Inspection and Maintenance of HVAC Systems

Course 206

PARTICIPANT GUIDE

RAIL CAR TRAINING CONSORTIUM

HVAC Systems

Inspection and Maintenance

Course 206

Participant Guide

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Rail Car Training Consortium

How to Use the Participant Guide

Purpose of the Course

Course 206: Inspection and Maintenance of HVAC Systems provides participants with the essential knowledge and skills in inspecting and maintaining HVAC systems on U.S. transit light and heavy rail cars. This course is organized into four modules:

1. Motors
2. Refrigerant Handling
3. Refrigeration Components
4. Heaters, HVAC and Electronic Controls

Approach of the Book

Each course module begins with an outline, a statement of purpose and objectives, and a list of key terms. The outline will discuss the main topics to be addressed in the module. A list of *key terms* identifies important terminology that will be introduced in this module. *Learning objectives* define the basic skills, knowledge, and abilities course participants should be able to demonstrate to show that they have learned the material presented in the module. *Exercises* are built in throughout the course materials to assist the participants in learning and reviewing key information.

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MODULE 1

Motors

Outline

Purpose and Objectives

The purpose of this module is to provide participants with the knowledge of AC and DC motors used in transit rail car HVAC systems, and the preventive maintenance and inspection tasks related to these motors.

Following the completion of this module, the participant should be able to complete the objectives with an accuracy of 75% or greater:

- Demonstrate knowledge of AC and DC motors used in Transit Rail Car HVAC Systems
- Demonstrate knowledge of inspection and maintenance of AC Motor
- Demonstrate knowledge of inspection and maintenance of DC Motor and Brushes
- Demonstrate knowledge of inspection and maintenance of Motor Coupling
- Demonstrate ability to inspect Motor Overload Device

Key Terms

- Electric Motors
- DC Power
- Single Phase Power (AC)
- Three Phase Power (AC)
- DC Motors
- Armature
- Field Winding
- Brushes
- Commutator
- AC Motors
- Rotor
- Stator
- Thermal Overload Relays

1-1 OVERVIEW

The goal of this module is to ensure every participant has working knowledge and hands-on experience with the inspection and preventive maintenance of motors used in rail car HVACs. Upon completion of this course, the participant should be able to apply their knowledge and demonstrate the ability to inspect and maintain motors used in HVAC units.

1-2 MOTORS IN HVAC

Electric motors (see Figure 1.1) are used to turn the prime movers of air, water, and refrigerant, which are the fans, pumps, and compressors. These motors provide the speed, torque, and horsepower necessary to operate the application. The motor changes one form of energy (electrical) to rotational or linear motion (mechanical).

