machines.

Each of the tasks statements appears as a chapter subheading. Some tasks are interconnected to one another (e.g., related steps in a process) and require no additional content within the subheading to describe them. All tasks statements are in a larger, blue font for ease in identification. While the examination does not test to the task level, meaning there may not be a test item that relates to every task, familiarity with each task improves a candidate's preparedness.

HVACR (RAC) SMEs helped create this resource and study guide. In addition to their expertise, research was done using international resources, such as reputable articles, fact sheets, websites, and books. These resources are listed at the end of this guide.

Why obtain the Refrigerant Driving License: Small Applications Certification?

Chlorofluorocarbons (CFCs) and hydrofluorocarbons (HCFCs) have already been or are slated to be phased out of use across the globe. Many of the newer replacement refrigerants to be phased in operate at much higher pressures or are more flammable or toxic. Equipment that operates with such refrigerants requires a significantly different approach in terms of design, installation, servicing, and operation to address the changes in safety requirements. HVACR (RAC) servicing technicians need to have the necessary skills for the safe management of all refrigerants and the equipment whose function depends on them. This certification is an important step toward that outcome.

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Fabricating Copper Tubing

Fabricating copper tubing is an important aspect of refrigerant management. Copper tubes carry refrigerant through the refrigeration system and can be a source of leaks if not properly used. Copper tubes should never carry ammonia because the two substances chemically react.

Locating, mounting, and routing refrigerant line installation

All refrigerant lines should be located and mounted according to the equipment manufacturer's installation instructions.

Specific design requirements for routing and protection of refrigerant tubing and piping are outlined in the applicable standards and codes.

Understanding limitation of length and diameter for refrigerant line installation

Three refrigerant lines connect the components of the refrigeration system:

1. the discharge line – the smaller of the two lines connected to the compressor,
2. the suction line – the larger of the two lines connected to the compressor
3. the liquid line

Copper tubing designed for refrigeration and air conditioning work is called ACR tubing. It is measured by the outside diameter and is available in various sizes.

Make a proper bend with spring benders for copper tubing

The copper tubing should either be placed within the spring bender or the spring bender should be placed within the copper tubing before bending.

Make a proper bend with cam type benders for copper tubing

The desired dimension should be measured from the end of the tube to the "R" mark on the bender. The total length of the pipe will be the sum of the straight lengths plus the length of the arc that connects them. A tool designed for tubing larger than the tubing you are working with will flatten the tubing.

Cutting, reaming, cleaning, swaging copper tubing

Copper tubing should be cut using a tubing cutter. Tubing that is cut too quickly will pinch the tubing and cause constriction. Burrs should be removed after cutting using a reamer or deburring tool.

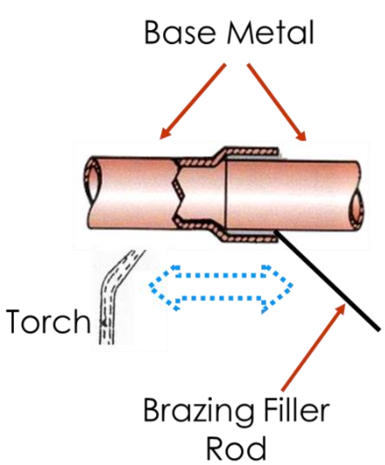
Lightly clean tube ends using sand cloth or nylon abrasive pads. Residue can be removed with a cloth.

Swage joints allow two pieces of copper tubing to be joined by soldering or brazing without using fittings. The swaging tool expands the end of a copper tube so it will fit over the end of a piece of copper tubing of the same size. The depth of the cup on the swage should be equal to the diameter of the pipe being joined.

Overview of brazing copper to copper

Always wear proper personal protective equipment (PPE) while brazing, including safety glasses, protective clothing, and gloves. Clean the copper fittings. Heating the pipe first, approaching a dull red color, and then the fitting. As the copper pipe is heated, it expands and tightens the joint space between the fitting and the copper pipe. The brazing rod can be introduced to the joint once it reaches brazing temperature. When copper pipe becomes “cherry red” it is very near its melting point and is in danger of being burned through.

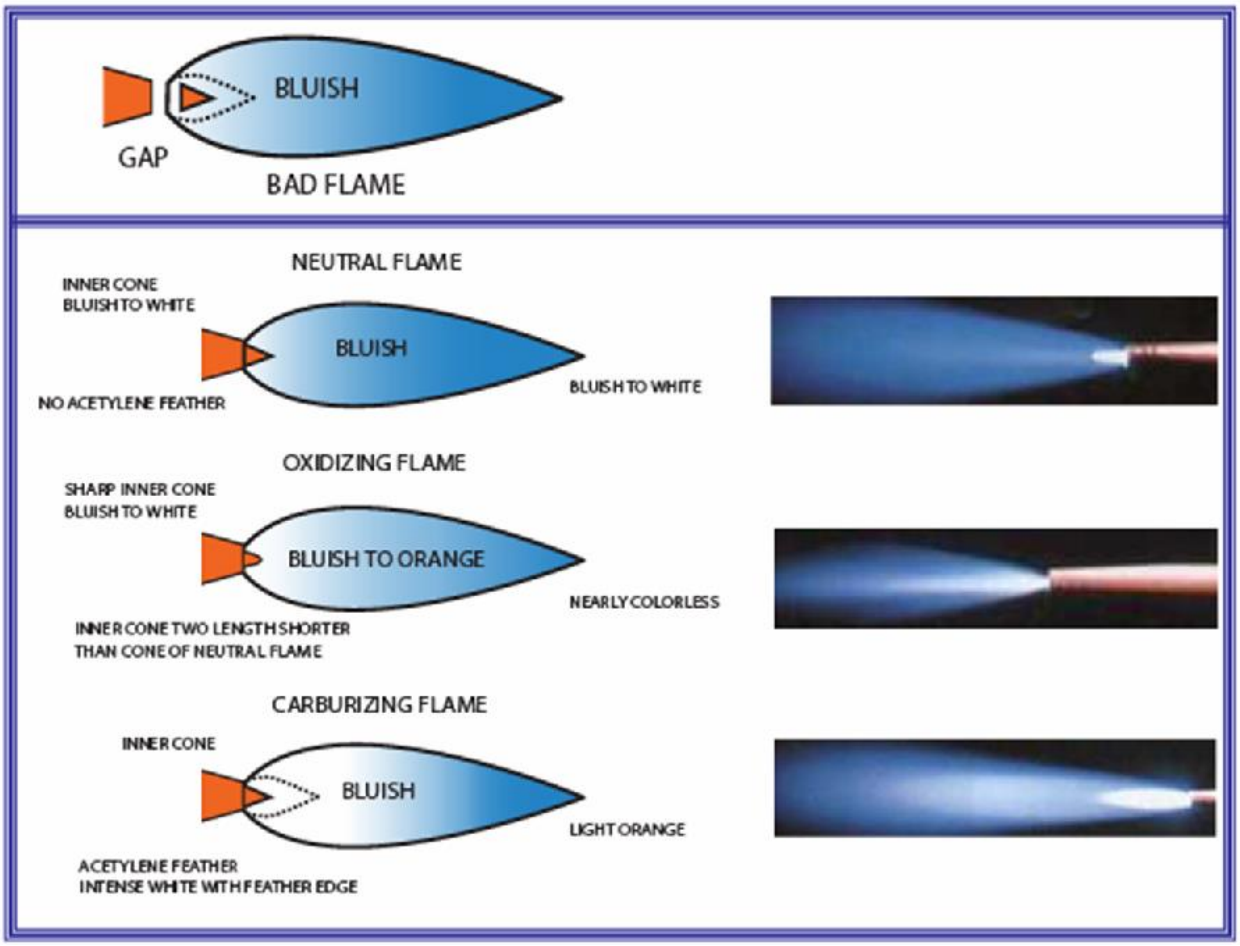
The filler metal from brazing will flow into the joint. Once the gap is filled, move the torch back up above the joint and add a small amount of braze metal until a fillet of metal surrounds the joint.



Oxyacetylene brazing

An oxyacetylene flame is often required to make braze joints in refrigerant systems. The torch requires an acetylene cylinder, an oxygen cylinder, a regulator for each cylinder, and a handle that mixes the two substances. Oxyacetylene torches have changeable tips whose sizes helps determine the temperature of the flame.

