DOCUMENT RESUME

ED 275 866 CE 045 462

AUTHOR	Hamilton, Donald L.; And Others
TITLE	Refrigeration Servicing.
INSTITUTION	Marine Corps Inst., Washington, DC.
REPORT NO	MCI-11-62
PUB DATE	23 May 85
NOTE	117p.; Document is set in small type. Some graphics may not reproduce clearly.
PUB TYPE	Guides - Classroom Use - Materials (For Learner) (051)
EDRS PRICE	MF01/PC05 Plus Postage.
DESCRIPTORS	*Air Conditioning Equipment; *Appliance Repair; Autoinstructional Aids; Continuing Education; Course Content; Extension Education; Independent Study; Learning Activities; Military Personnel; *Military Training; Postsecondary Education; *Refrigeration; *Refrigeration Mechanics; Service Occupations; Skilled Occupations
IDENTIFIERS	Marine Corps; Military Curriculum Materials; Troubleshooting

ABSTRACT

This self-study course is designed to familiarize Marine enlisted personnel with the services required to be performed on refrigeration equipment. The course contains four study units. Each study unit begins with a general objective, which is a statement of what the student should learn from the unit. The study units are divided into numbered work units, each presenting one or more specific objectives. Text is furnished, illustrated as needed, for each work unit. At the end of the work units are study questions, with answers listed at the end of the study unit. A review lesson completes the course. The four units of the course cover the following subjects: installation and preventive maintenance, troubleshooting, servicing refrigeration systems, and repairing major components. (KC)

UNITED STATES MARINE CORPS
MARINE CORPS INSTITUTE, MARINE BARRACKS
BOX 1775
ARLINGTON, VA. 22222 0001

11.62
23 May 85

1. ORIGIN

MCI course 11.62, Refrigeration Servicing, has been prepared by the Marine Corps Institute.

2. APPLICABILITY

This course is for instructional purposes only.

J. M. D. HOLLADAY
Lieutenant Colonel, U. S. Marine Corps
Deputy Director

ACKNOWLEDGMENT

The Marine Corps Institute, Marine Barracks, Washington, D.C. gratefully acknowledges the important contributions provided by the following MCI personnel in developing and publishing this course:

Course Developer	MSgt Donald L. Hamilton
Officer in Charge	Capt David G. Reist
Education Specialist	Ms. Betsy A. McCleary
Course Editor	Ms. Monica Noell
Wordprocessing Technician(s)	MSGT Donald L. Hamilton
Graphic Illustrator(s)	

The Marine Corps Institute gratefully acknowledges the assistance of Engineer Maintenance Company, 2nd Maintenance Battalion, 2nd Force Service Support Group, Camp Lejeune, North Carolina, in the validation of this course.

The Marine Corps Institute gratefully acknowledges the assistance of Marine Corps Engineer Schools, Marine Corps Base Camp Lejeune, North Carolina, in the formal review of this course.

INFORMATION

FOR

MCI STUDENTS

Welcome to the Marine Corps Institute training program. Your interest in self-improvement and increased professional competence is commendable.

Information is provided below to assist you in completing the course. Please read this guidance before proceeding with your studies.

1. MATERIALS

Check your course materials. You should have all the materials listed in the "Course Introduction." In addition you should have an envelope to mail your review lesson back to MCI for grading unless your review lesson answer sheet is of the self-mailing type. If your answer sheet is the pre-printed type, check to see that your name, rank, and social security number are correct. Check closely, your MCI records are kept on a computer and any discrepancy in the above information may cause your subsequent activity to go unrecorded. You may correct the information directly on the answer sheet. If you did not receive all your materials, notify your training NCO. If you are not attached to a Marine Corps unit, request them through the Hotline (autovon 288-4175 or commercial 202-433-4175).

2. LESSON SUBMISSION

The self-graded exercises contained in your course are not to be returned to MCI. Only the completed review lesson answer sheet should be mailed to MCI. The answer sheet is to be completed and mailed only after you have finished all of the study units in the course booklet. The review lesson has been designed to prepare you for the final examination.

It is important that you provide the required information at the bottom of your review lesson answer sheet if it does not have your name and address printed on it. In courses in which the work is submitted on blank paper or printed forms, identify each sheet in the following manner:

DOE, John J. Sgt 332-11-9999
08.4g, Forward Observation
Review Lesson
Military or office address
(RUC number, if available)

Submit your review lesson on the answer sheet and/or forms provided. Complete all blocks and follow the directions on the answer sheet for mailing. Otherwise, your answer sheet may be delayed or lost. If you have to interrupt your studies for any reason and find that you cannot complete your course in one year, you may request a single six month extension by contacting your training NCO, at least one month prior to your course completion deadline date. If you are not attached to a Marine Corps unit you may make this request by letter. Your commanding officer is notified monthly of your status through the monthly Unit Activity Report. In the event of difficulty, contact your training NCO or MCI immediately.

3. MAIL-TIME DELAY

Presented below are the mail-time delays that you may experience between the mailing of your review lesson and its return to you.

	TURNAROUND MAIL TIME	MCI PROCESSING TIME	TOTAL NUMBER DAYS
EAST COAST	16	5	21
WEST COAST	16	5	21
FPO NEW YORK	18	5	23
FPO SAN FRANCISCO	22	5	27

You may also experience a short delay in receiving your final examination due to administrative screening required at MCI.

4. GRADING SYSTEM

LESSONS			EXAMS	
GRADE	PERCENT	MEANING	GRADE	PERCENT
A	94-100	EXCELLENT	A	94-100
B	86-93	ABOVE AVERAGE	B	86-93
C	78-85	AVERAGE	C	78-85
D	70-77	BELOW AVERAGE	D	65-77
NL	BELOW 70	FAILING	F	BELOW 65

You will receive a percentage grade for your review lesson and for the final examination. A review lesson which receives a score below 70 is given a grade of NL (no lesson). It must be resubmitted and PASSED before you will receive an examination. The grade attained on the final exam is your course grade, unless you fail your first exam. Those who fail their first exam will be sent an alternate exam in which the highest grade possible is 65%. Failure of the alternate will result in failure of the course.

5. FINAL EXAMINATION

ACTIVE DUTY PERSONNEL: When you pass your REVIEW LESSON, your examination will be mailed automatically to your commanding officer. The administration of MCI final examinations must be supervised by a commissioned or warrant officer or a staff NCO.

OTHER PERSONNEL: Your examination may be administered and supervised by your supervisor.

6. COMPLETION CERTIFICATE

The completion certificate will be mailed to your commanding officer and your official records will be updated automatically. For non Marines, your completion certificate is mailed to your supervisor.

7. RESERVE RETIREMENT CREDITS

Reserve retirement credits are awarded to inactive duty personnel only. Credits awarded for each course are listed in the "Course Introduction." Credits are only awarded upon successful completion of the course. Reserve retirement credits are not awarded for MCI study performed during drill periods if credits are also awarded for drill attendance.

8. DISENROLLMENT

Only your commanding officer can request your disenrollment from an MCI course. However, an automatic disenrollment occurs if the course is not completed (including the final exam) by the time you reach the CCD (course completion deadline) or the ACCD (adjusted course completion deadline) date. This action will adversely affect the unit's completion rate.

9. ASSISTANCE

Consult your training NCO if you have questions concerning course content. Should he/she be unable to assist you, MCI is ready to help you whenever you need it. Please use the Student Course Content Assistance Request Form (ISD-1) attached to the end of your course booklet or call one of the AUTOVON telephone numbers listed below for the appropriate course writer section.

PERSONNEL/ADMINISTRATION	288-3259
COMMUNICATIONS/ELECTRONICS/AVIATION	
NBC/INTELLIGENCE	288-3604
INFANTRY	288-3611
ENGINEER/MOTOR TRANSPORT	288-2275
SUPPLY/FOOD SERVICES/FISCAL	288-2285
TANKS/ARTILLERY/INFANTRY WEAPONS REPAIR	
LOGISTICS/EMBARKATION/MAINTENANCE MANAGEMENT/ ASSAULT AMPHIBIAN VEHICLES	288-2290

For administrative problems use the UAR or call the MCI HOTLINE: 288-4175.

For commercial phone lines, use area code 202 and prefix 433 instead of 288.

FUNDAMENTALS OF REFRIGERATION

Course Introduction

REFRIGERATION SERVICING is designed to familiarize the student with services required to be performed on refrigeration equipment.

ADMINISTRATIVE INFORMATION

ORDER OF STUDIES

Study Unit Number	Study Hours	Subject Matter
1	1	Installation and Preventive Maintenance
2	3	Trouble-shooting
3	4	Servicing Refrigeration Systems
4	3	Repairing Major Components
	2	REVIEW LESSON
	2	FINAL EXAMINATION
	15	

RESERVE RETIREMENT CREDITS:	5
EXAMINATION:	Supervised final examination without text or notes with a time limit of 2 hours.
MATERIALS:	MCI 11.62, Refrigeration Servicing, review lesson and answer sheet.
RETURN OF MATERIALS:	Students who successfully complete this course are permitted to keep the course materials. Students disenrolled for inactivity or at the request of their commanding officer will return all course materials.

SOURCE MATERIALS

TM 5-745	Heating, Ventilating Air-conditioning and Sheet Metal Works, Oct 1968
NAVEDTRA 10660	Utilitiesman 3 & 2, Vol 1, 1983
NAVEDTRA 10661	Utilitiesman 3 & 2, Vol 2, 1983
NAVEDTRA 13004	Refrigeration and Air-Conditioning, 1980

HOW TO TAKE THIS COURSE

This course contains 4 study units. Each study unit begins with a general objective that is a statement of what you should learn from the study unit. The study units are divided into numbered work units, each presenting one or more specific objectives. Read the objective(s) and then the work unit text. At the end of the work unit are study questions that you should be able to answer without referring to the text of the work unit. After answering the questions, check your answers against the correct ones listed at the end of the study unit. If you miss any of the questions, you should restudy the text of the work unit until you understand the correct responses. When you have mastered one study unit, move on to the next. After you have completed all study units, complete the review lesson and take it to your training officer or NCO for mailing to MCI. MCI will mail the final examination to your training officer or NCO when you pass the review lesson.

TABLE OF CONTENTS

MARINE CORPS INSTITUTE STUDY GUIDE

Congratulations for enrolling in the Marine Corps Institute's correspondence training program! By enrolling in this program, you have shown a desire to improve the skills you need to enhance your on-the-job performance.

Since 1920, MCI has been helping tens of thousands of hard-charging young Marines, like yourself, achieve educational goals by teaching necessary new skills or reinforcing existing skills. MCI will do every thing possible to help you reach your individual goals, whatever they may be.

Before you begin your course of instruction, you may be asking yourself, "How much will I benefit from a correspondence training program?" The answer to this depends upon you, *"YOUR PROFESSIONAL TRAITS"* (what you bring to the learning situation).

Because you have enrolled in an MCI course, your professional traits are evident and we know that:

YOU ARE PROPERLY MOTIVATED. You made a positive decision to get training on your own. Self-motivation is perhaps the most important force in learning-or achieving—anything. Wanting to learn something badly enough so that you will do what's necessary to learn—*THAT IS MOTIVATION.*

YOU SEEK TO IMPROVE YOURSELF. You enrolled to learn new skills and develop special abilities.

YOU HAVE THE INITIATIVE TO ACT. By acting on your own, you have shown that you are a self-starter, willing to reach out for opportunities.

YOU ACCEPT CHALLENGES. You have self-confidence and believe in your ability to gain training in your areas of interest.

YOU ARE ABLE TO SET PRACTICAL GOALS. You are willing to commit time, effort, and resources toward accomplishing what you set out to do. [illegible] professional traits will help you [illegible] success in you MCI program.

To begin your course of study:

* Look at the course introduction page. Read the COURSE INTRODUCTION to get the "nitty gritty" of what the course is about. Then read the MATERIALS section near the bottom of the page to find out which text(s) and study aids you should have received with the course. If any of the listed materials are missing, see *Information for MCI Students* to find out how to obtain them. If you have everything that is listed, you are ready to begin your MCI course.

* Read through the *TABLE OF CONTENTS* of your text(s). Note the various subjects covered in the course and the order in which they are taught. Leaf through the text(s) and look at the illustrations. Read a few work unit exercise questions to get an idea of the types of questions that are asked. If MCI provides other study aids, such as a slide rule or a plotting board, familiarize yourself with them. Now, you are ready to begin work on your MCI course.

* Turn to the first page of study unit 1. On this page you will find the study unit goal. This is a statement of what you should be able to do when you complete the final exam. Each study unit is divided into work units. Each work unit contains one terminal learning objective and several enabling objectives. The terminal learning objective is what you should be able to accomplish when you complete the work unit exercises. The enabling objectives are the steps you need to learn to help you accomplish the terminal learning objective. Read each objective for the work unit and then read the work unit text carefully. Make notes on the ideas you feel are important.

* Without referring to the text, answer the questions in each exercise.

* Check your answers against the correct ones listed at the end of the study unit.

* If you miss any of the questions, restudy the work unit until you understand the correct response.

* Go on to the next work unit, repeating the above steps, until you have completed all the work units in the study unit.

* Follow the same procedure for each study unit of the course. If you have problems with the text or work unit questions that you cannot solve on your own, ask your training NCO for the name of someone who can help you. If they cannot aid you, request assistance from MCI on the Student Course Content Assistance Request included with this course, or refer to your INFORMATION FOR MCI STUDENTS (MCI-R24i-NRL) for the telephone number of the appropriate Course Developing Division at MCI.

* When you have finished all the study units, complete the course review lesson. Try to answer each question without the aid of reference materials. However, if you do not know an answer, look it up. When you have finished the review lesson, take it to your training officer or NCO for mailing to MCI. MCI will grade it and send you a feedback sheet (MCI-R69) with your final examination listing course references for any questions that you missed on the review lesson.

"RECON" Reviews:

To prepare for your final examination you *must* review what you learned in the course. Therefore, why not make reviewing as interesting as possible. The following suggestions will make reviewing not only interesting but also a challenge.

1. Challenge yourself. Reconstruct the learning event *in your mind*. Try to recall and recapture an entire learning sequence, without notes or other references. Can you do it? You just have to "look back" to see if you've left anything out, and *that* will be an interesting read-through (review) for you.

Undoubtedly, you'll find that you were not able to recall everything. But with a little effort you'll be able to recall a great deal of the information.

Also, knowing that you are going to conduct a "reconstruct-review" will change the way you approach your learning session. You will try to learn so that you will be able to "reconstruct the event."

2. Use unused minutes. While waiting at sick bay, riding in a truck or bus, living through field duty, or just waiting to muster—use these minutes to review. Read your notes or a portion of a study unit, recalculate problems, do self-checks a second time; you can do many of these things during "unused" minutes. Just thinking about a sequence of instruction will refresh your memory to help "secure" your learning.

3. Apply what you've learned. Always, it is best to do the thing you've learned. Even if you cannot immediately put the lesson to work, sometimes you can "simulate" the learning situation. For example, make up and solve your own problems. Make up problems that take you through most of the elements of a study unit.

4. Use the "shakedown cruise" technique. Ask a fellow Marine to lend a hand and have him ask you questions about the course. Give him a particular study unit and let him fire away. It can be interesting and challenging.

The point is, reviews are necessary for good learning, but they don't have to be long and tedious. Several short reviews can be very beneficial.

Semper Fi

STUDY UNIT 1

INSTALLATION AND PREVENTIVE MAINTENANCE

STUDY UNIT OBJECTIVE: WITHOUT THE AID OF REFERENCES, YOU WILL IDENTIFY THE PROCEDURES NECESSARY TO PROPERLY INSTALL REFRIGERATION AND AIR-CONDITIONING EQUIPMENT. ALSO, YOU WILL IDENTIFY THE NECESSARY PROCEDURES OF PREVENTIVE MAINTENANCE TO INSURE PROPER OPERATION OF THE EQUIPMENT.

Work Unit 1-1. INSTALLATION

STATE WHAT MUST BE CONSULTED PRIOR TO THE INSTALLATION OF REFRIGERATION AND AIR CONDITIONING EQUIPMENT.

STATE FOUR COMMON STEPS FOR PROPER INSTALLATION OF REFRIGERATION AND AIR-CONDITIONING EQUIPMENT.

Proper installation is very important to the operation of any item of refrigeration and air-conditioning equipment whether they be domestic or tactical. This includes leveling of the unit, correct electrical power and good ventilation, plus, when necessary, good drainage. The majority of equipment is carefully crated and shipped with full written instructions on how to ship, uncrate, and install the unit.

When installing a mechanical system, always insure that you consult the appropriate technical manual for the instructions pertinent to the individual item of equipment. However, generally speaking there are things that you must do to most units.

- Leveling - When a unit is installed it should be level so that the doors will open and close and the panels on the tactical unit fit properly. Units that are equipped with ice trays must be level so that water does not spill from the trays.

- Drainage - Adequate drainage must be provided for water-cooled units and other units requiring such drainage.

- Electrical Supply - The electrical supply (outlet) for the unit must provide the correct electrical voltage. Be sure to read the electrical rating on the unit and manual; check these against the electrical supply at the outlet. The more modern units may need more current than the older, simpler units.

All three (3) phase units should be checked for proper rotation. If not rotating properly, the technicion must switch two (2) of the three (3) power wires at the fuze box or incoming power supply.

It is best to have a separate circuit from the fuse or circuit breaker box to the unit. Electrical leads and installation should be performed by a qualified electrician.

If, in the event that one (electrician) is not available, the voltage at the unit supply can be quite easily checked with a voltmeter. The circuit capacity (wire size, etc.) is checked as follows: If at the instant of starting, the voltage at the unit supply drops more than 10 volts, this should indicate that the wiring in the circuit is not heavy enough to carry the current demand of the unit. A flicker in the lights at the instant the unit starts is a sure sign of a poor electrical supply.

The technician should always check to see that there is proper grounding in the outlet supply box which supplies current to any refrigerating mechanism.

- Ventilation - Since the majority of units used by the Marine Corps are air-cooled, proper ventilation is very important. Therefore, it is advisable to locate the unit where it will not be in direct sunlight, nor should it be near an oven, heat radiator, or warm air register. The location should be large enough to provide enough air to cool the condenser.

Once the unit has been uncrated and set in the desired location, you should check the condenser and evaporator for bent or damaged fins, and check the alignment of the compressor motor drive belts, if the unit is not hermetic (having an airtight seal). If it is hermetic, check the mountings for proper tension and spacing. Check all connections to make sure they are tight and do not leak. Check all soldered and sweated joints to make sure they are not cracked and do not show any signs of leaking. If you must charge the system with refrigerant or lubricant, make sure you are using the correct refrigerant or lubricant (consult the appropriate technical manual). Make sure that all electrical connections (fuse boxes, initial service connections, connections for timers and electrical controls, and external leads) are properly made and secure. Check blowers and fans, making sure that the fan blades are not bent and the shafts and motors are aligned. If a unit is air-cooled, make sure that there is plenty of airspace around the condensing unit for proper ventilation. These are just a few of the things that must be checked out and accomplished when a unit is installed. ALWAYS have a manual for the particular item of equipment to insure that you accomplish all of the installation procedures for the equipment.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. Prior to installing an item of refrigeration equipment, you should ____________

____

2. State four common installation steps required for all refrigeration and air-conditioning equipment.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

Work Unit 1-2. PREVENTIVE MAINTENANCE

LIST FOUR TYPES OF PREVENTIVE MAINTENANCE SERVICES PERFORMED BY THE OPERATOR ON REFRIGERATION AND AIR-CONDITIONING EQUIPMENT.

LIST FOUR COMMON CRITICAL INSPECTION POINTS OF REFRIGERATION AND AIR-CONDITIONING EQUIPMENT.

STATE INSPECTIONS AND MAINTENANCE TO BE PERFORMED ON REACH-IN AND WALK-IN REFRIGERATORS.

SPECIFY INSPECTION AND MAINTENANCE TO BE PERFORMED ON ICE-MAKING MACHINES.

Preventive maintenance involved with most refrigeration equipment is limited. You are required to perform four types of services on equipment: Before Operation, During Operation, After Operation, and Quarterly PM services.

Before Operation Services - These services include but are not limited to the following:

- Make certain the unit is properly installed, lubricated, and in good operating condition.
- Inspect the system's tubing to ensure that there are no disconnected tubes.
- Make certain all valves are in the correct operating position.
- Check the control box and other wiring to be certain that all parts are dry, all connections are tight, and all controls are in good condition.
- Check power supply for correct type and sufficient voltage.
- Check compressor sight glass for adequate oil and liquid sight glass for moisture (if the unit is equipped with one).

During Operation Services - These services include but are not limited to the following:

- Check gauge and temperature readings to make certain that unit is operating normally.
- Check liquid sight glass for adequate refrigerant in the system.
- Check the thermostat cut-in and cut-out temperature against the temperature in the unit and make certain the desired temperature is being maintained.

- Listen for unusual noises. If trouble is indicated, determine the cause and correct the problem.

- Be alert for smoke or odors indicative of overheated components or shorted wiring.

- Insure that nothing is placed in the cooler to prevent free circulation of air.

- Inspect the evaporator for frost. If the accumulation is over 1/4 inch, reset the timer for a shorter cycle.

After Operation Services - These include but are not limited to the following:

- Make certain that the starter switch is in the "OFF" position.

- Wipe the unit down with a damp cloth.

- Inspect the instruments and controls to see that they are securely mounted, properly connected and undamaged.

- Inspect the fans to see that they are correctly aligned and secure on the shaft.

- Check the alignment and tension of all the belts.

- Check the tightness of the screws and bolts.

Quarterly Services - Services that are required will be found in the appropriate technical manual for the particular item of equipment. Services are normally performed at 3-month intervals or 250 hours of equipment operation, whichever comes first. The hours of operation will be dictated by the appropriate manual.

As was previously stated, preventive maintenance required on most equipment is limited. However, making periodic inspection of critical points will insure a longer maintenance-free life for your equipment.

You should keep the condenser fins free from dirt and obstructions. Insure that the evaporators are kept free from excessive frost build-up. Check electrical contacts and connections and keep them free of dirt and grease. Also, make sure that the contacts are not burned. If the equipment is equipped with filters, check them at regular intervals and keep them clean; replace them if necessary. Check the unit for unusual noises and vibrations, making the necessary adjustments. These adjustments may include leveling the condensing unit, carefully bending copper tubing away from whatever it is hitting, adjusting belts, and making any other small adjustments that may be necessary.

If you keep track of the small things that may occur from time to time, the unit will give you long life, free of major maintenance problems.

Now that you are aware of the types of preventive maintenance and critical inspection areas in general, let's take a closer look at three items of refrigeration equipment that you will be maintaining, the reach-in and walk-in refrigerators plus the ice-making machine.

The first requirement for maintaining the larger refrigeration systems or units is to observe the mechanical equipment for normal operation. Investigate any unusual noises or vibrations that occur during operation. Doors must be checked for proper closing. Adjust latches to insure doors close tightly and lubricate hinges and latch mechanisms. Gaskets require examination for missing, or worn sections. Replace gaskets found to be defective. Refrigerant lines, connections, and components should be looked at for indication of damage or leakage. Use a leak detector to check suspicious areas: a liquid soap leak detector is recommended. Any leakage must be corrected either by tightening threaded connections or by soldering or brazing holes in components and cracks in previously soldered or brazed joints.

Cabinets surfaces should be checked for damaged areas. These areas should be cleaned up and retouched with paint to prevent further deterioration. Wood components should be checked for cracked, deteriorated wood, damaged or spread joints, and deteriorated finish. Defects should be repaired and the finish restored. If there is a possibility that the insulation has absorbed moisture or shifted, feel the outside of the cabinet for cold spots or look for areas of condensation on metal cabinets. If cold spots are found determine the cause. Damp or wet insulation must be replaced with dry insulation but only after the air leak has been sealed. Shifted insulation will have to be repositioned or the void filled with new insulation on boxes that allow this.

Clean the cooling coils, fins, drain pan, and drain line connections. Check the cooling coil supports, casing, and drain pan for rust. Clean and repaint when needed to prevent further deterioration. The cooling coil fan motor bearings should be checked and lubricated as required by the lubrication instruction. The fan should be observed for excessive vibration, and dirt wiped from both the fan and motor. The compressor motor bearings should be checked and lubricated and dirt, lint, and oil wiped from the motor housing and vents. Open compressors should be checked frequently for evidence of seal leakage and for proper oil level. Belt drives are examined for condition, alignment, and tension.

Frost does not normally accumulate on the evaporator when units operate at 35° F or above. On equipment that operates at lower temperatures, frost may accumulate on the evaporator, especially if it does not have an automatic defrost system. Ice should not be allowed to get over 1/4 inch thick before the unit is defrosted. The automatic defrost controls must be checked when ice accumulates on units that are designed to be self-defrosting.

Thermometers used to show the temperature should be checked for condition and checked for accuracy against one known to be correct. Adjust thermometers which have provisions for recalibration. Replace defective thermometers and ones that can not be calibrated.

The inspection and maintenance on ice-making machines, whether they are of the cube or flake type, are about the same.

The gear head, motor bearings, ice cutter bearings, evaporator drum shaft bearings, chain drive, and gear motor should be checked for condition and lubricated every 3 to 6 months depending on the machine and in accordance with the current lubrication instruction. Gear reducers should be checked for oil level periodically and the gear case drained and refilled with all purpose gear lubricant about every 6 months.

Note: Be sure to consult the appropriate TM and/or the LO for proper lubrication with the correct type lubricant and interval for each item of equipment.

Since ice is a food item, it is important that the water system be kept as clean as possible. The water tank should be drained and flushed daily. In addition, the circulating water system should be cleaned periodically depending on the analysis of the water. The water system is washed with a soap solution and water. After washing, the system is throughly rinsed to remove all traces of the soap solution. When the water system, including freezing tubes and evaporator drums, becomes coated with mineral deposits, added cleaning is required. In many cases, the mineral deposits can be removed by wire brushing and flushing with fresh water. The first full bin load should be discarded. On some equipment, mineral deposits may be scraped off or removed with fine steel wool or sanded with fine wet/dry sandpaper kept wet with water.

Chemical cleaning is needed when mineral deposits have been permitted to become heavy or hard scale has formed. Citric or acetic acid are preferred for chemical cleaning but if these are not effective it may be necessary to use muriatic acid. Chemical cleaning is done with the refrigeration system inoperative which may require removing the compressor belts or disconnecting the compressor. The acid should be mixed with water as directed, usually one part citric or acetic acid to one part water or 1.5 parts inhibited muriatic acid to 3.5 parts water. The acid solution is circulated through the water system until the scale is removed which normally takes from 30 minutes to an hour. The acid solution is then drained and a solution of baking soda and water is used to flush the system. The system should be flushed two or three times with clean water before putting the machine back into operation.

The ice cutter of a rotating drum ice-flaking machine is mounted on two self-aligning ball bearings on the machine frame. The clearance between the cutter blades and drum is important to the proper cutting of the ice. This clearance should be .006 to .008 of an inch when the drum is warm. This provides a clearance of .015 to .020 of an inch when the drum is cold. Cutter clearance is adjusted by loosening the bearing-to-frame bolts and moving the bearings backward or forward. The clearance must be adjusted so it is uniform for the full length of the drum. The beveled edge of the cutter blades should be toward the ice chute. The scraper blade should be adjusted to .010 of an inch clearance when the drum is warm to provide approximately .020 of an inch clearance when the drum is cold. Scraper blades clearance is adjusted by turning the slotted head screws holding the plate.

The evaporator drum is rotated by a drive chain driven by a gear motor mounted on an adjustable plate. One end of the adjustable plate is attached to the machine's frame. Two adjusting screws with locknuts are used at the other end of the adjustable plate to move it up and down to get the proper tension on the chain drive. The chain is properly adjusted when it can be depressed 1/2 inch by thumb pressure applied halfway between the two sprockets. Units with fixed evaporator drums should be checked for alignment. This is done by measuring the clearance between the ice removal blade and the drum at several places. The clearance should not be less than .003 of an inch at any point.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. List four types of services that are performed by the operator.

   a. ____________________

   b. ____________________

   c. ____________________

   d. ____________________

2. List four critical inspection points of refrigeration and air-conditioning equipment.

   a. ____________________

   b. ____________________

   c. ____________________

   d. ____________________

3. Specify the inspections and maintenance to be performed on reach-in and walk-in refrigerator doors.

   ____

   ____

   ____

4. State two methods used to repair leaks in refrigeration systems lines.

   a. ____________________

   b. ____________________

5. Indicate how it can be determined on a metal cabinet refrigeration unit if the insulation is wet or has shifted position.

   ____

6. State two maintenance tasks that must be performed on gear cases of ice-making machines.

   a. ____________________

   b. ____________________

7. Identify three chemicals used for cleaning the water system of an ice-making machine.

   a. ____________________

   b. ____________________

   c. ____________________

8. Explain the action to be taken after the chemical solution has completed its cleaning action.

___

___

___

9. What is the minimum clearance between the removal blade and the drum on a fixed drum ice-flaking machine?

___

SUMMARY REVIEW

In this study unit, you have learned the correct procedures required when installing refrigeration and air-conditioning equipment. You have also learned the preventive maintenance procedures required in order to insure the maintenance free operation of the equipment.

Answers to Study Unit #1 Exercises

Work Unit 1-1.

1. consult the appropriate technical manual.
2. a. Leveling
   b. Drainage
   c. Electrical supply
   d. Ventilation

Work Unit 1-2.

1. a Before Operation Services
   b. During Operation Services
   c. After Operation Services
   d. Quarterly PM Services
2. a. Condenser fins
   b. Evaporator
   c. Electrical contacts and connections
   d. Filters
3. Doors are checked for proper closing and latches adjusted when needed to insure a tight seal. Lubricate hinges and latch mechanism. Door gaskets are checked for missing, worn, and set sections, and replaced when defective.
4. a. Leaks are repaired by tightening threaded connections.
   b. Leaks are repaired by soldering or brazing holes in previously soldered or brazed joints.
5. Feel the outside of the cabinet for cold spots and look for areas of condensation.
6. a. Gear cases must be checked for proper oil level.
   b. The case must be drained and refilled at specified intervals.
7. a. Citric acid
   b. Acetic acid
   c. Muriatic acid
8. A solution of baking soda and water is used to flush the system. It then should be rinsed two or three times with clean water.
9. .003 inch

STUDY UNIT 2

TROUBLE-SHOOTING

STUDY UNIT OBJECTIVE: WITHOUT THE AID OF REFERENCES, YOU WILL IDENTIFY COMMON TROUBLE-SHOOTING PROCEDURES, LEAK DETECTION, ELECTRICAL TESTING, AND PURGING OF THE REFRIGERATION SYSTEM.

Work Unit 2-1. TROUBLE-SHOOTING

STATE WHAT TWO PRESSURES YOU SHOULD OBSERVE DURING REFRIGERATION TROUBLE-SHOOTING.

GIVEN TYPES OF ABNORMAL OPERATING PRESSURES FOUND IN REFRIGERATION SYSTEMS, STATE THE CAUSES AND REMEDIES.

SPECIFY FOUR PROBLEMS THAT MAY OCCUR IN EITHER THE OPEN (SEMI-HERMETIC) OR HERMETIC TYPE COMPRESSORS.

SPECIFY FOUR CONDITIONS THAT CAUSE LUBRICATION FAILURE IN THE SYSTEM.

LIST THREE PROBLEMS MOST OFTEN ASSOCIATED WITH EXPANSION VALVES.

SPECIFY TWO REASONS FOR BUBBLES IN A REFRIGERATION SYSTEM.

A good refrigeration technician must be able to quickly and accurately diagnose trouble within a refrigeration system. The trouble-shooting charts, located in the appropriate technical manual for a particular item of equipment will help you recognize many of the problems that may occur within a system. You should not try to memorize these charts. They are meant to serve as a guide to help you understand the workings of a system. As you go through these charts, think of the underlying reasons why each trouble could cause a particular complaint or symptom. It should be your ambition, as a refrigeration technician, to learn the workings of the various units used in the Marine Corps and be able to determine, for yourself, what is wrong in a particular case.

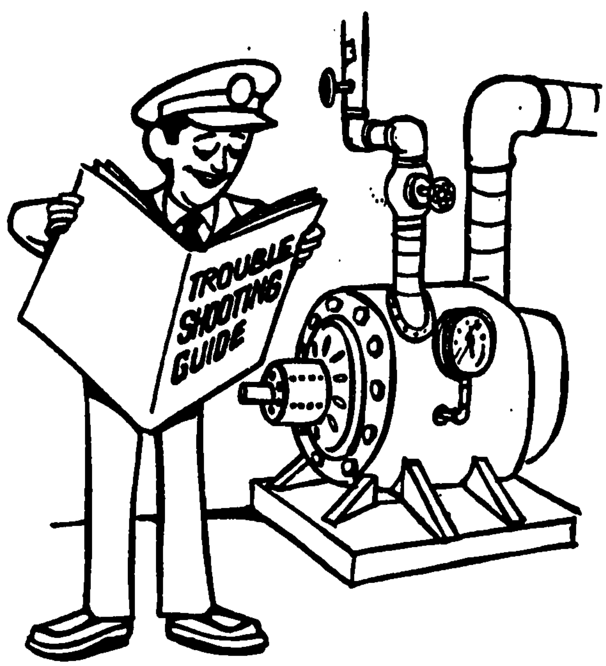


Fig 2-1. Consult trouble-shooting guide.