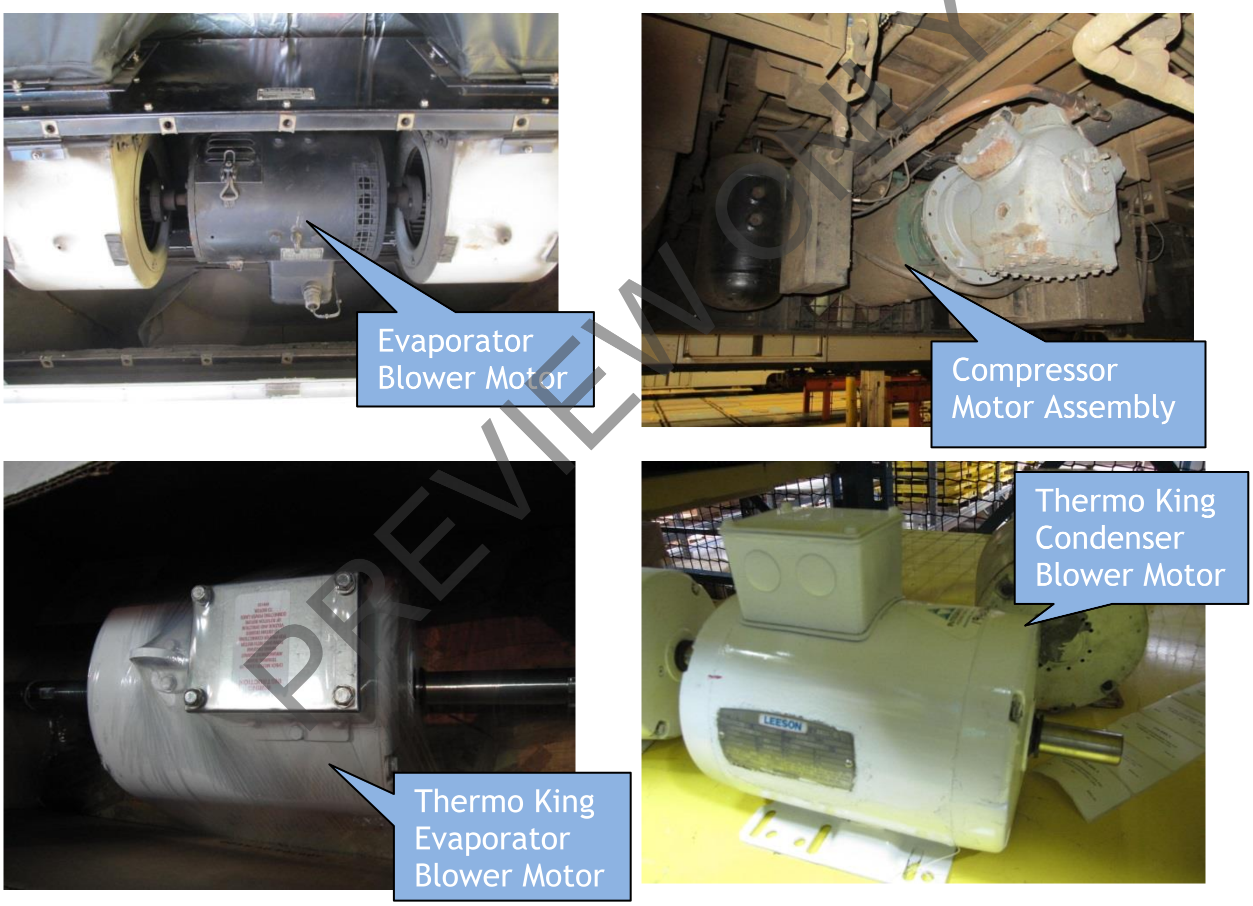

Figure 1.1 Electric Rail Car HVAC Motors (Courtesy of GCRTA & Denver RTD)

AC and DC motors are the two major types in use today that are related to the industrial HVAC applications. In rail car HVAC units, AC motors are generally used in newer equipment. Some systems have retrofitted their motors from DC to AC in recent years. To understand the differences of AC and DC motors, it is important to first review different phases of power.

Basic Guidelines to Motor Control Maintenance

The guidelines below will help you maintain motor controls.

Cleanliness. Blow out dirt regularly according to your system's maintenance schedule. Make sure that dust or contamination is kept off high-voltage equipment. This is important because dust may contain conducting materials that could form unwanted circuit paths, resulting in current leakage or possible grounds or short circuits.

Moving parts inspection. Moving parts should operate easily without excessive friction. Check operation of contactors and relays by hand, feeling for any binding or sticking. Look for loose pins, bolts, or bearings. If the control is dirty, it should be wiped or blown clean.

Contact inspection. Check contacts for pitting and signs of overheating, such as discoloration of metal, charred insulation, or odor. Be sure contact pressure is adequate and the same on all poles; verify with manufacturer's specification. Watch for frayed flexible leads.

Contact resistance testing. On essential controls, perform contact-resistance tests with a low-resistance ohmmeter on a regular basis. Proper contact resistance should be about 50 micro-ohms. Record readings for future comparison. This will indicate trends in the condition of contacts.

Overload relay/circuit breaker inspection. Overload relays that are accessible should receive a thorough inspection and cleaning. You also should check for proper setting. In general, maintenance requirements for these relays include checking that the rating or trip setting takes into account ambient temperature as well as the higher inrush currents of modern, energy-efficient motors. You also should verify that contacts are clean and free from oxidation and that the relay will operate dependably when needed. Relays should be tested periodically if accessible. Special equipment such as an OL relay tester can be used. Some rail HVAC systems (such as Thermo King) does not use serviceable circuit breakers. Specific circuit breakers have built-in overload relays. As you can see from Figure 1.16, the circuit breakers have an adjustment for the overload relay that is factory sealed, but can be adjusted.

