System Troubleshooting

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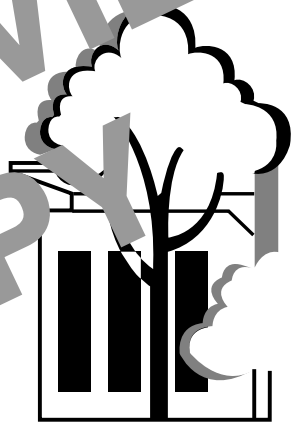
SYSTEM TROUBLESHOOTING

Lesson One

Preparation for Troubleshooting



TPC Training Systems

43901

Lesson

1 Preparation for Troubleshooting

TOPICS

Mechanical Refrigeration Systems
Keys to Effective Troubleshooting
Safety in Troubleshooting
Tools and Equipment
Supplies (Consumables)
Human Relations Skills

OBJECTIVES

After studying this Lesson, you should be able to…

- Give an example of each of the following applications: process refrigeration, commercial refrigeration, process air conditioning, comfort air conditioning.
- Tell what knowledge is essential for an effective troubleshooter to have.
- Tell what safety precautions must be followed when dealing with the mechanical, electrical, chemical, and environmental hazards involved in troubleshooting.
- List the necessary tools, equipment, and supplies needed to perform troubleshooting procedures.
- Explain why human relations skills are important to the refrigeration system troubleshooter.

KEY TECHNICAL TERMS

Gauge manifold set 1.16 device used to analyze system operation by measuring pressures
Vacuum pump 1.19 device used to create a vacuum in a system prior to charging
Multimeter 1.22 volt-ohm-milliammeter

Mechanical refrigeration systems are found nearly everywhere—in industry, commercial establishments, healthcare facilities, offices, recreational facilities, and homes. Some systems are used to ensure product quality, while others ensure human comfort. Whatever the use, keeping the system running efficiently is an important job. No matter how good a preventive maintenance program is, all systems will develop problems at some time. Finding and eliminating these problems requires skill and experience. This Unit will help you develop the needed skills.

Throughout this Unit, we will use the term "refrigeration system" to include commercial and process refrigeration systems as well as the refrigeration portion of air-conditioning systems. This Lesson will focus on the fundamentals of troubleshooting and the tools, supplies, and skills needed for the job. Basic safety considerations are also covered.

Mechanical Refrigeration Systems

1.01 In the United States, the food industry is the largest user of process air-conditioning and refrigeration equipment as well as commercial refrigeration equipment. Food processing plants use a variety of equipment to freeze products. In addition, many foods are stored in refrigerated warehouses. Food stores use refrigerated display cases and large refrigerated storage rooms.

1.02 The chemical and drug industries are also major users of air conditioning and refrigeration. Process air conditioning controls the atmosphere around equipment so that it operates properly. It also keeps germs, dirt, and moisture away from chemicals and drugs that could be ruined by them. Refrigeration cools and preserves drugs and chemicals and controls the speed of chemical reactions. Pharmacies use refrigeration to preserve drugs. Hospitals and medical laboratories use refrigeration to preserve drugs, blood, and medical specimens.

1.03 Process air conditioning keeps assembly areas for electrical products free of dust and controls temperature and humidity. Dust, moisture, and changes in temperature can all affect the accuracy of electrical and electronic parts. In textile mills, temperature and moisture affect the quality of the fabric and the way the fabric goes through the machines. Process air conditioning controls air conditions to ensure quality products.

1.04 You will find comfort air conditioning almost everywhere you go today. Stores, shopping malls, offices, hospitals, schools, homes, and cars have comfort air conditioning. Even some baseball stadiums and amusement parks are completely enclosed and air conditioned for your comfort. Manufacturers are now realizing how important comfort is to the productivity of workers. As a result, more and more manufacturing plants are being air conditioned.

1.05 Although these examples seem quite different, the basic components of a mechanical refrigeration system (evaporator, condenser, compressor, metering device, and thermostat) are very much the same, whether they are being used to keep food fresh or to keep office workers comfortable. At this point, you should be familiar with the names and functions of the basic components of a refrigeration system. Although their basic functions are the same from one system to another, you will find that there are differences in the construction of these components, depending on their application.