It is extremely important that the two hoses and regulators are connected correctly. Incorrectly connecting the components will cause the regulator to explode. Always ignite acetylene first and turn it off last. After igniting the acetylene, add oxygen to produce a neutral flame. Close the oxygen off first when done brazing.

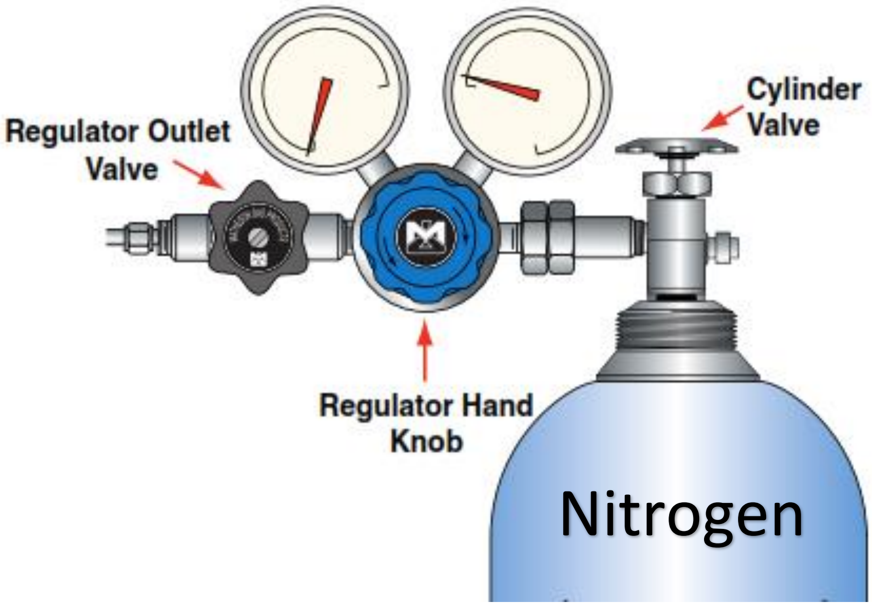


Using air / fuel to solder

Air / fuel torches can be used for soldering and light brazing. The torch is designed for a specific pressure and flame size and the correct adjustment will depend on the tip being used. After properly adjusting the pressure of the fuel, the tip of the torch can be lit. Never use a household lighter to light the torch. The flame should be a quiet blue flame. When done, turn off the tank first and remove the valve key. Then bleed out the remaining gas from the handle and regulator.

Use of purging gas when brazing

Refrigerant lines should be purged with “dry” or “oxygen free” nitrogen during brazing to prevent the formation of copper oxides inside the pipe. Nitrogen must be able to leave the system so that pressure does not build up. Introduce nitrogen at one point in the system and release it at another point.



Overview of brazing copper to brass

Brazing copper to brass is more difficult than brazing copper to copper. A proper brazing rod should be selected for the size and materials of the two metals being brazed. Flux should be used when brazing copper to brass.

Overview of brazing copper to steel

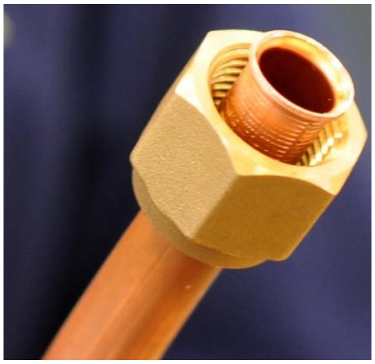
Brazing copper to brass is more difficult than brazing copper to copper. A proper brazing rod should be selected for the size and materials of the two metals being brazed. Flux should be used when brazing copper to steel.

Selection of brazing materials

Brazing materials should be selected according to the brazing application. A variety of torches and brazing rods can be selected depending on the size and materials of the two metals being brazed.

Making a flare fitting - single and double

Flare fittings join soft copper tubing that has been flared. Many different types of flare fittings can be used including flare nuts, ells, tees, caps, plugs, unions, and half unions. A double flare has two thicknesses of metal at the flare face instead of one, which gives the flare more strength. A double-flare adapter is used to make double flares.



Installing with flare fittings

The flared end of the tubing is squeezed between two brass fittings. The tube should be cut square and reamed to ensure removal of burrs. A flaring tool should be used to flare the tubing. The flare fitting can then be applied to the flared tube. Be careful not to overtighten the flare fitting and then check for leaks.

Brazing products - rods, flux, etc.

There are many different types of brazing products. Brazing rods are a mixture of metals used as a filler material. Normally a phosphorus-copper rod with 0 percent silver is used to join copper to copper. Higher silver content rods can also be used for brazing. Flux should be used when brazing metals other than copper-to-copper.

Oxyacetylene brazing equipment

Oxyacetylene brazing equipment includes the use of an acetylene cylinder, an oxygen cylinder, a regulator for each cylinder, and a handle that mixes the two substances.

Gas purging equipment in field brazing

Nitrogen or another inert gas purge must be used during the brazing process to ensure cleanliness. Flowing nitrogen displaces oxygen during the brazing process and prevents oxide formation.

Soldering products – solder, flux, and torches

There are many different types of soldering products. Solder alloy comes in a variety of forms, but typically is an alloy of 95 percent tin and five percent antimony. Flux can also be used when soldering. Soldering torches are typically air-acetylene, air-MAPP, or air-propane. Oxyacetylene torches are not recommended because flame temperature is high.

Tool maintenance and care

Tubing tool should be properly maintained. Check hoses and fittings for wear, leaks, and damage. Check orifices in brazing tips to be sure they are not plugged. Glass covers must be checked to ensure that they are working properly.

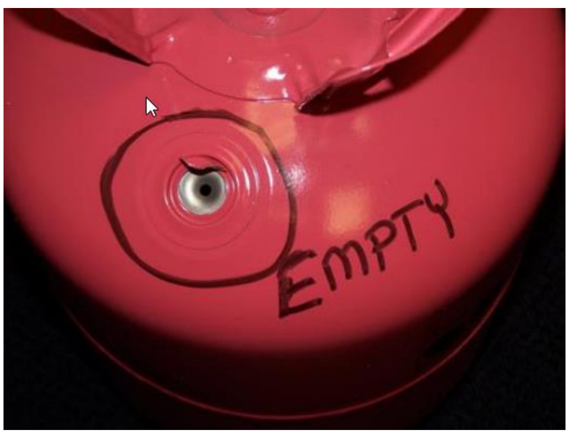
Evacuation & Charging

Introduction

Proper evacuation and charging of the refrigeration system are critical to the operating efficiency and life of the compressor. Evacuation ensures that all noncondensable gasses and water has been removed from the system and limits adverse system reactions. Correctly charging the refrigerant system also improves performance.

Disposal of refrigerant containers

Always follow all local laws and regulations for refrigerant disposal. Non-refillable refrigerant containers should not be used. A cylinder should be emptied of its contents into an appropriate pressure-rated recovery cylinder. For non-refillable cylinders only, open the valve on the cylinder. Verify that the cylinder is empty. For non-flammable refrigerant cylinders, open the rupture disc on the container, circle it, and write empty on the cylinder. The container can now be recycled with other steel recyclables. A non-sparking pick should be used to puncture the side of a flammable refrigerant cylinder.



Empty non-flammable refrigerant cylinder

Empty flammable refrigerant cylinder

Securing refrigerants for transport

During transport, the cylinder must be secured with a chain or rope in an upright position.

Signage and documentation for refrigerants

Always follow all local laws and regulations for refrigerant sign and documentation requirements. Servicing logs should contain information on refrigerants. Disposable cylinders are non-refillable and one use only. Label all cylinders with the contents.