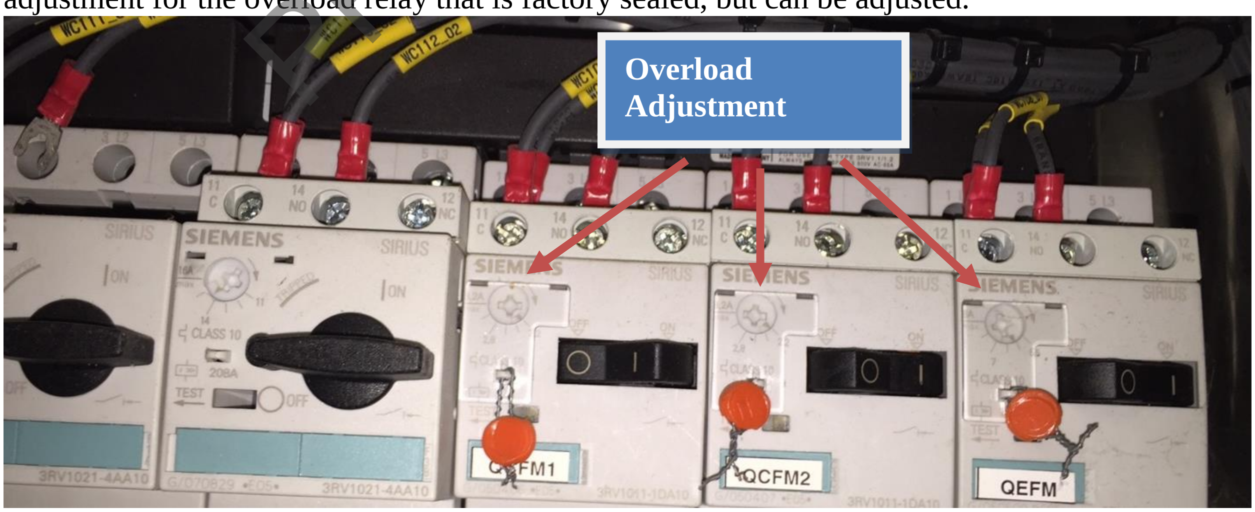

Figure 1.16 Motor Over-temperature Protection – Thermo King Circuit Breaker (Courtesy of CATS)

Once a motor is disassembled, you can test for a short or a ground using an ohmmeter. In this case, an infinite resistance indicates an open, and a resistance of zero indicates a short or a ground.

- **Testing for Shorts and Grounds Using Test Lamps (generally not used on transit properties):** After a motor has been disassembled, you can perform tests to determine which components are faulty. To locate a grounded field winding, disconnect and separate the internal connections between the windings. Position one lamp prod of a test lamp to the housing, and touch each winding lead individually with the other lamp prod. If the test lamp lights, that particular winding is grounded.

Testing Phase Rotation. Before the initial start-up of a large motor, make sure the motor is turning in the proper direction by simple observation or an air flow check. If the meter indicates that the motor is turning in the wrong direction, check to make sure that all connected elements, such as transformers and branch circuits, are connected correctly. If all connections are correct, check the individual phases of the motor. The rotation direction of a three-phase motor can be changed by switching any two of the three supply wires. When a direction change occurs, the source of the phase exchange should be located. It can take place anywhere from the motor connecting taps back through the system to the power distribution grid. It is important to locate the source of the problem so that all three-phase motors within the affected circuit will operate properly.

The phases are purposely rotated when the application calls for reversing motor rotation. For safety reasons, it is common to interchange phases one and three when reversing a three-phase motor.

Classroom Activity 1.2
Listing Motor Electrical Tests

In small groups or pairs, list the various electrical tests that are performed on Rail Car HVAC Motors. Then try to list the proper procedures for each test. Afterwards, *share* with the class – make a note of any key tests or procedures that your group omitted.

1-8 SUMMARY

Module 1 of Course 206 aims to provide participants with an understanding of AC and DC motors used in rail car HVAC units and the routine maintenance procedures for these motors. By the end of this course, participants should be able to describe phases of power, differences and similarities between DC and AC motors, and follow general guidelines for HVAC motor inspection and maintenance.

A disadvantage of this leak detection method is that it can only be used if you have a system that can be shut down for a period of time (usually overnight or longer.) This can be very time consuming because some low-level leaks may require a holding period of up to 48 hours or more. It's not that you have to stay with the system for that period of time, it's just the fact that the system may need to be out of operation for that amount of time.

The advantage, however, is that this method will positively identify whether or not a leak exists by monitoring pressure drop. If any pressure drop occurs, it means a leak is definitely present. The disadvantage is that this method does not identify where the leak exists, only if a leak is present. See Figure 2.21 for an example of pressure test procedures from MBTA.

The following procedures assume that all refrigerant has previously been recovered from the system .

Use dry nitrogen alone for a standing pressure test, or start with a small amount of R-22 if locating a leak.

It is necessary to energize the liquid line solenoid valves.

CAUTION:

UNDER NO CIRCUMSTANCES SHOULD OXYGEN, ATMOSPHERIC AIR OR GAS WHICH IS NOT THOROUGHLY DRY BE INTRODUCED INTO THE SYSTEM.

ALWAYS USE A REGULATOR WITH NITROGEN

- Disconnect all circuit breakers on control panel and energize the solenoid valves with power supply or magnet.
- Connect gauges to access port at refrigeration control panel.
- Charge @ 14 psi R-22 through purge valve if locating a leak.
- Charge 240 psi nitrogen through purge valve using regulator.
- Close purge valve and let the system to remain at this pressure for at least 24 hours. The solenoid valves must remain energized during the whole of this period. Use leak detector if locating a known leak.
- On completion of the leak test, release the gases through the purge valve and the low pressure valve access port , and remove power supply.

Figure 2.21 MBTA Light Rail No 8 HVAC Pressure Test / Leak Detection (Courtesy of MBTA)

Follow your specific transit authority procedures for a standing hold test.