Even though the reliability of equipment and systems in modern refrigeration work is quite high, as you can see from trouble-shooting charts there will be occasional breakdowns or failures. Some malfunctions are caused by defective equipment, some by poor installation, and some because of poor maintenance. The last point (poor maintenance) is in most cases the primary offender.

No matter what the cause, the skilled technician must be able to diagnose the malfunction and correct the situation. Frequently, time is also an urgent consideration in refrigeration breakdowns because there may be many dollars worth of perishable foods involved. Therefore, one of the most important skills to be learned by the refrigeration technician is the art of trouble-shooting.

TROUBLE-SHOOTING is the process by which a technician systematically and logically analyze systems, both positive and negative, to determine a problem, find the cause of the problem, and correct it.

When working on any piece of equipment while on a trouble call or in the shop, the serviceman must be fully aware of the elements which cause problems most frequently. By experience, most technicians have established an order of priorities on any particular type of equipment, by automatically checking certain known trouble spots first. In 80 percent of the cases, and possibly higher, the problem can readily be found and corrected without an extensive breakdown of the functional systems of a unit, or without having to spread out the blueprints or electrical schematics to get down to serious trouble-shooting.

By understanding the operation of individual components within various systems, the technician then can correct approximately 80 percent of the trouble-shooting problems which he is confronted. However, WHAT ABOUT THOSE TIMES (THE 20 PERCENT) WHEN HE CANNOT FIND THE PROBLEM AFTER HE HAS EXHAUSTED ALL HIS "KNOWNS" ??? These are the times which test the real professional ability of the technician. They immediately bring into the open the difference between the "barn-yard" mechanic and the guy who "has it all together."

The person who has not organized his service trouble-shooting processes and testing procedures will continue to "grab at straws" with the hope that one will lead to the problem. This is not only costly and time-consuming for the maintenance program, but it is extremely frustrating for you, the serviceman.

The person who has a logical, well-thought-out, systematic approach to such a situation will calm his emotions, and start recording negative and positive signs or symptoms which will lead him to the problem with positive, definite steps.

It should be made very clear that there is a great vacuum in the refrigeration servicing field in the area of trouble-shooting. Every manufacturer has his method for a particular item of equipment. However, the principles of trouble-shooting are never "spelled out," so the poor unsuspecting serviceman is bound to "specifics" rather than sound general principles which might be applied in every difficult trouble-shooting situation. This is not to say that there are not good trouble-shooters available in every service organization. There are many who, in some cases, have devoted numerous hours to servicing and particularly to trouble-shooting. These individuals have met the test of organizing their thinking, their trouble-shooting process, and refined it to a smooth working step-by-step process which leads them to success each and every time. Many servicemen do not have the time nor the opportunity to trouble-shoot on a continuous basis, to develop this treasured skill. They do need it in their work, sometimes frequently, sometimes infrequently. It is with these thoughts in mind that we move into the elements of trouble-shooting.

The trouble-shooting steps are shown here briefly and explained in detail one-by-one later.

- KNOW - The equipment, the function, the installation, and all the elements necessary for proper operation.

- DETERMINE THE SYMPTOMS - Any positive or negative clue, sign or indication given by the equipment. Specifically what areas could be potential trouble or problem spots.

- LOCALIZE TO A FUNCTIONAL UNIT - Specify the problem area, determine what the trouble IS and IS NOT. Determine which parts of the equipment are affected and those which are not. Record possible functional units in which the trouble might be found.

- ISOLATE TO A COMPONENT OR CIRCUIT - From the list of components in each potentially troubled functional unit, check the ones which could cause the symptom.

- FIND THE PROBLEM - FIX THE PROBLEM - TEST - RETEST - Make sure all problems are found, check all components which could cause the same symptoms. Test the functional system. Test the entire unit for proper operation; retest each.

A memory device might be utilized for those attempting to remember the above steps in order such as the first letter of each step: K-D-L-I-F, pronounced kid-lif.

Now that you are aware what is to be accomplished, let's take a closer look at each of the above steps and see what is done for each step in trouble-shooting:

(k) KNOW THE EQUIPMENT, THE OPERATION, THE INSTALLATION, THE REPAIR PROCEDURES, THE OPERATION SEQUENCES, THE TESTING PROCEDURES, HOW TO ADJUST EACH PIECE, AND OTHER REQUIRED ELEMENTS.

In this step you must:

- Study the equipment and each component's location. Read all available service literature (installation instruction, maintenance instructions, service data, specifications, etc).

- Manipulate - operate the equipment according to operating instructions. Operate through the cycle of operation, checking the sequence of operation.

- Perform check-out procedures for the entire unit and all components.

- Check the maintenance and service record for previous problems and repairs.

(D) DETERMINE THE SYMPTOMS - OBSERVE, RECORD, FEEL, LISTEN, REASON, CHECK, RECHECK. FROM OPERATING EQUIPMENT, OBSERVE OPERATION.

In this step:

- Record each symptom noted which is different from normal operation.

- Visually, by feeling, by listening sense changes, differences, interrupted balance of forces, or something new.

- Distinguish between positive and negative symptoms. Make sure you test for what IS and IS NOT, record what each negative symptoms IS. Record the EXTENT of the symptom (how large, small, many, few).

(L) LOCALIZE TO A FUNCTIONAL UNIT - OBSERVE, OPERATE, CHECK AND RECHECK EACH FUNCTIONING SYSTEM.

In this step:

- Analyze the listed symptoms. Specify which functional systems can be part of the problem or problems.

- Specify which functional systems can be excluded from further checking. Record these, so you do not forget them.

- List symptoms for each functional system, by functional system.

- Test and retest systems to be sure all problems are found or all functional systems are identified.

(I) ISOLATE TO A COMPONENT OR CIRCUIT - OBSERVE, OPERATE, TEST AND RECHECK EACH FUNCTIONING SYSTEM.

In this step:

- Make a list of all components for each functional system.

- Note which components or circuit might cause certain recorded symptoms.

- Operate each circuit or component observing its functioning.

(F) FIND THE PROBLEM - FIX THE PROBLEM - TEST - RETEST - TEST EACH COMPONENT, OBSERVE, RECORD, RETEST, REPLACE COMPONENT, TEST AND RETEST.

Remember, trouble-shooting is not as difficult as you may think. Equipment can not talk but it will do its best to indicate what is wrong and where the problems lie (see fig 2-2). Each component within the system has its own way of attracting attention: belts will squeak, valves will chatter, a leak will hiss or show an oil spot, or a motor will smoke. Each is saying the same thing - HELP!! It is your job to recognize these symptoms and interpret them properly.

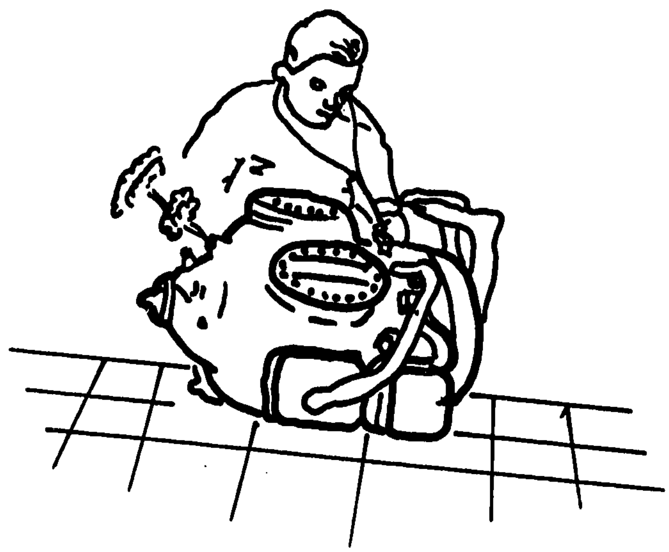


Fig 2-2. Trouble-shooting.

The best procedure for diagnosing refrigeration troubles is to observe the operating pressures. As long as the unit is properly designed and sized, both suction and head pressure should correspond to the pressure-temperature chart.

SUCTION PRESSURE of a system or unit, indicated by the suction pressure gauge, should correspond to a temperature approximately 10° F less than the temperature of a thermometer placed on the cooling coil.

Example:

A system using R-12, having a suction pressure of 37 psig, will have an evaporator temperature of approximately 50° F. By subtracting 10° F from the temperature difference between the inside and outside cooling coil condition, and by checking the Pressure - Temperature (P-T) chart, you can determine the temperature of the refrigerant in the suction line.

To determine the proper operating head pressure on forced convection air-cooled units, add 30° F to the ambient air temperature and obtain the head pressure from the P-T chart. This 30° is an average.

Example:

If the ambient temperature is 90°, add 30° (90° + 30° = 120°). With a system using R-12, a 120° temperature equals 157.1 psi on the P-T chart. Remember this is an approximation, and a few degrees or pounds per square inch variance from this may be considered normal.

This same procedure is employed to determine the head pressure of a water-cooled unit. However, only add 25° to the temperature of the inlet water.

Example:

If the inlet water temperature is 75° F, add 25° (75° + 25° = 100°). With a system using R-12, a 100° F temperature should have a corresponding pressure of 116.9 psi.

Operating pressures that are too low or too high are considered abnormal. One condition is just as bad as the other.

Low suction pressure may be caused by a low charge of refrigerant, obstructed liquid line, motor control out of adjustment, or not enough air passing over the evaporator.

A LOW CHARGE is usually indicated by bubbles in the sight glass, hissing at the expansion valve, a warm suction line, a cool liquid line, a low suction pressure, or a warm evaporator. Since these conditions also can be caused by a restriction in the liquid line, it may be necessary to check for both a low charge and a restriction to determine which is causing the trouble. If a unit is found to be low on refrigerant, find and repair the leak before recharging. If the unit is low on refrigerant, there has to be a leak some place where the refrigerant has escaped. If you charge the unit without stopping the leak, you will have to recharge again and again.

Restriction that causes low-suction pressures can usually be found at screens, valves, capillary tubes, and soldered joints. A restriction in the liquid line is usually indicated by a drop in temperature at the point of the restriction. Restrictions are usually caused by dirt, wax, small pieces of metal, solder, and other contaminants. When a restriction is found, it is just as important to determine the cause of the contaminants as it is to remove the restriction. A badly contaminated system may require disassembly and cleaning before satisfactory performance can be expected.

When low-suction pressure is attributed to insufficient air passing over the evaporator the cause can usually be traced as a dirty filter or placing of boxes and foodstuff in such a way as to restrict the flow of air. Clean the filter, rearrange the foodstuff, and instruct the user on the correct operation. A burned out motor on a forced convection evaporator will cause this same condition.

High suction pressure is caused by malfunctioning expansion valves, inefficient compressors, high heat load, and high head pressure.

After several years of operation, the valves, rings, and pistons on the compressor become worn. This results in low compressor capacity and a high head pressure. When this condition is found, repair or replace the inefficient compressor.

Each condensing unit is designed to handle a given size heat load at a given temperature. If the size of the load increases, the equipment must also be increased.

Low head pressure can be caused by a low charge, inefficient compressor, cooling medium too cold, or too much cooling medium. Most refrigerant controls are designed to operate with a pressure drop of at least 60 psi. If the pressure drop is not 60 psi, the amount of refrigerant passing through the expansion valve will also be reduced. This results in a starved evaporator. The head pressure can reduce to such a degree that flash gas will occur in the liquid line, causing bubbles in the sight glass that will give a false indication of a low charge.

A low charge results in a reduced amount of heat being removed from the evaporator. Therefore, the condenser does not have as much heat to dissipate and the head pressure remains low.

Cooling medium being too cold happens quite often on air-cooled units in cold areas. Each application has to be handled independently. It may be possible to restrict the airflow through the condenser or perhaps supply air at room temperature to the condenser. In some cases, it may be necessary to use an electrical heating element to heat the air before it goes through the condenser. Where several condensing units are being used in one place, it may be possible to install all of them in an equipment room and maintain the temperature in the room between 70° and 100° F. In cases of water-cooled units, restricting the flow of water usually raise the head pressure.

Excessive (high) head pressure will reduce the compressor capacity, cause the unit to be noisy, and increase the operating cost. High head pressure can be caused by an overcharge of refrigerant, noncondensable gas in the condenser, cooling medium to hot, flow of cooling medium restricted, or a dirty condenser.

Some refrigeration technicians seem to think that adding a little refrigerant will correct all malfunctions in a unit or system. One man will add a little gas and then leave without finding or repairing the real trouble. The trouble is still there, so 2 or 3 days later, the user requests another service call. The next man adds a little more gas. This process is repeated until the head pressure gets so high that the unit quits completely or until the compressor is damaged. Adding refrigerant everytime you put the gauges on a system is a very dangerous practice especially on capillary tube systems. If the unit is overcharged, purge the excess refrigerant to the atmosphere, determine and correct the cause of the original trouble.

A refrigeration technician speaks of noncondensable gases. This is a misnomer as all gases are condensable if the pressure is high enough and the cooling medium cool enough. In the refrigeration industry noncondensable gases are those gases that will not condense in a normal refrigeration system. Normally when we speak of noncondensable gases, we are referring to air. Noncondensable gases can enter the system during maintenance or when there is a leak in the low side and the low side pressure goes below 0 psig. If air is found in the system, purge it to the atmosphere. Purging will not eliminate all the air from a system, but you can purge enough to lower the head pressure to normal. Be sure to check the low side very closely for leaks. Air in the system usually indicates moisture. Therefore, a new drier should be installed.

Occasionally, boxes and material are stacked in such a way that the discharged air from the condenser will be recirculated through the condenser, thereby, causing the cooling medium to be too hot. Providing plenty of ventilation will eliminate this problem. If it is necessary for the unit to operate in a boiler room or other hot area, it may be necessary to use a water-cooled condenser. If it is not possible to reduce the temperature of the cooling air or use a water-cooled condenser, replace the expansion valve with one having a greater pressure drop and increase the size of the motor. Both R-12 and R-22 systems will operate as long as the temperature and pressure remain below the critical limit. In a water-cooled condenser, the water temperature is seldom too hot. If the water is too hot, it usually can be cooled by running it through a water tower before being used in the condenser.

In water-cooled units, the condenser may become clogged with dirt, scale and corrosion, thereby, causing a restriction of the cooling medium. The remedy is to clean the condenser and water pipes. In water-cooled units, providing plenty of ventilation will usually reduce the head pressure.

All condensers get dirty and must be cleaned. However, those operating in areas such as mess halls where the air is full of cooking fats get dirtier and cause more trouble than any of the others.

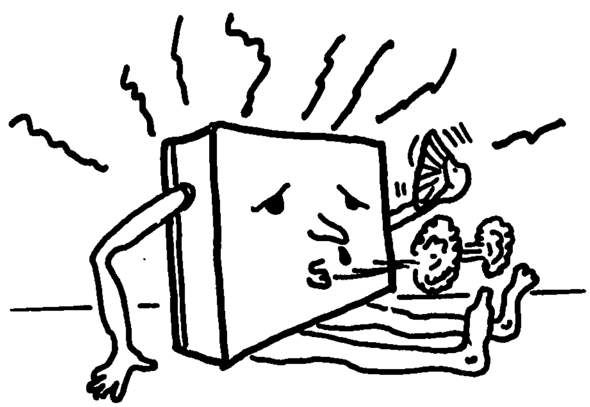


Fig 2-3. High head pressure.

In the air-cooled condenser, the most common complaint is high head pressure as illustrated in figure 2-3. You will find that the most frequent causes of this condition are:

- Reduced Air Quantity - This may be due to dirt on the coil, restricted air inlet or outlet, dirty fan blades, incorrect rotation of fan, fan speed too low, or fan motor going out on overload.

- Noncondensables in the System - Mainly due to poor installation or service techniques, leak on the low-side when the system is in a vacuum. A more specific symptom could be that pressure in the system will not correspond to ambient temperatures on shutdown. Only noncondensables will cause this. Example: The pressure of an idle R-12 system in a room at 80° F should be 84.2 psig.

- Short-Circuiting of the Condenser Air - Usually caused by poor site selection, temporary obstruction, wind conditions causing a portion of the discharge air to enter the inlet opening.

- Refrigerant Overcharge - You will find that this is ALWAYS caused by careless charging procedures. Specific symptom: a definite temperature drop can be felt at the liquid level on the condenser return bends during operation. The bleed off of excess refrigerant reduces head pressure but will not cause bubbles in the liquid line sight glass.

The general symptoms for all four of the aforementioned situations will be cycling on the high pressure switch and the possible opening of the compressor motor overload.

Problems in a water-cooled condenser are not always as easy to determine as those in an air-cooled condenser. Generally, the flow of the condensing medium (in this case, water) is controlled by a water regulating valve actuated by discharge pressure. Conditions that would cause a rise in head pressure on an air-cooled condenser merely increase the water flow rate on a water-cooled condenser.

Any one of the following problems on a water-cooled condenser, with a water regulating valve, will cause an increase in head pressure, unless the maximum water flow has been reached. In this type of condenser, it must be almost at the drowning point prior to any symptoms showing up; you will probably notice high water usage before this point is reached. Specifically, these problems are:

- Scaled Condenser Tubes - This reduces the efficiency of the condenser by decreasing the heat transfer rate from the hot gas to the water. In effect the scale is actually an insulator between the hot gas and the water.

  Symptoms: High volume of water, low water temperature. Depending on design and selection, the saturated condensing temperature (discharge pressure converted to temperature) should not be more than 5° - 10° F above the leaving water temperature.

- Refrigerant Overcharge - Most water-cooled condensers are designed to provide some refrigerant storage space in the shell below the bottom row of tubes. If the system is overcharged so that the level in the condenser covers some of the tubes, the capacity of the condenser will be reduced.

  Symptoms: The same as with scaling, high water quantity, low water temperature rise. If the overcharge does exist, the removal of some refrigerant will reduce water quantity and increase water temperature without causing gas bubbles in the liquid line.

- Noncondensables - Air in a water-cooled condenser dilutes the hot gas and seriously reduces the capacity of the condenser. Again, the symptoms are high water quantity and low water temperature rise. If air is present, the pressure in the system will not correspond to the ambient temperature on shutdown. Purging will decrease the water quantity and increase the water temperature rise.

Evaporator malfunction diagnosis depends a great deal on the medium being cooled, so for purposes of this work unit dealing with trouble-shooting, we will divide evaporators into the following two categories:

- Evaporators cooling air.
- Evaporators cooling liquid.

In the first category are bare, fin, and plate coils with either forced or gravity circulation. Practically all evaporators in this group are of the direct expansion type. The refrigerant feed is usually through expansion valves or capillaries.

In the second category, we will examine flooded, direct expansion chillers and plate type contact coolers. Here the refrigerant feed is usually an expansion valve or a low-side float.

There are two areas where trouble may be encountered in evaporators that cool air:

- Air supply and distribution.
- Refrigerant supply and distribution.

An evaporator just cannot do a proper job of cooling without sufficient air (see fig 2-4). A shortage of air can be caused by the following:

- Dirty filters
- Dirty coils
- Restricted duct work
- Fan running backwards
- Slipping fan belt
- Improperly set fan pulley
- Improperly adjusted dampers

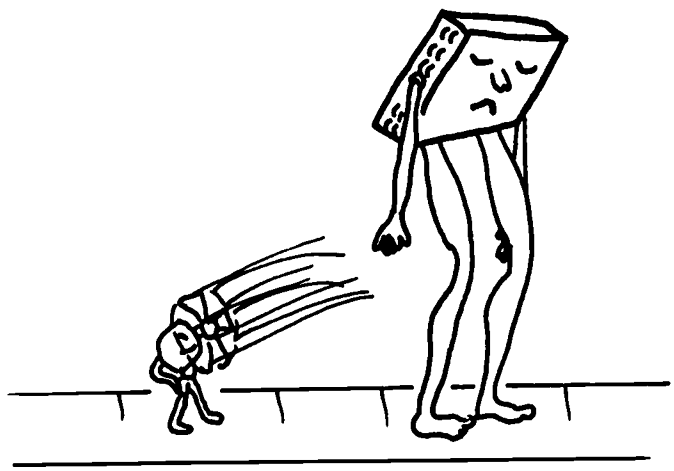


Fig 2-4. Proper ventilation required.

Generally, if the quantity of air has been reduced enough to seriously impair the system's performance, it will be obvious without air measuring equipment. Symptoms of low air quantity that you will encounter are as follows:

- Low suction pressure
- Frosted coil
- Iced coil
- Abnormally low air temperature

If poor system performance is caused by reduced air quantity, returning air quantity to normal should clear up any or all of the above symptoms.

You will find that high air quantity problems are very rare, but nevertheless, when they occur, noise is the usual symptom, along with occasional compressor overloading due to high suction pressure.

Proper performance cannot be accomplished by an evaporator with uneven air flow. Improper ductwork or coil placement is generally the cause for poor air distribution. Air, like electricity, will take the path of least resistance, and this is usually the shortest distance. Remember, however, that turbulence causes resistance, which will make even the shortest path the one with the greatest resistance.

Uneven air distribution over the coil may cause a lowering of capacity and will be indicated by lower than normal suction pressure due to uneven coil loading and possible refrigerant floodback due to lightly loaded refrigerant circuits. Some baffling may be required to get even air velocity over the coil. The valve (see fig 2-5) must have the proper supply of refrigerant to feed the coil. A shortage of refrigerant to the coil may be caused by any of the following:

- System refrigerant shortage

- Plugged drier
- Restricted line or fitting
- Faulty expansion valve

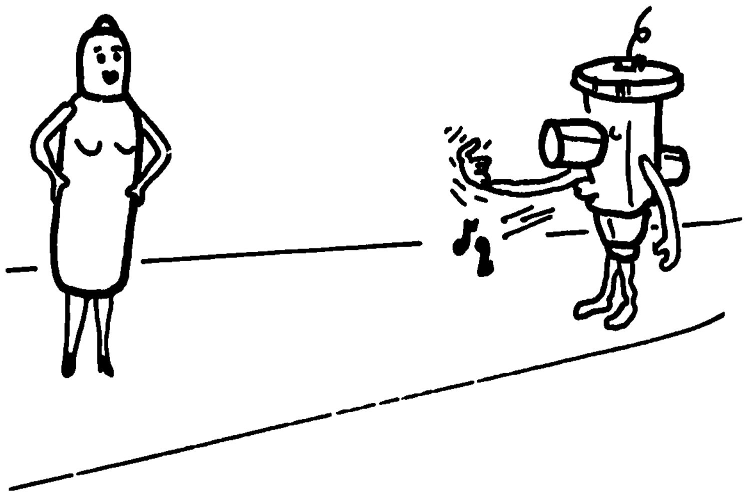


Fig 2-5. Proper supply of refrigerant required.

Symptoms of a refrigerant shortage to the coil will be

- low suction pressure.
- possible frosting or icing of the coil.
- bubbles in sight glass (depending on its location).
- temperature drop in the liquid line (if due to a restriction).
- high expansion valve superheat.
- flash gas due to long vertical liquid line.

If there is a shortage of refrigerant in the system, the addition of refrigerant should raise the suction pressure, clean up any frost, and clear the sight glass of bubbles. If a liquid restriction exists, the temperature drop at the restriction will persist until the restriction is cleared, in spite of the addition of more refrigerant.

In the event that ample refrigerant is present and no restriction exists, but you still have low suction pressure and high superheat, look for a faulty expansion valve or an improper temperature sensing bulb application.

Although trouble-shooting of both hermetic and open compressor problems will be discussed here, no attempt will be made to cover the electrical portion other than to mention electrical components. These two types of compressors have much in common, except in their electrical layouts. The following are problems that you may encounter in either open or hermetic compressors:

- Mechanical seizure
- Noise
- Failure to pump properly
- Overheating

Seizure is a major difficulty in compressors. Before rebuilding or replacing a seized compressor, the cause of the seizure should be determined in order to prevent a reoccurrence. A factory defect can show up at any time in the life of a compressor, but is most apt to appear shortly after being placed into operation in the system for the first time. It is best to eliminate all possible job causes first, since they can cause a repeat failure. A compressor that is low on oil or out of oil indicates a lubrication failure which could be caused by four conditions:

- Natural oil traps in the system.
- Refrigerant floodback to the compressor during operation due to a bad expansion valve or poor temperature sensing bulb location.
- Flooded start due to refrigerant accumulation in the compressor during shutdown.
- Refrigerant shortage, which causes oil trapping. The reason: a lack of sufficient mass flow of vapor.

If the compressor oil charge is normal on a seized hermetic compressor, it is safe to assume the compressor was mechanically defective. Seizure is fairly common without a burnout, so consider it <u>the result</u> of a burnout, not the cause.

On an open compressor, a tear-down of the unit and a knowledge of the quantity of oil in the crankcase will help determine the cause of failure.

Fig 2-6. Compressor asking for help.

The compressor in figures 2-6 and 2-7 are trying to tell us something. Excessive noise in a compressor generally indicates wear due to a lack of lubrication. Noise can also be caused by the same conditions that lead to seizure of the compressor.

Rattling of the compressor on startup, sometimes referred to as "slugging," is caused by an accumulation of liquid refrigerant in the compressor crankcase during the "OFF" cycle. The sudden reduction in crankcase pressure as the compressor starts causes the refrigerant oil mixture to foam. This foam passing through the valve causes the rattle, which continues until the refrigerant is distilled out and the oil level stabilizes. Crankcase heaters or pumpdown control will eliminate initial slugging.

Fig 2-7. Help has arrived.

Fig 2-8. Failure to pump properly.

A lowering in system capacity can be the result of a failure of the compressor to pump properly (fig 2-8). If you were to compare this compressor to a human being, you would say he was suffering from low blood pressure. A serious deficiency in compressor pumping capacity is obvious. The suction pressure will be high, the discharge pressure will be low; the discharge line temperature will be much lower than normal, and the compressor will be hotter. Less serious losses in pumping capacity are more difficult to pinpoint. The following are two good but simple checks that can be made to pinpoint the loss:

- With the compressor running, close the suction service valve. At normal head and with no refrigerant in the crankcase, the compressor should pull down to a range of 15 in to 25 in vacuum in less than a minute.

- Close the discharge valve quickly and tightly immediately after stopping the compressor. Pressure in the discharge side of the compressor should not drop more than 3 to 4 lbs. in a minute's time.

If the compressor is the open or semihermetic type and fails either test listed above, remove the cylinder head and inspect the compressor valves. Look for blown gaskets or broken or badly worn valves.

Many welded hermetic compressors have no service valve, so a judgment about pumping efficiency must be made on the basis of pressure and temperature. When no gauge ports are provided, diagnosis is on the basis of temperature alone. Remember, that hermetic compressors are cooled by the gas flowing through them. If the gas flow is down, due to poor pumping ability, the compressor will run hotter than normal.

A system will fail to cool when the compressor shuts down in response to its temperature device. Several things may cause a compressor to overheat:

- Low voltage (hermetic)
- High voltage, low suction (hermetic)
- Shortage of refrigerant (hermetic)
- High load (high suction pressure)
- High load pressure
- Low oil charge
- Very high compression ratio

Controls also can contribute their share of headaches to the system. Although there may be a number of controls on a particular unit, this discussion will be confined to the metering device and pressure switches, since both actually tie into or form a part of the refrigeration cycle. Metering devices will be covered first.

Fig 2-9. Blaming the expansion valve.

As illustrated in figure 2-9, the expansion valve is quite often mistakenly held responsible for operating malfunctions in the cycle. The three problems most commonly blamed on expansion valves are:

- Overfeeding (flooding)
- Underfeeding (starving)
- Erratic (hunting)

Flooding (overfeeding) may be caused by the valve sticking in an open position; however, it may also be caused by the following:

- Improper superheat on the valve
- Improper valve bulb location on the suction valve
- Wrong type of valve for refrigerant in the system
- Loose expansion valve bulb
- Light load
- Excessive oil in the system

Starving (underfeeding) may be due to the valve sticking closed, or by the partial loss of the gas charge in the power element of the valve. You may find the coil being starved for the following reasons:

- Wrong type of valve for the refrigerant used
- Shortage of refrigerant
- Improper superheat setting
- Plugged drier
- Plugged refrigerant distributor
- Improper valve bulb location
- Plugged equalizer line

In the performance of your job, you will find that expansion valves by their very nature will "hunt" to some degree. Remember, a valve tries to control the superheat of the gas leaving the evaporator by varying the flow of liquid refrigerant entering the evaporator several feet upstream. Therefore, the response is not immediate. Excessive "hunting" can be caused by internal parts that stick or bind. Aside from the faults in the valve itself, the following may cause excessive "hunting":

- Oversize expansion valve
- Very light load
- Long refrigerant circuit
- Rapid changes in condensing pressure or temperature
- Rapid load changes
- Intermittent flashing in the liquid line

Capillaries, though simple in themselves, behave in such a manner as to make the problems .n a system hard to diagnose. In all other devices, the pressure drop takes place within a short distance, through an orifice. In a capillary tube, the pressure drop from high-side to low-side is spread out over the entire length of the tube. The only way a capillary can malfunction is to become partially or completely restricted. However, many other conditions in a system affect the performance of the tube, yet give the same symptoms.

Low suction pressure and a starved evaporator can be due to:

- Shortage of refrigerant
- Too much oil in circulation
- Plugged drier
- Low head pressure

Flooding of the evaporator and increased suction pressure can be caused by: (1) high head pressure; (2) excessive subcooling; (3) overcharge of refrigerant.

Remember, for any given pressure difference across it, a capillary tube can pass more weight of liquid than weight of gas, because the liquid has a much greater density. This fact makes a capillary tube very sensitive to excess oil, excess subcooling, or flashing.

Excess oil in circulation displaces some refrigerant in the capillary tube, and thus reduces the actual weight of refrigerant flowing through the tube and starves the coil.

Excessive subcooling reduces flashing in the capillary to such a point that too much refrigerant flows through the tube, and flooding results.

Excessive flashing due to shortage of gas, liquid line restriction, or capillary in contact with a hot surface will reduce the amount of liquid the tube can pass and result in a starved coil.

The operation of the other types of metering devices such as automatic expansion valves or low and high side floats is much more simple and straightforward than that of either thermostatic expansion valves or capillaries. Sticking or leaking can occur in all three, but the symptoms of starving or flooding the coil are quite obvious.

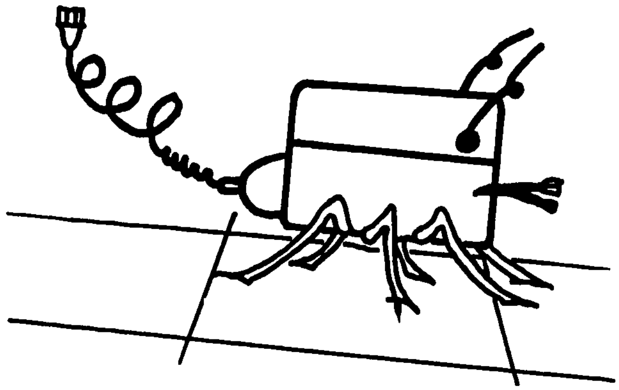


Fig 2-10. Pressure switches.

Most low and high pressure switches (fig 2-10) are of the automatic reset type. This is to prevent service calls for an occasional nuisance tripping of a switch; however, these trips sometimes become a system "bug." Such a nuisance trip of a low pressure switch will usually occur on start-up. The expansion valve may be slow in adjusting to the proper feed. During this period the suction pressure may pull down and the system may be stopped once by the low pressure switch before balancing out and continuing to run.

Occasionally, a high pressure nuisance trip occurs because of heat buildup in an air-cooled unit exposed to the sun during the OFF cycle. When the system is started, the high-pressure switch may open once before the condenser fan can clear the accumulated heat from the unit. The fact that the compressor comes up to speed faster than the fan motor also tends to cause a high pressure trip out.

With the automatic reset or closing type of pressure switches, it is sometimes difficult to tell if they have opened and are the cause of a problem. A simple way to check it is to place a small fuse across the pressure switch terminals. The fuse must have a lower value than the current carried in as the switch opens. A check of the fuse on the next call will tell whether the switch has opened.

Besides the basic components that were just covered there are other components that make up a system. You will cover the trouble-shooting procedures for strainer driers, solenoid valves, water valves, and sight glasses.

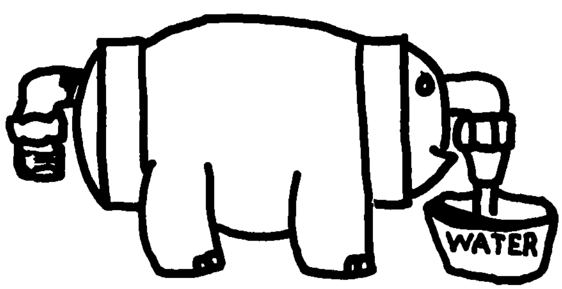


Fig 2-11. Strainer drier.