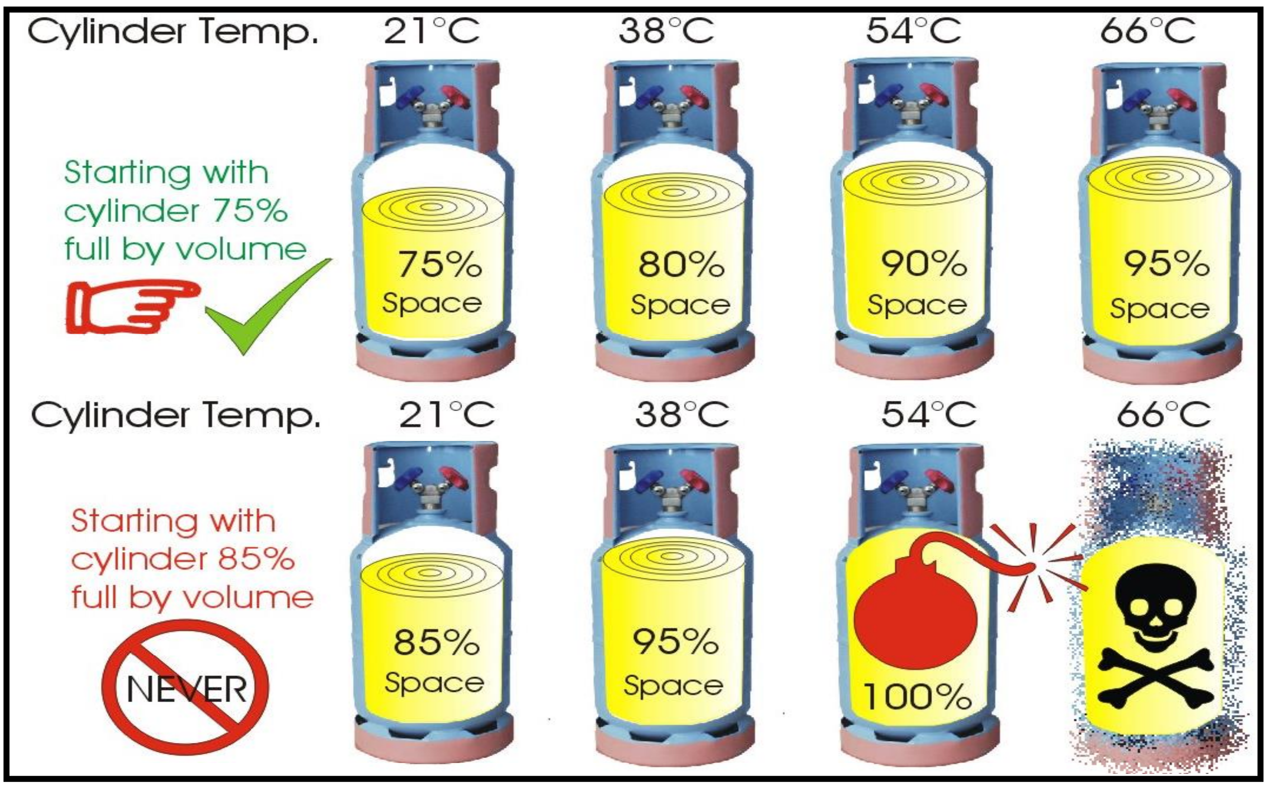
Proper storage of refrigerant containers

Fit the valve cap when the cylinder is not being used. Refrigerant cylinders should not be exposed to high temperatures. Do not modify or repair cylinders or their valves. Always weigh the cylinder to check content amount.

Proper refrigerant container filling

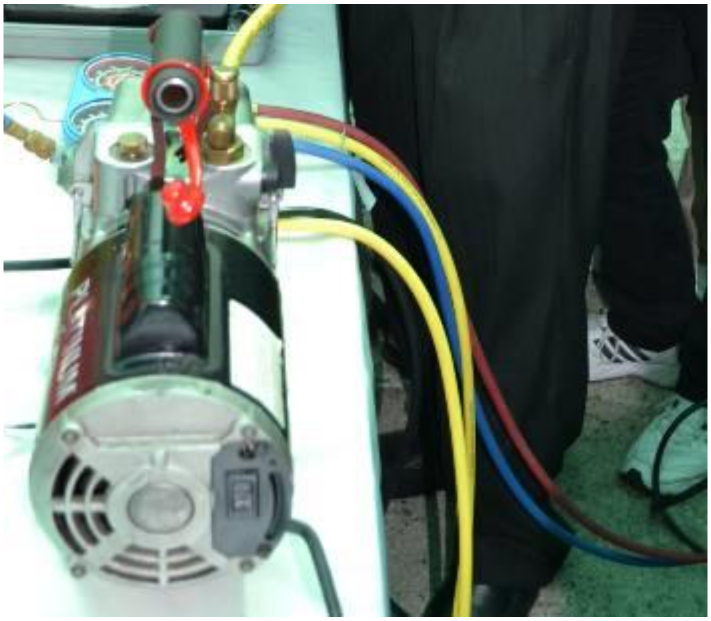
Only fill a recovery or refillable cylinder. Refillable cylinders have a combination valve with separate ports for liquid and vapor and a pressure relief device.

Fill the cylinder up to 80 percent of capacity.



Overview - use of a vacuum pump

Vacuum pumps reduce the pressure of the refrigerant system. The vacuum pump and vacuum gauge, gauge manifold, and connecting hoses can remove the air, noncondensable gasses, and water from a system.

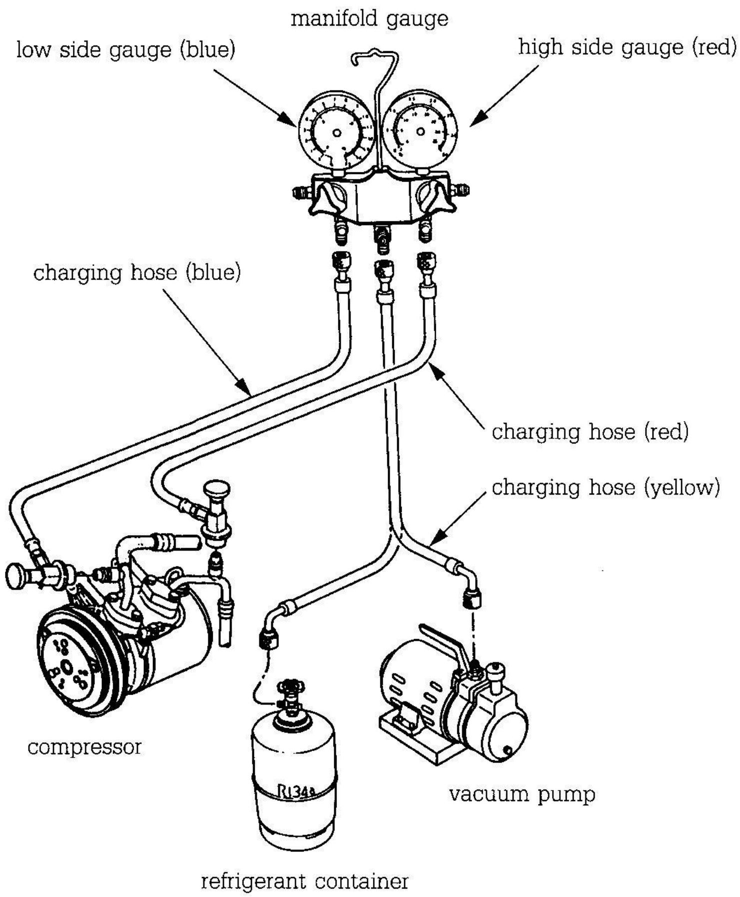


Overview - use of a micron gauge

The micron gauge is used to measure deep vacuums. It measures how much pressure remains within a system and is hooked up to the system to do so. Micron gauges provide a readout on the display that shows the pressure of a system. Evacuating a system to 500 microns or less is considered a good vacuum.

Use of a manifold gauge set in evacuation

The manifold gauge set is used to connect the vacuum pump through the middle port of a standard three port gauge. Some manifolds are designed specifically for evacuation. In any scenario hoses should be kept as short as possible.



Deep single evacuation process

The vacuum gauge can be connected directly to the system and the vacuum pump can be connected to the middle port of a standard three port manifold gauge on systems with three access valves. All refrigerant should be removed before pulling a vacuum. The system should then be simultaneously evacuated from both the high side and the low side. Check the integrity of connections before evacuating the system.

Removing core of access valve

Schrader valve core tools with side can be used to connect both the vacuum hose and the vacuum gauge to a single Schrader valve. Removing the core speeds up evacuation by removing the valve core and reducing restriction. Be sure to use a vacuum-rated core tool to prevent the introduction of air into the system.