Classroom Activity 2.1

What are your agency's procedures for a standing hold test?

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Isolation of the Sealed System

Classroom Activity 2.3

What are your agency's procedures for refrigeration system evacuation?

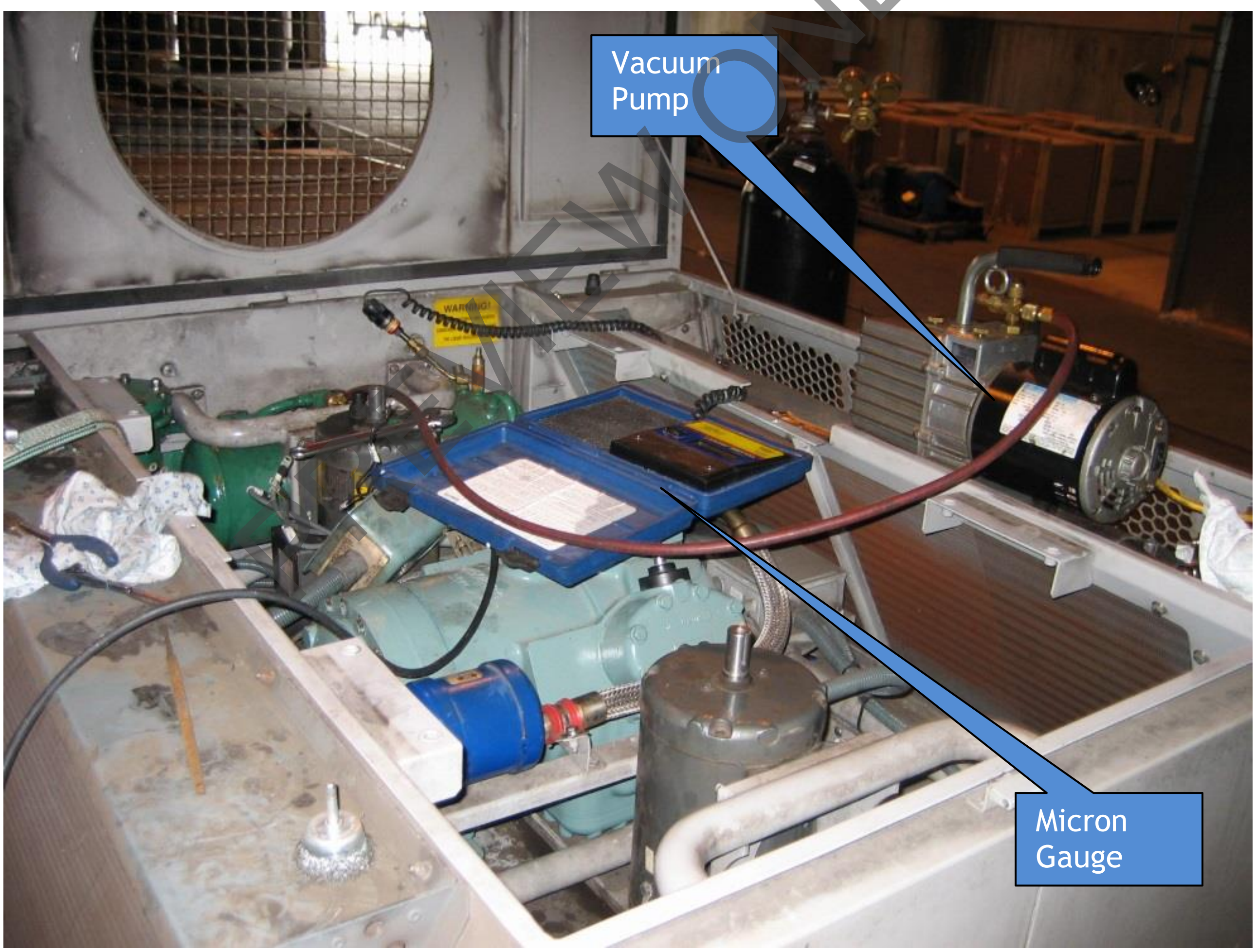

Figure 2.27 MBTA Type 8 Light rail Vehicle HVAC System on Test Stand (Modular System)