Keys to Effective Troubleshooting

1.06 When it comes to troubleshooting a refrigeration or air-conditioning system, the keys are a knowledge of how the system operates, how each component functions in the system, and the effect that the operation of each component has on the others. A problem in one component can cause problems in another. Knowledge of refrigeration theory is also necessary for successful troubleshooting. In addition, because electricity powers and controls most systems, knowledge of electrical principles and practice is essential.

1.07 In addition to component failures, external factors can cause refrigeration system problems and should not be overlooked. These factors include water or air in the system, power supply disruptions, improper operating procedures, weather conditions, and load changes. Several of these factors may exist at any given time. Therefore, it is vital that you have an overall knowledge of system performance.

Safety in Troubleshooting

1.08 Your safety and that of your co-workers is the most important thing to keep in mind. Certain safety situations are unique to refrigeration and air-conditioning troubleshooting, however, and you should be aware of them. Often these involve working in high-risk areas such as on rooftops, in wet basements, and in cramped quarters. For your own safety and protection, always wear proper work clothing and observe all safety rules.

1.09 Make sure you take the time to protect yourself from all possible safety hazards—mechanical, electrical, chemical, and environmental. The safety guidelines given here are only a partial list of common-sense safety precautions you must follow:

- Protect your eyes with safety goggles, like those shown in Fig. 1-1, and protect other parts of your body with the proper protective equipment.
- Do not work on electrical systems unless the power is locked out. A slip of your screwdriver could injure or kill you.
- Never block or jump safety controls.
- Never use oxygen to pressurize a refrigeration system. Oxygen in contact with oil can cause a violent explosion. Use nitrogen instead when leak testing.
- Oil and sludge from a compressor burnout may contain acid. Wear rubber gloves and avoid contact with these materials.
- Do not breathe fumes from a torch-type halide leak detector.
- Do not allow the discharge of fluorocarbon refrigerants into a room where there are open flames. Some refrigerants form a poisonous gas when in contact with a flame.
- Always think safety.

Fig. 1-1. Safety goggles

Tools and Equipment

1.10 One essential element of successful troubleshooting is having the tools and equipment necessary to do the job. Although many of the tools you will need are commonly found in most shops, at times you will need special test instruments and supplies. The following brief inventory should help you prepare for your refrigeration or air-conditioning troubleshooting assignments.

1.11 **Wrenches.** In addition to the open-end and box wrenches found in most mechanics' toolboxes, you might find the flare nut wrench useful around refrigeration equipment. This wrench is a special tool that looks like a combination between an open-end and a box wrench. The open end allows you to fit it over a refrigerant line, and the box shape makes it easy to tighten a fitting without marring the hex nut.

1.12 **Nut driver set.** Along with an assortment of screwdrivers, you should have a set of nut drivers of various sizes. Hex-headed sheet metal screws are commonly used to fasten sheet metal panels and covers, and hex nuts are often found on electrical terminals. With a nut driver, you can install or remove these assemblies rapidly.

1.13 **Torches.** If possible, you should have your own propane torch and oxyfuel welding set. You will

use the propane torch to soft-solder on small jobs, and the oxyfuel torch will be needed for brazing, welding, or silver soldering on larger jobs.