Overview of leak checking and detection

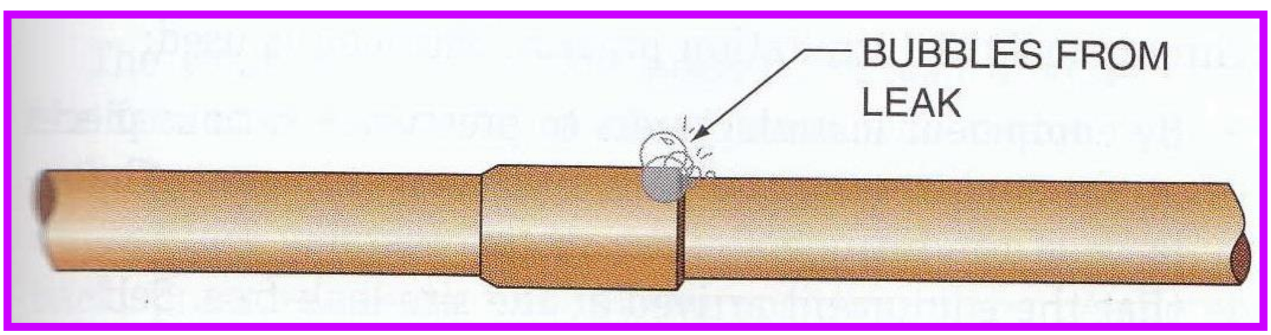
Leak checking and detection should be performed to increase system performance, reduce emissions, and improve safety during servicing. Many different types of leak detectors can be used to measure refrigerant concentration and care should be taken to especially check valves and joints for leaks. HFC leak detectors cannot detect hydrocarbons and are **not** safe for use with flammable refrigerants. Halide leak detectors, for example, should not be used for checking flammable refrigerant leaks.

Leak checking with electronic leak detectors

Electronic leak detectors can detect HCFC, CFC, and HFC gasses. Electronic detectors have a pump that draws air to a sensing tip. The detector will indicate when a leak exists, and visual or auditory signals will increase as the concentration of refrigerant increases.

Leak checking with soap solutions

Soap solutions can be placed on sections of the refrigerant system and the solution will bubble when leaks are detected.



Gas pressurization for leak checking

After servicing, nitrogen can be used to pressurize the system up to 10 bar. Leak detectors can then measure for any leaking nitrogen before refrigerant is introduced into the system. After pressurizing with nitrogen, the system should be vented and evacuated of all nitrogen.

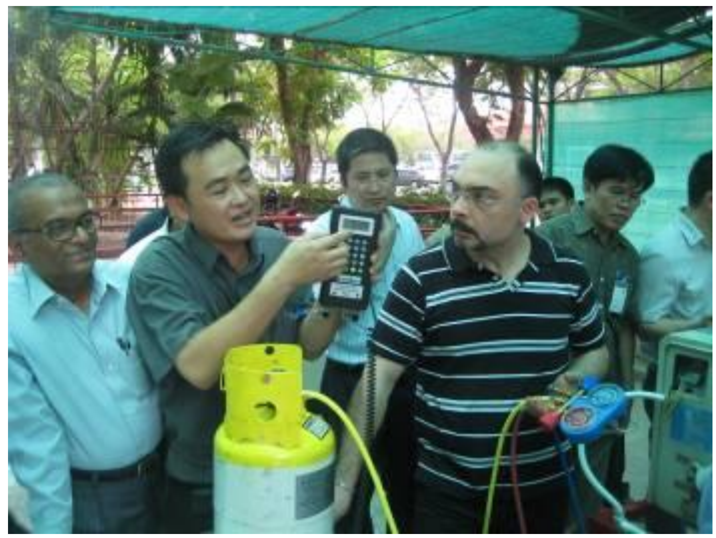
Leak checking with ultrasonic leak detectors

Ultrasonic leak detectors will detect any gas leaking through an orifice because of the sound the refrigerant makes.

Leak checking with ultraviolet leak detectors

Ultraviolet leak detectors will detect a refrigerant that is leaking by recognizing the ultraviolet light spectrum absorbed by the refrigerant.

Weigh in method for charging



Turn the system off, evacuate, and attach manifold gauges to the high and low side with the valves closed. Connect refrigerant cylinder to the middle hose on the manifold gauges and purge the center hose with refrigerant vapor from the cylinder. Invert the cylinder (in the case of a non-refillable cylinder) and zero the scale with the cylinder on it.

Open the high side manifold valve to allow liquid refrigerant into the system. Close the manifold valve after achieving the desired charge.

Charging superheat method and where used

Superheat can be used to very accurately measure the charge for the system. Charging charts give the correct system superheat for any operating condition. Take the suction line temperature and pressure near the compressor to calculate the charge. Compare to the manufacturers recommendation to determine whether to add or remove charge.

Charging subcooling method and where used

Subcooling can be used to check the charge on expansion valve systems. Measure liquid line temperature and pressure leaving the condenser to calculate the charge. Use a pressure-temperature chart to determine the saturation temperature that matches the liquid pressure. Compare to the manufacturers recommendation to determine whether to add or remove charge.

Charging blended refrigerants

Refrigerants that fractionate, mainly zeotropic refrigerants (e.g. R-410A), must be charged as a liquid into the system. The refrigerant needs to be metered carefully by gauge manifold or a charging device.

Refrigerant Circuit Tools

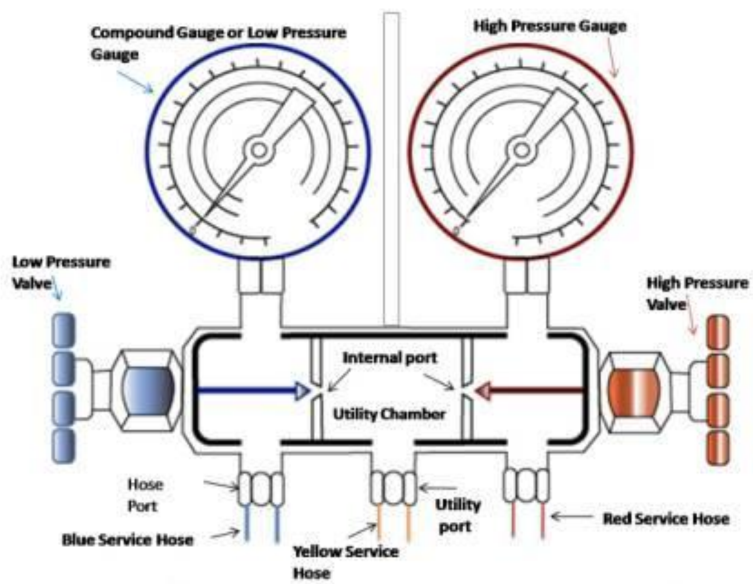
Introduction

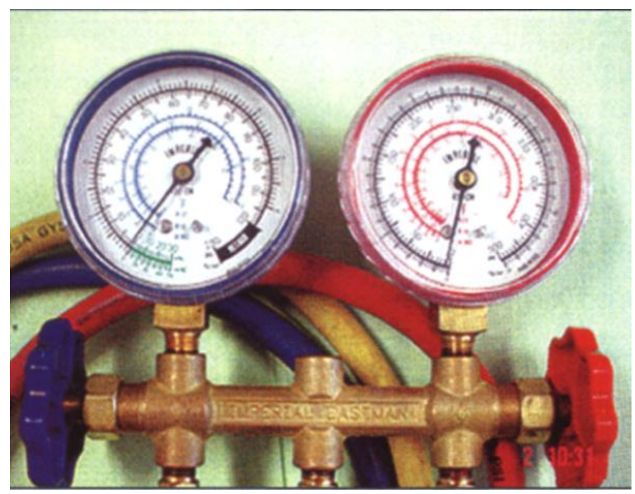
Measuring and testing is the only way to verify correct system installation and operation. System pressures and temperatures are measured to verify system operation. The temperatures and pressures within a refrigeration system are key pieces of information to diagnose refrigeration problems.