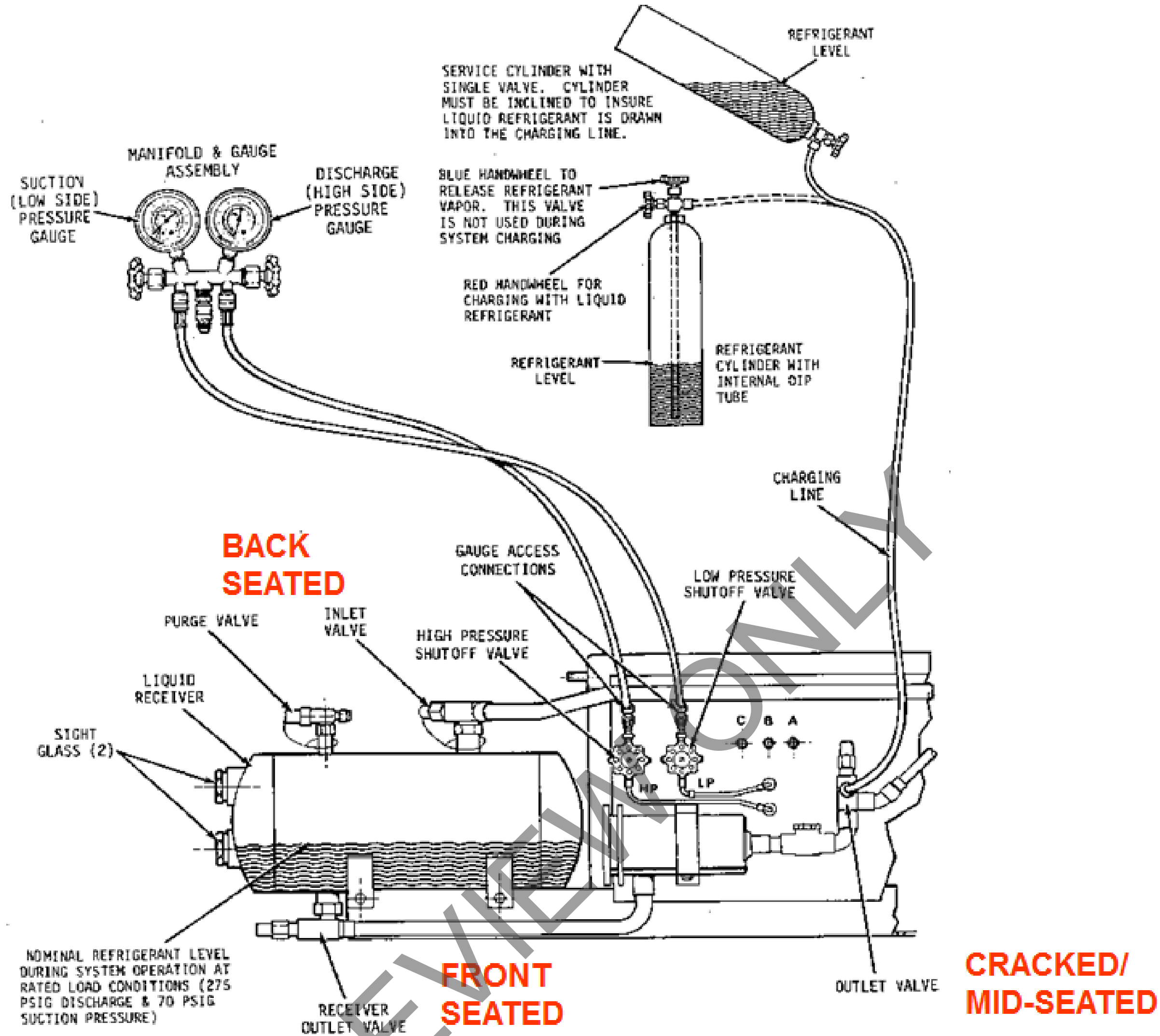

Figure 2.28 System Charge (Courtesy of MBTA)

Classroom Activity 2.4

What are your agency's procedures for refrigeration system charge?

Condensers

Condensers usually use water or air to remove heat from the refrigerant (Figure 3.32). Thus condensers are classified as **air-cooled** or **water-cooled** condensers. A third type, the evaporator condenser, uses both air and water. This is mostly used in industrial refrigeration systems. Condensers used in transportation vehicles generally use air to remove heat from refrigerant.