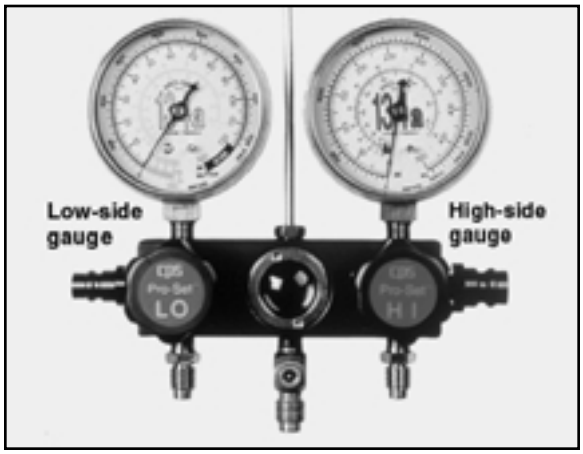
1.14 **Thermometers.** The thermometer is one of the most important and useful test instruments you will use. Thermometers are useful in determining how a system is operating. You should have at least two thermometers of the type that clip onto your shirt pocket. In addition, you should have a very accurate strap-on type for measuring the temperature of hydronic and refrigerant lines. A couple of long-stem, mercury-filled thermometers and a dial-type insertion thermometer are also useful. Make sure these thermometers have a wide enough range for both high- and low-temperature work. For a more accurate analysis, or to substantiate a questionable complaint, you might also want a recording thermometer.

1.15 Thermometers used in refrigeration and air-conditioning work should be accurate to ±0.5˚F. To be useful, they must be properly calibrated and periodically checked. You could make an error if your thermometer is off by one or two degrees. When taking readings, make sure to check a representative sample. Several readings averaged together are usually more accurate than a single reading.

1.16 **Gauge manifold set.** Earlier Lessons in this Course covered various instruments and meters useful for testing and checking refrigeration systems. All of these are useful, but perhaps the most necessary and useful is the gauge manifold set, like the one shown in Fig. 1-2. With this device attached to the service ports, you can analyze system operation by measuring the high- and low-side pressures on your compressor. By using the center port on the gauge manifold set, you can also evacuate and charge the system. A good set will have heavy-duty valves and hoses, and its low-side gauge will read both positive pressures and inches of vacuum.

1.17 This device gives you clues to the inner workings of the system. The gauges must be in good working order, calibrated to read accurately, and checked periodically with a deadweight tester. If no tester is available, attach the gauge to a drum or cylinder of refrigerant that has been stored at a constant temperature for several hours—this will give you quick check. To do this you need to know the type of refrigerant in the drum and have an accurate thermometer and a pressure-temperature chart for that particular refrigerant.

Fig. 1-2. Gauge manifold and service gauges



1.18 When installing gauges, clean off the fittings to keep dirt out of the system. Use the correct tools to remove access caps or plugs. Follow EPA procedures when connecting, disconnecting, and purging the hoses. These procedures were covered in detail in Lesson Six of TPC Unit 432, *Refrigerants and Refrigerant Oils*.

1.19 **Vacuum pump.** Used with a gauge set, the vacuum pump will allow you to draw a vacuum on the system before charging. High-vacuum pumps are generally two-stage models, like the ones shown in Fig. 1-3 on the following page. They can reduce system pressure to 50 microns or lower.

1.20 **Leak detector.** Sometimes a refrigeration system problem stems from a leak in the refrigeration lines or in the heat exchanger coils. To locate these leaks, you will need a leak detector. Although there are several kinds available, an electronic leak detector, like the one shown in Fig. 1-4 on the following page, is useful in nearly every application and has the advantage of being easily carried into the field.

1.21 **Air-balancing instruments.** You will need accurate, reliable airflow instruments to test for and correct air-distribution problems. Lesson Five of TPC Unit 438, *Air-Handling Systems*, explains how to use testing and balancing instruments on an air-delivery system.