Manifold gauge set

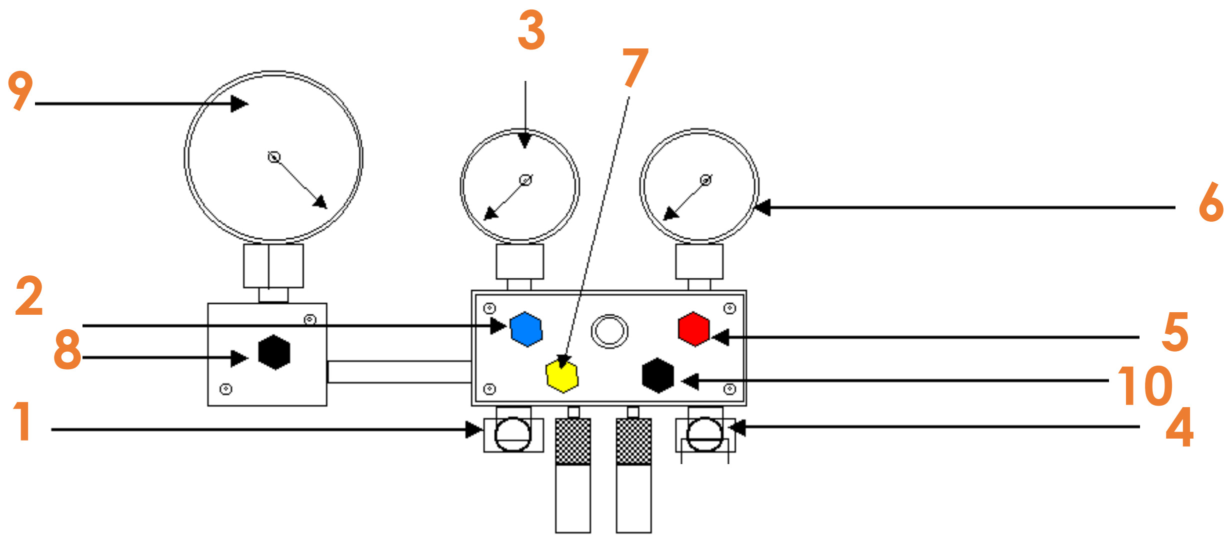
A manifold gauge is a device constructed to hold compound and high-pressure gauges and valves to control flow of fluids through it. It contains a combination of gauges and control valves to control the flow of refrigerant for service applications. Manifolds are available with both three and four hoses and either two or four valves. Refrigerant R-410A requires manifolds rated for its higher pressure.

Gauge Manifold – 2 way





Manifold – 4 way



1 - Low side connection

2 - Low side valve

3 - Low side compound gauge

4 - High side connection

5 - High side valve

6 - High side pressure gauge

7 - Vacuum pump valve

8 - Vacuum gauge isolating valve

9 - Vacuum gauge

10 - Charging valve

The valves do not control the flow of refrigerant to the gauges. Instead, they control the flow of refrigerant to the center port. The low-side gauge will always read pressure whenever the blue hose is connected to pressure. The high-side gauge will always read pressure whenever the red hose is connected to pressure.

The hand wheels that control the valves at the end of the manifold can be set in one of the three positions: fully closed, fully open, or partially opened.

With the low-side valve closed, cracking open the high-side valve will allow some refrigerant to flow from the high-side to the center hose. Fully opening the high-side valve opens the high-side port to the center port to remove refrigerant from the system or for system evacuation.

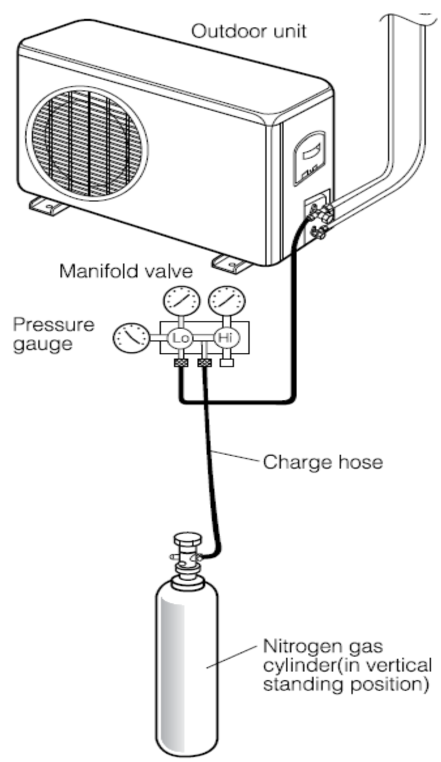
Opening both the low- and high-side valves opens both the low- and high-side ports to the center port. In fact, opening both valves will cause the two pressures to equalize through the manifold, making the readings inaccurate. This valve position is used for system evacuation and recovery.

How to read the gauge set

Refrigeration gauges read system pressure and refrigerant saturation temperature of common refrigerants. The saturation temperature of a refrigerant may be determined by observing the colored scale for that refrigerant.

Digital gauges often have built-in saturation temperature tables for multiple refrigerants, and the refrigerant saturation temperature is displayed by pressing a button on the gauge.

How to connect the gauge set for different purposes



Manifold gauge sets are utilized for the purposes of vacuuming, testing, and recovery.

Evacuation: The utility port (middle chamber) is the place where the hose is connected to the vacuum pump, recovery units, or the port to add or remove refrigerant from AC units.

Testing: Connect the high or low side to pressure to read the system pressure.

Recovery: The recovery machine must properly be connected to the system and the recovery cylinder so that there is minimal refrigerant loss. All the refrigerant must be recovered from the system by switching the unit on/off, monitoring its operation including proper opening/closing valves until full recovery of all refrigerants from the system and hoses is complete and

Types and styles of gauge sets

Two types of gauge sets include gauge sets with four-port manifolds and gauge sets with large-bore manifolds.

Four-Port Manifolds: More advanced gauge manifolds are available that have four hose connections and four shutoff valves. Besides the low-side and high-side connections, there are two center connections, each with its own shutoff valve. Typically, one of the middle connections allows the use of a ⅜-in. hose for faster evacuation. The extra shutoff valves give the technician more control over the flow through the manifold.

Large-Bore Manifolds: Manifolds are available with a larger bore to speed recovery and evacuation.

There are two major groupings of gauge manifold sets. One group is designed to be used with R-12, R-22, R-134a, R-408A, R-407C, and R-404A. The other groups of gauge manifold sets are designed to be used with R-410A. Do not use gauges designed for the lower-pressure refrigerants on the very-high-pressure R-410A system.

Using the gauge set for diagnostics

Diagnostics is the methodical identification of symptoms to identify problems with operating equipment. Many manufacturers provide a list of common symptoms and their most common causes.

A list of fault conditions is typically located in the service manual and frequently on the unit.

When troubleshooting the refrigeration cycle in a system, key performance indicators include the following:

- Low-side pressure
- High-side pressures
- Suction-line temperature
- Discharge-line temperature
- Liquid-line temperature
- Air or water temperature rise across the condenser
- Air or water temperature drop across the evaporator
- Suction-line superheat
- Liquid-line subcooling
- Refrigerant to air delta T (condenser and evaporator)

Low loss fitting connections

A low loss fitting connection is a fitting on the end of a refrigerant hose designed to prevent refrigerant from leaving the hose when it is disconnected from the system.

Vacuum pump

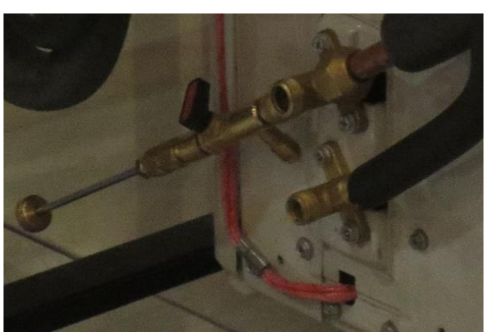
A vacuum pump is a high efficiency vapor pump used for creating deep vacuum in refrigeration systems for testing and/or drying purposes. The purpose of a vacuum pump is to ensure that the refrigeration system has no air, noncondensable gasses, or moisture in it before charging it with refrigerant. The low pressure created by the vacuum pump causes any water droplets in the system to boil to a gas so the water can be removed by the vacuum pump. Vacuum pumps work best when oil is changed frequently.