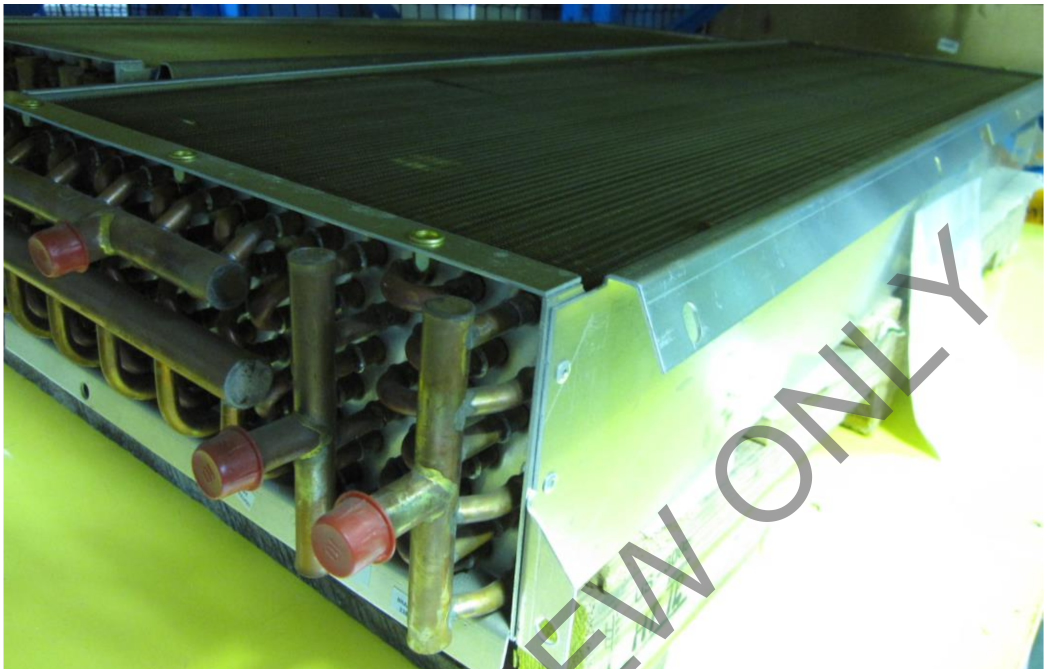

Figure 3.32 Condenser (Courtesy of Denver RTD)

Air-Cooled Condenser

An **air-cooled condenser** is usually a fins-and-tube coil. It looks much like and an evaporator. The refrigerant transfers heat to the tube and condenser condenses inside the tube. Then the heat transfers to the fins; from the fins the air passing over the fins.

Evaporator and Condenser Fins

There are two types of air conditioner fins: evaporator fins and condenser fins. Each performs a similar job of allowing air to flow smoothly through and out of an air conditioner, while each does this in a unique way.

Evaporator fins (Figure 3.33) are located on the evaporator and as it extracts heat from the air the metal fins help with the thermal energy exchange process that occurs with the

Figure 3.33 Thermo King Evaporator (Courtesy of Denver

The unloader mechanism is used on older rail HVAC systems like the one shown in Figure 3.48. The section below explains its operation. Refer to the diagram in Figure 3.49 when you read. An increase in suction pressure, which requires increased compressor capacity, causes needle valve to close. Therefore, the lubrication oil pressure in the power element increases. Increased oil pressure in the power element moves the power piston upward and the suction valve discs are allowed to seat.

Figure 3.48 Typical compressor with unloaders inside an HVAC unit (Courtesy of MBTA)

The capacity control is of the step type in which variation in capacity is obtained by unloading two compressor cylinders in sequence. This is accomplished by holding the suction valve open continuously. The vapor drawn into the cylinder during the suction stroke is thus forced back through the suction valve to the suction manifold instead of being compressed and discharged through the discharge valve. As a result, cylinder capacity is reduced to zero with the minimum use of power. Two of the three cylinders may be unloaded providing 100%, 66-2/3%, and 33-1/3% of full capacity.

Capacity control is automatically obtained in response to suction pressure change. The lubrication oil supply is used to furnish the power to operate the mechanism which is so arranged that in the absence of oil pressure, the cylinder suction valves are held open. This automatically provides for starting the compressor without load.

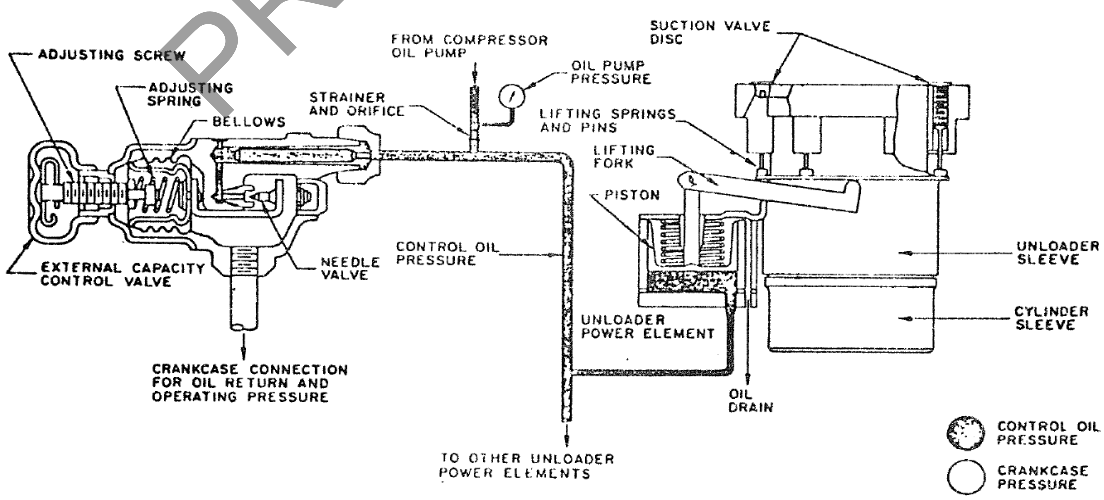

Figure 3.49 Compressor Capacity Control System with Unloaders (Source: GCRTA Breda LRV Running Maintenance Manual)