Fig. 1-3. Vacuum pumps

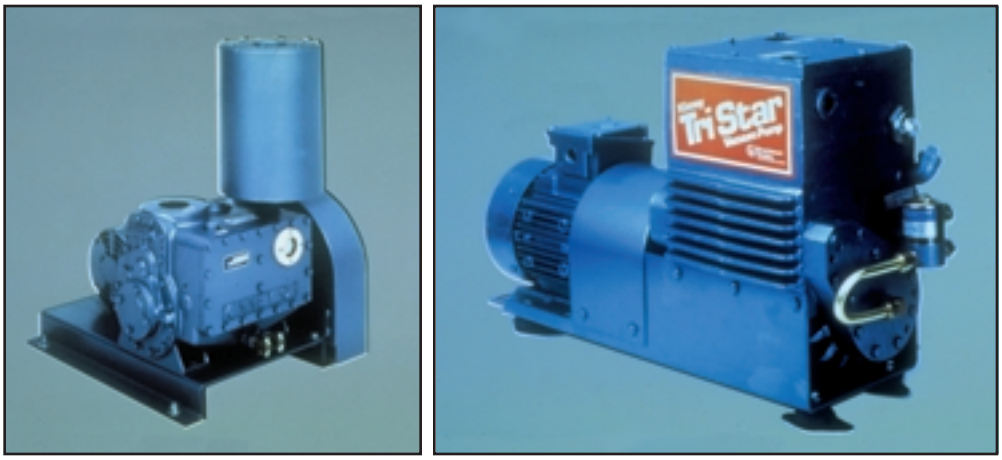
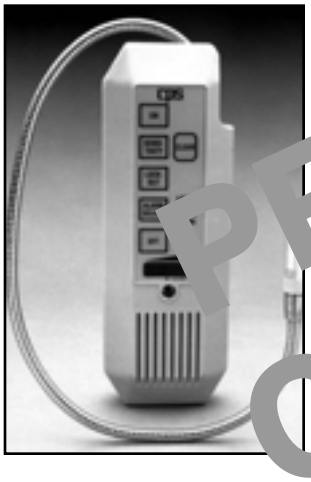


Fig. 1-4. Electronic leak detector



1.22 **Electrical test instruments.** Electrical meters are among the more valuable test instruments you will carry. A clamp-on ammeter and a multimeter (like the ones shown in Fig. 1-5) are essential items in the toolbox of every refrigeration maintenance technician. You will use the clamp-on ammeter to determine the current drawn by an electric load. The multimeter will give you accurate voltage and resistance readings. Used as an ohmmeter, the meter is particularly useful in locating open circuits and contacts. It also indicates if the load has an open circuit or a short. You will want the best meter that you can afford. Keep it in good repair and properly calibrated.

1.23 Taking electrical readings requires caution. Power must be on while you are taking current and

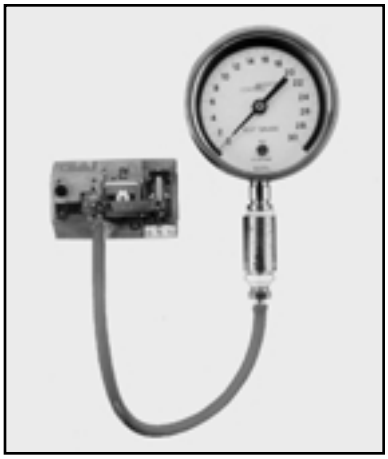
Fig. 1-5. Electrical test instruments

voltage readings. Power must be off when taking resistance readings. It must also be off when you look for loose connections, broken wires, burned contacts, etc. Never work on terminals on a hermetic compressor unless the pressure in the compressor is reduced to atmospheric (0 psig).

1.24 **Conductors and connectors.** To test for continuity in the circuits, you need either a test light set or your own arrangement of conducting probes and signaling devices. Fused starter cords of various lengths—with assorted probes, alligator clips, or other types of connecting terminals—are also useful.

1.25 **Pneumatic controls test instruments.** If your system has pneumatic controls, you will need a few more specialty items. The most useful instrument for performance evaluation is a pressure gauge. An example is shown in Fig. 1-6. Obtain a high-quality gauge with a 0- to 30-psi range. This range will cover the pressures you are likely to find in your control system. You will also need a squeeze-bulb hand pump to operate and cycle the controlled devices manually and a set of Allen wrenches to remove and replace the covers.

Fig. 1-6. Pressure gauge for calibrating pneumatic controls



The Programmed Exercises on the next page will tell you how well you understand the material you have just read. Before starting the exercises, remove the Reveal Key from the back of the book. Read the instructions printed on the Reveal Key. Follow these instructions as you work through the Programmed Exercises.