Micron gauge

The micron gauge measures deep vacuums in microns of mercury absolute pressure, and this is below the level that a compound gauge on a manifold gauge set can display Most manufacturers consider a vacuum level of 500 microns or less the level for a good vacuum. To ensure that refrigeration systems are free of moisture, systems are dehydrated by pulling a deep vacuum on them before they are charged with refrigerant.

Valve opening tools - core removers, etc.

Valve core tools are used to remove the core from Schrader valves without losing refrigerant. They can be used to change a Schrader valve core without recovering the system refrigerant. Using a core removal tool also has the advantage of improving flow through the valve, saving time during evacuation and recovery processes.



There are six steps to connect gauges to a system using a valve core tool:

1. Turn the core remover slowly counterclockwise while feeling for the tool to engage the valve core. Hold the core remover in with the thumb of one hand while turning it slowly with the other until you feel the core click.
2. Let the core remover slide back to the end of the valve.
3. Close the isolation valve and unscrew the end of the core tool.
4. Remove the valve core.
5. Connect the gauge hose to the end of the core tool.
6. Open the isolation valve allowing the gauges to read system pressure.

There are six steps to remove the gauges and put the valve core back in:

1. Close the isolation valve
2. Remove the hose
3. Replace the core
4. Open the isolation valve
5. Screw the valve core back in
6. Remove the valve core tool

Gauge calibration and maintenance

Mechanical gauges, like the ones on a refrigerant manifold set, have a small adjusting screw on the gauge face. The needle moves in the opposite direction of the screw, and turning the screw clockwise moves the needle counterclockwise.

When calibrating the gauge, there are two ways to determine what the needle should read:

1. Adjust the needle to the 0 kPa with the gauge open to atmospheric pressure.
    a. Problem: atmospheric pressure changes. If the needle is just slightly off of 0 kPa, it may simply indicate a change in atmospheric pressure.
2. Attach the gauge to a known pressure source and adjust the needle to point at that pressure.
    a. One possible pressure source is a source attached to a certified pressure gauge, which can be adjusted to ensure that the gauge reads accurately all the way across the scale.

Another way to set the gauge is to attach it to a nearly full new refrigerant cylinder that has a stable measured temperature. Compare the temperature of the refrigerant to a pressure temperature chart to determine the saturation pressure. Then adjust the gauge to read this pressure.

Some digital gauges have calibration buttons that allow the gauge to be set to either atmospheric pressure or a known pressure. Other digital gauges allow an altitude entry for adjusting psig measurements to the local atmospheric pressure. Many digital gauges do not allow calibration.

Charging scales

A charging scale is a digital scale that measures the weight of refrigerant added or removed from a refrigeration system precisely.

Programmable scales are also available with a built-in solenoid controlled by the scale. They can be set to shut the flow of refrigerant off after a programmed amount of weight change.

Recovery/Recycling Machines

Introduction

The process of recovery includes removing refrigerant from a system and storing it in an external container without cleaning or processing the refrigerant, whereas recycling includes removing refrigerant from a system, processing it using filters and oil separators, and storing it in an external container.

Introduction to recovery machines

Recovered refrigerant has been removed in any condition from an appliance and stored in an external container without necessarily testing or processing it in any way. Follow all local laws and regulations for recovered refrigerant.

Types and styles of recovery machines

Recovery equipment is classified as either system dependent or self-contained.

System-dependent recovery equipment depends on the system from which the refrigerant is being recovered to help remove the refrigerant.

Self-contained recovery equipment does not rely on the system because the recovery equipment has its own means of moving the refrigerant, typically a compressor. These devices are usually small, specialized condensing units with a compressor, a condenser, and valves that are used to control the refrigerant flow in and out of the recovery machine.

Typical recovery procedures

If possible, operate the system before beginning refrigerant recovery (system should be off during recovery), use large-diameter, short-length hoses, and recover liquid first. Begin recovery at the lowest available access point.

Heat the system from which refrigerant is being recovered and cool the cylinder the refrigerant is going into.

Recover from both sides of the system during vapor recovery.

There are a few different recovery procedures:

- Push-Pull Recovery
- Liquid Recovery Without Push-Pull
- Vapor Refrigerant Recovery

- Very-High-Pressure Recovery

Recovery machine maintenance and cylinder maintenance

Non-refillable cylinders should not be used for refrigerant recovery. Recovery cylinders are normally available in different water capacities. Store recovery machines and cylinders appropriately.

Introduction to recycling machines

Recycled refrigerant has been removed from an appliance and cleaned for reuse without meeting all of the requirements for reclamation. In general, recycled refrigerant is refrigerant that is cleaned using oil separation and single or multiple passes through replaceable-core filter driers, which reduce moisture, acidity, and particulate matter. Although recycled refrigerant is safer than recovered refrigerant, it has the same basic restrictions. It may not be removed from one owner's system and then charged into a system owned by someone else, but it may be charged into the system it came from or another system of the same owner.

Types and styles of recycling machines

There are four types of recycling machines:

- Refrigerant Recovery Equipment. A piece of self-contained or system-dependent equipment capable of removing refrigerant, in any condition, from a system and storing it in an external container.
- Refrigerant Recycling Equipment. A piece of self-contained equipment capable of reducing contaminants in used refrigerants by separating oil, removing noncondensable gasses, and reducing moisture, acidity, and particulate matter to the levels prescribed in Industry Recycling Guideline..
- Refrigerant Recovery and Recycling Equipment. A piece of self-contained equipment capable of refrigerant recovery and recycling functions as noted above.
- System Dependent Equipment. Refrigerant recovery equipment which requires for its operation the assistance of components contained in an air-conditioning or refrigeration system.

Typical recycling procedures

Follow manufacturer instructions for any recycling machine. Contaminants are reduced by separating oil, removing noncondensable gasses, and moisture, acidity, and particulate matter. Recycling machines have a recycling flow rate of refrigerant while extracting the refrigerant from a unit and the recovery process is similar to a recovery machine. Recycling machines should be connected to the system depending on the conditions and equipment specifications.

Recycling machine maintenance and cylinder maintenance

Nonrefillable cylinders should not be used for refrigerant recovery and recycling. Follow manufacturer instructions for recycling machine maintenance. Purge the machine after recovery and use an appropriate amount of oil during operation. Inspect filters and replace or clean as needed. Keep all ports and valves clean.

Overview of refrigerant system diagnostics

Problem	Discharge Pressure	Subcooling	Condenser Delta T	Suction Pressure	Superheat	Evaporator Delta T	Compressor Amps
Low flow of evaporator air or water	↓	↑	↓	↓	↓	↑	↓
Dirty evaporator	↓	↑	↓	↓	↓	↑	↓
Liquid-line restriction	↓	↑	↓	↓	↑	↓	↓
Underfeeding expansion device	↓	↑	↓	↓	↑	↓	↓
Undercharge	↓	↓	↓	↓	↑	↓	↓
Low-capacity compressor	↓	↑	↓	↑	↑	↓	↓
Low flow of condenser air or water	↑	↓	↑	↑	↓	↓	↑
Dirty air-cooled condenser	↑	↓	↑	↑	↓	↓	↑
Scaled water-cooled condenser	↑	↓	↓	↑	↓	↓	↑
Overcharge	↑	↑	↓	↑	↓	↓	↑
Overfeeding expansion device	↑	↓	↓	↑	↓	↓	↑

The first thing to check with any refrigeration problem is the flow across the evaporator and condenser. Most refrigeration problems can be solved by establishing a proper flow across both the condenser and evaporator.

Many problems can be identified by looking at the following system performance indicators:

- Low-side pressure
- High-side pressures
- Suction-line temperature
- Discharge-line temperature
- Liquid-line temperature
- Air or water temperature rise across the condenser
- Air or water temperature drop across the evaporator

Four of the most important indicators require a comparison of data:

- Suction-line superheat
- Liquid-line subcooling
- Condenser temperature rise (condenser delta T)
- Evaporator temperature drop (evaporator delta T)

Most manufacturers supply some form of troubleshooting chart in the service manuals for their equipment. These tend to take three general forms: logical troubleshooting flowcharts, lists of common symptoms and causes, and references to fault codes provided by diagnostic LEDs on the system controls.