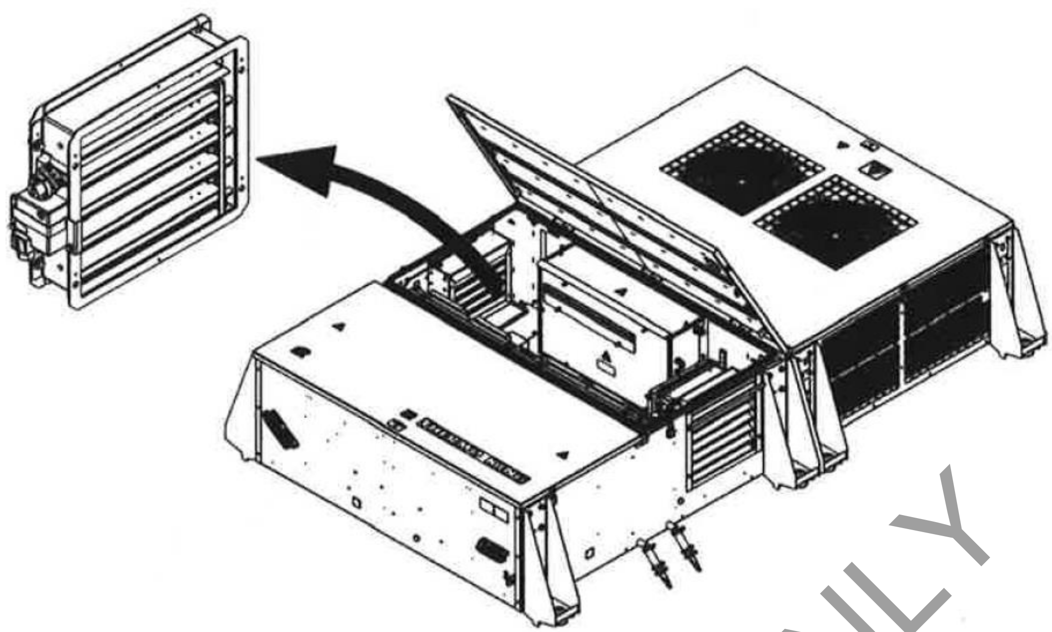

Figure 3.67 Fresh Air Damper (Courtesy of San Diego MTS)

Air Filters

Fresh air coming from the outside will go through the fresh air vent and be filtered before entering any HVAC component. It is much like the air filters used in a residential air-conditioner. It may be a dry-type filter that filters all entering air. Return air filter filters air that recirculates in the rail cars. Air filters are categorized by Minimum Efficiency Reporting Values (MERV) number. The higher the number the smaller molecules it filters. In the winter months, static electricity arcing out onto the carbody frame, or reacting to the carbon dust from the pantograph has been known to cause fires. Adhere to manufacturer's recommendations when selecting air filters. For example, some rail HVAC systems require a MERV 10 rating. The air filter must be kept clean, or pressure will drop, causing excess running times.

Sight Glass

followed: Adjust the torch for a reducing flame (one that contains more fuel gas than oxygen). The flame should be soft enough and large enough to envelop both the tube and fitting.

Start heating the tube about an inch away from the end of the fitting, then shift the heat to the fitting. Sweep the heat steadily back and forth from tube to fitting, with most of the heat being applied to the heavier (and slower to heat) fitting.

Heat the assembly until it reaches brazing temperature. If the part has been fluxed, it will become clear or transparent at this temperature. If you have not used flux, you'll know you're at brazing temperature by the dull red color of the metals being heated.

At this point, pull the flame back a little and apply the filler metal firmly against the tube at the junction of the tube and fitting. If you are using a phosphorus-bearing alloy, lay the rod on and wipe it around the joint, as these alloys tend to flow sluggishly. If the joint has been properly heated, the filler metal will melt, penetrate and completely fill the joint.

After the joint has been completed, make one final pass of the flame at the base of the joint, and even twist the joint if possible, to expel any entrapped gas or flux and to provide maximum wetting by the filler metal.

Once the assembly has reached brazing temperature the filler metal is applied.

A well brazed joint *– Proper alloy flow reaches inside the joint*

Improper alloy flow does not penetrate into the joint and produces a weak bond.

Figure 3.84 Brazing Procedures (Source: achrnews.com)

6. Cleaning the Brazed Joint

Generally speaking, brazed joints in HVAC units require no post braze cleaning operations. However, in the minority of cases where flux has been used, it may be necessary to remove the flux residues after the joint has set. A hot water wash, assisted by brushing or swabbing usually does the job. If necessary, you can remove more stubborn residues with a wire brush.