The main purpose of a strainer drier in the system is to pick up moisture (see fig 2-11). However, it must be remembered that this device can also release moisture back into the system. The strainer drier's water retention capability will vary with the desiccant being used. However, the moisture capacity of all driers is reduced as the liquid refrigerant temperature rises. A drier installed in a 70° F liquid line during the winter may suddenly release moisture back into the system in summer, when the liquid line temperature rises to 100° F. This could cause a mysterious freeze-up of the expansion valve (only if the drier was saturated at the 70° winter temperature).

No amount of moisture will restrict a strainer drier, but contamination in the system will. A partly restricted strainer drier will act as a metering device and cause a pressure drop. Along with this pressure drop is a temperature drop, which can generally be felt with the hand. Sweating and even frosting may occur on lower temperature systems. Seldom is a strainer drier plugged so tightly that all flow is stopped.

Capillary tubes are very sensitive to premature flashing of the liquid. A very slight restriction in a strainer drier, too small to be felt by touch, can cause sufficient flashing to greatly reduce the capacity of the capillary and thus cause a serious drop in system capacity.

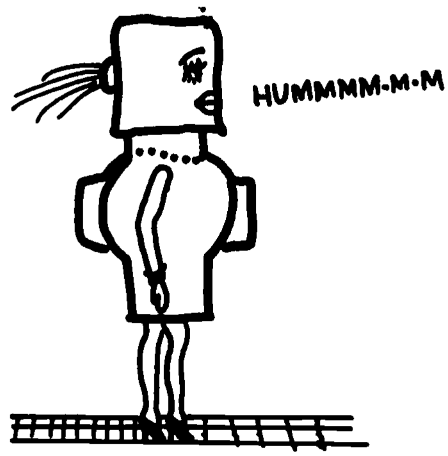


Fig 2-12. Solenoid valves.

Solenoid valves, like the "lovely lady" in figure 2-12, may hum because of low voltage, a loose connection, or a sticking plunger. They may fail to open because of sticking, an open coil, or excessive pressure difference across the valve. Check the maximum operating pressure difference on the valve name plate before concluding that the valve is stuck.

Leakage frequently occurs with a liquid line solenoid, and this can be determined by feeling the line on both sides of a closed valve when a pressure difference exists. If the valve leaks, a temperature drop can be felt across the valve.

The purpose of a water regulating valve is to maintain a uniform head pressure while the system is in operation and to stop the flow of water when the system is shutdown. Water valves may stick and fail to shut off tightly, but do not blame the water valve for a large flow of cool water during operation. This may be due to: (1) noncondensables in the system keeping the head pressure up; (2) scale or dirty condenser; (3) valve set too low.

Remember, a water valve requires a differential between operating and shutoff pressure. It can not maintain an operating head pressure of 125 psig and be expected to shut off tightly at 120 psig. Most valves will require 10 to 20 psig difference between operating and shutoff pressures.

Figure 2-13 shows the eye acting as a sight glass or window in a refrigeration system. It is important, when looking through a sight glass, that a completely full glass is not mistaken for a completely empty one; this is an easy mistake to make. Many, but not all glasses have flow indicators to prevent such errors.

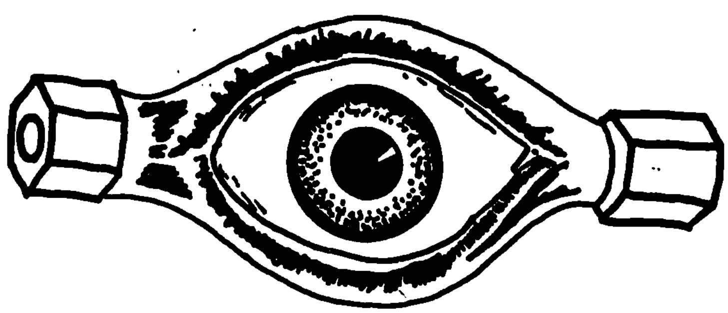


Fig 2-13. Sight glass.

Bubbles in the sight glass indicate either a shortage of refrigerant in the system or a pressure drop due to a restriction, liquid lift, or an undersized liquid line. Be sure you determine the cause of the bubbles before adding refrigerant; otherwise, you may merely overcharge the system.

Some sight glasses are equipped with moisture indicating devices, which change color when safe moisture limits are exceeded. In effect, these devices change colors at a certain relative humidity of the liquid refrigerant. This gives them two characteristics worth remembering. First, the indicator will not read properly unless it is completely submerged in liquid refrigerant. Second, the color change always occurs at the same relative humidity, but as the temperature of the refrigerant goes up it takes more moisture in parts per million (ppm) to cause the same relative humidity. For example, 10 percent relative humidity in R-12 at 80° F represents 10 ppm, while 10 percent relative humidity in R-12 at 100° F represents 16 ppm.

A moisture indicator element that has been subjected to excess water will not read correctly, since the salts in the indicator may have been leaked out. An element subjected to burn out acids will also be damaged. Do not keep changing driers in an effort to get the proper color on a moisture indicator. Check the indicator on a fresh drum of refrigerant with a known low moisture content (most refrigerant manufacturers specify 10 ppm of moisture or less in their refrigerant).

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. State the two pressures that you should observe in diagnosing refrigeration troubles.

   a. ______________________________

   b. ______________________________

2. Referring to the answers to question #1 above, how do you determine if the two operating pressures are within normal ranges?

   a. ______________________________

   ____

   ____

   b. ______________________________

   ____

   ____

3. State the causes and give the remedies of the following abnormal pressures.

   a. Low-suction pressure:

      (1) Causes: ______________________________

      ____

      (2) Remedies: ______________________________

      ____

   b. High suction pressure:

      (1) Causes: ______________________________

      ____

      (2) Remedies: ______________________________

      ____

c. Low head pressure:

(1) Causes: ______________________________

____

(2) Remedies: ______________________________

____

d. High head pressure:

(1) Causes: ______________________________

____

(2) Remedies: ______________________________

____

4. Specify four problems that may occur in either the open or hermetic compressor.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

5. Specify four conditions that cause lubrication failure in the system.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

6. List three problems most often associated with expansion valves.

a. ______________________________

b. ______________________________

c. ______________________________

7. Specify two reasons for bubbles in the sight glass of a refrigerant system.

a. ______________________________

b. ______________________________

Work Unit 2-2. LEAK DETECTION

STATE THE MOST COMMON CAUSE FOR LEAKS IN A REFRIGERATION SYSTEM.

DIFFERENTIATE BETWEEN A POSITIVE AND NONPOSITIVE METHOD OF LEAK DETECTION.

NAME THE SPECIAL METHOD OF LEAK DETECTION.

A refrigeration unit, to operate efficiently, must remain perfectly sealed. The refrigerant must be kept in the system, and air, foreign matter, and moisture (normally classified as noncondensables) must be kept out. The most common cause of leaks is poor workmanship, such as improper flaring, poor soldered or sweated joints, and failure to tighten connections. Other causes can be traced to normal operation, such as wear due to friction, heat, pressure, and vibration. Some units may come from the manufacturer in a defective condition or are damaged in moving from one place to another. You should thoroughly check all units upon receipt or when it is necessary to move them to another location. There are three methods used to detect leaks in a system: (1) positive method, (2) nonpositive method, and (3) special method.

A POSITIVE METHOD is one that is used not only to determine if a leak is present in the system, but it also determines its exact location. The use of the soap or oil bubble test (fig 2-14) to detect leaks is a positive method.

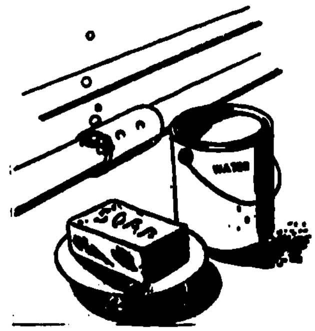


Fig 2-14. Bubble test (soap and water).

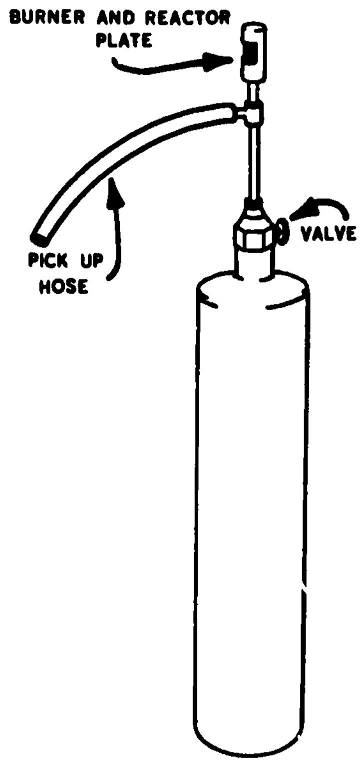


Fig 2-15. Halide torch.

Using the positive method, you mix soap and water together to make a thick solution. Let it sit until the bubbles from mixing have disappeared. Then apply the solution to the suspected leak with a soft brush. If a leak is present, bubbles will appear in the solution (see fig 2-14). This method of leak detection is very useful when testing under hazardous conditions. Oil can also be used in the same manner. Spread a film of oil around the joint or suspected leak and if there is a leak present, bubbles will appear.

A NONPOSITIVE METHOD indicates the presence of a leak, but does NOT indicate its exact location. Pressure and vacuum tests are nonpositive methods of detecting leaks.

A nonpositive method, when used, will let you know that there is a leak somewhere within the system. In the pressure test, a positive pressure is built up throughout the system and a reading is taken. After 24 hours another reading is taken. Any drop in pressure from the first reading will indicate the presence of a leak. In the vacuum test, you would draw the system down to a vacuum; any rise in pressure over a 24-hour period will indicate a system leak.

A SPECIAL METHOD is also classified as a positive method of detection, but it is one that can only be used on equipment using certain types of refrigerants. The halide torch and electronic leak detectors are special methods. This method is special because it is used only on systems that use halogen type refrigerant (R-22, R-12, R-11, R-500, R-502, etc.).

Alcohol, propane, acetylene and most other torches burn with an almost colorless flame, but if a strip of copper is placed in this flame, the flame will continue to be almost colorless. However, if even the tiniest quantity of a halogen refrigerant is brought into contact with this heated copper, the flame will immediately take on a light green color. This principle is used in halide torches to detect leaks in a refrigeration system.

Referring to fig 2-15, the torch burner is shown at the top. One end of a rubber tube (sniffer tube) is connected into the base of the burner. The other end is free to be moved about to various parts of the refrigeration system. The rubber tube will draw air from the open end into the burner. If the open end of the tube is brought near a leak in the system, some of the leaking refrigerant vapor will be drawn up the sniffer tube into the burner. Immediately, the color of the flame will change to green, indicating a leak.

When using this method of leakdetection, you must be careful because the mixture of gases during usage could cause phosgene gas. Which could be deadly. It is important that the torch have a small flame, as a large flame will require more (larger leak) refrigerant to make it change color and the small leak may go undetected.

A-1 HT

Fig 2-16. Electronic leak detector.

The most sensitive leak detector of all is the electronic type (fig 2-16). There are three types: the ion source detector, the thermosister type (based on a change of temperature), and the most commonly used one today, the dielectric type. The electronic type detectors measures a balance in surrounding air and then responds only to halogen gas.

The principle of operation is based on the dielectric difference of gases. In operation, the detector is turned on and adjusted in a normal atmosphere. The leak detecting probe is then passed over surfaces suspected of leaking. If there is a leak, no matter how small, the halogenated refrigerant is drawn into the probe. The leak detector will then give a piercing sound, or a light will flash, or a combination of both, because the new gas changes the resistance in the circuit.

This is probably the most sensitive of any of the leak detecting devices. It uses transistorized circuitry. Flashlight batteries supply the necessary energy. The plastic tip guard should be used only in situations that may be potentially contaminating to the sensing tip. The internal construction of a popular leak detector is shown in figure 2-16.

When using an electronic leak detector, minimize drafts by shutting off fans or other such devices which cause air movement. Always position the sniffer below the suspected leak, because refrigerants, being heavier than air, settle downward.

Move the tip slowly (about one inch per second). One can measure this by moving an inch after each "one-thousand" verbal count. A detector adjusted in ambient air will only buzz, but the instrument will squeal when the tip sniffs refrigerant R-12, R-11, R-22, R-502, or any of the other halogen family of refrigerants. Remove the plastic tip and clean it before each use. Avoid clogging it with dirt and lint.

The methods used to test for leaks will vary with the refrigerant used. However, all methods have one procedure in common: at the start of testing, a positive pressure (greater than atmospheric) of 5 to 30 lbs is necessary throughout the system. If no leaks are found, then test again at the normal condensing pressure for the refrigerant used (i.e., 135 psi for R-12).

Check for leaks before the unit is evacuated. Moisture could enter the system through leaks during evacuation or pump down.

Most manufacturers recommend using the refrigerant in the system to test for leaks. However, with proper care, nitrogen or carbon dioxide may be used safely when pressure testing for leaks. The pressure in the nitrogen cylinder is about 2000 psi and in a carbon dioxide cylinder about 800 psi. A pressure reducing device which has both a pressure regulator and a pressure relief valve, must ALWAYS be used when testing with either of these gases.

A refrigeration system would explode if excessive pressure were to build up in the system. Numerous accidents could have been prevented had the technician not used excessive pressure when testing for leaks.

Before using either of these two gases, look at the name plate. In the majority of cases, it will give the recommended testing pressure. If these pressures are not given and you are unable to find them, as a general rule, never exceed 170 psi pressure when testing all or part of a system.

> Note: NEVER, under any circumstance, use oxygen or acetylene to develop pressure when checking for leaks. Oxygen will cause an explosion in the presence of oil; acetylene will decompose and explode if it is pressurized over 15 to 30 psi.

Testing for leaks using the system's own refrigerant is the most common practice. It is convenient because there is no need for an inert gas cylinder and leak detection devices are a standard component of each refrigeration tool kit.

To do this, you would proceed in the following manner:

- Install a pressure gauge in the system. The liquid line valve (King valve) should be opened just enough to build up a 15 to 30 psi pressure throughout the system.

- Test for leaks using one of the previously mentioned methods: soapsuds (most recommended method), halide torch, electronic detector.

- If no leaks are detected at low pressure, increase the system to the full pressure of the refrigerant (vapor only) and again test for leaks.

- If a leak is located, purge the system at atmospheric pressure, open the system at the leak point, inspect all parts, replace any defective components, clean and assemble. If a soldered or brazed joint is leaking, flux, heat and take the joint completely apart. Clean and assemble; then repeat the leak detection procedure.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. What is the most common cause for leaks in a system?

____

2. Give four examples of common causes of leaks in a refrigeration system.

   a. ____

   b. ____

   c. ____

   d. ____

3. State the primary difference between positive and nonpositive methods of leak detection.

____

4. Give an example of a positive method of leak detection.

____

5. Give an example of a nonpositive method of leak detection.

____

6. What type of system requires the use of a special method of leak detection?

____

Work Unit 2-3. ELECTRICAL TESTING

IDENTIFY ELECTRICAL CIRCUIT TROUBLES AND TEST EQUIPMENT REQUIRED TO LOCATE EACH TYPE.

IDENTIFY COMMON ELECTRICAL PROBLEMS FOUND IN A REFRIGERATION SYSTEM.

STATE THE FIRST STEP TO BE TAKEN IF AN ELECTRICAL PROBLEM IS SUSPECTED.

SEQUENCE THE STEP-BY-STEP PROCEDURE USED TO LOCATE AN OPEN IN AN ELECTRICAL CIRCUIT.

SPECIFY THE TYPES OF SHORT CIRCUITS AND THE STEP-BY-STEP PROCEDURES FOR LOCATING THEM.

IDENTIFY THE CATEGORIES OF SHORT CIRCUITS.

GIVEN A SCHEMATIC AND METER READING, SELECT THE TROUBLE THAT CAUSES THE UNIT TO BE INOPERATIVE.

SPECIFY THE CORRECT WAY TO REPLACE DEFECTIVE UNITS IN COMPONENTS.

STATE THE PROCEDURES USED TO MAKE MINOR REPAIRS TO ELECTRICAL CIRCUITS OR UNITS.

GIVEN TROUBLE SITUATIONS, SELECT THE TEST EQUIPMENT THAT WOULD BE USED IN EACH SITUATION.

The most expensive equipment in the Marine Corps inventory is worthless if it will not operate properly. PROPER MAINTENANCE will keep equipment in an operational condition over a long period of time, and TROUBLE-SHOOTING will return it to service in less time should it malfunction. These are areas of your job that require the most dedication and knowledge.

The electrical troubles that occur in electrical systems generally can be categorized into basic types. Knowing the circuit symptoms that each type of trouble indicates will aid you greatly in the location and repair of the circuit that is causing the malfunction. This usually requires some type of test equipment. You should first identify the type of electrical trouble, and then select the correct test equipment to locate the exact wire or component causing the trouble. It should then be an easy matter to repair the trouble. Let's consider first the types of troubles that can occur.

IMPROPER POWER is one form of trouble you will encounter. Improper power simply means that the circuit is not receiving the correct voltage and current that it needs to function correctly. This may be caused by aging of the circuit or equipment, corrosion of connections, wire too small for the length of the circuit, the circuit connected to the wrong voltage or an increase in circuit resistance caused by loose or aging connection. Indications of improper power are usually slow or sluggish operation of equipment, heating of conductors or equipment, or incorrect operation of the equipment.

If these conditions are noted, the obvious meters that you will require is a VOLTMETER and or an AMMETER. All of the meters that will be discussed in the work unit are combined in the MULTIMETER (Simpson 260). The source voltage should be checked at the panel and also at the equipment. This is the first step to be taken when an electrical problem is suspected. Check the data plate of the equipment to assure that it is rated for the applied voltage. If the voltage at the equipment is different from the applied voltage by more than 5 percent, it will usually require replacement of the existing circuit with a circuit of larger wire. Corrosion maintenance can be required on contacts and connections. An excessive voltage input can cause incorrect operation of equipment. In some cases, an excessive voltage can cause equipment damage.

SHORT CIRCUITS are another example of circuit troubles. A short circuit simply means that resistance has been unintentionally removed from a circuit. The amount and condition under which the resistance is removed determines the type of short circuit that is created. In any situation in which resistance is removed, current flow will increase. If the current flow increase is high enough (if enough circuit resistance is bypassed), the protective device will operate and protect the circuit, if the circuit is equipped with a protective device. All electrical circuits should be so equipped. Because of this situation, a dead circuit meter, better known as an OHMMETER, will be required to trouble-shoot the circuit. An ohmmeter has its own power supply. Types of shorts that you may encounter are cross short, shorted control device, and short to ground. A SHORT TO GROUND (also called a ground) is a circuit in which all resistance in the circuit has been bypassed. This usually means that a phase (hot) conductor has come into direct contact with a grounded conductor. This grounded conductor may be a neutral wire, an equipment ground, or a conduit system. All of these are connected to a ground electrode.

Another type of circuit malfunction is an OPEN CIRCUIT. This means that an unintended break has occurred in the circuit, causing the current flow to stop in all or part of the circuit. Either a voltmeter or ohmmeter can be used to hunt trouble in this type of malfunction.

The most important aspect of trouble-shooting is COMMON SENSE. Use a logical sequence to begin your trouble-shooting. If possible, talk to someone who was present when the unit malfunctioned. Ask them to describe what happened. Make a visual inspection and do not overlook the obvious. Check to see if the unit is connected and turned on. Look for broken wires or terminals and loose connections. Quite often a visual inspection will locate the trouble. If a wiring diagram or schematic is available, make use of it. Check to see where the circuit goes, where power is applied, and what components are connected. Make an operational check. See what parts of the system are functioning and what components are not. Analyze the malfunction. Determine the part of the circuit in which the open has occurred. Now select the meter you need to check the circuit.

Let's start with a voltmeter. With a voltmeter you will need the power on to the system. Set the voltmeter to the power range for the voltage applied. Figure 2-17 shows how a voltmeter is used to locate an open circuit in a parallel lighting circuit. Notice that two lamps are controlled by one switch. One lamp lights when the switch is closed; the other lamp does not light. You change the lamp bulb, but the lamp will not light. Your meter indicates zero voltage between the contacts of the fixture. You check and the circuit breaker panel shows 115 volts. A check at the junction box shows 115 volts. Now you remove the fixture from the ceiling box and [illegible] the silver and gold terminals, your meter indicates that there are 115 volts present. In trouble-shooting a circuit, your trouble is always located between your difference in readings. In this case, your difference in readings (zero voltage at the contacts of the fix[illegible] volts at the fixture terminals) is the fixture. Therefore the fixture must be replaced. You have now located and repaired your trouble.

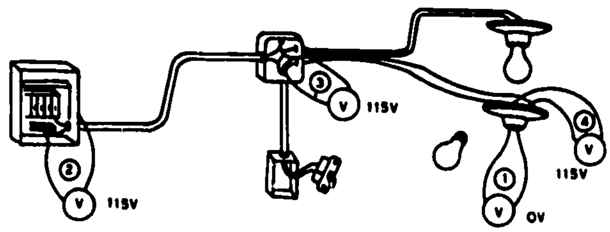


Fig 2-17. Connecting a voltmeter.

Be sure to turn off the circuit breaker and tag the panel before you start to disconnect the fixture terminals. Now let's compare the indications that you would receive with a voltmeter and an ohmmeter on the same circuit.

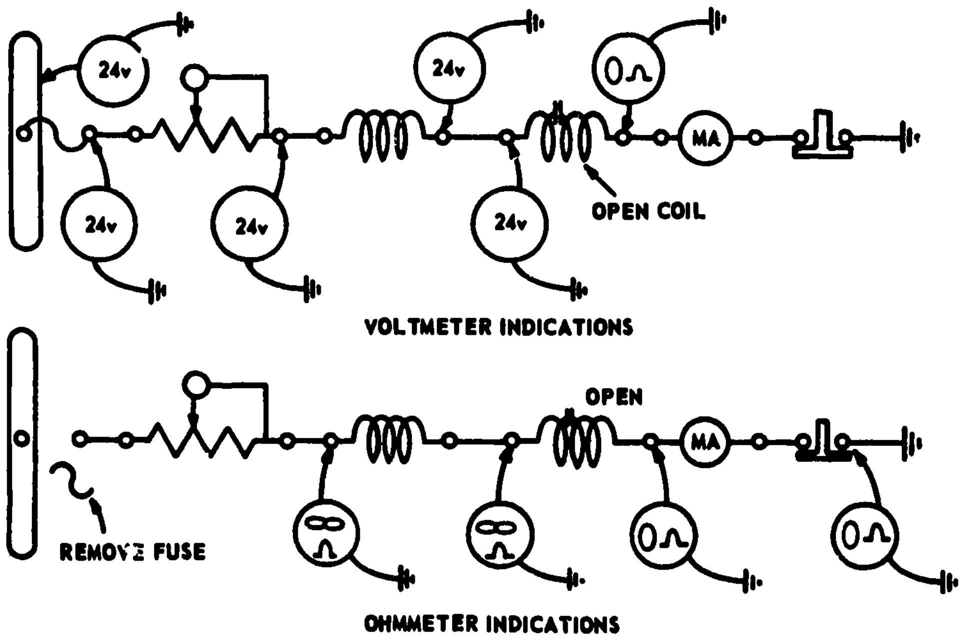


Fig 2-18. Checking a circuit with both a voltmeter and ohmmeter.

Figure 2-18 shows the same circuit being checked by the voltmeter and ohmmeter. Notice that the fuse is removed when the ohmmeter is used. This is because the ohmmeter supplies its own power and MUST NOT be used in a live (hot) circuit. In both cases, you will notice that the trouble is located between your difference in readings. In this case, the coil must be replaced.

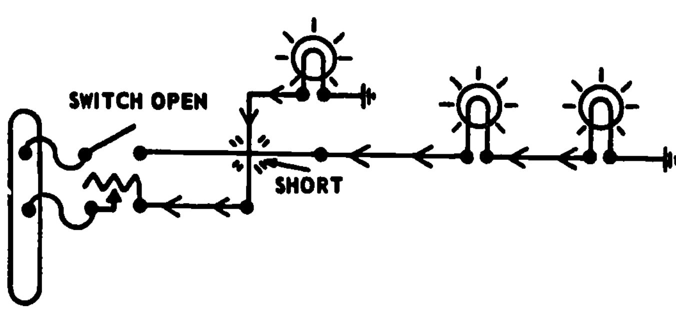


Fig 2-19. Cross short.

As previously stated, several types of short circuits exist. Figure 2-19 shows a cross short. Notice that two separate circuits are operating from one control device. Figure 2-20 shows a circuit in which part of a coil has shorted out, thereby reducing the total circuit resistance and increasing the total current flow. In this type of a short the current flow may not increase sufficiently to burn out the fuse, but the circuit will not operate correctly. Figure 2-21 shows a short between a positive conductor (hot) and a negative conductor (ground) so that all of the resistance in the bottom circuit is bypassed. The result is a blown fuse. This is a short to ground. The same results can happen in a circuit encased in conduit should the insulation of the phase (hot) wire become damaged so that the conductor comes into contact with the conduit that is grounded. Figure 2-22 shows this condition.

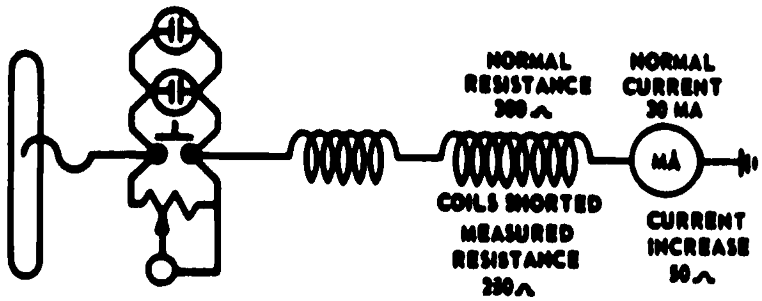


Fig 2-20. Circuit with coil shorted.

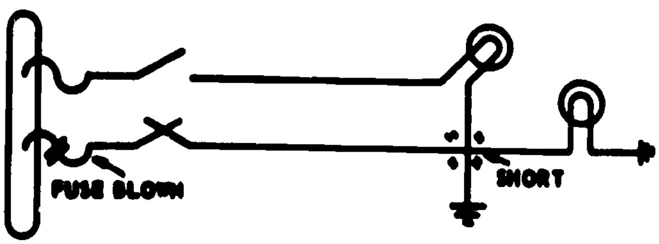


Fig 2-21. Short between a positive and negative conductor.

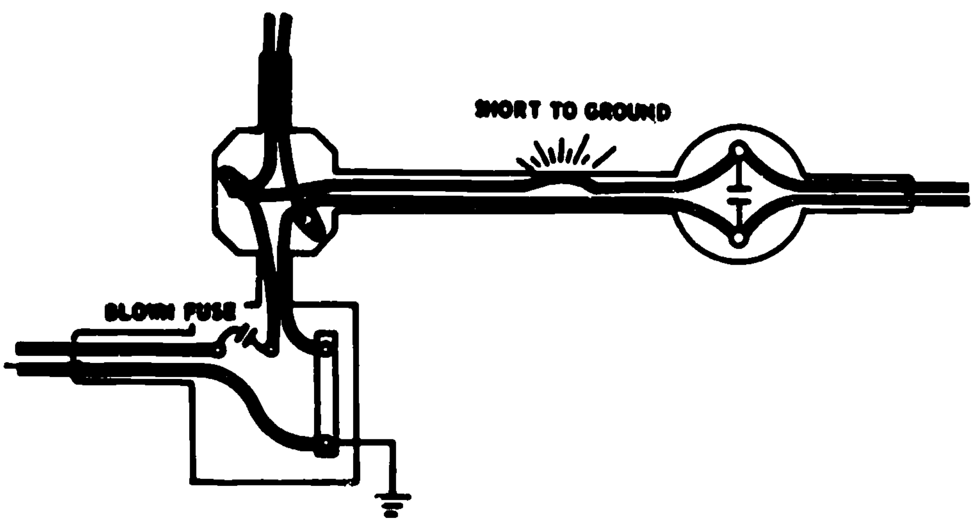


Fig 2-22. Conduit shorted.

From the different type and conditions of shorted circuits you could assume that several techniques will be required to trouble-shoot short circuits. Some basic procedures must be followed. Shut off the power to the equipment. In some cases, the short circuit will have already accomplished this by tripping the circuit breakers or burning out the fuse. In any event, the power must be shut off. Talk to the people who were present when the unit malfunctioned. Did they notice sparks arcing? Did they smell insulation burning? If the circuit is fused, check the fuse condition. Did the element simply melt or did it vaporize? A fuse with extensive blackening indicates a very high overload. This might indicate a short to ground where all resistance was removed from the circuit. If the fuse element only melted, then a cross short or a shorted unit may be indicated. Check the wiring diagram and then perform a visual inspection. Use your senses of sight, smell, and touch. A blackened spot on the component or conduit may locate the short. The smell of hot insulation can give you the location. A hot spot on the component can help you find the shorted area.

If a visual inspection does not show the trouble, you will need to use an OHMMETER to locate the exact problem area. An ohmmeter is used since, in many cases, it will not be possible to have circuit power applied to the equipment. Your next step will be to isolate the circuit involved. This means that the circuit must be disconnected from the ground. With the circuit now open at both ends, you can take your metering readings. A normal reading between circuits would be identified as infinity (oo) on the ohmmeter. Since a short exists in the circuit, you will get a zero reading. Now go as near the middle of the circuit as possible and open the circuits at a junction box or terminal strip. Check between the circuits in both directions. One direction should show clear of any trouble by reading infinity on the meter. The other half should show the circuits still shorted (zero ohms). Move down the shorted portion of the circuit to the next junction box and repeat the process until the short is isolated to a single wiring section. Normally, the wiring in this section will have to be replaced. Should the phase wire be contacting a grounded conductor (neutral wire, equipment ground wire, chassis, or conduit system), it will be necessary to take your ohmmeter readings between the affected phase wire and each of the grounded conductors. To do this, open the neut.al at the power panel and check from the phase conductor to the neutral. A zero reading indicates a short. An infinity (oo) indicates that the two conductors are not in physical contact and therefore not shorted. Check the neutral ground (green) conductor in the same manner. If the equipment ground is clear, then check from the phase wire to the conduit. Somewhere the phase wire is making physical contact with the conduit. Refer to figure 2-22 for a visual display of this situation.

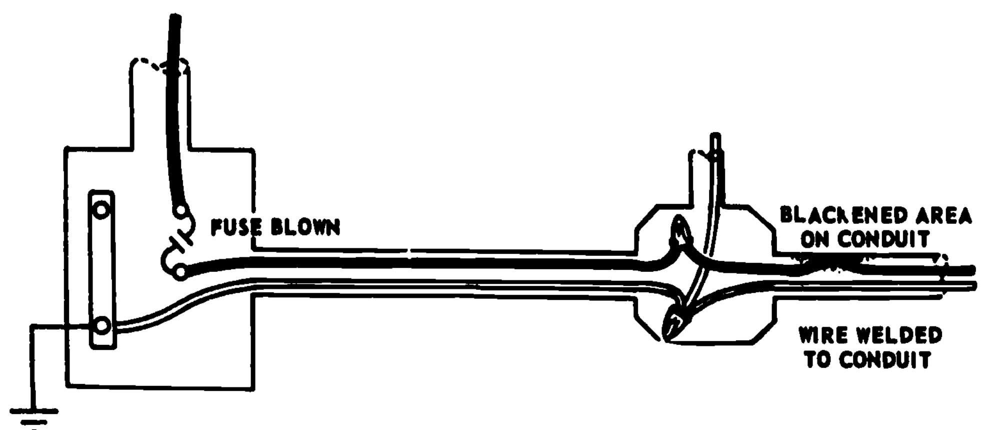


Fig 2-23. Solid Short.

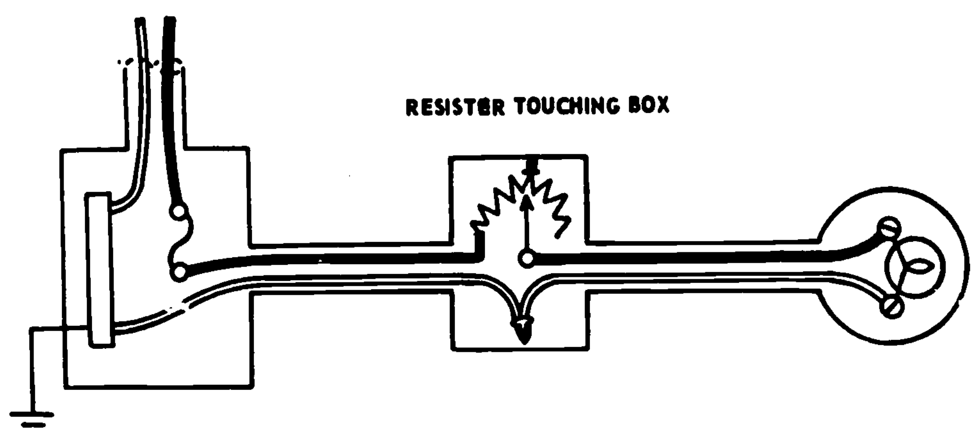


Fig 2-24. Partial short.