Using superheat

Superheat is heat energy added to a gas so that the enthalpy is higher than saturated vapor at the same pressure. It includes the heat added to a vapor to raise the sensible temperature of the vapor above its boiling point.

Using subcooling

Subcooling is the lowering of a liquid's temperature below its saturated liquid pressure. Although subcooling accounts for a very small amount of heat compared to the rest of the process, it is still very important because subcooling ensures that the refrigerant entering the metering device is 100 percent liquid. Any pressure drop in the liquid line between the condenser and the metering device will cause a saturated liquid to flash, creating gas bubbles. Bubbles of refrigerant vapor decrease the amount of refrigerant the metering device feeds, reducing the system's operating efficiency.

Analyzing overall refrigerant circuit performance

During the initial visual inspection, try to determine the following:

- Unite model and serial numbers
- Required supply voltage and phase
- Current ratings of motors
- Full load amps (RLA) for compressor motors
- Type of metering device
- Used
- Type of refrigerant in the system
- Condition of the evaporator and condenser coils
- Overall condition of the equipment

It may be necessary to remove panels on the equipment to see everything. A crucial part of the initial inspection is the examination of the evaporator and condenser coils.

Identifying the refrigerant type helps to determine the correct operating pressure when time comes to install a set of service gauges on the system to read its working pressures. Finding the correct supply voltage and whether it is a single-or three-phase system will also help when testing the circuit.

Locating problems based on refrigerant circuit temperatures

Ask pertinent questions about the system, including:

- How old is the unit?
- When was it last repaired, and what was done?
- Has the unit been working OK up until the time of the breakdown?
- Have you noticed any strange sounds or erratic operation lately?

Look for any oily pipes or parts, which is usually a good indication of a refrigerant leak.

Electrical Troubleshooting

Electrical troubleshooting can be divided into two areas: (1) electrically diagnosing controls (switches, relays, and contactors) and (2) electrically diagnosing loads (coils, tan motors, and compressors).

Mechanical Refrigeration Troubleshooting

Troubleshooting the mechanical side of a system involves analyzing or investigating the refrigerant flow either throughout the entire system or through any of the components. This requires being able to determine the refrigerant's pressure and temperature at various locations throughout a system.

When analyzing the entire system, the actual refrigerant conditions at various locations in a system are com-pared to the design conditions of a properly operating system.

Compressor check

Compressor problems can be divided into two groups: mechanical or electrical.

Mechanical defects are problems that affect the operation of the mechanical pump inside the compressor, such as blown valve plates, a broken crankshaft, or worn pistons. These defects will either cause a compressor not to pump any refrigerant or pump to below its rated capacity. Compressor manufacturers will publish a rating chart for each compressor they manufacture. The compressor chart will list the correct amperage draw for the compressor under its various operating conditions.

There are three major electrical defects that will cause a compressor not to operate:

1. The motor windings of the compressor are open, shorted, or grounded.
2. The starting relay or capacitor are defective.
3. The incorrect voltage is applied to a compressor.

To see if a compressor is not pumping adequately, verify that the compressor is electrically energized at start-up, and then measure its amperage draw.

To determine whether a compressor is pumping to its rated capacity, measure the compressor's actual amperage draw and compare this to the amperage draw as stated by the manufacturer. The amperage should be within ±5 percent of the manufacturer's stated value.

To check the condition of the compressor's motor windings, measure the resistance of the windings using a standard ohmmeter. For single-phase compressors, measure the resistance value of both the run and start windings and measure the resistance of each winding to the ground. For three-phase compressors, each of the three windings will need to be checked. If the correct resistance value is measured across its windings, and an OL is measured from the windings to the ground, then the windings are satisfactory.

There is a common scenario in which a compressor may appear to be defective when in fact it is not. A compressor with an internal overload that has overheated will shut down and will not restart until the compressor has cooled.

Incorrect voltage applied to a compressor may cause it to run for a brief time then cycle off on its overload or not start at all. Most compressors are rated with a tolerance of ±10 percent. If the applied voltage is outside these limits or those stated by the manufacturer, it must be corrected before the compressor can be properly diagnosed.

Some typical causes of compressor failure are:

- Liquid returning to the compressor
- High return-gas temperature
- High discharge-gas temperature
- Incorrectly applied voltage to the compressor

TEV's check

TEV or Thermostatic Expansion Valve is a valve operated by temperature and pressure within the evaporator coil. The valve measures the suction line temperature with a refrigerant-filled sensing bulb that installs on the suction line leaving the evaporator.

Filter-drier check


Filter-drier Replacement

The king valve (the three-way service valve at the liquid receiver's outlet that controls liquid refrigerant leaving the receiver) is front-seated while the system is running, which causes all of the refrigerant from the king valve downstream through the compressor to be pumped into the condenser and receiver, so the entire filter drier or drier core can be replaced. This process is often referred to as a pump down.

After a pump down has been completed and after shutting the refrigeration system off, apply a 500-micron vacuum to the pumped-down part of the system before putting the new filter drier into service. Never use a torch when removing a filter drier from a system, always cut the old filter drier out with tube cutters or the like. When installing a new filter drier, an arrow on the filter drier's housing will indicate which direction refrigerant is designed to flow.

Overheating when brazing might scorch the internal filters, drying agents, and other important parts of the dryer. A properly adjusted oxygen/acetylene flame is perfect for this kind of work.

Also, leave one part of the pumped-down section of the refrigerant line open to the atmosphere while brazing the new drier into place.

Troubleshooting

As filters become dirty, the airflow will become restricted, which can lead to increased energy use due to inefficient system operation.

Any restriction or damage to the liquid line from the receiver outlet to the metering device inlet will have symptoms similar to a restricted filter drier. Because the filter drier is located in the liquid line, a restricted filter drier is often referred to as a liquid line restriction.

A sight glass after the filter drier is a good method to tell if the drier is starting to plug because of the refrigerant flash from the added pressure drop in the restricted drier. Filter driers can be purchased with Schrader valves (pressure taps) on their inlets and outlets or just on the inlet. A pressure drop of more than 2 psi measured with the same gauge indicates the drier has started to restrict.

A sight glass right before the thermostatic expansion valve (TXV) will identify if liquid flashing is occurring there. However, just because the sight glass is bubbling doesn't necessarily mean an undercharge, so do not automatically add refrigerant.

A filter drier should be replaced anytime a refrigeration system is opened for service, regardless of refrigerant type. The pressure drop across a filter will increase when the filter is clogged. Always make sure the refrigerant has been recovered or the system pumped down before removing a liquid-line filter drier.

Suction line - oil traps, risers, etc. check

A suction line includes tubing or pipe used to carry refrigerant vapor from the evaporator to the compressor in single function systems or from the reversing valve to the compressor in dual function systems.

Some manufacturers recommend oil traps on vertical risers to ensure oil return up the riser. The oil trap/oil lift is located at the bottom of a riser, and the free oil droplets and oil on the side of the riser are blown upward by the velocity of the refrigerant.

When the vertical rise is over 3 m on either suction or discharge lines, it is recommended that line traps be installed approx. every 6 m so that the storage and lifting of oil can be done in smaller stages.

Liquid line - vertical height, static pressure loss, etc. check

A liquid line is the tube that carries liquid refrigerant from the condenser or liquid receiver to the pressure reducing device.

Liquid lines are critical for pressure loss both from a pressure drop due to pipe size and, in the case of the vertical upflow line, vertical lift of the refrigerant.

Long, large-diameter liquid lines can add a considerable amount of charge to the system. Line lengths that cause the system charge to exceed the maximum charge limit of the compressor should be avoided. Do not arbitrarily change the liquid line size form the original specifications because incorrectly sized liquid lines can seriously reduce system capacity and reduce the equipment life.

Solenoid valves check

A solenoid valve is a flow-control device that stops or allows the flow of a refrigerant in a refrigeration system, and it can be installed in any of the refrigerant lines.

The direction in which a solenoid valve is installed is important to its proper operation. Normally there will be an arrow stamped on the body of the valve to indicate the direction of refrigerant flow. If installed incorrectly, the solenoid will not properly shut down and stop the flow of refrigerant when needed.

Condensate drains check

A cleanout should be provided to allow service.