1-1. The largest user of both process and commercial refrigeration equipment is the _____ industry.	1-1. FOOD Ref: 1.01
1-2. Process air conditioning keeps electrical assembly areas free of _____ and controls temperature and _____.	1-2. DUST; HUMIDITY Ref: 1.03
1-3. Name the basic components of a mechanical refrigeration system.	1-3. EVAPORATOR; CONDENSER, COMPRESSOR; METERING DEVICE; THERMOSTAT Ref: 1.05
1-4. In addition to component failures, _____ should not be overlooked as a cause of refrigeration system problems.	1-4. EXTERNAL FACTORS Ref: 1.07
1-5. What is the most important thing to keep in mind when troubleshooting a refrigeration or air-conditioning system?	1-5. SAFETY Ref: 1.08
1-6. Do not work on an electrical system until the power is _____.	1-6. LOCKED OUT Ref: 1.09
1-7. One of the most useful instruments for troubleshooting a refrigeration system is the _____, which can help analyze system operation.	1-7. GAUGE MANIFOLD SET Ref: 1.16
1-8. Power must be on while taking _____ and _____ readings, but off when taking _____ readings.	1-8. CURRENT; VOLTAGE; RESISTANCE Ref: 1.23

Supplies (Consumables)

1.26 **Welding and soldering supplies.** You might be called upon to repair a refrigerant line or coil. Therefore, welding rod, brazing rod, silver solder, and tin solder, with the appropriate fluxes and soldering pastes, are among the consumable supplies you will need. You should also have on hand an assortment of copper fittings and a coil of "clean" copper tubing of the correct size for your unit. Tees and restrictors to fit the tubing on your pneumatic control system can also be invaluable.

Table 1-1. Refrigerant container color code

Refrigerant	Color code
R-11	Orange
R-12	White
R-22	Light green
R-123	Gray
R-134a	Light blue
R-404a	Orange
R-507	Dark green
R-717	Silver

1.27 **Refrigerants.** You should have a supply of the refrigerants used in your systems. Check the nameplates on the systems for specific types required. Bulk refrigerant containers and smaller refrigerant cans are usually color coded, as shown in Table 1-1. Be careful not to confuse the green color of R-22 containers with the green used for oxygen cylinders. In addition, you might keep a tank of nitrogen on hand for test charging and to prevent oxidation while brazing.

1.28 **Electrical supplies.** You will need wire nuts (for completing connections in both line-voltage and low-voltage circuits) and an assortment of wire terminals and rubber grommets (for protecting wires where they pass through holes in metal). A connector/crimping tool is a "must" item, as is a wire cutter/stripper. The all-purpose electrician's tool shown in Fig. 1-7 can perform these functions and more.

1.29 **Troubleshooting worksheet.** A troubleshooting worksheet, like the one shown in Fig. 1-8 on the following page, will give you a good picture of a system's operation. (Figure 1-8 shows three condensers and two evaporators, one direct expansion and one chiller. Just cross out the components that do not relate to the job.) Use this worksheet to record the date, work order number, model and serial numbers, the nature of the problem, and the name of the person who reported the problem at the top of the sheet. Mark on the diagram such data as the compressor head and suction pressure, air temperature entering and leaving the condenser and evaporator, cooling water temperature, sight glass indications, etc. As you proceed, this information can help you locate the problem and decide how to repair it.

1.30 **Manufacturers' manuals.** Although they are not classified as tools, equipment, or supplies, a necessary part of your troubleshooting kit is a file of manufacturers' manuals for the various components in your system. Any instruction manuals or general engineering data can be valuable when servicing