Short circuits can be categorized as solid, partial, or floating. A SOLID SHORT circuit means that a complete contact is made, and usually the conductors are fused or welded together or to the conduit or chassis. The solid short is the most destructive to circuits and components of electrical systems. It is also the easiest short to locate (see fig 2-23).

A PARTIAL SHORT means that some, but not all, of the circuit resistance has been bypassed. Enough resistance has been removed to affect circuit operation. This type of short will either be in the unit or in the control device rather than in the conductors (see fig 2-24).

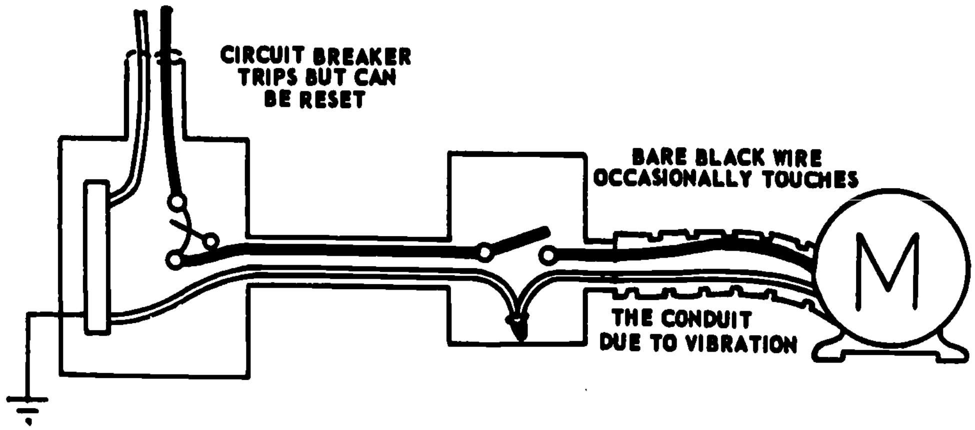


Fig 2-25. Floating short.

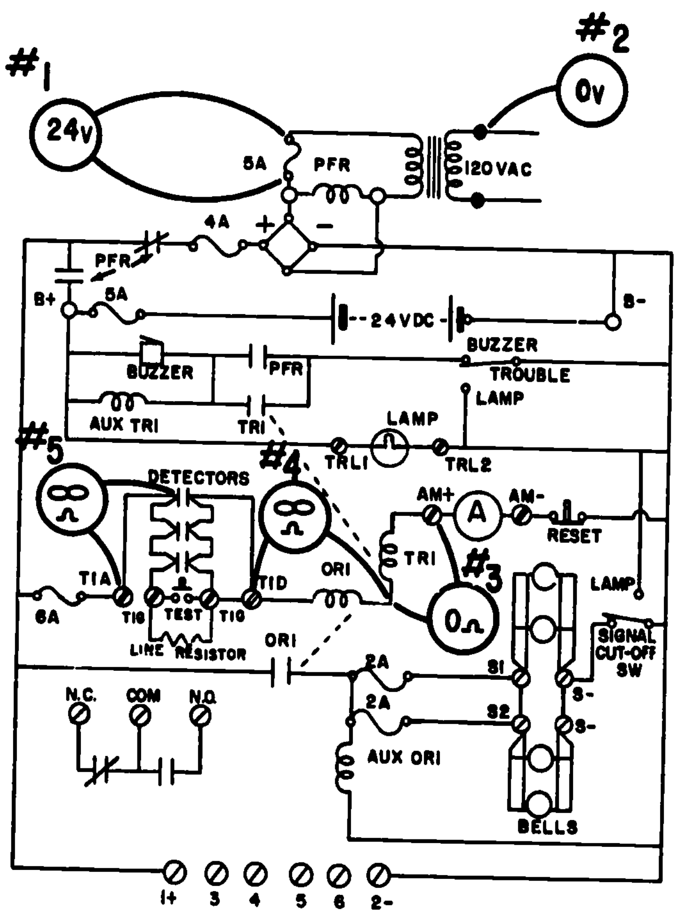


Fig 2-26. Malfunctioning circuit.

A FLOATING SHORT is a trouble that will appear and disappear in the circuit. That is, sometimes the circuit is shorted and sometimes is is not. Electrical contact only occurs sporadically. Because the short comes and goes it is the most difficult to locate. The normal method of trouble-shooting this short is to replace the conductors (see fig 2-25).

Look at figure 2-26 and note that five separate and individual troubles are indicated. Each will be considered one at a time, indication will be stated, an analysis will given, the meter reading discussed, and the trouble identified for each.

Trouble number one was indicated by no alternating current to the system. Since no power was reaching the rectifier from the transformer, an open circuit is indicated. When a voltmeter was placed across the fuse, the reading was 24 volts. Normally, a fuse does not offer resistance to a voltage drop. Since this fuse is using all the voltage in the circuit, it must be open. When the 5-amp fuse is replaced, the circuit operates normally.

Trouble number two was indicated by no alternating current to the system. This also indicates an open circuit the same as number one above. A voltmeter is placed across the primary coil of the transformer and indicates a zero reading, which implies that no voltage is being applied to the system. Check to see if the system is connected. The system shown in the drawing is a fire alarm system, so the primary of the transformer is not fused at the panel but connects directly to the service drop. The service drop is fused at the distribution transformer. Therefore, you will need to seek help from the electrical line crew to repair this trouble.

Trouble number three is indicated by a continuous trouble buzzer operation. Operating the reset switch will not clear the trouble. The ammeter reads higher than normal. You isolate the zone circuit by removing the 6-amp fuse and taping the reset switch open. When the ohmmeter is placed across the trouble relay coil (TR1) it reads zero ohms resistance. The normal resistance for this coil is 250 ohms. This indicates that the coil is shorted and must be replaced. When the relay is replaced the circuit resumes normal operation.

Trouble number four is indicated by a trouble buzzer signal. The same indications exist as in trouble number three, except that the ammeter reads zero. The same procedures as used in trouble number three are used to isolate the circuit. When the ohmmeter is inserted across the operating relay coil (OR1) it reads infinity. The normal resistance for the OR1 coil is 350 ohms. The infinity reading across the coil indicates that the coil is open. When the operating relay is replaced, the system operates normally.

Trouble number five gives the same trouble indications as trouble four. The zero ammeter reading indicates an open in the zone circuit. The ohmmeter readings are all normal until the ohmmeter is placed across the positive detector conductor. The conductor should not offer any resistance to the circuit. The infinity reading on the ohmmeter indicates that this conductor is open. When the conductor is replaced, the system returns to normal.

Once a unit or component has been identified as the source of trouble it is necessary to replace the malfunctioning part. It will be necessary to exactly identify the unit or component that you are replacing. Components can look alike without operating the same. Relays differ in operation of numbers of contacts and arrangement of contacts as well as voltage required and coil resistance.

Once you have obtained the exact replacement part (by part number, series, and model), you are ready to start your replacement. You would be well advised to make a sketch of the installed unit prior to removing it. Identify the conductor terminals by color, number, and location on the unit. Check the position of the installed unit or component since it is possible in some cases for part of the operation to rely on gravity, as in the case of motor starters. Check for insulation blocks on the installed component or unit.

Be sure to shut off all electrical power and tag the circuit breaker that controls electrical power to the unit to preclude someone from reenergizing the unit while your are working on it. You might need to shut off and bleed down pressure of gas or liquid lines if the replacement would require the opening of these lines in the replacement of a component as in the case of a solenoid valve.

Now you can loosen the conductor terminal connections and move the conductors out of the way. Loosen devices used to mount the unit or components. These can be bolts, screws, or nuts. If the unit is attached by soldering, care must be used in heating the solder joints to prevent damage to the joints or insulation. If insulation is a factor, check distances and measurements involved. Remove the component or unit. Set the replacement in, align mounting holes and start the holding devices. Align the new component if this is a factor, making necessary adjustments. Make the necessary mechanical connections and tighten the holding devices. Refer to your sketch and make the electrical connections. Remember to install the terminal loops so that they close as the terminal screws are tightened. Go to the circuit breaker panel, remove the tag, and reset the breakers. Perform an operational check on the system to assure that it is operating properly.

Minor repairs to electrical circuits or units include switches on controls, tightening terminals and connectors, cleaning contactors, and replacing fuses, lamp bulbs, and other small replacement items. Operator checks will show minor maintenance items that require attention. Fair wear and tear will gradually require replacement of switches, lamp bulbs, and other minor parts. Terminals and contactors require periodic cleaning and tightening to prevent corrosion build up or arcing.

Where there is a possibility of coming in contact with a live circuit, power is removed from the circuit prior to working on it. This can not be stressed enough "POWER OFF WHEN WORKING ON A ENERGIZED CIRCUIT." Neutrals or ground are disconnected LAST and connected FIRST. These are your primary safety protection when working with electrical circuits. DO NOT assume that a circuit is deenergized simply because it is not operating. ALL CIRCUITS SHOULD BE TREATED AS ENERGIZED UNTIL PROVEN OTHERWISE.

When replacing units that are color coded (switches, duplex receptables, etc.) be sure to observe this color code (black to gold, white to silver). Be sure that connections are clean and tight. Dirty or loose connections will cause resistance or arcing in the circuit and prevent proper operation. If ferrule fuses are used, pay particular attention to the fuse contacts. Fuse clips will overheat and lose tension unless they are tight and clean. In-line fuse holders will corrode over a period of time and require cleaning. Use care when moving taped splices and connections in boxes since extreme bends or twists can break the conductors or insulation.

Let's consider some trouble situations that can arise in a motor system, and the test equipment that you will require to locate the malfunction.

If a motor fails to start, the obvious type of trouble is an open circuit somewhere within the electrical system. The best meter to use would be a voltmeter. The voltmeter would be used to locate the point in the system where the voltage terminates. Check the power panel to see that voltage has been applied to the system. Quite often someone failed to turn on the switch. Continue through the controller to the motor until the open in the circuit is identified.

If the motor fails to come up to speed your first check should be the load. Disconnect the load and see if the motor runs normal. Check the input voltage with a voltmeter to assure that excessive line loss has not reduced the voltage below its normal value. In the case of a three-phase motor, check to see that all phases have power. Loss of one phase will give this indication. Use a voltmeter to check input power and fuses.

Motors that will not continue to run when the start button is released normally indicate an open in the holding circuit in the motor starter. Use a voltmeter and check the holding circuit.

The fuses blown on the motor starter usually indicate either a shorted circuit or excessive current draw. Disconnect the load from the motor and restart the motor. If the fuses blow, a short is indicated and an ohmmeter will be needed. If the motor runs without a load, check the input voltage. Also, check to see that the load is not binding or misaligned.

Motor starters, as a general rule, are simple and trouble-free in operation. Contacts and connections are readily accessible. Overload relays are mostly plug-in type. Operating coils are encapsulated in epoxy compounds to reduce burnouts. Spare parts are normally readily accessible. If the motor starter was correctly selected and installed originally, only minor problems will be encountered. Areas that should be checked are the thermal overload relays for proper size and operation, contactors for noise and movement, contacts for spring tension and surface condition, shunts (windings) for broken strand or corrosion, and coils for proper voltage and connections.

Thermal overload devices should be periodically tested. Aging and inactivity can lead to metal fatigue in some relays that can prevent their operation under any load condition. Since the overload relay is specifically built as a safety valve for the motor system, lack of its operation at the proper time can cause serious damage to the equipment. A requirement exists to test these relays every two years.

Contactor section of the motor starter includes the coil and the contacts as well as the armature and solenoid. If the laminated armature is not held tightly together or if the pole pieces do not fit well together, noise will result. Dirt or rust may prevent proper closure and cause noise and heat. Grease can prevent closure of the contacts. Should the shading coil become broken, noise will become very objectionable, at this point the shading pole should be replaced.

The contactors of the motor starter close and open under a heavy electrical load. To reduce arcing most contacts are designed to provide a rolling action so that the circuit is closed and opened at the tips of the contacts rather than the flat surfaces. This reduces pitting of the contacts. Since the contacts are subject to mechanical wear as well as electrical burning, they will eventually require replacement. Both the moving and stationary contacts should be replaced at the same time. Check the spring pressure to assure that the pressure is firm and even on all sets of contacts. Springs may lose their tension due to heat and aging. Adjust or replace springs as required to provide good solid pressure between contacts. Contacts are usually made of copper or silver. Silver will form a dark oxide when exposed, this oxide is conductive and therefore requires very little cleaning. Copper oxide is not sufficiently conductive and requires occasional attention to prevent overheating. Use sandpaper or a fine file such as a burnishing tool. When cleaning contacts, be sure to retain their original shape. Shunts are the name given to the flexible woven bands of copper that carry the current from the movable contacts to the stationary studs. Shunts with broken strands should be replaced to prevent overloading the remaining strands. Be sure that the terminals of the shunts are tight. The solenoid coils require very little maintenance. The coils should be operated at their rated voltage. Either over or under voltage will shorten the life of the coil.

Many controls on refrigeration systems today are electrical. To maintain units properly, you must be able to make electrical tests and discover the electrical problem involved. Common electrical problems that you may encounter are improperly made, loose, and dirty connections; bad relays; burned-out capacitors; burned-out motors; and defective timers.

Loose electrical wiring can cause many problems and, at times, may be extremely difficult to locate. The problems caused by loose wiring do not follow any set pattern. Most loose wiring can be found by visual inspection (refer to fig 2-27). However, when a loose wire is suspected, it is, at times, necessary to check each wire and its connection individually. This is usually a time-consuming and a grueling task to say the least, but it must be accomplished before the unit will operate satisfactorily again. Once the bad wire or connection is found, it must be repaired or replaced. Any wiring that is not properly repaired will only cause problems in the future.

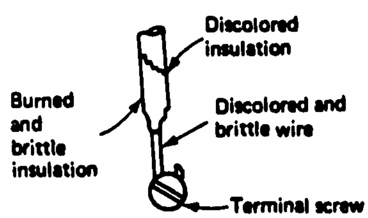


Fig 2-27. Visual inspection of electrical wiring.

Improperly wired units will operate inefficiently, if at all. They will not produce the results desired of the equipment. Each manufacturer designs his own wiring diagrams for each item of equipment, designs that will cause the unit to produce the desired results if it is correctly wired. If you are in doubt about the wiring on a piece of equipment, the recommended wiring diagram should be consulted and the wiring changed to match the diagram.

Low voltage to a motor can cause it to overheat and will damage the motor windings. This overheating is due to excessive current draw due to low voltage. There are several causes of low voltage, such as wire that is too small, loose connections, or low voltage provided by the power supply. To check for low voltage, connect a voltmeter to the common and run terminals of the motor (refer to fig 2-28). Start the unit and observe the voltage reading. It should not vary more than 10 percent from the rated voltage of the unit. If a voltage drop of more than 10 percent is experienced, check the size of the wire going to the unit. Be sure that it is at least as big as the recommendation of the equipment manufacturer. If not, it should be replaced with proper size. If the wire is of sufficient size and the voltage is still low, check for loose connections. These connections will usually be indicated by the wire insulation being overheated or burned. Repair these connections as required.

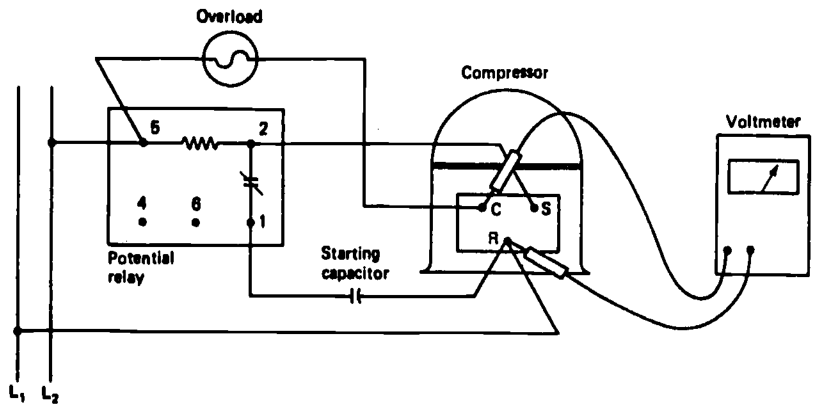


Fig 2-28. Low voltage check.

CAPACITORS are used by numerous manufacturers to improve the starting and running characteristics of their motors. Capacitors are manufactured both for use in starting and running motors. Each manufacturer determines the proper size for his own motors. Therefore, you must follow the recommendation in the technical manual.

STARTING CAPACITORS, as the name implies, are used in the starting circuit of the motor. They are generally round, encased in a plastic casing, and have a relatively high microfarad (mfd) rating. These capacitors are designed for short periods of use only. Prolonged use will usually result in damage to the capacitor. If a starting capacitor is found to be defective, be sure to check the starting relay before the unit is placed in service or the new capacitor may also be damaged. The best way to check a capacitor is by the use of a capacitor analyzer. This type of meter provides a direct reading of the mfd output of a capacitor without the use of bulky equipment and mathematical formulas. Starting capacitors that are found to be out of the range of 0% to +20% of the mfd rating of the capacitor must be replaced with the proper size.

Replacement capacitors must have the same voltage rating as those being replaced. Also the voltage rating of any capacitor must be equal to or greater than the capacitor being replaced. When replacing a starting capacitor, be sure that a 15,000 - 18,000 ohm, two-watt resistor (bleed resistor) is soldered across the terminals of the capacitor. This is a precautionary measure to prevent the arcing and burning of the starting relay contacts. To wire a starting capacitor into the circuit see figure 2-29.

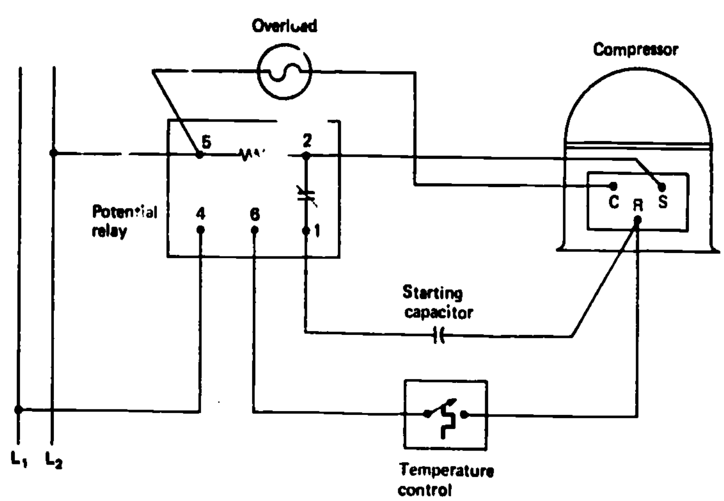


Fig 2-29. Starting capacitor in circuit.

RUNNING CAPACITORS are in the operating circuit continuously. They are normally of the oil-filled type. The MFD rating of these capacitors is relatively low, even though they are larger in size than the starting capacitor. They also provide enough torque to start the permanent split capacitor (PSC) type motors. Running capacitors are provided with a terminal marked with a red dot. Because of the relatively high voltage generated in the starting winding, the unmarked terminal is connected to the starting terminal on the motor. The red dot indicates the terminal that is most likely to short out in case of a capacitor breakdown. If the terminal with the red dot is connected to the motor starting terminal, damage to the winding could result. Capacitors that are determined to be out of range by plus or minus 10 percent of the mfd rating must be replaced. Again, the voltage rating must be equal to or greater than the one being replaced. Higher than normal running amperage usually indicates a weak capacitor. Refer to figure 2-30 to wire a running capacitor into the circuit.

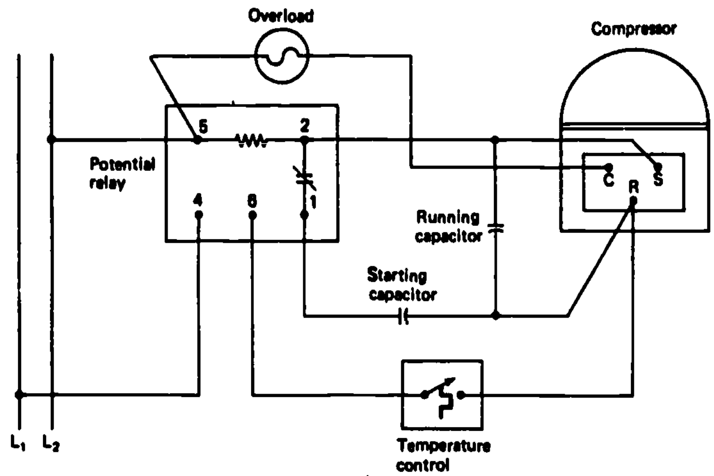


Fig 2-30. Wiring a running capacitor into the circuit.

STARTING RELAYS are the device used to remove the starting circuit from operation when the motor reaches approximately 75 percent of its normal running speed. Its function is basically the same as the centrifugal switch used in split-phase motors. The following are four types of starting relays in use today:

- Amperage (current) relay.
- Hot wire relay.
- Solid state relay.
- Potential (voltage) relay.

The horsepower size and the design of the equipment regulates the type of starting relay to be used.

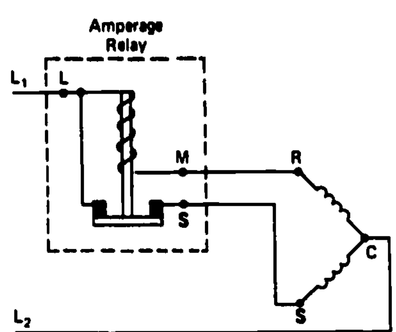


Fig 2-31. Amperage relay.

The AMPERAGE (CURRENT) RELAY (fig 2-31) is an electromagnetic type relay, which is normally used on 1/2 hp units and smaller. These relays are positional types and must be properly mounted for satisfactory operation. They must be sized for each motor horsepower and amperage rating. To check an amperage relay, turn off the electricity to the unit and remove the wire from the "S" terminal and touch it to the "L" terminal of the relay. Place an ammeter on the common wire to the compressor. Start the compressor and immediately remove the "S" wire from the "L" terminal. If the compressor continues to run and the amperage draw is within the rating of the compressor, replace the relay.

Caution: DO NOT allow the loose wire to come into contact with anything or anyone so as to prevent electrical shock.

An amperage relay that is too large for a motor may not allow the relay contacts to close, thus leaving out the starting circuit. The motor will not start under these conditions. A relay that is rated too small for a motor may keep the contacts closed at all times while electrical power is applied, leaving the starting circuit engauged continuously. Damage to the starting circuit may occur under these conditions. A motor protector must be used with this type of relay.

The HOT WIRE RELAY (fig 2-32) is a form of current relay, but it does not operate with a electromagnetic coil. It is designed to sense the heat produced by the flow of electrical current through a resistance wire.

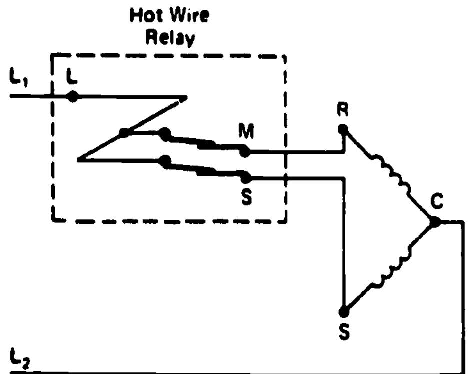


Fig 2-32. Hot wire relay schematic.

There are two sets of contacts in these relays, a set for starting and a set for running. To check these relays, turn off the electrical current and remove the wire from the "S" terminal on the relay and touch it to the "L" terminal on the relay. Place an ammeter on the common wire to the compressor. Start the compressor and immediately remove the "S" wire from the "L" terminal. In order to prevent electrical shock, do not allow the loose end of the wire to touch anything or anyone. If the compressor continues to run and the amperage draw is within the rating of the compressor, replace the relay. If the compressor operates within the amperage rating indicated by the manufacturer but still stops within one or two minutes, the overload portion of the relay is defective. Replace the relay with one of the proper size for the horsepower and amperage rating of the compressor motor.

A hot wire relay that is too large for the motor will not remove the starting components for the circuit resulting in possible motor damage. One that is rated too small will stop the motor with the overload after one or two minutes of operation. An additional overload is not necessary when these relays are used as they are nonpositional relays.

SOLID STATE RELAYS (fig 2-33) use a self-regulating conductive ceramic developed by Texas Instruments, Inc., which increases in electrical resistance as the compressor starts, thus quickly reducing the starting winding current flow to a milliampere level. The relay switches in approximately .35 second. This allows this type of relay to be applied to a refrigerator compressor without being tailored to each particular system within the specialized current limitations. These relays will start virtually all split-phase 115-volt hermetic compressors up to 1/3 hp. An overload must be used with these relays. Since these relays are push-on type devices, the easiest methods of checking their operation is to simply install a new one. Be sure to check the amperage draw of the compressor motor.

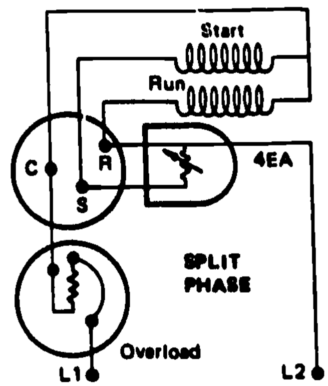


Fig 2-33. Solid state relay schematic.

POTENTIAL RELAYS operate on the electromagnetic principle. They incorporate a coil of very fine wire wound around a core. These starting relays are used on motors of almost any size. They are nonpositional. The contacts are normally closed and are caused to open when a plunger is pulled into the relay coil. These relays have three connections to the inside in order for the relay to perform its function. These terminals are numbered 1, 2, and 5. Other terminals numbered 4 and 6 are sometimes used as auxiliary terminals. To check a potential relay, turn off the electrical current and remove the wire from terminal #2 on the relay and touch it to terminal #1 on the relay. Place an ammeter on the common wire to the motor. Start the motor and immediately remove the #2 wire from the #1 terminal on the relay.

Caution: Here again, as mentioned earlier, DO NOT allow the loose wire to touch anything or anyone so as to prevent electrical shock.

If the compressor continues to run and the amperage draw is within the rating of the compressor, replace the relay.

The sizing of potential relays is not as critical as with the amperage and hot wire relays. A good way to determine what relay is required is to manually start the motor and check the voltage between the start and common terminals while the motor is operating at full speed. Multiply the voltage obtained by .75 and this will be the pick-up voltage of the required relay.

A starting relay that is mounted so that it vibrates will cause the contacts to arc excessively and become burned. When a relay is mounted on such a surface, it must be remounted on a more solid surface. Generally, the relay will need to be replaced during the process. Be sure to replace the relay with the proper type and size. If it is a positional relay, it must be mounted to satisfy the manufacturer's recommendations.

The purpose of a MOTOR STARTER or CONTACTOR is to provide the switching action of the high current and voltage required by a compressor. This is done by a signal given by the control circuit on demand from the thermostat or temperature controller. These are electromagnetically operated devices.

A burned coil will prevent the operation of starters and contactors because there will be no electromagnetic field to operate the device.

To check for a burned coil, first you must turn off the power supply to the unit. Then remove the electric wiring from the terminals of the coil. Zero the ohmmeter and check the continuity of the coil. The meter should reflect no continuity if the coil is open. On numerous occasions you may find coils that are discolored, indicating that they have been overheated.

Permanent damage to the motor or compressor may result from a sticking motor starter or contactor. A starter or contactor that sticks may prevent the motor from starting or may keep it running when there is no demand for it. When sticking occurs during the initial start-up, it will usually buzz and either prevent starting or cause a delayed starting of the motor. In the event that the contactor or starter sticks closed, the compressor or motor will never stop. There are several types of sprays available that may be used to lubricate these troublesome and dangerous controls. However, it is generally recommended that devices which fall into this category should be replaced.

Burned starter or contactor controls may cause permanent damage to the motor windings by preventing the proper flow of current through them. These contacts will be severely pitted and will not make good contact, thus causing a higher than normal current draw.

These contacts may be lightly filed until the mating surfaces match. Refer to figure 2-31 for the right and wrong mating surfaces. However, damaged contacts should be replaced as soon as possible because they will burn and become pitted again in a very short time.

Fig 2-34. Proper contact mating.

There may be occasions when these contacts become so bad that they will not make contact at all. You may determine this by energizing the starter or contactor and checking across the contact points with a voltmeter. If the contacts are open, the applied voltage will be indicated. In the event that the contacts are closed, there will be no indication of the applied voltage.

The compressor, as you should already know, is a component in the system used to circulate the refrigerant through the system. It basically has two functions: (1) it draws refrigerant vapor from the evaporator and lowers the pressure of the refrigerant in the evaporator to the desired evaporating temperature; (2) it raises the pressure of the refrigerant vapor in the condenser high enough so that the saturation temperature is higher than the temperature of the cooling medium used to cool the condenser and condense the refrigerant.

The compressors in use today by the Marine Corps are usually of the hermetic and semihermetic, and open types. Therefore, the problems encountered could be electrical, mechanical, or a combination of the two.

The problems encountered in the electrical circuit of a compressor may be divided into the following classifications: open windings, shorted windings, or grounded winding. An accurate ohmmeter is needed to check for these conditions.

The following checks are good for any type of electric motor:

- OPEN COMPRESSOR MOTOR WINDINGS - This will occur upon the path of electrical current being interrupted. This interruption occurs when the insulation wire becomes bad, allowing the wire to overheat and burn apart. To check for an open winding, remove all external wiring from the motor terminals. With the aid of an accurate ohmmeter, check the continuity from one terminal to another terminal. Be sure to zero the ohmmeter. The open winding will be indicated by an "infinity" resistance reading on the ohmmeter. There should be no continuity from any terminal to the motor case.

- SHORTED COMPRESSOR MOTOR WINDINGS - This condition will occur when the insulation or windings becomes bad and allows a shorted condition (two wires to touch) to exist, which allows the electrical current to bypass part of the winding. In some cases, depending on how much of the winding is bypassed, the motor may continue to function but will draw an excessive amount of amperage. To check for a shorted winding, remove all external wiring from the motor terminals. Use a ohmmeter, be sure to zero the meter, to check the continuity from one terminal to another. The shorted winding will be indicated by a less than normal resistance. In some cases, it will be necessary to consult the manufacturer's data for a particular motor to determine the correct resistance requirements. There should be no continuity from any terminal to the motor case.

- GROUNDED COMPRESSOR MOTOR WINDINGS - Grounding windings will occur as the insulation on the winding breaks down and the winding becomes shorted to the housing. In this instance, the motor will rarely, if ever, run and will immediately blow fuses or trip the circuit breaker. To check for this malfunction, remove all external wiring from the motor terminals. Using a zeroed ohmmeter, check the continuity from each terminal to the motor case. This condition will be indicated by a low resistance reading on the meter. You may find it necessary to remove some paint from the motor case so that an accurate reading may be obtained.

When working with hermetic or semihermetic compressor motors, you will be required to determine the COMMON, RUN, and START terminals of a compressor. This is a relatively simple process.

First, be sure to remove all external wiring from the compressor so that no false readings are indicated. Draw the terminal configuration on a piece of paper. Then measure the resistance between each terminal with an ohmmeter. Be sure that you have zeroed your meter. Now, record the resistance found on the diagram. Apply the following formula: the least resistance indicated is between the run and common terminals; the medium resistance indicated is between the common and start terminals; the largest resistance indicated is between the start and run terminals. The compressor may now be properly wired.

If in the event that you are on a maintenance call and the complaint leads you to suspect that the malfunction is electrical, you should:

- Make sure the switch is turned ON.
- Check the fuses or breakers. If fuses are blown, replace them. If breakers are tripped, reset them.
- If unit is equipped with wall plugs and the checks in the previous steps do not solve the problem, check and see if it is making proper contact in the wall. If it is not, repair or replace the plug.
- Check the name plate for proper voltage, frequency. If your electrical supply does not agree with the name plate, change the motor.
- Check the motor starting with a voltmeter. If the voltage drop is more than 10 percent, you should either decrease the line load or install a larger line.
- Check the voltage at the line and motor terminals. If you have voltage at the line terminals, but not at the motor terminals, the starting relay may be defective. To correct this, clean the contact points or replace the relay.
- Check the capacitor for ground or open by running a continuity test. If it is defective, replace the capacitor.
- Check the motor for open or ground by running a continuity check. If the motor is open or grounded, replace it.

On numerous occasions the wires between the controls and the motors will get broken or the insulation will break down and cause shorts. Before replacing the controls, run a continuity test on the internal wiring to insure that all the circuits are complete. Check all connections and insure that they are clean and tight. A thorough and systematic check of all the wiring and electrical controls will often solve many of your problems with refrigeration equipment.

EXERCISE Answer the following questions and check your responses against those listed at the end of this study unit.