Some Things to Consider

When you're heating an assembly for brazing, you want to heat the joint area as rapidly and as uniformly as possible. So in those instances where you're joining metals of unequal mass and thickness you'll have to apply some extra heat to the heavier section which heats more slowly. And where you're joining dissimilar metals with differing heat conductivity (copper to steel),

a. Relays

Relays are electrically operated control switches. The schematic symbols used to represent relays are the same as those for manually operated switches, except that relay symbols often include a solenoid coil.

There are several possible ways of depicting the solenoid coil. Figure 4.101 shows two different schematic representations of a DPDT (double-pole, double throw) relay.

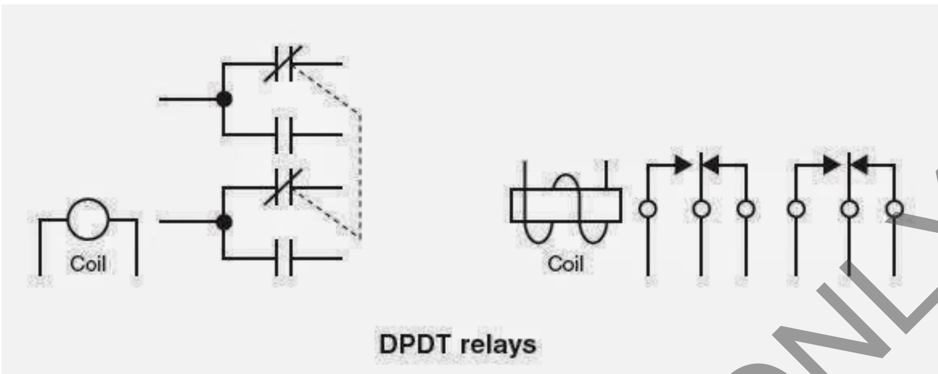

Figure 4.101 Double-Pole Double-Throw Relays (Source: http://www.electrical-knowhow.com/)

Note that multiple-pole relays, like multiple-pole switches, are connected mechanically but not electrically.

b. Contactors

A **contactor** is a type of heavy-duty relay that handles higher voltages and higher currents than a control relay. Contactors appear nearly identical to relays on schematic diagrams.

Some manufacturers employ contactors that use a single set of contacts. A "bus bar" is placed over the connection where the other set would be, as shown in Figure 4.102. Bus bars can also be used to provide power across a series of circuit breakers.

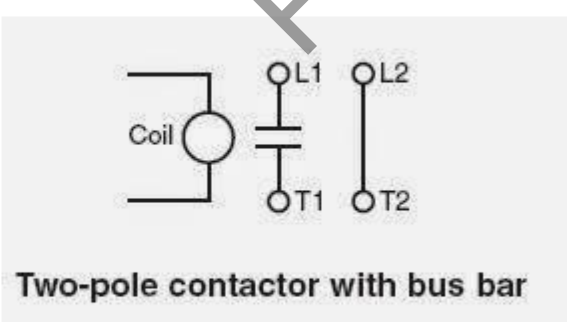

Figure 4.102 Two Pole Contactor with Bus Bar (Source: http://www.electrical-knowhow.com/)

Loads

The unit shifts from Heat Stage 3 to Heat Stage 2, when return air temperature increases by 1.7 K (3.1°F)* below set-point.

The unit remains in Heat Stage 3 as long as the return air temperature remains 4.4 K (7.9°F)* below set-point and 1.7 K (3.1°F)*below set-point.

Heat, Stage 4

During Heat Stage 4, both heaters in LRV unit and both external heaters are energized in addition to Evaporator blower motor.

During heat stage 4 the controller will energize the following:

- Evaporator Fan Motor Contactor
- Stage 1 Heat Contactor
- Stage 2 Heat Contactor
- External Heater Contactor 1
- External Heater Contactor 2

The unit shifts from Heat Stage 4 to Heat Stage 3, when return air temperature increases by 2.8 K (5.0°F)* below set-point.

The unit remains in Heat Stage 4 as long as the return air temperature remains 4.4 K (7.9°F)* below set-point and 2.8 K (5°F)*below set-point.

* This default value is a parameter, can be modified using communication software.

Classroom Activity 4.2
Explaining the HVAC Normal Operating Modes

In small groups or pairs, use the HVAC Operating Modes/Ladder Diagram from your property or Figure 4.2107. Explain each mode and complete Table 4.3 below with parts energized under each mode. The first row is filled out as an example.

Table 4.3 Classroom Activity 2 - Explaining HVAC Operating Modes Worksheet

Explaining HVAC Normal Operating Modes	
Mode	**Components Energized**
Full Cool	• Evaporator Fan Motors Contactor • Condenser Fan Motor Contactors • Liquid Line Solenoid Valve • Compressor Motor Contactors