Fig. 1-7. All-purpose electrician's tool

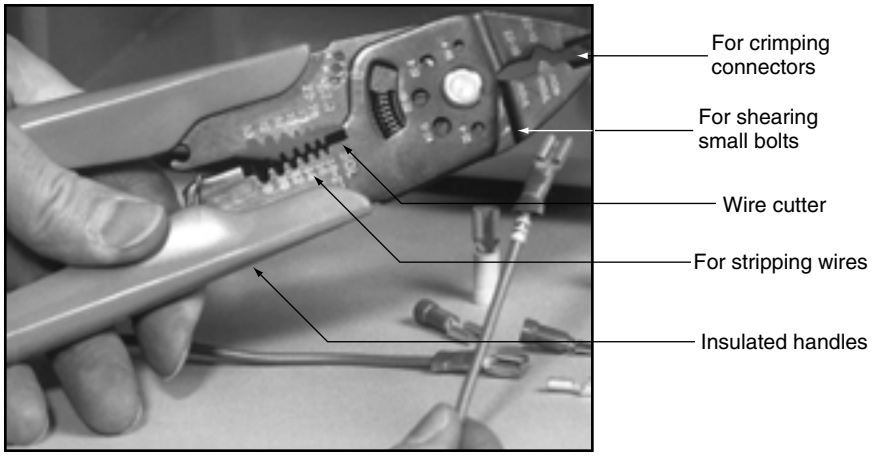
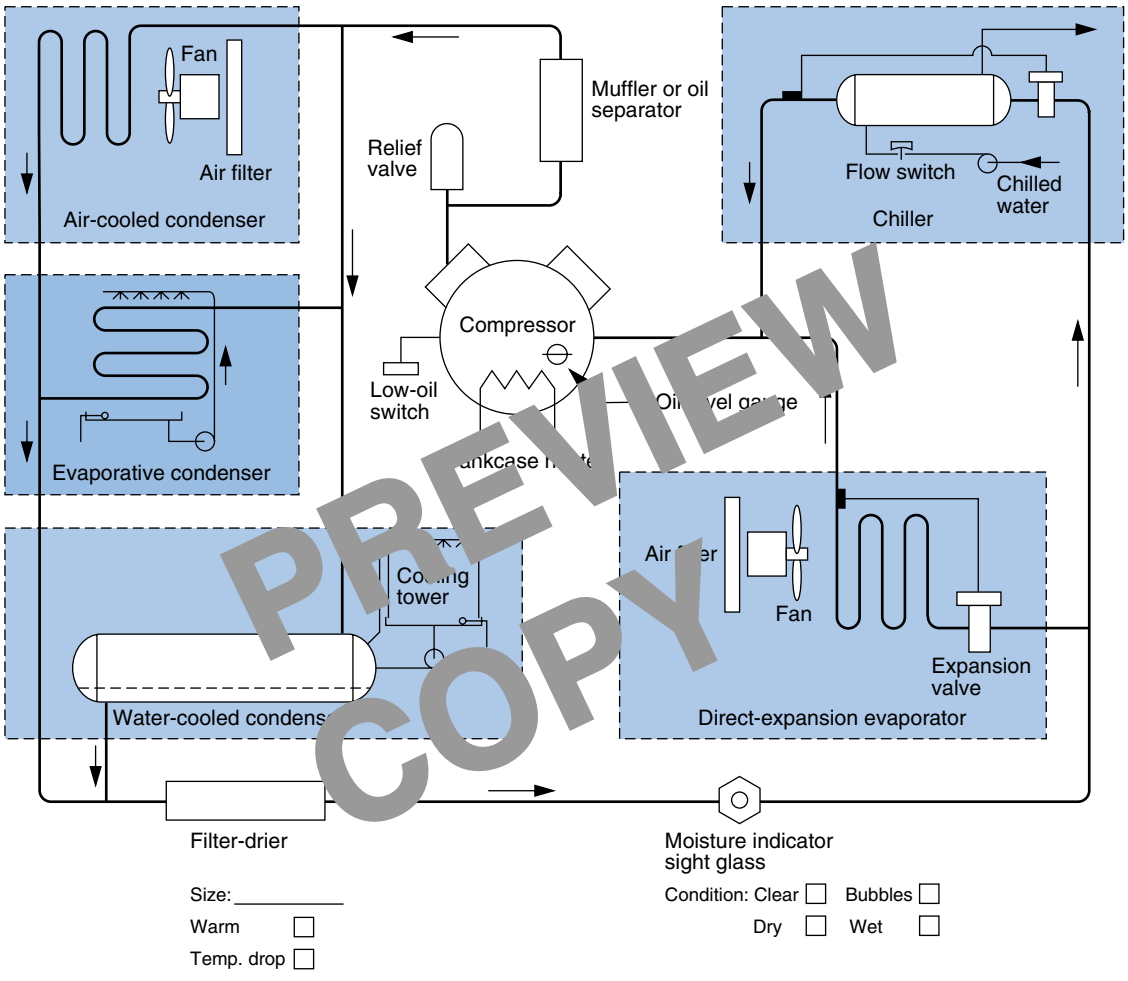