1. What type of meter would you use to check for improper power?

____

2. If the circuit breaker trips and will not stay reset, what type of trouble would you suspect?

____

3. What are the five most common electrical problems found in a refrigeration system?

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

4. What is the first step to be taken if an electrical problem is suspected?

____

5. Indicate the sequence of trouble-shooting an open circuit by numbering the steps listed below. Place the numbers 1 thru 6 in the space provided.

a. Perform an operation check. ________

b. Perform a visual check. ________

c. Select meter. ________

d. Analyze the trouble. ________

e. Take meter readings. ________

f. Check wiring diagram. ________

6. List the types of short circuits.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

7. List three steps in locating a short circuit in an electrical system.

a. ______________________________

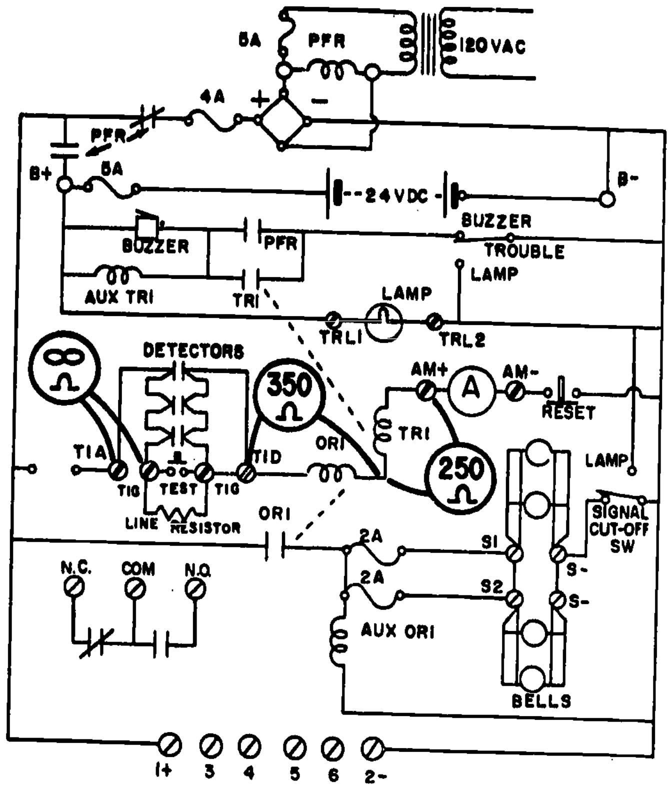
b. ______________________________

c. ______________________________

8. A short where the conductors have become fused together is called a __________ short.

9. The most difficult short to locate is a __________ short.

Refer to the schematic to solve the following questions (10 through 11). The indications are as follows: The trouble buzzer is operating. The ammeter reads zero. You remove the fuse and isolate the circuit. Your ohmmeter readings are as shown on the drawings.



10. What type of trouble is indicated?

____

11. Where is the trouble located?

____

12. What information will you require from the components that you are replacing?

13. Why should you prepare a sketch of the component being replaced?

____

14. What is the last thing you should do before leaving the repair job?

____

15. Why should electrical terminals be tight?

____

16. What conductor in an electrical circuit should be disconnected last?

____

Indicate in the space provided the type of trouble and the meter required in each of the following situations (17 through 20).

17. A three-phase motor has been operating normally in the past, but when you try to start it this time the motor hums but will not start under a load.

    a. Trouble: ______

    b. Meter: ______

18. A motor has been operating normally but suddenly stops under a load; there is no indication of overheating of the motor.

    a. Trouble: ______

    b. Meter: ______

19. A motor that has been operating starts to smoke and overheat.

    a. Trouble: ______

    b. Meter: ______

20. A motor operates sluggishly, tends to stall under load, overheats, and the motor starter thermal relay activates.

    a. Trouble: ______

    b. Meter: ______

Work Unit 2-4. PURGING THE SYSTEM

DEFINE NONCONDENSABLE GASES.

STATE THE PROCEDURES NECESSARY TO DETECT NONCONDENSABLE GASES.

STATE THE PROCEDURES NECESSARY TO REMOVE NONCONDENSABLE GASES FROM A SYSTEM.

As was stated previously, Noncondensable gases are those substances that remain in a gaseous state after the refrigerant has liquefied. These gases are usually a combination of oxygen, nitrogen, hydrogen, water vapor, chlorine, and oil vapors. These gases collect in quiet spaces of the condenser, reduce the rate of heat transfer, and cut down on the efficiency of the condenser.

These noncondensable gases enter the system in several ways. They could be in the refrigerant drum used for charging the system; through leaks when the system is under a vacuum; be the cause of incomplete evacuation before charging; or they could result from decomposition of the oil or from chemical reaction within the system.

Air is considered a noncondensable under the pressures and temperatures normally encountered in an air-conditioning or refrigeration system. Air can enter the system in the same ways as were listed previously.

In some cases, it may not be practical or desirable to purge the complete refrigerant charge and evacuate the system. However, the air must be removed to prevent damage to the system due to chemical reaction and to help keep the system operating efficiently.

The air will normally be trapped in the top of the receiver and the condenser because of the liquid seal at the receiver or condenser outlet. Air, in the system, may be detected by a higher than normal condensing pressure caused by the trapped air. The amount of increase in pressure will be determined by the amount of trapped air.

If there is only relatively dry air in a refrigeration system, it is less harmful than moist air, but in either case oxygen may react with oil or metals to produce sludge, metal oxides, etc. The same applies if dry nitrogen or dry carbon dioxide has been used to pressure test a system and has not been completely removed. However, moisture laden air in the system indicates that it was opened for repair or component replacement and was not evacuated properly. Proper evacuation is absolutely necessary to eliminate both air and moisture.

Space in the condenser occupied by the air or other noncondensables is not available for the proper function of that component, and can affect heat removal from the superheated vapor and condensation of the saturated vapor. A reduction of the heat transfer area in the condenser will make a greater temperature difference between the cooling medium and the condensing refrigerant necessary to permit removal of the required amount of heat from the refrigerant. At higher condensing temperatures, there will be a corresponding increase in head pressure.

The question now is how to determine if there is a noncondensable gas such as air in the condenser. To make a test, the temperature of the refrigerant in the condenser should be the same as the air surrounding it. Therefore, the compressor must be shut off (if it is in operation) and the refrigerant allowed to give up its heat to the surrounding air. This process can be speeded up if it is possible to bypass the controls and operate the condenser fan alone.

°F	R-12	R-13	R-22
16	18.4	211.9	38.7
18	19.7	218.8	40.9
20	21.0	225.7	43.0
22	22.4	233.0	45.3
24	23.9	240.3	47.6
26	25.4	247.8	49.9
28	26.9	255.5	52.4
30	28.5	263.2	54.9
32	30.1	271.3	57.5
34	31.7	279.5	60.1
36	33.4	287.8	62.8
38	35.2	296.3	65.6
40	37.0	304.9	68.5
45	41.7	327.5	76.0
50	46.7	351.2	84.0
55	52.0	376.1	92.6
60	57.7	402.3	101.6
65	63.8	429.8	111.2
70	70.2	458.7	121.4
75	77.0	489.0	132.2
80	84.2	520.8	143.6
85	91.8	-	155.7
90	99.8	-	168.4
95	108.3	-	181.8
100	117.2	-	195.9
105	126.6	-	210.8
110	136.4	-	226.4

Fig 2-35. Refrigerant table.

The difference in pressure within the condenser should not be more than 5 psig from the pressure corresponding to the temperature of the refrigerant being used. Assuming that R-12 is the refrigerant and that the ambient temperature (and that of the refrigerant in the condenser) is 95°F, the Refrigerant Table in figure 2-32 shows a corresponding pressure of 108 psig. Therefore, the pressure within the condenser--as indicated on the gauge--should be 108 psig but not exceed 113 psig. If it does exceed 113 psig, the air or noncondensables must be purged from the unit.

Most small condensers do not have purge valves at the top, so the purging must be done in small amounts, with a few moments of time elapsing between the brief periods of purging. This will permit the air or noncondensable gas to collect at the high point, which would be the gauge manifold, and thus, allow it to be purged without losing too much refrigerant. It is impossible to purge a system without the loss of some refrigerant, since complete separation cannot be obtained. Purging should continue until the head pressure drops to the proper point corresponding to the temperature of the refrigerant. Purging of capillary tubes or other critical charge systems is not recommended--only proper and complete evacuation procedures should be followed.

The following are seven steps for purging the unit of air and noncondensables:

Step 1 Locate and remove the source of noncondensables.

Step 2 Connect the gauges to the system.

Setp 3 If possible, pump the system down.

Step 4 Stop the unit. Leave the condenser fan running on air-cooled units or block the water valve open on water-cooled units and leave the water pump running. Allow the unit to cool down for approximately ten minutes. During this time, the noncondensables should rise to the top of the highest point.

Step 5 If the units are equipped with purge valves, use them for the purging process. If not, the gauge port on the compressor discharge may be used. To purge, slowly open the purge valve. Allow the vapor to bleed off very slowly for only a short period of time to prevent the boiling off of excess refrigerant and the remixing of the air and refrigerant and the purging of an excess of refrigerant. After the system has sat idle for a few minutes, repeat the purging process. Repeat this process three or four times.

Step 6 Start the system and check the pressure after a few minutes of operation. If the discharge pressure is still abnormally high, repeat the purging process starting with step 4. Repeat steps 4, 5, and 6 until satisfactory operation is obtained.

Step 7 Place the system back into normal operating condition.

In the event that the unit you are working on is equipped with an evaporative condenser, you should use the same procedures as previously discussed. The only difference is that the thermometer is placed in the condenser coil so that the temperature is determined after the sprays have been turned off and the coils have dried thoroughly.

The difference in the procedure for water-cooled condensers is that the temperature should be obtained from the leaving water. The water is permitted to flow until it has the same temperature as the refrigerant. The pressure/temperature check is the same. Remember, the actual pressure should not be over 5 percent more than the pressure shown on the chart.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. Define noncondensable gases.

____

____

2. Air and noncondensables must be removed from a unit to ____________________

____________________ and ______________________________.

3. The difference in pressure within the condenser should not be more than ________ from the pressure corresponding to the temperature of the refrigerant being used.

4. Assume that R-12 is the refrigerant and that the ambient temperature is 90°F, with a corresponding pressure of 112 psig. Upon checking your pressure/temperature chart for R-12, you find that R-12 at 90°F should exert a pressure of 99.6 psig. What should this tell you about the system?

____

____

SUMMARY REVIEW

In this study unit, you have learned the more common trouble-shooting procedures, the different types of procedures used to detect leaks, electrical testing procedures, and the procedures used to determine the necessity of purging and how to purge the unit.

Answers to Study Unit #2 Exercises

Work Unit 2-1.

1. a. Suction pressure
   b. Head pressure
2. a. Suction pressure. The pressure gauge reading should correspond to a temperature approximately 10° F less than the temperature of a thermometer placed on the cooling coils.
   b. Head pressure. Add 30° F to the ambient air temperature for air-cooled condensers and 25° F to the temperature of the inlet water on water-cooled condensers and obtain the head pressure from the pressure-temperature (P-T) chart.
3. a. (1) Causes: low charge; obstructed liquid line; faulty motor control; or too little air passing over the evaporator.
      (2) Remedies: recharge system; clean screens valves, capillary tubes and joints; adjust motor control; clean filters or rearrange obstructions.
   b. (1) Causes: malfunction of the expansion valves; inefficient compressors; high heat load; high head pressure.
      (2) Remedies: repair or replace the expansion valve; repair or replace the compressors; increase the size of the equipment.
   c. (1) Causes: low charge; inefficient compressor, cooling medium too cool or too much.
      (2) Remedies: recharge the system; repair or replace the compressor; restrict the airflow through the condenser or warm the air between 70° to 100° F; install condensers in a room that has a temperature of 70° to 100° F; reduce the amount of cooling medium.
   d. (1) Causes: overcharge; noncondensable gases in the condenser; cooling medium to hot; restricted air flow or dirty condenser.
      (2) Remedies: purge the unit of excess gases and air and install a new drier; provide plenty of ventilation or change expansion valve to one having a greater pressure drop and increase the motor size; clean the condenser and water pipes.
4. a. Mechanical seizure
   b. Noise
   c. Failure to pump properly
   d. Overheating
5. a. Natural oil traps in the system.
   b. Refrigerant floodback to the compressor during operation due to a defective expansion valve or poor bulb location.
   c. Flooded start due to refrigerant accumulation in the compressor during shutdown.
   d. Refrigerant shortage, which causes oil trapping. The reason being a lack of sufficient mass flow of vapor.
6. a. Overfeeding (flooding)
   b. Underfeeding (starving)
   c. Erratic (hunting)
7. a. Shortage of refrigerant
   b. A pressure drop due to a restriction

Work Unit 2-2.

1. Poor workmanship
2. a. Improper flaring
   b. Poorly soldered joints
   c. Poorly sweated joints
   d. Failure to tighten connections
3. Positive methods give the exact location of the leaks, but the nonpositive does not.
4. Soap and oil bubble test
5. Pressure and vacuum test
6. A system employing the halogen family of refrigerant

Work Unit 2-3.

1. Voltmeter
2. Short
3. a. Improperly made, loose, and dirty connections
   b. Defective relays
   c. Burned-out capacitors
   d. Burned-out motors
   e. Defective timers
4. Check to see if the unit is connected to electrical power and turned on.
5. a. 4
   b. 2
   c. 5
   d. 1
   e. 6
   f. 3
6. a. Shorted control
   b. Short to ground
   c. Short to phase
   d. Cross short
7. a. Shut off power
   b. Isolate the circuit
   c. Take readings
8. Solid
9. Floating
10. Open circuit
11. The circuit should have a low resistance since it is a solid wire. The infinity reading indicates that the circuit is open between T1A and T1G.
12. a. Name of component
    b. Number
    c. Series
    d. Model
13. To assure proper terminal wiring replacement
14. Perform an operation check.
15. To reduce resistance and arcing
16. Neutral or ground
17. a. Open circuit
    b. Voltmeter
18. a. Open circuit
    b. Voltmeter
19. a. Short circuit
    b. Ohmmeter
20. a. Improper power
    b. Voltmeter

Work Unit 2-4.

1. Substances that remain in a gaseous state after the refrigerant has liquefied
2. prevent damage to the system to chemical reaction and to help keep the system operating efficiently
3. 5 percent
4. That the system requires purging

STUDY UNIT 3

SERVICING REFRIGERATION SYSTEMS

STUDY UNIT OBJECTIVE: WITHOUT THE AID OF REFERENCES, YOU WILL LEARN THE CONSTRUCTION AND USE OF SERVICE VALVES AND THE BAR GAUGE MANIFOLD, THE CORRECT PROCEDURES FOR INSTALLING THE BAR GAUGE MANIFOLD, THE PROCEDURES TO EVACUATE A SYSTEM, AND THE CORRECT PROCEDURES TO USE TO PUMP A SYSTEM DOWN. ALSO, YOU WILL LEARN THE CORRECT STEPS TO TAKE TO CHARGE A SYSTEM WITH REFRIGERANT. LASTLY, YOU WILL LEARN HOW TO REMOVE AND ADD REFRIGERANT OIL TO THE REFRIGERATION AND AIR-CONDITIONING SYSTEMS.

Work Unit 3-1. BAR GAUGE MANIFOLD INSTALLATION AND USE

LIST THE TWO MAIN CATEGORIES OF SERVICE VALVES ON THE COMPRESSOR.

NAME THE PORTS OF A THREE-PORT, TWO-WAY VALVE.

STATE WHAT SHOULD BE DONE TO A SERVICE VALVE THAT HAS A BAD SEAT OR FACE.

STATE THE FUNCTION OF THE BAR GAUGE MANIFOLD.

STATE THE STEPS NECESSARY TO INSTALL AND REMOVE THE BAR GAUGE MANIFOLD FROM THE SYSTEM.

SERVICES VALVES may be placed into two main categories: one-way type and two-way type. The one-way type is similar to the common water faucet valve. It has an inlet port, an outlet port, and a valve stem. The positions of the valve are either "closed" (no flow), "open" (full flow), or some setting between these two extremes. The two-way valve is more complex. It has a third port. By manipulating the valve stem, you can divide the flow between these ports as necessary. Two-way valves are normally found on the compressor inlets and outlets.

● ONE-WAY, TWO-PORT VALVES - The valve body itself is usually composed of brass or copper alloys. The valve ports (fig 3-1) are known as inlet and outlet ports, respectively. Depending upon valve location and installation, either port of a one-way valve may be used for outlet or inlet purposes. The purpose of a one-way valve is to provide a manual shut off at various points in the system. By providing a manual shut off at the outlet of the receiver (King Valve), you can isolate some components of the system for repair without evacuating the entire system. The applications of this of type valve are of great assistance, particularly in multiple installations where considerable time would be required to "pump down" the unit. These valves allow repair, and/or replacement of one evaporator at a time without putting the entire system out of operation.

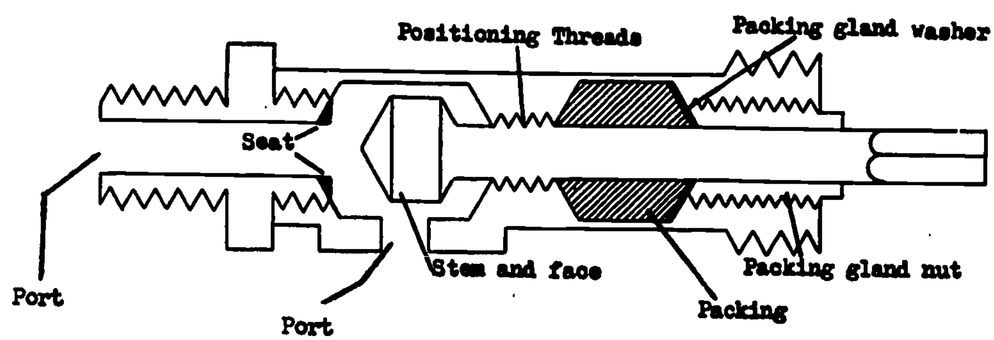
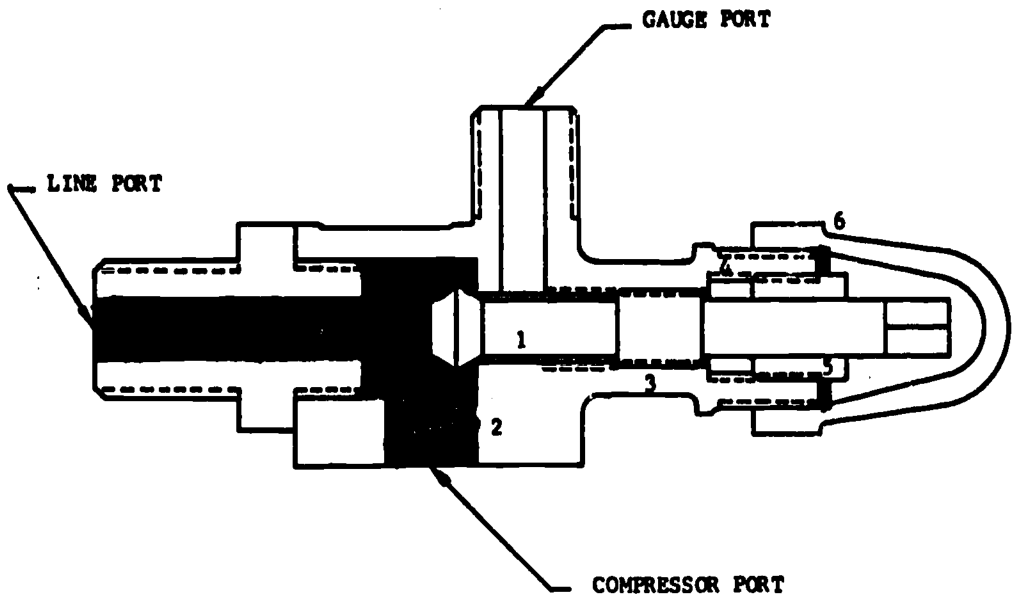


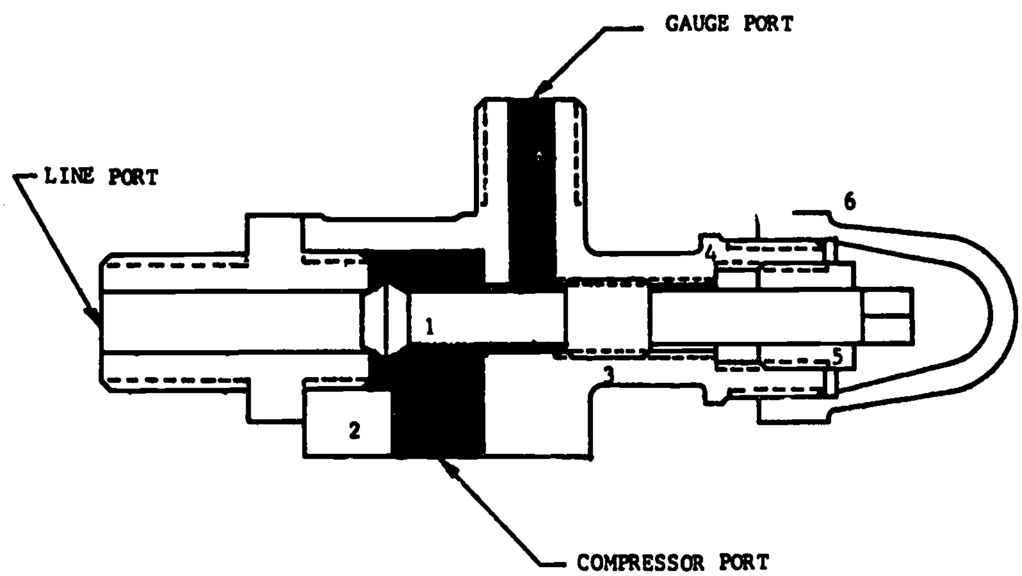
Fig 3-1. Two port one-way valve.

● TWO-WAY, THREE-PORT VALVES - Two-way valves have three ports and offer two possible routes of travel for the circulating fluid. Of the three ports (figs 3-2 and 3-3), only the gauge and line ports are controllable. The compressor port is always open. These valves have two valve seats. They are known as the "front seat" and "back seat" (figs 3-2, 3-3, and 3-4). Note that the valve stem contains a two-sided face to accommodate these seats. The stem passes in front of the gauge port. The line port is capable of handling more refrigerant than the gauge port because it is not obstructed by the valve stem.



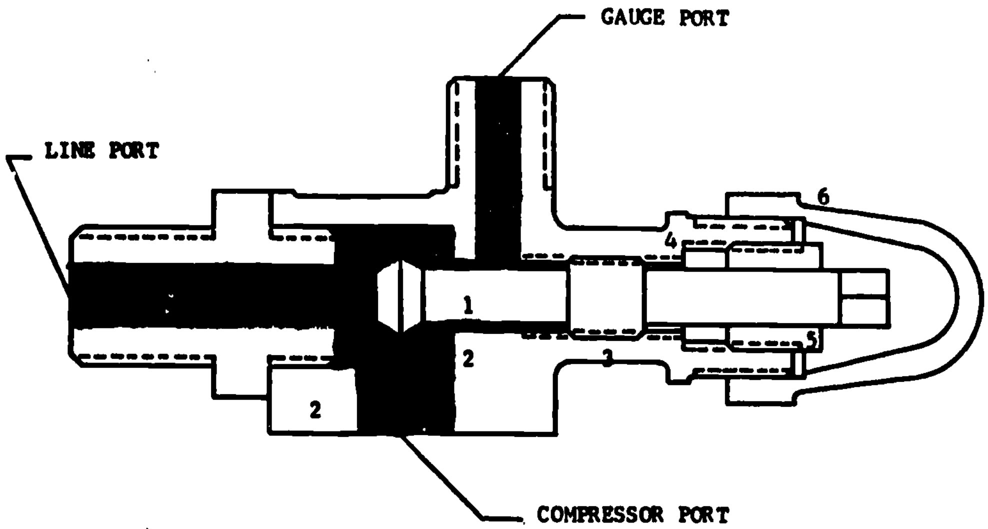
1. Stem and face
2. Back Seat
3. Positioning threads
4. Packing
5. Packing gland nut
6. Cap

Figure 3-2. Two-way, three port valve (back seated).



1. Stem and face
2. Front Seat
3. Positioning threads
4. Packing
5. Packing gland nut
6. Cap

Fig 3-3. Two-way, three-port valve (front seated).



1. Stem and face
2. Seat
3. Positioning threads
4. Packing
5. Packing gland nut
6. Cap

Fig 3-4. Two-way, three-port valve (cracked position).

Most conventional systems have two valves of this type bolted to the compressor. The valve is always connected to the compressor at the compressor port. The valve mounted on the compressor inlet (low side) is called the SUCTION SERVICE VALVE. The valve mounted on the compressor outlet (high-side) is called the DISCHARGE SERVICE VALVE. In construction, both valves are exactly alike, and are made of either brass or copper alloys.

- TWO-WAY VALVE NORMAL OPERATION (backseated) - During normal system operation the valves are "BACKSEATED." In this position the gauge port is closed and all of the refrigerant passes through the compressor and line ports (fig 3-2). In the backseated position the packing gland is not subject to the operating pressures unless the stem or valve seat or face is faulty. It is recommended that the valve cap be replaced and tightened after each use. To backseat the valve, turn it counterclockwise as far as possible.

- TWO-WAY VALVE (front seated) - If the valve stem is turned clockwise as far as it will go, the line port will be completely sealed off. In this position all of the refrigerant will flow through the compressor and gauge ports. This is known as the "FRONTSEATED" position (see fig 3-3).

- TWO-WAY VALVE (cracked position) - If the valve stem is turned 1/8 to 1/4 of a turn away from the backseat, the valve is said to be "cracked off the backseat." In this position some refrigerant will pass through the gauge port as well as the line and compressor ports. If you wish to read operating pressures a pressure gauge (or Bar Gauge Manifold) is connected to the gauge port, and the valve is placed in the "cracked off the backseat" position (See fig 3-4). If the valve stem is turned 1/8 to 1/4 of a turn away from the front seat, the valve is said to be "cracked off the front seat." In this position most of the refrigerant will pass through the gauge and compressor ports. Some refrigerant will also bleed through the line port.

Table 3-1. Positions of Valve Stem and Seat

Position of valve stem	Compressor Port	Gauge Port	Line Port
Front Seat	Opened	Opened	Closed
Back seat	Opened	Closed	Opened
Cracked	Opened	Opened	Opened

Service valves on commercial installations must be kept in very good condition because they are used much more frequently than those used on domestic units. Three things may be noted which will assure good service and valve life:

- Fitting the wrench to the valve stem.
- Maintaining the packing so that the service valve will not leak.
- Oil the threads of the gauge connection each time gauges are used.

Occasionally, after a certain period of use, these service valves have to be replaced. After gauges have been mounted in the gauge opening of the valve a number of times, the pipe threads in the valve gauge openings become worn and leak at this point. If the fittings inserted in these gauge openings are given a thin coat of solder, this trouble will be eliminated.

One of the most frequent valve troubles is the breaking of the valve stem because of the stem sticking in the valve body. Most valves are made with a drop-forged brass body and a steel valve stem. If one will heat the service valve with a torch, the difference in expansion qualities of the two metals will loosen the stem from the body and make it easy to turn. If one does this and at the same time taps the valve stem lightly with a hammer, there will be no difficulty in turning the valve stem.

If the gauge plug is "frozen" in the service valve, it can be loosened easily by first heating the outside of the service valve body with a flame from a torch. This heating will cause the body to expand and will weaken the body thread grip on the plug. The wrench can then be used to loosen the plug.

Packing is used to prevent leakage around the stem. The stem opening should be checked periodically for leaks. These leaks can usually be remedied by exerting more pressure on the packing by tightening the packing nut.

A leaky valve could be caused by a faulty seat. Since the seat is nearly always cast as part of the valve, the valve must be replaced if the seat is faulty. You will find in some of the larger more expensive valves many have replaceable seats.

The GAUGE MANIFOLD is probably the most important tool in the technician's toolbox. The purpose of the Bar Gauge Manifold is to allow the service technician to observe operating pressure from both the high side and the low side of the refrigeration system at the same time. It enables the technician to check the system's operating pressures, add or remove refrigerant, add or remove refrigerant oil, purge noncondensables, by-pass the compressor, analyze system conditions, and perform many other operations without replacing gauges or trying to operate service connection in inaccessible places.

The manifold is very simple in construction. It is made up of a hollow brass or copper bar with three openings, one at either end and one in the middle. The center opening (port), known as the charge port is equipped with a removable cap. The end ports are fitted with one-way valves, called MANIFOLD VALVES. When these valves are open, refrigerant can pass through them and the pressure gauges (upon proper installation) will indicate the pressure of the refrigerant. When the manifold valves are closed, the flow of refrigerant is stopped, but the gauges will still operate correctly. A drilled passage in the valve body always allows the gauges to indicate the pressures in the system. REMEMBER, when the bar gauge manifold is correctly installed, the gauges will indicate pressure whether the manifold valves are open or closed.

The GAUGE MANIFOLD SET (fig 3-5) consists of a compound gauge, a pressure gauge, and a manifold that is equipped with hand valves to isolate the different connections or to allow their use in any combination as may be required.

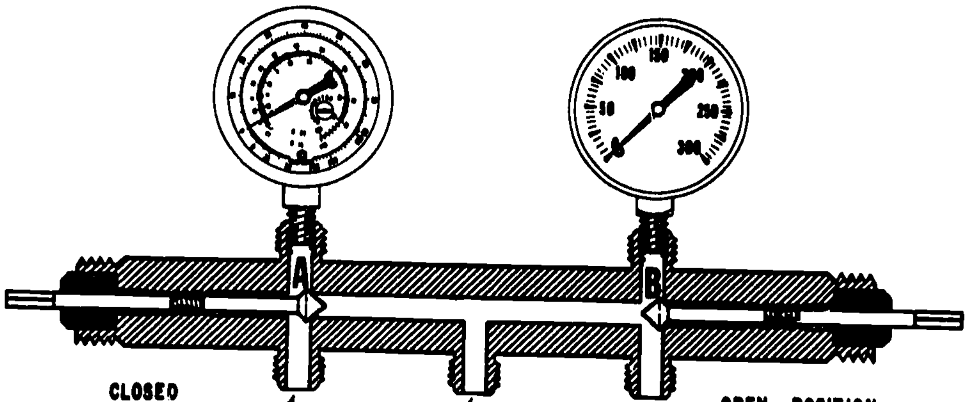


Fig 3-5. Gauge manifold.

The ports to the gauge and the line connections are connected so that the gauges will indicate the pressure when connected to a pressure source. Flexible, leak-proof hoses are used to make the connections from the gauge manifold to the system.

One of the most common service functions is hooking the gauges to the system. It is very important to install a bar gauge manifold in a system carefully and correctly. If the bar gauge manifold is installed carelessly, contaminants may enter the refrigeration system and/or leaks may occur; care should be taken to prevent contaminants from entering the system. The hoses should be purged by allowing a small amount of refrigerant to escape from the fittings before tightening. The specific procedures for connecting the gauges to a system containing refrigerant are discussed below.

On a system where it is certain that both pressures are <u>above</u> 0 psig (pounds per square inch gauge), use the following procedures:

- Front-seat the valves on the gauge manifold.

- Back-seat the system service valves (suction and discharge valves). This is to isolate the gauge ports from the rest of the system.

- Make the hose connections to the system. Connect the pressure gauge line from the bar gauge manifold to the discharge service valve gauge port. Tighten the hose connection. Connect the compound gauge line from the bar gauge manifold to the suction service valve gauge port. Leave this hose connection loose. Make sure the center charge port on the bar gauge manifold is capped tightly.

- Crack the system service valve off the back seat. Do this slowly to prevent a sudden in rush of high pressure gas to the gauge.

- Crack open one valve on the gauge manifold and allow a small amount of refrigerant vapor to escape out the center hose for a few seconds. Close the gauge manifold valve and repeat this process with the other valve.

- The gauge manifold is now connected to the system and is ready for use (see fig 3-6).

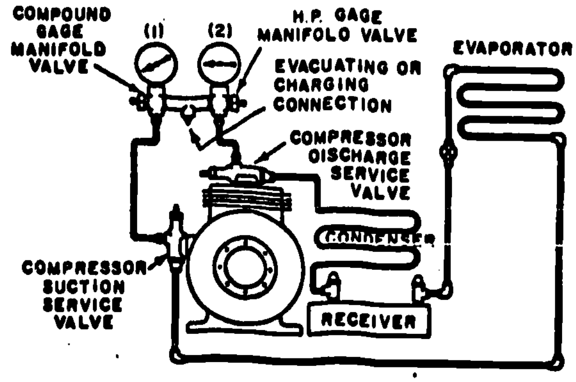


Fig 3-6. Gauge manifold connected to a system.

On systems where the low side pressure is below 0 psig, use the following procedures:

- Front-seat the valves on the gauge manifold.
- Back-seat the system service valves (suction and discharge valves). This is to isolate the gauge ports from the rest of the system.
- Make the hose connections to the system. Tighten the hose connection to the discharge service valve, loosen the hose connection to the suction service valve, and plug the center hose connection to prevent the escape of refrigerant at this point.
- Crack the system discharge service valve off the back seat. Do this slowly to prevent a sudden in-rush of high pressure gas to the gage.
- Crack open the high side gauge manifold valve and allow a small amount of refrigerant vapor to escape out the low side hose connection at the system service valve. Tighten the hose connection after a few seconds. Close the gauge manifold valve.
- Crack the system suction service valve off the back seat.
- The gauge manifold is now connected to the system and is ready for use (see fig 3-6).