Check valves

Check valves are used on some larger refrigeration systems to ensure that the refrigerant flows in one direction only. They are located on the discharge line, usually near the compressor. Liquid refrigerant returning to the compressor during the off cycle can seriously harm the compressor on start-up. These valves are also used on systems with two evaporators operating at different temperatures and controlled by a single condensing unit. A check valve is placed in the suction line of the lower temperature evaporator to prevent the suction vapor from the higher temperature evaporator from entering the lower temperature evaporator.

Evaporator and condenser coils check

Ensure that there is not too much ice or condensation on the coils and check the temperature of the coils.

If the superheat value of the refrigerant leaving an evaporator is higher than normal, the evaporator is starved for refrigerant. If the superheat value of the refrigerant is lower than normal, the evaporator is flooded with refrigerant. Finding the reason why the evaporator is either being starved or flooded, however, will require looking at the entire system and analyzing other conditions.

If the evaporator's surface becomes insulated as the result of either being dirty or covered with ice, the amount of heat transfer will be dramatically reduced.

Ice building can occur when the heat load on the evaporator is reduced. As a result, the temperature of the evaporator drops, and an excessive amount of frost and ice accumulates on its surface.

A frozen evaporator coil is a common problem found when troubleshooting freezers. To effectively troubleshoot this problem, defrost the coil by manually initiating the defrost cycle or manually defrosting the coil.

Fixed orifice metering devices/piston check

A metering device controls the flow of refrigerant into the evaporator of a refrigeration system. During correct operation of a fixed orifice metering device, the pressurized fluid passes through a small hole, resulting in a drop in pressure because of the resistance to flow through the hole. Improper sizing can easily lead to flooding or starving the evaporator, both of which may be harmful to the compressor.

Systems using fixed-restriction metering devices do not use liquid receivers. Systems can counteract the problem of refrigerant floodback by using a suction line accumulator at the entrance to the compressor.

Like capillary tubes, fixed orifices can become clogged. Like capillary tubes, a clogged orifice will operate with a low suction pressure, a high superheat, and normal to high subcooling.

Any orifice problem can usually be solved by recovering the refrigerant; installing a new filter drier; replacing the orifice with a new, correctly sized orifice; evacuating the system; and charging the system with clean refrigerant.

Do not try to clean or resize a metering-device orifice by drilling it out. The orifice in a fixed-restriction metering device should never be drilled out. Simply changing the piston takes less time and is much safer for the system.

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Appendix

Refrigerant Driving License: Small Applications Examination Study Plan

When preparing for an exam, it is helpful to have a study plan to identify what areas you need to focus on and to organize your time. Then you can decide what study methods will best help you. If you follow your plan, you are more likely to develop an effective study routine, learn the material, and commit it to memory.

1. Start to plan as soon as you register for the examination to give yourself as much time to study as you need.
2. Begin by reviewing the content areas and decide how confident you feel about each. You may want to look through the study guide to see what information will be covered. Rate each of them using the Table 1.
3. Now you need to make a schedule. Begin by choosing the date you plan to take the exam. Determine how many weeks you have available from the time you registered. You should **not** wait until the last possible minute because unexpected delays could occur. If you are confident with most of the topics (you have a lot of 1s and 2s), then it may take you much less time to prepare for and take the exam. If the information is new (you have a lot of 3s and 4s), take more time to study.
4. Look at your calendar between today's date and the date when you plan to take the exam. For each week, identify all of your important commitments such as work, appointments, and vacation. To be successful, you have to balance studying with the rest of your life, so also include times for relaxing, eating, and sleeping. You should now see some free time that you can use for studying. Some people like to study for half an hour each day, while others might prefer bigger blocks of time on the weekend. Whatever you prefer and your schedule permits, make sure to include breaks for study times that are more than two hours. Write the dates of each week you plan to study in the schedule below (Table 2). Then add the days and hours you have free to study for each week.
5. Decide how many days or weeks you think you will need for studying each content area. Some people like to start with the hardest material first, while others like to start with the easiest topics to build up their confidence. Others like to mix it up. Add the content to the schedule in a way that works best for you.

Table 1.

Domain VI: *Fabricating Copper Tubing*	**Confidence Level 1=very; 2=mostly; 3=somewhat; 4=not at all**
Task 1: Locating, mounting, and routing refrigerant line installation	
Task 2: Understanding limitation of length and diameter for refrigerant line installation	
Task 3: Make a proper bend with spring benders for copper tubing	
Task 4: Overview of brazing copper to copper	
Task 5: Cutting copper tubing	
Task 6: Reaming copper tubing Cleaning copper tubing Swaging copper tubing	
Task 7: Overview of brazing copper to copper	
Task 8: Oxyacetylene brazing	
Task 9: Using air / fuel to solder	
Task 10: Use of purging gas when brazing	
Task 11: Overview of brazing copper to brass	
Task 12: Overview of brazing copper to steel	
Task 13: Selection of brazing materials	
Task 14: Making a flare fitting - single and double	
Task 15: Installing with flare fittings	
Task 16: Brazing products - rods, flux, etc.	
Task 17: Oxyacetylene brazing equipment	

Task 18: Gas purging equipment in field brazing	
Task 19: Soldering products – solder, flux, and torches	
Task 20: Tool maintenance and care	
Domain VII: *Evacuation & Charging*	**Confidence Level 1=very; 2=mostly; 3=somewhat; 4=not at all**
Task 1: Disposal of refrigerant containers	
Task 2: Securing refrigerants for transport	
Task 3: Signage and documentation for refrigerants	
Task 4: Proper storage of refrigerant containers	
Task 5: Proper refrigerant container filling	
Task 6: Overview - use of a vacuum pump	
Task 7: Overview - use of a micron gauge	
Task 8: Use of a manifold gauge set in evacuation	
Task 9: Deep single evacuation process	
Task 10: Removing core of access valve	
Task 11: Overview of leak checking and detection	
Task 12: Leak checking with electronic leak detectors	
Task 13: Leak checking with soap solutions	
Task 14: Gas pressurization for leak checking	
Task 15: Leak checking with ultrasonic leak detectors	
Task 16: Weigh in method for charging	

Task 17: Charging superheat method and where used	
Task 18: Charging subcooling method and where used	
Task 19: Charging blended refrigerants	
Domain VIII: *Refrigerant Circuit Tools*	**Confidence Level 1=very; 2=mostly; 3=somewhat; 4=not at all**
Task 1: Manifold gauge set	
Task 2: How to read the gauge set	
Task 3: How to connect the gauge set for different purposes	
Task 4: Types and styles of gauge sets	
Task 5: Using the gauge set for diagnostics	
Task 6: Low loss fitting connections	
Task 7: Vacuum pump	
Task 8: Micron gauge	
Task 9: Valve opening tools - core removers, etc.	
Task 10: Gauge calibration and maintenance	
Task 11: Charging scales	
Task 12: Gauge calibration and maintenance	
Domain IX: *Recovery/Recycling Machines*	**Confidence Level 1=very; 2=mostly; 3=somewhat; 4=not at all**
Task 1: Introduction to recovery machines	

Task 2: Types and styles of recovery machines	
Task 3: Typical recovery procedures	
Task 4: Recovery machine maintenance and cylinder maintenance	
Task 5: Introduction to recycling machines	
Task 6: Types and styles of recycling machines	
Task 7: Typical recycling procedures	
Task 8: Recycling machine maintenance and cylinder maintenance	
Task 9: Overview of refrigerant system diagnostics	
Task 10: Using superheat	
Task 11: Using subcooling	
Task 12: Analyzing overall refrigerant circuit performance	
Task 13: Locating problems based on refrigerant circuit temperatures	
Task 14: Compressor check	
Task 15: TEV's check	
Task 16: Filter-drier check	
Task 17: Suction line - oil traps, risers, etc. check	
Task 18: Liquid line - vertical height, static pressure loss, etc. check	
Task 19: Solenoid valves check	
Task 20: Condensate drains check	
Task 21: Check valves	
Task 22: Evaporator and condenser coils check	
Task 23: Fixed orifice metering devices / piston check	

Take the Exam

Make sure to check the completed column when you have finished a week of studying because it helps to recognize your success and to keep you motivated for the rest of your studying. You can adjust your schedule if things change but stick with studying regularly. Remind yourself of your goal to get this certificate and how it will be worth the effort you put into it.