Fig. 1-8. Troubleshooting worksheet for refrigeration system

Name of equipment _____ Order No. _____ Date _____
Model No. _____ Serial No. _____ Location _____
Problem _____
_____ Reported by _____
Disposition _____ Serviced by _____



TEST READINGS

Compressor				Condenser			Evaporator		
Head pressure		Head temperature			Inlet	Outlet		Inlet	Outlet
Suction pressure		Suction temperature		Temperature, dry bulb			Temperature, dry bulb		
Oil pressure		Line voltage		Temperature, wet bulb			Temperature, wet bulb		
		Motor current, amps		CFM			CFM		

refrigeration system equipment. The more knowledge you can gain concerning the specific unit you are working on, the more competent you will be as a troubleshooter.

1.31 Many component manufacturers have their own troubleshooting charts, custom tailored for the particular features of their units. Copies of these charts are available for purchase or they might be supplied without charge to owners of the equipment. Look for the ones that go with your unit if you do not already have them on hand. They can be extremely useful in collecting and analyzing data.

Human Relations Skills

1.32 Before you begin a detailed study of the troubleshooting process, consider some general observations about the types of complaints you are about to deal with. The most difficult problems are the ones that originate from the opinions of individuals rather than from facts. Even maintenance personnel will sometimes give you subjective opinions having no technical basis. Sometimes a person merely feels warm or cold because of a temporary health problem.

1.33 Therefore, a troubleshooter must be prepared to handle questions of a psychological as well as technical nature. This means you will need to polish your human relations skills in addition to your technical skills. User complaints should not be ignored or belittled. An ounce of understanding can avoid tons of future hostility.

1.34 You can best minimize complaints by explaining the system's capabilities and limitations to the complainer. Point out that temperature, humidity, and air distribution might be near perfect under design conditions. However, sudden and extreme variations in outside conditions can cause a temporary deviation from the setpoint until the system catches up. In addition, some discomfort might result as energy conservation measures are put into effect. Often you will find a "too cold" or "too hot" complaint stemming from a Monday morning start-up following the weekend shutdown. Your explanations might not eliminate all complaints, but they might help avoid extreme reactions.

1-9. If you must repair a refrigerant line or coil, you should have _____ equipment and supplies on hand.	1-9. WELDING or SOLDERING Ref: 1.26
1-10. What color is a cylinder of R-134a?	1-10. LIGHT BLUE Ref: Table 1-1
1-11. Be careful not to confuse the green color of an R-22 cylinder with a green _____ cylinder.	1-11. OXYGEN Ref: 1.27
1-12. The all-purpose electrician's tool can function as a crimping tool and as a wire _____ and _____.	1-12. CUTTER; STRIPPER Ref: 1.28, Fig. 1-7
1-13. You can get a good picture of a system's operation by recording information on a troubleshooting _____.	1-13. WORKSHEET Ref: 1.29, Fig. 1-8
1-14. An essential part of your troubleshooting kit is a file of _____ for the various components in your system.	1-14. MANUFACTURERS' MANUALS Ref: 1.30
1-15. The most difficult problems you will deal with are those that stem from _____ rather than from _____.	1-15. OPINIONS; FACTS Ref: 1.32
1-16. You can minimize future complaints by explaining the system's _____ and _____ to the complainer.	1-16. CAPABILITIES; LIMITATIONS Ref: 1.34

Answer the following questions by marking an "X" in the box next to the best answer.

1-1. What industry is the largest user of air-conditioning and refrigeration equipment?