It is also important to exercise caution when removing a Bar Gauge Manifold. Proper removal will insure a minimum loss of refrigerant, and reduce the possibility of getting air in the system.

- Back-seat the discharge service valve.
- Back the compound gauge valve off the seat two complete turns.
- Make sure the unit is running (if possible).
- Crack the pressure gauge valve off seat very slowly, allowing the discharge pressure in the gauge lines to bleed into the low side of the compressor.
- Backseat the suction service valve.
- Remove the Bar Gauge Manifold, install gauge port caps, and valve covers.

The following are typical procedures that can be followed using the bar gauge manifold. It is highly recommended that you consult the manufacturer's literature or the appropriate technical publications for any specific information.

o **TO OBSERVE OPERATING PRESSURES (refer to fig 3-6).**

- Back-seat service valves c and d.
- Close manifold valves a and b.
- Connect color coded hoses as shown.
- Move services valves c and d off the backseat.
- Purge hoses at manifold.
- Start unit and allow to run at least five minutes.
- Read operating pressures or corresponding temperatures on gauges.

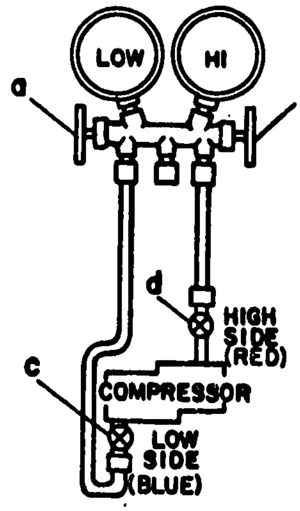


Fig 3-6.

o **TO PURGE REFRIGERANT FROM SYSTEM (refer to fig 3-6).**

- Be sure the system is turned off.
- Close manifold valves a and b.
- Connect color coded hoses as shown.
- Service valves c and d should be open but not back-seated.
- Slowly open manifold valves a and b.
- Purge through center port.
- When gauges read 0 lbs. pressure, purging operation is complete.

TO ADD VAPOR REFRIGERANT THROUGH SUCTION SERVICE VALVE (refer to fig 3-7).

- Close manifold valves a and b and turn system off.
- Back-seat service valves c and d.
- Connect color coded hoses as shown.
- Open refrigerant cylinder valve r and manifold valves a and b. Purge hoses at service valves c and d.
- Close manifold valves c and d.
- Move high side service valve d off back-seat.
- Open low side service valve c about half way.
- Start unit.
- Meter in correct amount of refrigerant by opening and closing low side manifold valve a.

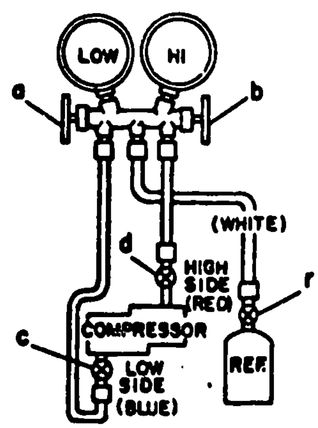


Fig 3-7.

TO EVACUATE AND VAPOR CHARGE A SYSTEM (If system is running) (refer to fig 3-8).

- Observe operating pressure using procedures described previously.
- Turr system off.
- Purge system using procedures previously described.

TO EVACUATE THE SYSTEM.

- Close manifold valves a and b.
- Connect color coded hoses as shown
- Be sure the service valves c and d are open but not backseated.
- The refrigerant cylinder valve r should be closed.
- Open manifold valves a and b.
- Open vacuum pump valve v and start vacuum pump.

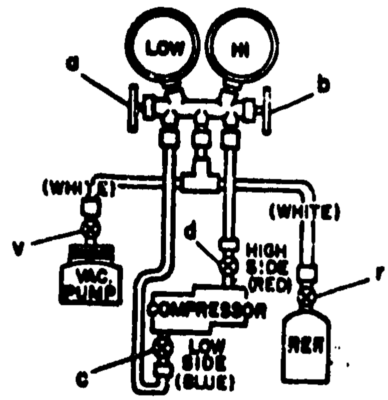


Fig 3-8.

WHEN DESIRED VACUUM IS REACHED.

- Close manifold valves a and b.
- Close vacuum pump valve v.
- Stop vacuum pump.

TO BREAK THE VACUUM AND CHARGE.

- Open refrigerant cylinder valve r.
- Low service valve c should be about half way open.
- Start refrigeration unit.
- Meter in correct amount of refrigerant by opening and closing low side manifold valve a.

TO CHARGE OIL THROUGH SUCTION SERVICE VALVE (refer to fig 3-9).

- Close manifold valves a and b.
- Make sure unit is turned off.
- Connect color coded hoses as shown.
- Oil container should be filled with enough oil to fill the compressor plus enough to insure that the hose opening remains immersed.
- Open refrigerant cylinder valve r.
- Open manifold valves a and b.

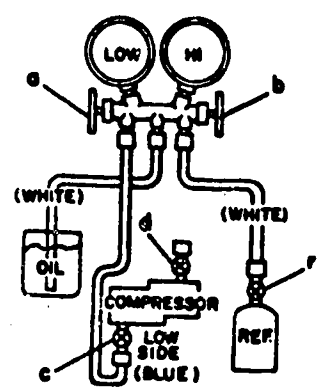


Fig 3-9.

- Purge air at low side service valve c and at oil reservoir.
- Close manifold valves a and b.
- Close refrigerant cylinder valve r.
- Front seat low side service valve c.
- Start unit and allow to run to build up low side vacuum.

Caution: Hermetic type compressors should not be operated over 18" hg vacuum to avoid possible damage to motor windings.

- Turn off unit.
- Meter in correct amount of dry refrigerant grade compressor oil, by opening and closing low side manifold valve a.

TO TEST CONDITION OF COMPRESSOR (reed) VALVES.

HIGH SIDE (refer to fig 3-10).

- Be sure system is not operating.
- Close manifold valves a and b.
- Purge all refrigerant from system and/or compressor.
- Connect color coded hoses as shown.
- Frontseat service valves c and d.
- Open high side manifold valve b and apply pressure to compressor discharge valve.
- Read and record pressures.
- Close manifold valve b.
- Wait several minutes.
- Reread high side pressure. If valves are good, readings will not change appreciably.

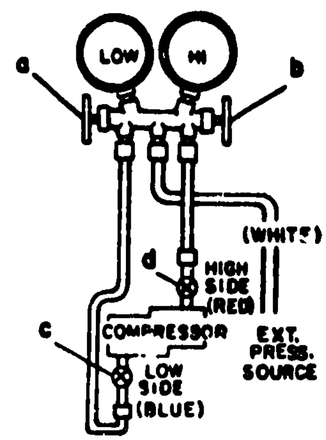


Fig 3-10.

ALTERNATE METHOD - IF SYSTEM IS OPERATING (refer to fig 3-11).

- Close manifold valves a and b.
- Connect color coded hoses as shown.
- Simultaneously close the low side service valve c while stopping the compressor.
- Read the low side pressure.
- Wait several minutes.
- Reread pressure. If valves are good, reading will not change appreciably.

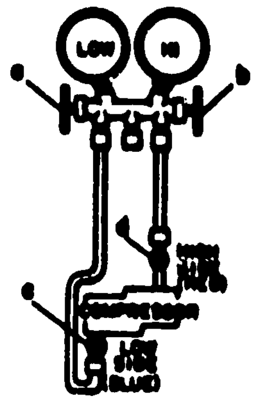


Fig 3-11.

LOW SIDE (refer to fig 3-12).

- Be sure system is not operating.
- Close manifold valves a and b.
- Purge all refrigerant from system and/or compressor.
- Connect color coded hoses as shown.
- Frontseat service valves c and d.
- Open manifold valve a and vacuum pump valve v.
- Start vacuum pump and run untill system stabilizes.
- Close manifold valve a and vacuum pump valve v and turn off vacuum pump.
- Read and record vacuum.
- Wait several minutes.
- Reread low side compound gauge. If valves are good, readings will not change appreciably.

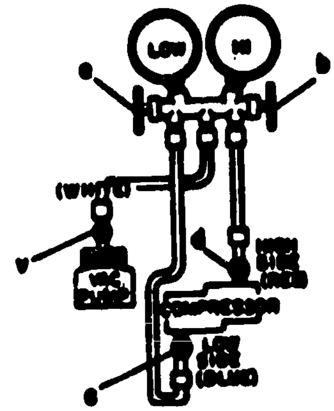


Fig 3-12.

The COMPOUND GAUGES (fig 3-13) are used to read pressures above atmospheric and below atmospheric (vacuum). In practice, they are used to determine pressures in the low side of the system. The outside scale is in pressure (psig). The inside scales are the corresponding temperatures for different refrigerants.

Gauges operate from the action of a Bourdon tube. When the pressure inside the Bourdon tube is increased, the element tends to straighten. As the pressure is decreased, the element tends to curve again. A Bourdon tube is a flattened metal tube sealed at one end, curved, and soldered to the pressure fitting on the other end. The movement of the element will pull a link which is attached to the pointer through a series of gears. This movement will be shown by the gauge hand, or pointer.

Compound retard gauges have a retarder which permits accurate readings within a given range. In refrigeration work, this range would be between 0 psig and 100 psig. These gauges can be recognized by the change in graduation at pressures higher than those usually encountered.

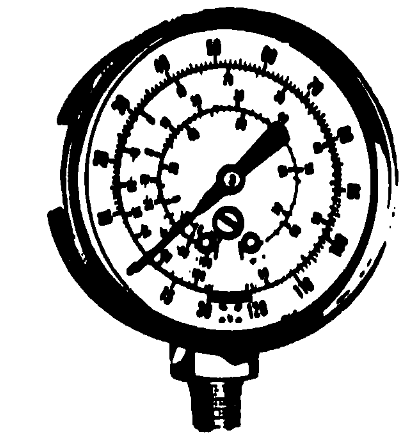


Fig 3-13. Compound gauge.

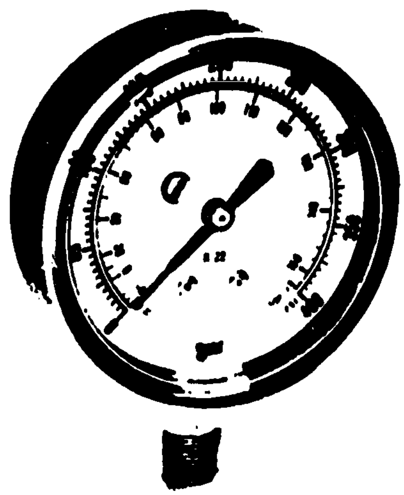


Fig 3-14. Pressure gauge.

PRESSURE GAUGES (fig 3-14) are used to determine pressures on the high side of the system. The outside scale is calibrated in psig and the inside scales indicate the corresponding temperatures of the different types of refrigerant. Some pressure gauges are not designed to operate at pressures below atmospheric pressure. Therefore, caution should be used during evacuation procedures to prevent damage to these gauges.

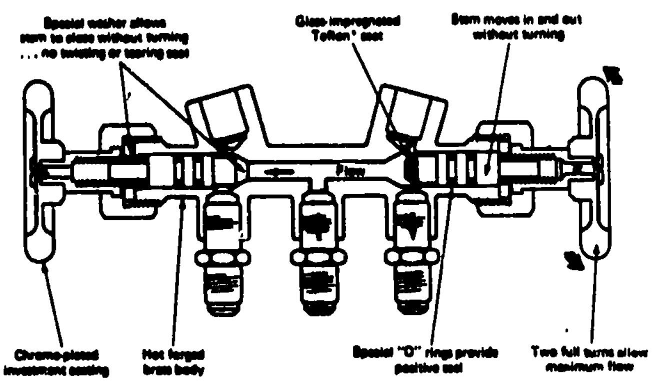


Fig 3-15. Valve manifold.

The VALVE MANIFOLD (fig 3-15) provides openings through which the various service operations are performed on the refrigeration system. The proper manipulation of the hand valves will permit almost any function. When the valves are screwed all the way in, the gauges will indicate the pressure on the corresponding line. The center line is usually connected to a vacuum pump, a refrigerant cylinder, or an oil container.

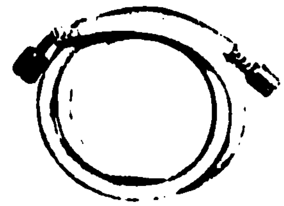


Fig 3-16. Charging hoses.

CHARGING HOSES (fig 3-16) are flexible and are used to connect the gauge manifold to the system. Charging hoses are equipped with 1/4-inch (6.5 mm) flare connections on each end. One end usually has a valve core depressing attachment for attaching the gauges to schrader valves. This is a type of service valve which is used on systems not provided with a means of servicing. Charging hoses may be obtained in a variety of colors which facilitate making the connections to the unit and are designed for a working pressure of 500 psi (35.15 kg/cm^2) and an average bursting pressure of 2000 psi (140.6 kg/cm^2). Many equipment manufacturers color code the low-side gauge casing and hose blue and the high-side gauge and hose red. The center or refrigerant hose is colored white. This system is very helpful to avoid crossing hoses and damaging gauges.

These gauges are delicate instruments and should be treated with care. Do not drop the gauges or subject them to pressures higher than the maximum pressure shown on the scale. Gauges should be kept in adjustment so that the proper pressures are indicated.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. Identify the two types of service valves on compressors.

   a. ________________________

   b. ________________________

2. What three ports are found on the three-port, two-way valve?

   a. ________________________

   b. ________________________

   c. ________________________

3. What should you do to a service valve that has a defective seat or face?

   ____

4. State the purpose of the Bar Gauge Manifold.

   ____

   ____

5. When installing the Bar Gauge Manifold, what should be accomplished to prevent contaminants from entering the system?

   ____

   ____

6. What is the first step to be performed when connecting the Bar Gauge Manifold to observe operating pressures?

____

____

Work Unit 3-2. SYSTEM EVACUATION PROCEDURES

STATE THE PURPOSE FOR EVACUATION OF A REFRIGERATION SYSTEM OR UNIT.

NAME TWO METHODS USED TO EVACUATE A REFRIGERATION SYSTEM OR UNIT.

DIFFERENTIATE BETWEEN THE TWO METHODS OF EVACUATION.

Proper evacuation of a system or unit will remove noncondensables (mainly air, moisture and inert gas) and assure a tight, dry system before charging. Evacuation is accomplished by the use of pumps specially designed for this purpose. A discarded refrigeration compressor is not suitable. Once the system or unit has been evacuated, NEVER run the motor compressor, to do so may result in very serious damage to the motor windings. Evacuation is required any time a system has been contaminated or the compressor or system has been exposed to the atmosphere for long periods of time.

Purging a system will remove a good portion of the air, and driers will remove a part of any moisture from the system, but only up to the capacity of the drier. Therefore, there are still contaminants left in the system, and evacuation is the best means of being reasonably sure that the system is free of these contaminants.

Newly installed systems and existing systems that have become contaminated with moisture, dirt, or foreign gases must be evacuated before they will perform properly. In existing systems, the refrigerant's characteristics will change, and it cannot meet the necessary temperatures and pressures for efficient cooling. When this happens, you must evacuate the system.

Under normal atmospheric pressures, water boils at 212° F, but if the pressure is reduced to about 2.2 inches Hg it will boil and vaporize at about 100° F. If the pressure is further reduced, the moisture will vaporize at even lower temperatures. You need a high vacuum (or a deep vacuum pump) to evacuate the system low enough to remove as much of the contaminants as mechanically possible. By using an ordinary compressor such as a vacuum pump, you can only pull enough vacuum to rid a system of water. The two most common vacuum pumps in the field today are the SINGLE-STAGE and the TWO-STAGE. The single-stage pump is normally used with the triple method of evacuation, and the two-stage pump is used to evacuate by the deep vacuum method. Pumps are rated on two characteristics; (1) the blank-off pressure, or the vacuum level the pump can achieve, and (2) the speed with which it can pump the system down. There are two designs of pumps: the piston (or vapor) pump and the vane (or rotary) pump. The rotary-type pump is by far the more efficient of the two pumps.

The rotary type consists of a cylinder with an enclosed eccentric disk. Moveable vanes run through the disk and seat against the cylinder. These vanes create suction as they move past the intake valve, thus exhausting the gas. The better rotary pumps are two-stage or two rotary units in series. The first stage takes the air from the low pressure of the refrigeration system and exhausts it to a higher pressure environment. The second stage sucks in the exhaust gas and exhausts it into the atmosphere. Much lower vacuums can be pulled with a two-stage pump over a single stage.

During the evacuating procedure the water vapor and the pump oil come in contact with each other. The oil will absorb the water vapor until the vapor pressure of the water in the oil is so high that the pump cannot maintain a high vacuum. The oil in small vacuum pumps should be changed after approximately 10 hours of operation. Oil that contains a large amount of absorbed moisture loses its lubricating properties. A large number of vacuum pumps are damaged each year because of the oil not being changed often enough.

When you evacuate a large system or use the vacuum pump in the shop under continuous conditions, a cold trap between the refrigeration system and the vacuum pump will keep the water vapor from contacting the pump oil. As the moisture vapor contacts the cold service, it will turn to ice. We then simply close valves on both sides of the trap, unbolt it, and remove the ice.

There are basically two evacuation procedures: (1) DEEP VACUUM METHOD, and (2) TRIPLE EVACUATION. Deep vacuum evacuation is used on systems containing only a minimum of contaminants. Triple evacuation is used on systems containing a greater amount of contaminants. Remember that the most careful evacuating and purging will not clean a system or unit that was carelessly put together with dirt in the system.

A system opened for any type of repair must be completely evacuated to remove air and moisture. As previously stated, two main methods are used, the deep vacuum and triple evacuation methods.

In the first (deep vacuum), a vacuum of 500 microns (.5 millimeter) or deeper is pumped on the system until no moisture or other gas remains in the system.

In the second (triple evacuation), a vacuum of 28" Hg or 50mm is drawn, the system is charged to 0 psi with vapor refrigerant. A vacuum of 28" Hg is drawn again. Once more, the system is charged to 0 psi with vapor refrigerant and again a vacuum of 28" Hg is drawn. At this point the system is ready for charging.

R-22 has a higher discharge pressure and temperature than R-12. Dirt, sludge, moisture and air must be removed from the system in order to avoid any possibility of burnouts where R-22 is used. Complete (high) evacuation is one of the best means to clean a system.

Triple evacuation will not remove all of the moisture. Only warmth and a deep vacuum will vaporize and remove the moisture and any solvents. Some solvents in the system will vaporize only under a deep vacuum. A deep vacuum gauge is the best way to determine, if the system has water in it, if the system has leaks. To check: stop the vacuum pump; close the valve to the vacuum pump; watch the high vacuum gauge, if it rises, there is still moisture in the system.

Large openings must be used for deep vacuum. Piercing valve openings are not large enough.

The system should be pressure-tested first. Use either dry nitrogen or dry carbon dioxide. These gases should be used only with a pressure regulator and a large capacity pressure relief valve set to release at 175 psi. Test the system at 150 psi. The system should hold this pressure after the gas valve is closed for several hours (no decrease in pressure).

Note: NEVER heat nitrogen or CO_2 cylinders. The maximum cylinder temperature should be 110° F (43° C).

The evacuating and drying of the unit is a very important part of the assembly work. The system should be as close to 100 percent clear of air, moisture, solvents and other foreign matter as possible. Here again, REMEMBER that the most careful evacuating and purging will not clean a unit that was carelessly put together with dirt in the system.

A vacuum pump should be used to remove as much air as possible from the unit. No pump will remove all air. A pump that produces a 28" vacuum (28" Hg.) will take out only about 93 percent of the air. With a 28" Hg vacuum moisture particles must be heated to 100° F (38° C) or above, before they will evaporate and can be pumped out as water vapor.

To remove the moisture, the unit must be heated to a temperature that will not only vaporize the moisture, but will drive the moisture out of all the crevices. For the same reason the unit should be run for a part or all of the operation. This is to be sure all pockets in the compressor and the bearings are vibrated to release pocketed air. This also warms the motor windings which are an additional source of trapped moisture. It is considered good practice to evacuate for 8 hours at 250° F (121° C) or for 24 hours at 150° F

(66° C). Carbon dioxide attracts moisture and circulating it in the system helps to remove moisture.

To eliminate still more air, charge some refrigerant vapor into the system. Evacuate the system again. This will take out more of the air. Repeat the charging and evacuating. Only about .01 percent of the air will then remain in the system.

However, if a deep vacuum pumps draws 50 to 100 microns and holds this pressure, the system is clear of moisture and air.

To use the deep vacuum method, you should follow, in the same sequence as stated, the procedures listed below:

- Connect the gauge manifold to the system.
- Purge all pressures from the refrigeration system by opening the system service valves and the gauge manifold hand valves.
- Connect the center hose on the gauge manifold to the vacuum pump.
- Start the vacuum pump and pump a vacuum of at least 500 microns; a vacuum of 50 to 100 microns is preferable.
- Close off the gauge manifold hand valves.
- Stop the vacuum pump. <u>DO NOT</u> stop the vacuum pump before closing the gauge manifold hand valves. This is to prevent air from entering the system.
- Disconnect the center hose of the gauge manifold from the vacuum pump and connect it to a cylinder containing the proper refrigerant.
- Open the cylinder valve.
- Loosen the center hose connection at the gauge manifold. Purge the hose for a few seconds; then tighten the connection.
- Open the gauge manifold hand valves and admit refrigerant into the system.
- Close the high-side hand valve on the gauge manifold.
- Start the unit and add the proper charge of refrigerant.

To use the triple evacuation method, use the following procedures

- Connect the vacuum pump and pump a vacuum of approximately 1,500 microns.
- Purge all pressure from the refrigeration system or unit by opening the system service valves and the gauge manifold hand valves.
- Connect the center hose on the gauge manifold to the vacuum pump
- Start the vacuum pump and pump a vacuum of approximately 1,500 microns.
- Close off the gauge manifold hand valves.
- Stop the vacuum pump. However, <u>DO NOT</u> stop the vacuum pump before closing the gauge manifold hand valves. This is to prevent air from entering the system.
- Disconnect the center hose of the gauge manifold from the vacuum pump and connect it to a cylinder containing the proper refrigerant.
- Open the cylinder valve.
- Loosen the center hose connection at the gauge manifold. Purge the hose for a few seconds; then tighten the connection.
- Open the gauge manifold hand valves and admit refrigerant into the system or unit until a pressure of about 5 psig is indicated on the gauges.

- Close the refrigerant cylinder valve and the gauge manifold hand valves.
- Disconnect the hose from the cylinder.
- Open the gauge manifold hand valves and purge the pressure from the system.
- Repeat steps indicated by single asterisk (*).
- Repeat steps indicated by a double asterisk (**). Pump a vacuum of 50 microns rather than 1,500 microns.
- Open the gauge manifold hand valves and admit refrigerant into the system until cylinder pressure is indicated on the gauges.
- Close the high side gauge manifold hand valve.
- Start the unit or system and add the proper charge of refrigerant.

You will find that there is another method of evacuation that may be used as was mentioned earlier and that is to use the unit's compressor.

When using the compressor, install a compound gauge on the compressor suction service valve and draw a vacuum of approximately 20 inches, thus removing the refrigerant from the crankcase. Next, install a purging line into this gauge opening of the discharge service valve. Run this line to a location that is safe (refrigerant vapors can be harmful to people); shut off the condenser openings; open the suction lines; and pump a vacuum. After obtaining as high a vacuum as possible with the compressor, allow a small amount of refrigerant back in the suction line by cracking open the refrigerant valve that is farthest from the compressor on the low side. Pump the refrigerant from the system. Now flush the system with refrigerant again and evacuate the system again. This should generally remove the greater percentage of the air and contaminants. The same procedures are generally followed with a vacuum pump, except that the compressor is not used.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. State the purpose of refrigeration systems evacuation.

____

____

____

2. What are two methods used to evacuate a refrigeration system or unit?

 a. ____________________

 b. ____________________

3. Of the two methods of evacuation, which is the preferred?

____

4. A single-stage vacuum pump is normally used with what type of evacuation?

____

Work Unit 3-3. SYSTEM PUMP DOWN

STATE THE PURPOSE OF PUMPING A SYSTEM DOWN.

STATE THE PROCEDURES NECESSARY TO PUMP A SYSTEM DOWN.

STATE THE PURPOSE FOR LOOSENING THE FLARE NUT ON THE SUCTION SERVICE VALVE WITH THE VALVE FRONTSEATED PRIOR TO OPENING THE KING VALVE.

Before you open a system (to change the compressor for instance), you must arrange to save the refrigerant that is in the system and prevent air from entering. The usual procedure is to pump the system down, or to run all the refrigerant from the system down to the receiver.

To do this you simply close the receiver outlet valve (King valve) and operate the compressor until the suction pressure gauge levels off between 3 to 5 psig. Then you close the receiver inlet valve (Queen valve) and stop the compressor. The system can then be opened. You may need to let a small amount of refrigerant back into the system to maintain a positive pressure. This helps keep air out and requires less work when the system is put back into operation.

As you can see, it is a very simple operation to save the refrigerant when repairs are required on the components of the system. To accomplish the pump down on a system, it must be equipped with a service valve and a liquid line shut-off valve.

To begin the pump down of a system, use the following procedure. If possible, you should allow the compressor to run until it is warm before pumping it down. Then begin by:

- Installing the bar gauge manifold.
- Closing (frontseat) the liquid line shut-off valve (King valve).
- Setting the low pressure control at 3 psig, or holding the pressurestat switch closed so that the unit will not trip off on low pressure.
- Running the compressor until the compound pressure gauge (registering low side pressure) registers 3 psig.
- Stopping the compressor and watching the compound pressure gauge. If the pressure rises, pump down again. Repeat the operation until the pressure remains at 3 psig.
- Frontseating the compressor discharge and suction shutoff valves.

If the compressor is to remain pumped down for any length of time, tag the disconnect switch stating that the unit is in a pumped down condition to prevent accidental starting of the unit.

The refrigerant is now trapped between the King valve and the discharge service valve. At this time, you may repair or replace any lines or parts from the King valve up through the evaporator, metering device, drier, and back to the discharge service valve, including the compressor itself.

If the compressor is the only component to be removed, pumping down the crankcase will be sufficient. This may be accomplished by frontseating the suction service valve and completing the first five steps listed previously. You must stop the compressor several times during pump-down to prevent excessive foaming of the oil as the refrigerant boils out since the foaming oil may be pumped from the crankcase.

> Note: To make sure that the discharge reeds in the valve plate are not leaking back to the low side, you should frontseat the suction service valve and run the unit until 0 psig is reached. Then stop the unit. If the compound pressure gauge remains at 0 psig, the discharge valves are NOT leaking.

Once pump-down has been completed and the components have been repaired or replaced as required, you may restore the unit to operation. To do this, you would tighten all connections, then loosen the flare nut on the suction service valve with the valve frontseated. Now, open the King valve and allow the refrigerant to push whatever air has entered the system out through the loose flare nut at the suction service valve. Tighten the flare nut on the suction service valve and then open all other valves to resume normal operation.

> Note: All parts of the system that have been exposed to the atmosphere must be pulled down to a vacuum to remove all noncondensable, contaminants, and mositure prior to resuming normal operation. The filter drier must also be changed to remove an contaminants or mositure from the system.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. State the purpose of pumping down a refrigeration system.

____

____

____

2. What is the first step in pumping down a system?

____

3. Prior to frontseating the compressor discharge service valves, what should the compound gauge reading be?

____

4. What is the purpose of holding the low-pressure cutout switch closed?

____

____

5. To place a unit into operation from a pump-down condition, state the purpose for loosening the flare nut on the suction service valve with the valve frontseated prior to opening the King valve.

____

Work Unit 3-4. CHARGING A REFRIGERATION SYSTEM

STATE FOUR METHODS USED TO DETERMINE IF THE SYSTEM IS PROPERLY CHARGED.

SPECIFY THE TWO METHODS OF CHARGING REFRIGERANT INTO A SYSTEM.

SPECIFY THE PROCEDURES USED TO CHARGE A SYSTEM OR UNIT.

The quantity of refrigerant to be added to the system for the initial charge or recharging depends on the size of the equipment and the amount of refrigerant to be circulated. In very large systems, it is common practice to simply weigh the charge by placing the refrigerant cylinder or drum on a suitable scale and observing the reduction in weight in pounds. This method is fine for systems that have receivers or condenser volume ample enough to take a slight overcharge.

On smaller systems, and particularly those that are self-contained packaged units without receivers, the system's refrigerant charge is critical to ounces, rather than whole pounds. In this case a "charging cylinder" is recommended as illustrated in figure 3-17. Refrigerant for the refrigerant drum is transferred to the charging cylinder. The charging cylinder has a scale that is visible to the operator so that you may precisely measure the quantity of a specific refrigerant and compensate for temperature and pressure conditions. These cylinders are accurate to within one-quarter of an ounce. Optional electric heaters are available to speed the charging operation.

Where considerable installation and service work is performed, a charging station, as illustrated by figure 3-18, may be employed if your unit rates one.

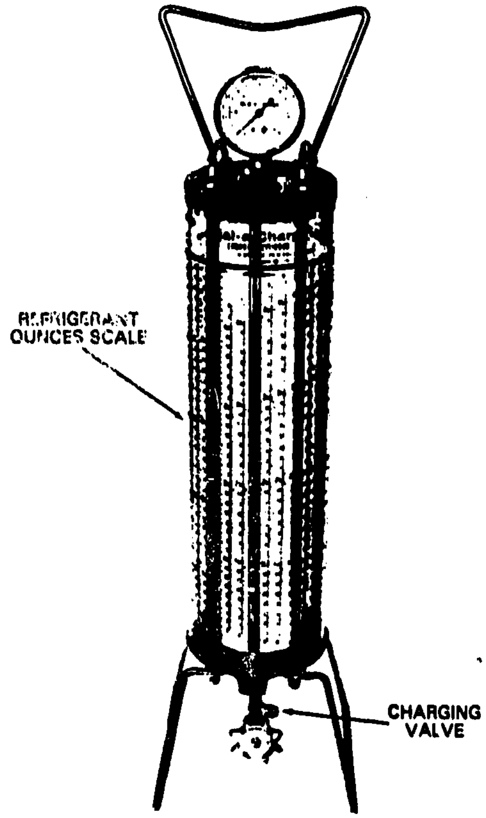


Fig 3-17. Charging cylinder.

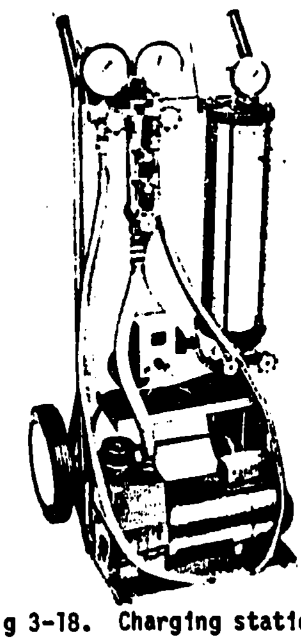


Fig 3-18. Charging station.

A charging station is a charging cylinder mounted on a portable handcart, complete with a manifold gauge assembly and a vacuum pump. The main advantage of using this type of unit is that it is fast. A given amount of refrigerant can be put in the system in a relatively short time. It removes the guesswork. If you know exactly how much refrigerant a unit requires, this amount is automatically placed in the system. The ease of operation makes this unit quite valuable, because it permits inexperienced personnel to be used. A qualified refrigeration technician does not have to be available when using this charging station, as long as the operator observes details carefully.

Refrigerant is added to the system or unit through the suction service valve (low-side charging) or the discharge service valve (high-side charging). In LOW-SIDE CHARGING, the refrigerant is ALWAYS added in GASEOUS form. Low-side charging offers good control of the charging process and should be used whenever possible. Although it takes longer, it is much safer and you are in complete control of the entire process. In high-side charging, the refrigerant is ALWAYS added in LIQUID form. HIGH-SIDE CHARGING is very rapid. The amount of refrigerant to be added must be weighed or measured. While the high-side charging process is going on, the service cylinder must be inverted (turned upside down).

To charge into the low-side as a gas follow the procedures listed below:

- Insure all evacuation procedures have been correctly followed prior to these steps.
- Back-seat the compressor suction and discharge service valves and connect your manifold gauges to the appropriate compressor gauge connection.
- Connect a refrigerant service cylinder or drum to the middle manifold hose.
- Open the service cylinder or drum valve and purge the hoses, gages, and manifold. Then tighten all hose connections.
- Turn the suction service valve a couple of turns from the back-seat position and open the service cylinder valve as far as possible.
- REMEMBER, keep the refrigerant drum in an upright position to prevent the liquid refrigerant for entering the compressor.
- Now turn the compressor discharge service valve about one-fourth to one-half turn from the back-seat position so that compressor discharge pressure can be read at the manifold discharge pressure gauge.
- Start the unit's compressor.
- Charge the required amount of refrigerant into the system. If the exact charge is unknown, charge a small quantity at a time and continually observe the operating pressures, sight glass, and frost line. To speed up the charging process, you may place the service cylinder in a container of WARM water.
- When the system or unit is sufficiently charged, close the refrigerant service cylinder valve and back-seat the compressor discharge service valve. Prior to closing the compressor suction service valve allow a few seconds for the compressor to draw the remaining refrigerant from the lines. Back-seat the suction service valve.
- Allow the unit to operate, keeping a close watch on the frost line on the evaporator. Make sure there is enough frost, but prevent it from going beyond the suction line.
- When you have a proper charge of refrigerant, close all valves and remove the charging equipment and cap all ports.

In HIGH-SIDE CHARGING, you must remember several important things: First, as was previously mentioned, the refrigerant is always added in liquid form and the exact charge must be in the service cylinder--no more and no less. Remember too, that the unit is not running, the service cylinder must be inverted, and that this is a rapid method of charging a unit. You should also be aware that high-side charging is dangerous and unless it is done correctly, considerable damage to the unit may result; lines may be ruptured and the compressor may be damaged beyond repair. In order to charge liquid refrigerant into the high side of a refrigeration system, the pressure in the service cylinder must be higher than that in the refrigeration system being charged. If the system being charged is water-cooled, the pressure in the liquid receiver, with the water running, will be low enough to force the refrigerant from the cylinder into the system. If the unit to be charged is an air-cooled system, the pressure in the refrigerant service cylinder will have to increased.

In order to perform high-side charging follow the following procedures:

- Backseat both of the service valves (suction and discharge).
- Install the bar gauge manifold and leave the connections loose at the service valves.
- Open both of the valves on the manifold.

- Attach a flexible charging hose from the center port of the manifold to the service cylinder.

- Open the service cylinder valve and purge the lines to the service valves.

- Tighten the connections at the service valves after a few seconds of purging.

- Close both valves on the bar gauge manifold.

- Invert the service cylinder and support it secur . Prior to inverting the cylinder insure that the cylinder contains the exact charge ed for the unit being charged.

- Open the pressure gauge valves.

- Crack both service valves (suction and discharge).

- At this point the liquid refrigerant will be forced into the condenser and receiver.

  Note: To speed the process apply heat to the service cylinder by using rags soaked in hot water; when the cylinder is empty, remove the rags. DO NOT apply direct heat from any type of flame.

- When the cylinder is empty, close the cylinder valve.

  Note: When performing the process of high-side charging with liquid refrigerant, the refrigerant will make a gurgling sound. When this stops the cylinder is empty.

- Close the pressure gauge valve.

- Remove the service cylinder.

- Start the unit and check its operation.

It is sometimes difficult to determine when a system is correctly charged. No one method will work in all applications. Each system, the units in it, and its temperature range, and application must be considered. The following guidelines will help you, but experience and trial and error are necessary before you will become competent in determining the correct charge in a refrigeration system. There are four methods of determining whether you have the correct refrigerant charge in a system: (1) sight glass; (2) pressure determination; (3) weighting the charge; and (4) frost line.

The most common way of checking the charge in small systems is with a sight glass in the liquid line. If there are no bubbles in the sight glass, it is assumed that the system is correctly charged. In a system that is fully charged, the sight glass will show a clear flow of refrigerant. In fact it will appear empty. However, this assumption can be wrong. If the sight glass is located near the outlet of the receiver, a restriction in the liquid line may reduce the flow of the refrigerant enough to eliminate bubbles in the sight glass even if the system is only half charged. If the sight glass is located near the expansion valve, a restriction in the liquid line will cause bubbles in the sight glass even if the system is overcharged. The use of a sight glass at the outlet of the receiver and another at the inlet of the expansion valve will give a good indication of both the system charge and possible restriction in the liquid line.

A sight glass in the receiver will indicate the amount of liquid refrigerant in the receiver. A system is correctly charged when the unit is operating normally and the receiver is one-fourth to one-third full.

It is difficult to determine the correct charge of refrigerant in a system without a sight glass. The following steps are helpful in determining the correct charge, but they are only indications. First install a manifold gauge assembly and attach a thermometer to the evaporator outlet. Run the compressor for about 10 minutes, observing both of the gauges and the thermometer. Record these readings. Add some refrigerant as a vapor on the low-side, and observe the gauges and thermometer after another 10 minutes of operation. Record these readings and compare them with the previous readings. Continue operation at 10-minute cycles and record the gauge and thermometer readings, until there is no change in the readings. When the system has reached equilibrium, use a P-T chart to convert the thermometer readings to the refrigerant saturation temperature. Use the refrigerant temperature-pressure relation chart.

The suction pressure reading and the saturation temperature of the refrigerant should correspond. Finally, add a small amount of refrigerant and observe the thermometer for any change. If there is no change, there is a full liquid flow being supplied to the expansion valve.

After charging a unit with an estimated charge, it may be necessary to determine if the charge is correct by using the pressure determination method. This may be done in two ways, either by using the head or discharge pressure, or by using the suction pressure. After the charge has been added to the system, the unit must be run until the pressure stabilizes. Once the pressure stabilizes, the ambient temperature must be determined. The ambient temperature will vary depending on the type of condensing unit that the system employs. The actual temperature of the condenser is taken and then a certain number of degrees Fahrenheit is added (refer to figure 3-19 for the correct number of degrees to be added to each type of condenser). Then by checking the pressure-temperature chart you can determine whether the pressure is correct.

Type of condenser	Temperature
Natural convection	Ambient temp. + 35° F
Forced convection	Ambient temp. + 30° F
Water-cooled	Ambient temp. + 20° F

Fig 3-19. Temperature chart of determining ambient temperature.

Example:

To determine the head pressure of a natural convection unit, first take the temperature of the condenser. If the temperature is 75° F, you add 35° F to it. Thus: 75° F + 35° F = 110° F. Now, check the pressure-temperature chart, assuming the the refrigerant in the system is R-12, you will find that the pressure gauge should read 136.4 psig. If it reads less, more refrigerant is needed. If, in the event, it reads more, some refrigerant will have to be evacuated.

The normal suction pressure of a unit would be equal to the evaporator temperature minus 10° F regardless of the type of condensing unit employed. Assume you find that the evaporator temperature is 30° F. You subtract 10° F to give you an ambient temperature of 20° F. The pressure-temperature chart shows that the gauge should read 21.04 psig. If it reads less, more refrigerant is needed. If it reads more, some refrigerant will have to be evacuated.

On a system requiring a critical charge, this system is charged by weight, according to the manufacturer's specifications. Use a scale or a charging panel to measure an exact weight of refrigerant. Weighing the charge is a simple method; however, the charge must be known in advance. First an evacuated cylinder is weighed and then the necessary refrigerant is put into the cylinder.

Example:

If an evacuated cylinder weighs 15 lbs. and the TM specifies that the unit needs 5 lbs. of R-12, the filled cylinder should weigh 20 lbs. once the refrigerant is added. The cylinder is placed on a scale and the system is charged (filled) until the scale again reads 15 lbs. This would indicate that the system has been charged with the required 5 lbs. of refrigerant.

The last method of determining the charge of a system is by the use of the frost line. A small portion of the suction line should be frosted. This frost line should not extend more than 1 inch beyond the evaporator. An excessive frost line indicates an overcharge. No frost line and the evaporator being warm indicates an undercharge.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. What are the two methods used to charge a refrigeration system?

   a. ______________________________

   b. ______________________________

2. In which method of charging is refrigerant always added to the system in a gaseous form?

   ____

3. In which method of charging is the refrigerant always added to the system in liquid form?

   ____

4. To maintain complete control of the charging process, which method of charging would you employ?

   ____

5. In which method of charging is the refrigerant service cylinder maintained in the up-right position?

   ____

6. State four methods used to determine if the refrigeration system is properly charged.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

7. State how to determine the proper charge of refrigerant using the following methods.

   a. Sight glass in liquid line: ______________________________

   ____

   b. Sight glass in receiver: ______________________________

   ____

   c. No sight glass: ______________________________

   ____

   d. Critical charge system: ______________________________

   ____

SPECIFY THREE METHODS OF DETERMINING PROPER OIL CHARGE IN A REFRIGERATION SYSTEM.

STATE TWO METHODS OF ADDING REFRIGERANT OIL TO A COMPRESSOR AND THE PROCEDURES FOR EACH.

SPECIFY STEPS NECESSARY TO REMOVE EXCESS OR CONTAMINATED OIL FROM A REFRIGERATION SYSTEM.

STATE THREE PRECAUTIONS TO BE OBSERVED IN CHARGING AND REMOVING REFRIGERANT OIL.

All refrigeration compressors require a specific amount of refrigerant oil. This oil is required for lubrication of the moving parts, and helps to make a refrigerant seal between the components. An abnormally low oil level in the system will, in all probably, result in a loss of lubrication and compressor damage. An excessive amount of lubricating oil will result in oil slugging, probable damage to the compressor valves, and lost system efficiency due to oil logging of the evaporator.

There are several means by which the proper amount of refrigerant oil can be measured into the system.

In a new system it can be measured or weighed in as is the refrigerant itself. Unit installation instructions include the compressor oil requirements, in either weight or liquid measurements. This method is also applicable following a compressor overhaul, when all the oil has been removed from the compressor; however, it should be used only when the system has no oil in it.

A second method is by the use of a dip stick. This is used primarily with vertical-shafted hermetic compressors, but you will find some larger, open types of compressors may have openings designed for the use of a dip stick. The TM and for manufacturer's recommendations of the correct level should always be followed.

The third method used to arrive at the proper oil charge is by the use of a sight glass located in the crankcase (fig 3-20). When determining the proper oil charge by this method, the system should be allowed to operate for a period of time (10 to 15 minutes) under normal conditions before the final determination is made. This will assure proper oil return to the crankcase of the compressor; it will allow the oil lines and reservoirs to fill and, where halogenated hydrocarbons are used, give the refrigerant an opportunity to absorb its normal operating oil content.

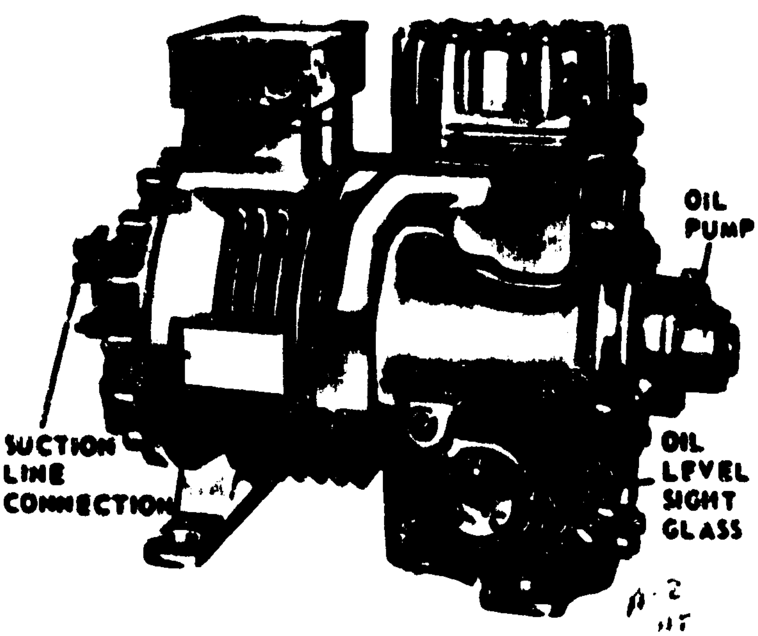


Fig 3-20. Crankcase oil sight glass.

To determine accurately the proper level of oil, it may be necessary to use a flashlight. The oil level should be at or slightly above the center of the sight glass (refer to fig 3-20) while the unit is operating. If less than this, oil should be added. If more than this is seen in the sight glass, the excess oil should be removed.

Oil is normally introduced into a refrigeration system by one of two methods, the oil plug method or the low-side vacuum method. It may be poured in as shown in figure 3-21, providing the compressor crankcase is at atmospheric pressure. This method is normally used prior to dehydration, since it will expose the compressor crankcase interior to air and the moisture the air contains. This method is referred to as the oil plug method.

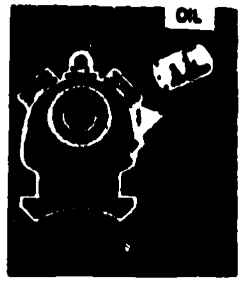


Fig 3-21. Oil plug method of adding oil.

Figure 3-22 illustrates the method normally used with an operating unit. In this case, the crankcase is pumped down below atmospheric pressure and the oil is drawn in. When this method is used, the tube in the oil container subjected to air pressure should never be allowed to get close enough to the surface of the oil to draw air. As shown in figure 3-22, the tube is well below the level of the oil in the container. This method is referred to as the low-side vacuum method.

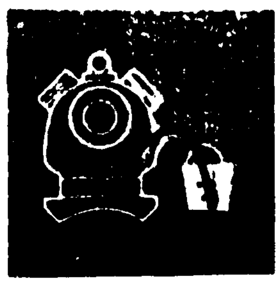


Fig 3-22. Low-side vacuum method of adding oil.

Determining the amount of oil in the compressor is difficult on sealed systems that are not equipped with a sight glass. Only rarely is it necessary to add oil to a sealed system. However, leaking refrigerant always carries some oil with it and this lost oil should be replaced. The conventional methods of adding oil to a system may be used if the system is completely equipped with service valves. That is, oil may be siphoned in or poured in.

When a leak occurs and the amount of oil lost is small and can be reasonably calculated, add that amount of oil to the system. If there has been a large amount of oil lost, the compressor must be removed, the oil drained, and the correct oil charge added to the system before placing it back in operation.

There are three precautions to take in charging and removing refrigerant oil.

The first is to use only clean, dry oil. Second, pressure must be controlled when the crankcase is opened to the atmosphere. Too much pressure can force oil out through the opening rapidly and create quite a mess.

Third, system overcharging should be avoided. Not only will this create the possibility of oil slugs damaging the compressor, but it also may hinder the performance of the refrigerant in the evaporator. Oil overcharging will also cause liquid refrigerant to return to the compressor from the evaporator.

The following are the step-by-step procedures for adding refrigerant oil. As was previously stated, there are two methods of adding oil to the compressor; (1) low-side vacuum method, and (2) the oil plug method.

- Oil plug method

- Attach a compound gauge to the low side.

- Start the compressor and slowly frontseat the suction service valve until a pressure of approximately 2 psig is reached.

- Stop the compressor and frontseat both of the service valves.

- Slowly remove the oil gauge or the oil filler plug.

- Slowly add the required amount of oil through a clean, dry funnel. DO NOT add more than 1/4 pint at a time.

- Replace and tighten the oil plug or gauge.

- Compressor should be pulled to a vacuum to remove all impurities amd mositure.

- Return the service valves to their normal positions.

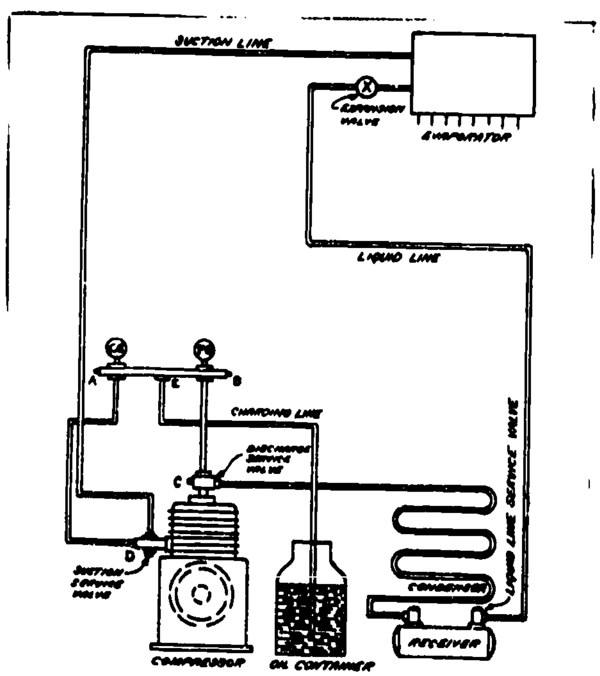


Fig 3-23. Adding oil to the compressor using the vacuum method.

- Vacuum method (refer to fig 3-23).

- Install the bar gauge manifold.

- Frontseat the suction service valve.

- Run the unit the compound gauge registers in a 15-inch vacuum.

- Stop the unit.

- Install a flexible charging line from the center port of the manifold to the oil container.

Note: Always place the end of the charging line well below the surface of the oil in the oil container. This will insure that only moisture-free oil is drawn into the compressor.

- Crack the compound gauge valve and atmospheric pressure will force the oil into the compressor crankcase.

- Add only about 1/4 pint of oil at a time.

The following are the procedures for removing refrigerant oil that has become contaminated, or it must be changed, or the system has an overcharge and the excess must be removed.

- Attach a compound to the low-side of the system.

- Start the compressor and gradually frontseat the suction service valve until the pressure in the crankcase drops to 1 pound.

- Stop the compressor and frontseat both the service valves.

- Drain the oil through any valve or plug below the oil level.

- Replace the plug and tighten or close the valve.

- Place the system back into operation if required.

Note: Always purge air from a system, whenever it has been opened.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. What are three methods used to determine the charge of refrigerant oil in a system?

   a. ______________________

   b. ______________________

   c. ______________________

2. What are the two methods used to add refrigerant oil to a system?

   a. ______________________

   b. ______________________

3. In the oil plug method of adding oil to a compressor, which valve is frontseated after the compressor is started?

   ____

4. In the vacuum method of adding refrigerant oil to the compressor, how deep of a vacuum is pulled before stopping the compressor?

   ____

5. What are the three precautions to observe in charging and removing refrigerant oil?

   a. ______________________

   b. ______________________

   c. ______________________

SUMMARY REVIEW

In this study unit, you have learned the construction and use of service valves and the bar gauge manifold, and the correct procedures for using the manifold assembly. You, also, learned to evacuate, pump-down, and charge the refrigeration system. Lastly, you learned the procedures required to add and remove refrigerant oil from the system.

Answers to Study Unit #3 Exercises

Work Unit 3-1.

1. a. One-way valves
   b. Two-way valves
2. a. Gauge port
   b. Line port
   c. Compressor port
3. You must replace the valve.
4. To allow the technician to observe operating pressure from both the high-side and low-side of the refrigeration system at the same time
5. It must be purged by allowing a small amount of refrigerant to escape from the fitting before tightening.
6. Frontseat the valve on the gauge manifold.

Work Unit 3-2.

1. To remove noncondensables and assure a tight, dry system before charging.
2. a. Deep vacuum method
   b. Triple evacuation method
3. Deep vacuum evacuation is used on systems containing only a minimum of contaminants whereas triple evacuation is used on systems containing a greater amount of contaminants.
4. Deep method

Work Unit 3-3.

1. To save the refrigerant that is in the system and to prevent air from entering
2. Allow the compressor to run until it is warm.
3. 3 psig
4. To keep the compressor from stopping due to low pressure
5. Allow the refrigerant to push whatever air has entered the system out through the loose flare nut at the suction service valve.

Work Unit 3-4.

1. a. Low-side charging
   b. High-side charging
2. Low-side charging
3. High-side charging
4. Low-side charging
5. Low-side charging
6. a. Sight glass
   b. Pressure determination
   c. Weighting the charge
   d. Frost line
7. a. Normally the system is properly charged if there are no bubbles in the sight glass.
   b. If this sight glass registers between one-fourth to one-third full.
   c. Observe and record both gauge connections of the manifold and a thermometer. Add refrigerant. Again observe and record the readings at 10-minute intervals. When there is no change the charge is sufficient.
   d. Use a scale or charging panel and determine the proper weight.

Work Unit 3-5.

1. a. Liquid measure or weight
   b. Dip stick
   c. Sight glass
2. a. Oil plug method
   b. Low-side vacuum method
3. Suction service valve
4. 15 inches
5. a. Use only clean, dry oil.
   b. Control pressure when the crankcase is opened to the atmosphere.
   c. Avoid overcharging the system.

STUDY UNIT 4

REPAIRING MAJOR COMPONENTS

STUDY UNIT OBJECTIVE: WITHOUT THE AID OF REFERENCES, YOU WILL LEARN TO MAKE NECESSARY REPAIRS TO MAJOR COMPONENTS OF THE REFRIGERATION SYSTEM. THESE COMPONENTS INCLUDE THE ELECTRIC MOTOR AND ITS CONTROLS, COMPRESSORS, THE CONDENSER AND EVAPORATOR, AND LASTLY, THE AUTOMATIC CONTROLS.

Maintenance is the primary job of a refrigeration technician. Good maintenance will usually catch the refrigeration problem before it is received on a work order. The quality and quantity of maintenance performed by a shop and personnel will have an effect on the amount of equipment that is down. There is no substitute for good maintenance.

To insure long and satisfactory operation of refrigeration units, there are additional tests and maintenance procedures necessary to determine whether to repair or replace a major component of a system.

Work Unit 4-1. MOTORS AND CONTROLS

STATE THE PROBLEMS AND PROBABLE SOLUTIONS FOR PROBLEMS WHICH MAY CAUSE TROUBLES IN MOTORS AND CONTROLS.

GIVE SPECIFIC DETAILS CONCERNING TROUBLE-SHOOTING TECHNIQUES FOR 3-PHASE AND SINGLE-PHASE MOTORS AND CONTROLS.

IDENTIFY PROBABLE CAUSES OF COMMON MALFUNCTIONS FOUND IN MOTORS AND CONTROLS.

Motor failure may be due to a number of causes. Some of the things that may cause motor failures are an overload, low or high voltage, frozen or worn motor bearings, failure of motor windings, and failure of motor controls.

Many things that cause motor failure are not the fault of the motor. Several conditions which may cause motor failure are listed below. These conditions should be checked before disconnecting electrical powerlines or trouble-shooting the electrical system.

- Overload
- Loss of power
- Driven machine blocked
- Frozen or worn bearings
- Bad or improper connections

If a 3-phase or single-phase motor has been operating satisfactorily and suddenly stops, a temporary OVERLOAD condition may exist. You should allow sufficient time for the overload device to cool before actuating the reset device. If sufficient cooling has occurred, the reset will hold in the locked position and you can follow the normal starting operation. If the motor fails to start, employ a systematic procedures for locating the trouble. Check current draw with an ammeter to determine if the motor is overloaded.

Use a voltmeter to determine if power is being supplied to the magnetic starter. Likewise, determine if power is being supplied to the motor.

Before a motor is removed from the line, check all electrical connections. Determine if the control connections are in accordance with the control wiring diagram. When you have checked the control connections, check the terminal lead connections in both the control apparatus and the motor.

Motors with wound rotors are more susceptible to malfunctions due to their construction. Other than insulation checks, which are similar to the stator windings, rotors often have opens caused by overheating. Sometimes these opens can be repaired using a soldering gun to restore the circuit.

Brushes that have been worn to half their original length must be replaced. Check brushes for broken leads, a chipped or broken face, correct tension, and freedom of movement in its holder.

Determine if the driver machine (compressor, fan, etc.) is at fault. To do this, disconnect the motor from its load and rotate the rotor shaft of the motor by hand to determine if rotation is free.

Try operating the motor without the load of the driven machine. Lubrication may be needed and, in some cases, will free the rotor. If the bearings are frozen or stuck, it may be necessary to take the motor apart to free the bearings. If the rotor shaft will turn, look for wobbling, which indicates a bent shaft. Before handling the shaft, however, put on gloves; or use a piece of cloth to insure against injury to hands from burrs or sharp edges that may be in the keyway. Check the rotor shaft for any up-and-down play (movement). Any noticeable movement indicates worn bearings, which may be causing the rotor to be dragging in the stator. This is probable when belt tension is applied. The bearings should be replaced if up-and-down movement is noted. Also check for rotor end play. This is noted by moving the rotor shaft in and out. Some end play is not detrimental; however, it should not exceed 1/64 of an inch. Excessive end play may be removed by adding fiber spacer washers.

Other things to check for are: misalignment of endbells, a loose pole piece, or foreign objects in the motor. If the trouble is not mechanical, then analyze the motor electrical circuits.

The most common causes of bearings trouble may be attributed to improper alignment at installation and inadequate lubrication.

If a bearing gives you trouble, it must be replaced. Bearings should not be removed unnecessarily because they are easily damaged. Normally, to remove a ball bearing, the end bells of the motor are removed and the rotor, shaft, and bearing assembly are removed from the motor. If the bearing housing has a removable outer cap it is sometimes possible to remove the bearings without removing the end bells.

When removing a ball bearing from the shaft, exert pressure only on the inner race. If this is not possible, pressure on the outer race must be distributed over the entire race. Pressure should be applied steadily, parallel to the shaft and at a right angle to the bearing. Before removing a sleeve bearing, an air gap measurement is normally made to determine the amount of wear and to see if the bearing is out of round. Small sleeve bearings may be carefully tapped out, but bearing pullers are usually required to remove the larger size sleeve-type bearings.

Bearings are replaced by applying steady, even pressure or by tapping lightly. Ball bearings must not be forced on a shaft that is too large or is badly worn. Grease retainers and oil slingers must be in place. Dirt and foreign matter must be kept out of bearing recesses as they will scar the bearing surfaces and cause the races of ball bearings to become distorted. If a race is distorted, the balls will get out of round and cause an excessive friction load on the motor. After installation, bearings should be rotated by hand to see that they roll freely and without noise. Protective covers must be in place and be tight to prevent dirt and moisture from entering the bearing housing.

Of all components that comprise a motor, the brushes are most subject to wear. Even in normal service, brushes will occasionally have to be replaced.

On small motors, brushes are usually held in place by coil springs seated in threaded cup-shaped retainers which usually screw directly into the housing or end bell. The brushes may be replaced by unscrewing the retainer and pulling or shaking out the old brush. The new brush will be longer, but the spring is designed so that only part of the stroke is used and the retainer may be fully screwed in without danger of excessive brush pressure.

On larger motors, brushes are mounted in holders or riggings and are pressed against the slip-rings or commutator by spring-operated fingers. The current is carried by pig tails attached to the upper end of each brush. When a brush is installed, it may be necessary to adjust the brush spring to get proper brush contact pressure. Brush-spring pressure should be from 1-3/4 to 2-1/2 psi of contact area for light metalized and carbon or graphite brushes, and from 3 to 5 psi for heavy metalized brushes on slip-rings and commutators. Excessive brush pressure will cause rapid wear of brushes, commutator, and slip-rings. Low spring tension will cause arcing due to poor brush contact and may cause burning and pitting of brushes, commutator, and slip-rings. Spring pressure should be checked by a spring balance (fig 4-1) held directly above the brush and attached to the spring or aimed at the point of contact with the brush. A direct upward pull is given and the reading taken as the brush leaves the face of the slip-rings or commutator (or when a piece of paper can be drawn between the brush and the rings, or commutator). When you install new brushes they may have to be seated to give the brush face the same curvature as the commutator or rings. To do this slip a piece of fine sandpaper (00), face up, under the brush, draw it tightly against the commutator or rings, and sand off the brush face. Very little sanding is necessary as the brush material is quite soft.

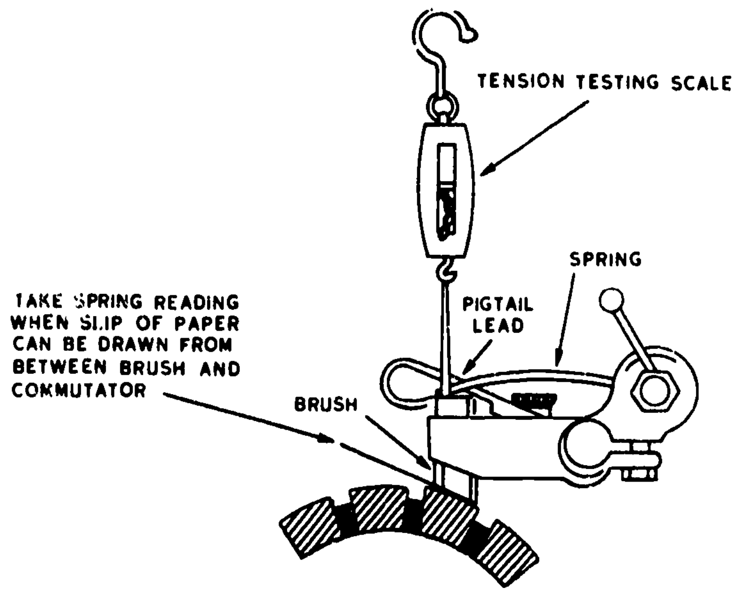


Fig 4-1. Method of checking brush pressure with a tension scale.

While in service, the motor should be cleaned regularly. Dust and lint in the motor will prevent proper air circulation. Compressed air or a hand bellows should be used frequently to blow dirt out of the motor.

Any oil which may overflow from the bearings should be wiped off. A little attention will result in efficient operation with the motor giving good service for many years.

If the motor must be dismantled, all parts should be carefully cleaned before being worked on or reassembled. Cleaning fluids must be used that are not harmful to the electrical insulation material or to the technician's health. Only fluids of good dielectric quality should be used. There are several cleaning fluids approved for motor cleaning.

Belts will be found on units that employ an open-type motor/compressor. In order to obtain long and satisfactory service from V-belts, the compressor flywheel and the motor pulley must be in line with each other in two different ways. First, the center line of the compressor must be parallel with the center line of the electric motor shaft. Secondly, the pulley grooves must be in line with each other.

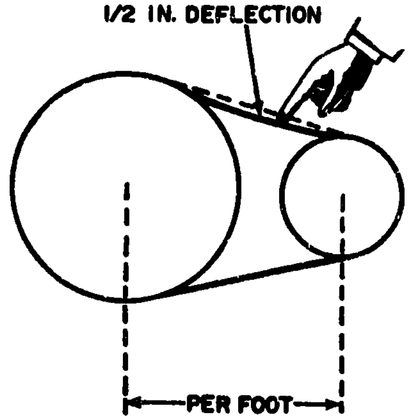


Fig 4-2. Belt tension adjustment.

When installing belts, be careful to adjust them for proper tension as well as alignment. They should fit snugly but not tightly. One should be able to depress a properly tensioned belt about 1/2 inch with a 10-lb. force. Since you do not always have ten pounds of force in your tool box, remember, a correctly adjusted belt can be depressed 1/2 to 3/4 inch by the pressure of one finger at a point midway between the motor pulley and the flywheel (Refer to fig 4-2). You can adjust the belts by moving the adjustable motor rails or by adjusting the belt-tightening device.

When replacement of one belt of a multiple V-belt drive is necessary, a complete new set of matched belts must be installed. This is due to belts stretching considerably during the first few hours of operation. If you were to replace a single belt, the load balance would become upset between the old and new belts causing the load to be unbalanced.

Belts, motor pulleys, and flywheels should be kept free of oil and grease and kept dry at all times.

All electrical circuits of three-phase motors and controls are subject to three common malfunctions. These circuits faults are: open, grounded, and shorted circuits.

Starting with the source of power, an open circuit may exist at any point between there and the rotor of the motor. It is necessary to isolate the trouble. This must be done on a step-by-step basis. Make the following checks on the equipment shown in figure 4-3. It is very important to remember that you are working with an ohmmeter, and it should not be connected to a live circuit. Figure 4-3 shows a 3-phase motor connected to a 3-phase starter.