- ☐ a. Chemical
- ☐ b. Electronics
- ☐ c. Food
- ☐ d. Pharmaceutical

1-2. More and more manufacturing plants are being air conditioned because

- ☐ a. increased comfort improves productivity
- ☐ b. it is a relatively inexpensive improvement
- ☐ c. it is required by OSHA
- ☐ d. ozone depletion has caused global warming

1-3. To troubleshoot a refrigeration system successfully, you must have knowledge of

- ☐ a. meteorology
- ☐ b. the function of each component
- ☐ c. the fundamentals of fluid power
- ☐ d. the laws of physics

1-4. You should always lock out power before working on a system because

- ☐ a. a live circuit can kill you
- ☐ b. OSHA will fine your employer if you do not
- ☐ c. the circuit might be overloaded
- ☐ d. the system might not be grounded

1-5. To pressurize a refrigerant system for testing, use

- ☐ a. compressed air
- ☐ b. hydrogen
- ☐ c. nitrogen
- ☐ d. oxygen

1-6. To substantiate a questionable complaint, you might want to use a _____ thermometer.

- ☐ a. dial-type insertion
- ☐ b. long-stem, mercury-filled
- ☐ c. recording
- ☐ d. strap-on

1-7. Probably the most useful item for analyzing refrigeration system operation is the

- ☐ a. gauge manifold set
- ☐ b. leak detector
- ☐ c. multimeter
- ☐ d. vacuum pump

1-8. Electric power must be off when taking _____ readings.

- ☐ a. current
- ☐ b. pressure
- ☐ c. resistance
- ☐ d. voltage

1-9. Which refrigerant is supplied in a light blue container?

- ☐ a. R-12
- ☐ b. R-123
- ☐ c. R-134a
- ☐ d. R-717

1-10. If you receive a complaint about system operation and you feel that no problem exists, your reaction should be to

- ☐ a. explain the system's capabilities and limitations to the complainer
- ☐ b. ignore it and hope the complainer will forget about it
- ☐ c. try to confuse the complainer with a technical response
- ☐ d. try to convince the complainer that he has a health problem

SUMMARY

Both refrigeration and air-conditioning systems are very widely used in many industries—the food, chemical, and drug industries are important examples. Comfort air-conditioning is found in homes, schools, offices, and malls. All of these cooling systems have many common aspects. The basic components of all mechanical refrigeration systems and their operation are remarkably similar from application to application.

Troubleshooting a mechanical refrigeration system requires a knowledge of system operation and component function—information you studied in earlier Units in this Course. Knowledge of safe work practices is also essential. To be successful, you should have on hand certain tools and equipment—hand tools, welding equipment, thermometers, a gauge manifold set, a vacuum pump, a leak detector, electrical and pneumatic test instruments, and air-balancing equipment. A troubleshooting worksheet and manufacturers' manuals and troubleshooting charts can also be very valuable.

You will also need to polish your human relations skills and be prepared to respond to a person making a system-related complaint. Sometimes you might receive an opinion from someone who has no technical knowledge. Sometimes the complainer is simply not familiar with the capabilities and limitations of the system. Never ignore a complaint—a little bit of understanding in the present can help avoid problems in the future.

Answers to Self-Check Quiz

1-1. c. Food. Ref: 1.01

1-2. a. Increased comfort improves productivity. Ref: 1.04

1-3. b. The function of each component. Ref: 1.06

1-4. a. A live circuit can kill you. Ref: 1.09

1-5. c. Nitrogen. Ref: 1.09

1-6. c. Recording. Ref: 1.14

1-7. a. Gauge manifold set. Ref: 1.16

1-8. c. Resistance. Ref: 1.23

1-9. c. R-134a. Ref: 1.27, Table 1-1

1-10. a. Explain the system's capabilities and limitations to the complainer. Ref: 1.34

Contributions from the following sources are appreciated:

Figure 1-1. Cabot Safety Corporation
Figure 1-2. CPS Products, Inc.
Figure 1-3. Tuthill Corporation, Kinney Vacuum Division
Figure 1-4. CPS Products, Inc.
Figure 1-5. CPS Products, Inc.; Tektronix, Inc.
Figure 1-6. Johnson Controls, Inc.
Figure 1-7. Ideal Industries, Inc.