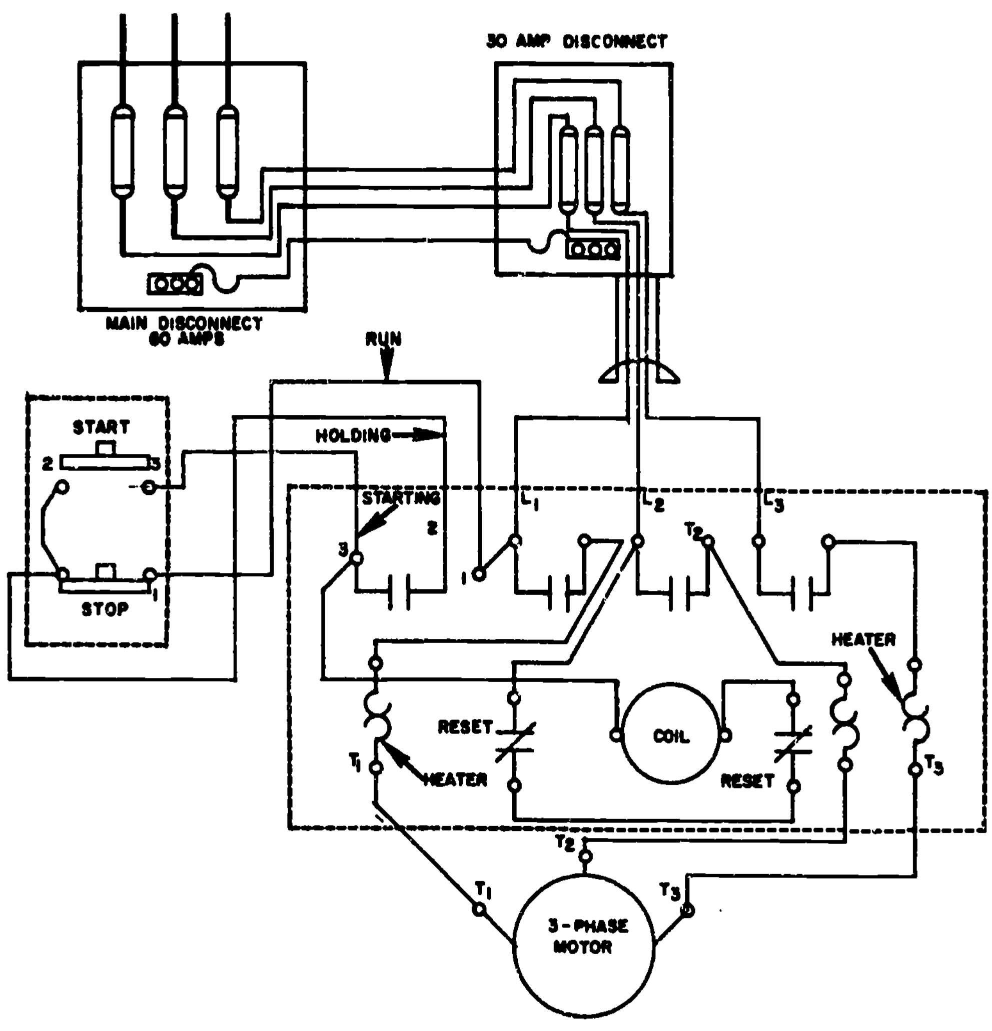


Fig 4-3. Three-phase motor connected to a three phase starter.

With an ohmmeter, check from the source of power to the live terminals of the starter, making sure continuity exists at the starter line terminals, L1, L2, and L3. Make sure of a continuous circuit between the start-stop station and the starter. Remember, the conductor connected to L1 is common to both the starting and holding circuit.

Make sure there is a continuous path for current flow from the switch side of the starter through the holding coil and through the resets, back to L2. This circuit normally is from switch terminal 3, to starter terminal L2. Be sure you have continuity through the heaters. Raise the armature until the contacts are closed and check for continuity between L1 and T1; L2 and T2, and L3 and T3. If there are no opens at this point, power should exist to the motor terminals, T1, T2, and T3 of the starter, when the start button is pushed.

Check for continuity between the starter terminals, T1, T2, and T3. If you have continuity to the motor terminals, it will be necessary to check the stator of the motor for an open circuit. This is done in a wye-connected motor, as shown in figure 4-4.

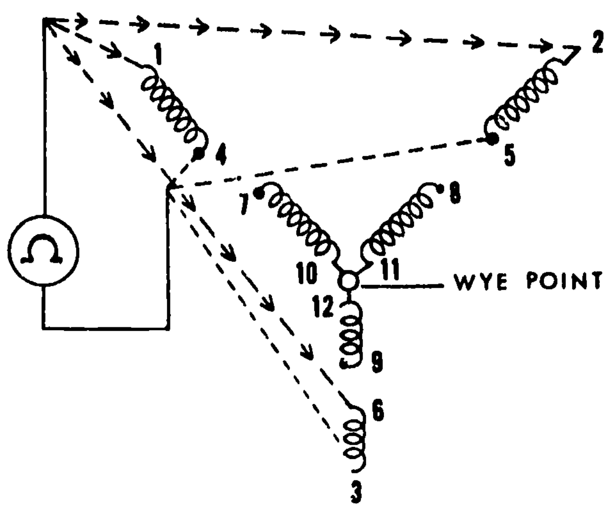


Fig 4-4. Testing the stator of a 3-phase wye-connected motor for an open circuit.

Disconnect the motor leads from the power leads. Check for continuity between leads 1 and 4, 2 and 5, and 3 and 6. Continuity should exist when testing across the above mentioned pairs. Since the opposite end of leads 7, 8 and 9 are connected at a wye point in the wye-connected motor, continuity should exist between leads 7 and 8, 7 and 9, or a combination of 7, 8 and 9.

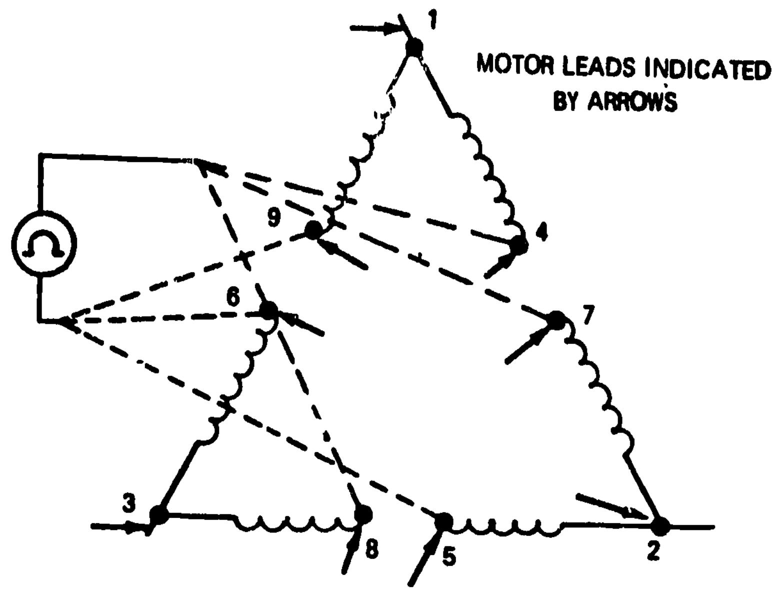


Fig 4-5. Testing a delta-connected motor for an open circuit.

Check the stator of a delta-connected, 9-lead motor for an open circuit as shown in figure 4-5. Disconnect the motor leads from the power leads. Check for continuity between leads 4 and 9, 6 and 8, and 5 and 7. This will check all the windings in the delta motor, inasmuch as lead 10 is connected internally to lead 2, lead 11 to lead 3, and lead 12 to lead 1, as shown in figure 4-5.

There is little likelihood that a squirrel-cage rotor will be open. If an open does exist, the motor slows down under load. It also has low starting torque. Signs of heating are usually evident. Fractures in the rotor bars are usually found either at the connection to the end rings or at the point the bars leave the laminations. If the motor has a wound rotor, it may be necessary to check it for an open circuit by using the external growler.

The same methodical process must be followed in finding a grounded circuit as was employed in finding an open circuit. It is necessary to start with the source of power and work toward the motor. With the main disconnect open, check with an ohmmeter across each power phase to ground. Follow this step all the way to the starter, to insure that no grounds exist from the source of power to the starter. Any ground existing in the power supply or any extremity connected to L1, L2, or L3 of the starter will be indicated at any point tested, by the needle movement on the ohmmeter. This is assuming any disconnects between the source of power and the starter are closed. Disconnection of conductors at certain points will be necessary to isolate the grounded circuit. One at a time, check across each of the conductors, connected to the start-stop station to ground (conduit), to determine if a ground exists to the start-stop station.

Check throughout the starter at points of possible grounds. Also check the control circuit (through the coil) and then your load circuit. In checking T1, T2, and T3 of the starter to ground, remember that any grounds existing in the connected motor will be indicated at these points. Whether the ground exists in the motor or on the conduit can be determined by disconnecting the motor from the starter. If the ground does not exist in the conduit from the starter to the motor, the motor windings must be checked for grounds.

The motor windings are tested for grounds, as shown in figure 4-6. Position one test prod to the motor housing, being certain metal-to-metal contact is established. With the other lead, touch each station lead in succession. If the needle moves, a ground is indicated. All internal motor troubles must be repaired by a motor rewind shop; so if an internal problem is discovered, you should not disassemble the motor, instead, send it out for repairs.

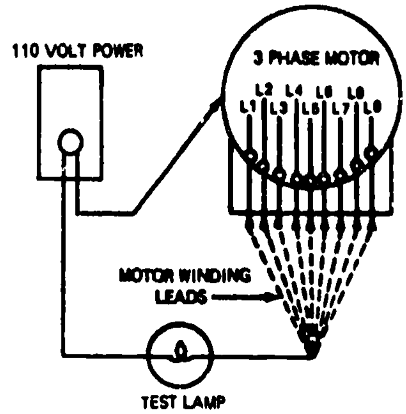


Fig 4-6. Testing motor leads for grounded windings.

Shorted circuits in electrical motors are found by checking across conductors with the power off. If continuity exists across two conductors when the circuit is purposely open, the circuit is shorted. As in checking for opens and grounds, checking for shorted circuits should start with the source of power and be carried through to the motor windings. Figure 4-7 may be used for applying tests for short circuits. With the main disconnect open, start by checking across the fuses (bottom end). Assuming any disconnects are closed between the source of power and the starter, continuity across any two conductors will indicate a short circuit exists between the main disconnect and the starter. Disconnection of conductors at certain points will be necessary to isolate the shorted circuit. Press the stop button and check across the conductors on terminal 2 of the starter switch to L1. Pressing the stop button on the start-stop station opens the circuit to the starter. A continuity reading would then indicate a shorted circuit in the holding part of the circuit.

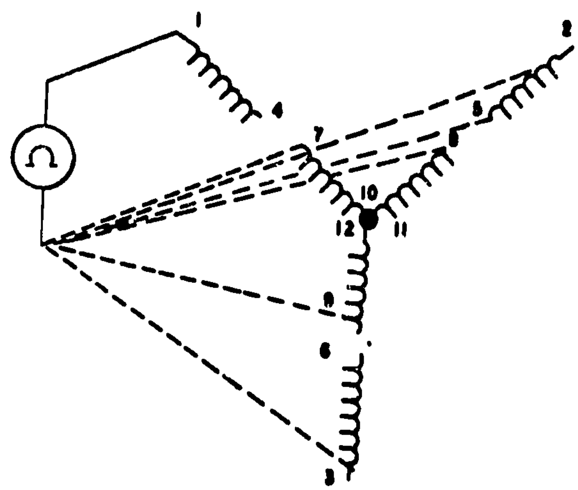


Fig 4-7. Testing a wye-connected stator for a shorted circuit.

Note: This circuit is normally closed due to the construction feature of the start-stop station.

Continuity across L1 to number 3 in the starter would indicate a shorted circuit in the starting part of the circuit.

Note: This circuit is normally open due to the construction feature of the start-stop station.

When checking across the terminals, (T1, T2, or T3), it will be necessary to disconnect the motor leads from the source of power; otherwise, there will be a continuity reading due to reading across the motor windings. After disconnecting the motor leads, continuity will exist when checking across T1, T2, and T3. Also, a short circuit will exist in the conduit between the motor and the starter.

Check a wye-wound motor for a shorted motor winding as shown in figure 4-7. Use an ohmmeter to check across the stator leads of the motor where continuity should not exist. Continuity should exist between leads 1 and 4, 2 and 5, 3 and 6, and the leads of which the other ends form the wye point. The external leads involved in the wye are: leads 7, 8, and 9. Therefore, in testing for a shorted stator, if continuity should exist between any combination of lead numbers other than those which form a winding, a shorted stator is indicated.

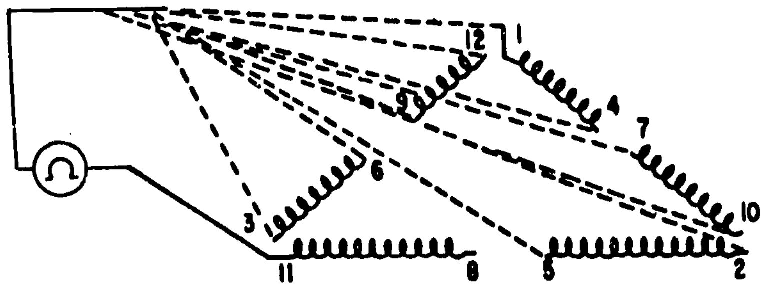


Fig 4-8. Testing a 12-lead, delta-wound stator for a shorted circuit.

Procedures for checking a delta-wound, 12-lead motor for a shorted stator winding are accomplished, as shown in figure 4-8.

Continuity should exist across the following leads of a delta-wound stator having 12 external leads: 1 and 4, 2 and 5, 3 and 6, 7 and 10, 8 and 11, and 9 and 12. Therefore, in testing for a shorted stator, if continuity should exist between any combination of numbers other than those shown above, the stator is shorted.

In the 9-lead delta motor, which is most commonly used, 3 end windings are internally connected. Lead 12 is connected to lead 1, lead 11 to lead 3, and lead 10 to lead 2. Continuity should exist across leads 4 and 9, 6 and 8, and 5 and 7. Therefore, in testing for a shorted stator, if continuity should exist between any combination other than those listed above, providing leads 1, 2, and 3 are not used, the stator is shorted. Leads 1, 2 and 3 are not used because internal leads 12, 10, and 11 are connected to them.

All electrical circuits in single phase motors and controls are subject to the same malfunctions as 3-phase motors. Therefore, we will discuss only open circuits.

Starting with the source of power, an open circuit may exist at any point between there and the rotor of the motor. It is necessary to isolate the trouble. This must be accomplished on a step-by-step basis also. Make the following checks on the equipment shown in figure 4-9. Check with an ohmmeter from the source of power to the line terminals of the starter, making sure continuity exists at the starter line terminals, L1 and L2. Make sure of a continuous circuit between the start-stop station and the starter.

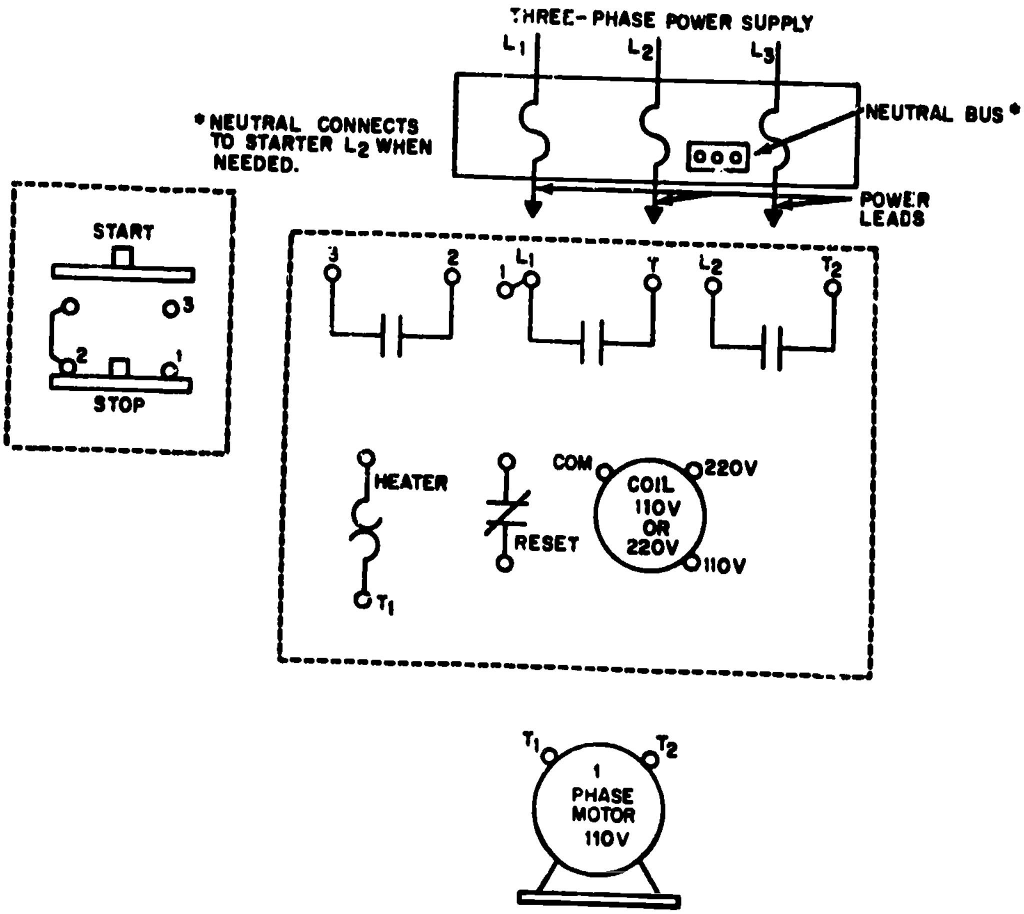


Fig 4-9. Single-phase motor control system.

Note: The conductor connected to L1 is common to both the starting and holding circuit.

Make sure there is a continuous path for current flow from the switch side of the starter through the holding coil and through the resets, back to L2. This circuit normally is from switch terminal 3, to starter terminal L2. Be sure you have continuity through the heaters. Raise the armature until the contacts are closed and check for continuity between L1 and T1 and L2 and T2. If there are no opens to this point, power should exist to the motor terminals T1 and T2 of the starter, when the start button is pushed.

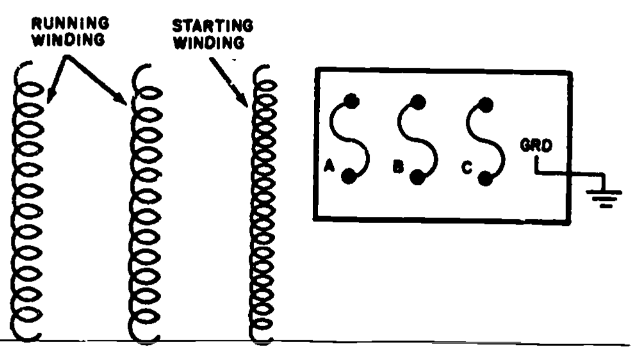


Fig 4-10. Testing the stator of a single-phase motor for an open circuit.

Check for continuity between the starter terminals, T1 and T2, and the motor terminals, T1 and T2. If you have power to the motor terminals, it will be necessary to check the stator of the motor for an open circuit. This is done in a single phase motor, as shown in figure 4-10.

Disconnect the motor leads from the power leads. Check for continuity between leads 1 and 2, 3 and 4, and 5 and 8. There is little likelihood that a squirrel cage rotor will be open. It also has low starting torque. Signs of overheating are usually evident.

All malfunctions in motors and controls may be corrected by a technician except malfunctions in the internal wiring of the motors. Common malfunctions are:

- Motor will .ot start
- Motor runs hot
- Motor stops running
- Motor operates with excessive noise
- Motor runs slowly

Let's take a closer look at each of these common malfunctions.

Motor will not start - This malfunction may be due to a voltage failure. Check the line voltage. Check for blown fuses and broken or loose connections. Replace any bad conductors.

Motor runs hot - The motor may be operated under an overload. Check the full-load amperage against the data plate rating. Check the rating of the overload relay against the full-load current. If the rating of the relay is too high, replace it with the power rated relay.

Check the available voltage to be sure the motor is not operating on under or over voltage. It may be necessary to lighten the load or install a larger motor to carry the load.

Check for proper motor and power connections. Be sure the motor is properly connected to the available voltage.

Check for proper ventaliation. Clean any dirt from around vents or windings.

Check the motor to determine if it has been properly lubricated. It it has not been, oil it according to the lubrication instruction and or manufacturer's instruction.

The motor may be overheated due to starting too frequently. Determine if the motor is rated for intermittent duty. If it is not rated for the service required, it must be replaced with one of the proper design.

Motor stops running - If the motor stops running, allow sufficient time for the motor control to cool. Push the reset into the locked position and push in the start button. If the motor starts, maintain close observation until the operator is sure the motor failure was not due to any severe circumstances, the recurrence of which would result in serious damage to the motor. A brief overload or a power failure may have been the cause of the failure. Occasionally, the relay must be replaced because it has become faulty. If the motor cannot be restarted, it may be necessary to recheck all the things previously discussed.

Motor operates with excessive noise - Excessive noise may result from the motor not being securely mounted. This condition may be remedied by tightening the mounting bolts and the motor support securely. You may also find that dry motor bearings may cause excessive noise while the motor is in operation. Proper lubrication may stop the excessive noise, providing permanent damage has not been sustained by the bearings. Sufficient damage to the bearings may require the bearings to be replaced. Follow a regular lubricating schedule. Be certain the lubricant is the type suggested by the lubrication instruction or the motor manufacturer.

Excessive noise may be the result of loose motor accessories. You can eliminate this by tightening the oil well cover and the connection box cover. The motor may not be mounted on a soiled surface. Replacing the mounting surface may quiet the operation of the motor.

Motor runs slowly - When a motor runs slower than it is rated to run, considering slip in induction motors and no overloading of the motor, then you must consider other factors. The voltage supply may be deficient, causing a motor to run too slowly. Correct the supply voltage. The voltage must be within 10 percent of the voltage rating for the motor.

The bearings of a motor may be binding. This will cause the motor to run at less than rated speed. The bearings should be replaced if needed. Cleaning and relubrication may correct the trouble.

The driven machine may cause a motor to run slowly. When it is suspected that the driven machine is at fault, the motor should be disconnected from its load and tested independently of the load.

Occasionally a motor may be open. This will result in the motor slowing down under a load. The rotor must be repaired or replaced.

When trouble-shooting single phase motors, you should check for such items as bad centrifugal switches, bad brushes, and bad capacitors.

If a split-phase motor hums but will not start, the trouble will probably be in the centrifugal switch or bad start windings. This same problem with a capacitor start motor might mean the motor has a bad capacitor. All other checks are the same for both single-phase and 3-phase motors.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. List five problems which may cause trouble in motors.

   a. ____________________

   b. ____________________

   c. ____________________

   d. ____________________

   e. ____________________

2. What instrument should you use to determine if a motor is overloaded?

   ____

3. How can you repair opens in rotors caused by overheating?

   ____

4. How can you determine if the driven machine is at fault?

   ____

5. How can you remove excessive end play in bearings?

   ____

6. Where may an open circuit exist in a 3-phase motor?

   ____

7. Why is it sometimes necessary to disconnect the motor from the starter in a 3-phase motor?

   ____

8. What would indicate a short circuit between the main disconnect and the starter?

   ____

9. How does a open circuit affect a single-phase motor with a squirrel-cage motor?

____

Matching: Match the causes in column A with their malfunctions in column B. Place your answer in the space provided.

Column A	Column B
Causes	**Malfunctions**
10. ______ Improper ventilation	a. Motor will not start
11. ______ Blown fuses	b. Motor runs hot
12. ______ Power failure	c. Motor stops running
13. ______ Faulty relay	d. Motor operates with excessive noise
14. ______ Open rotor	e. Motor runs slowly
15. ______ Deficient voltage supply	
16. ______ Dry motor bearings	
17. ______ Too frequent starting	
18. ______ Insecure mounting	
19. ______ Bad conductors	
20. ______ Faulty driven machine	
21. ______ Voltage failure	

Work Unit 4-2. COMPRESSOR REPAIR

IDENTIFY THE PROCEDURE NECESSARY TO TEST A COMPRESSOR FOR LEAKS AT THE VALVES, PISTONS, AND HEAD GASKETS.

SPECIFY THE CORRECT PROCEDURES TO SERVICE A COMPRESSOR.

LIST TWO PROBLEMS MOST OFTEN ENCOUNTERED WITH CRANKSHAFT SEALS.

STATE WHAT TYPES OF OIL SEALS ARE USED, HOW YOU REMOVE AND REPLACE THEM, AND HOW YOU CHECK FOR PROPER SEALING.

Common troubles that you will encounter, in the performance of your job, are: (1) leaks at the suction or discharge valves; (2) leaks at the gaskets; and (3) leaks past the piston and piston rings. These leaks may cause such malfunctions in the system as: (1) a sudden decrease of refrigerating ability; (2) a gradual decrease of refrigerating ability; or (3) an inability to produce or maintain the necessary low-side pressures or vacuums which would cause the compressor to either run continuously or too long during each cycle.

Before you tear into a compressor you must be sure that the trouble is in the compressor and not in another part of the system. The following are procedures for testing the compressor to determine if leaks are present at the valves, pistons or gaskets. If you follow these procedures you will discover where the problems are and effect the necessary repairs.

- Connect a compound gauge to the suction service valve and a pressure gauge to the discharge service valve by the use of the bar gauge manifold.

- Start the compressor and partly close the suction service valve. This must be accomplished carefully so that the vacuum is reduced to 20 to 25 inches of mercury in not less than 10 minutes. This will require you to constantly adjust the suction service valve and maintain an eye on the compound gauge and the clock. By slowly reducing the low-side pressure, you prevent rapid separation of the refrigerant from the crankcase oil and excess oil from getting on the compressor valves which may make them temporarily free of leaks. If you cannot obtain a vacuum of more than 10 or 15 inches of Hg, or if it takes a longer time (15 minutes or longer) to get the vacuum down to 20 or more inches of Hg, indications are that the suction service valve or compressor valves are leaking.

- Stop the compressor, open the suction service valve to its fullest, and wait for 0 psig low-side pressure to build up. To speed up the buildup of pressure, open the cabinet doors or warm the evaporators with warm rays of water.

- Start the compressor again. Close the suction service valve and wait for a maximum vacuum to build up. As soon as maximum vacuum is obtained, stop the compressor. Maximum vacuum should be obtained in 30 seconds or less. This vacuum shot should remain almost without change for as long as 5 minutes. If the vacuum does not hold, it indicates either leaky valves or leaks past the piston or piston rings. This could also indicate a leaky head gasket.

> Note: DO NOT attempt this test until after the suction service valves and compressor valve have been tested for leaks as described earlier, because so much refrigerant may be released from the crankcase oil that the gauge pressure could be raised even with the suction service valve closed.

- Open the suction service valve. Wait for the vacuum to decrease. Then close the discharge service valve.

- Using the flywheel, turn the compressor over slowly by hand until the pressure gauge reaches 125 to 150 psig. If the pressure rises slowly, or rises and falls or does not rise high enough, to would indicate that: the discharge valve is leaking, there are leaks past the piston or piston rings, or the head gasket is leaking. If the pressure drops rapidly after the compressor has been stopped, the same faults listed above are indicated. If there are no leaks, the head pressure will increase to a certain point (between 125 to 150 psig) and remain constant. After observations have been made and you are satisfied as to what is or is not wrong, the high head pressure must be relieved.

When servicing the compressor, remove only the components necessary to effect the required repairs. Before reassembling the unit, inspect any other component which have become accessible. All parts should be carefully cleaned with an approved cleaning fluid and allowed to dry in the air. When disassembling a compressor, be very careful not to scratch or mar gasket sealing surfaces. New gaskets of the correct material and thickness must be installed when reassembling a compressor. Upon disassembling a compressor, all components should be clearly marked so that they may be replaced in their original positions. Clean lubricant should be applied to all bearing and rubbing surfaces of components that are being installed. The compressor crankcase should be drained, cleaned, and filled with fresh oil in the quantity specified in the lubrication instruction.

Once tests have shown a decided possibility of valve problem, the valve plate assembly will be accessible by removing the cylinder head. Pump down the compressor to 2 psig and remove the compressor head capscrews. Tap the head with a wooden or plastic mallet to free it if it is stuck, and remove the cylinder head. Check the sealing surfaces to insure that there are no dirt particles or foreign matter on them that would cause the valves to leak. Also at the same time insure that the sealing surfaces are not marred or scarred as this will cause leaking too.

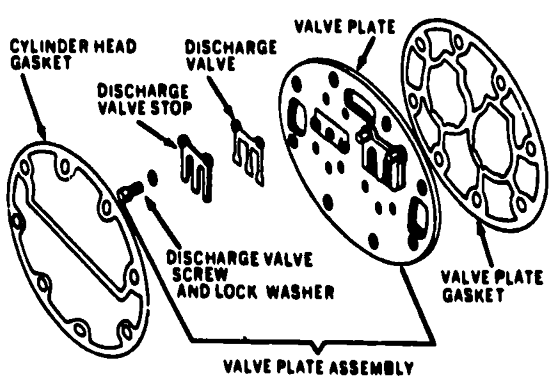


Fig 4-11. Valve plate assembly.

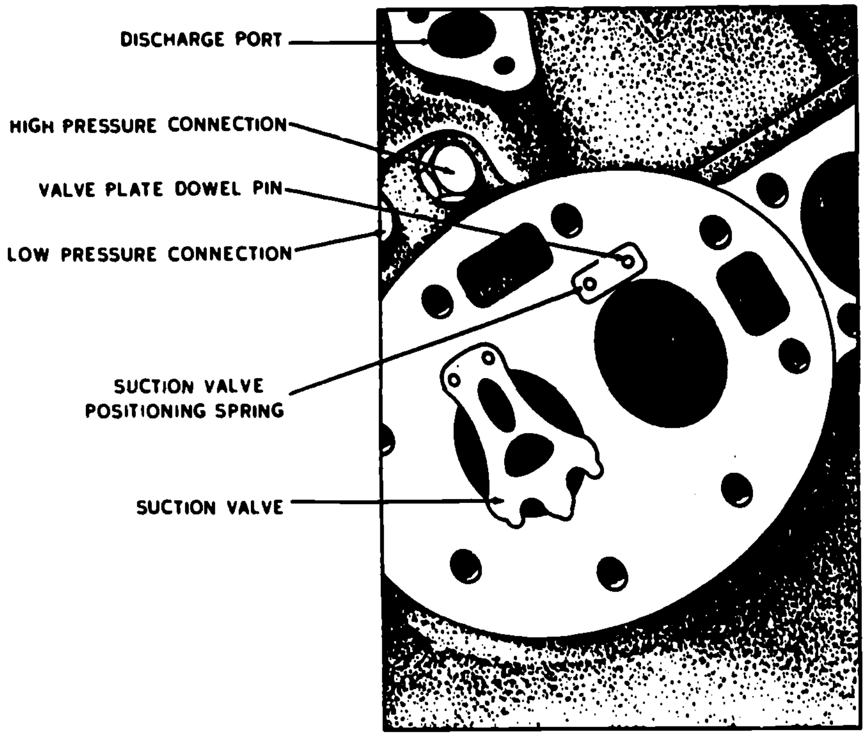


Fig 4-12. Suction valve positioning spring.

Remove the discharge valves and valve stops as shown in figure 4-11. Free the valve plate from the dowel pins and cylinder deck. Many valve plates have tapped holes. The capscrews are screwed into them and function as jacking screws. Now you can remove the suction valves from the dowel pin. Figure 4-12 shows the suction valve, suction valve positioning spring, dowel pin, etc. Inspect the valve seats and valves. If the valve seats look worn or damaged, replace the valve plate assembly (see fig 4-11).

It is preferable to install new valves with a new valve plate. If new valves are not available, turn the old valves over and install them with the unworn side toward the valve seat. If the valve seats and valves are not noticeably worn, it is still good practice to rotate the discharge valves; otherwise they may not set properly.

The suction valves are doweled and must be reinstalled as they were originally. You must never interchange valves. Be careful when replacing the suction valves. The positioning string must be placed on the dowels first. Place them with their ends toward the cylinder deck and with the middle bowed upward.

Usually, if valve operation is faulty, the valve seats as well as the valves are damaged. Broken valves will usually cause scratches in the valve plate seat. If a broken valve is discovered, every piece must be accounted for. If any piece is left in the compressor, damage to the piston, piston rings, cylinders, or bearings may result.

New valves should not be used in old or damaged seats unless the seats are put in perfect condition. This is accomplished by lapping, which should not be done without the proper tools and qualification. A machinist or an experienced automotive mechanic may do the job for you. However, if you are qualified and the proper tools are available, plus using the lapping compound of the right grit, you may do the job yourself.

After lapping, the parts should be washed in an approved cleaning solvent and air dried. They should then be coated with oil to protect them against fingerprints and moisture until they have been put back into the compressor.

Once the valve plate is reassembled and put back into the compressor, all sealing surfaces cleaned, and new gaskets (valve plate and head gasket) installed, place the head back on.

All head bolts should be turned down snugly, but not tightly. Starting with the center bolt and working outward, tighten all head bolts to the proper torque. This torque is obtained from the TM and/or manufacturer's publication.

Install the suction and discharge service valves at this time. Insure that the seating surfaces and new jackets are installed prior to installing and tightening the bolts.

As a general rule, you will encounter only a couple of troubles with the crankshaft seals:

- A squeaky noise caused by a dry seal.
- A leaky seal caused by a scored seal surface.

A noisy seal left uncorrected will soon become leaky. Air that enters a system because of a leaky seal is indicated by high condensing pressures.

Testing with a halide torch for shaft seal leaks can often be misleading because the normally small amount of oil that leaks through the seal will have traces of refrigerant in it which is picked up by the torch. The best method for detecting shaft seal leaks is the soap solution method. To employ this method, first, raise the low-side pressure, then apply the soap solution as you would when testing for refrigerant leaks. These seals should be capable of holding the highest vacuum possible (approximately 30 inches of mercury) for many hours.

In the event that a shaft seal is found to be defective, it must be replaced. The tolerances and surface finish of these seals are very critical.

To remove the seal, the compressor is pumped down and the low-side pressure balanced. The drive belts are removed and then the flywheel. If the seal cover does not extend below the oil level in the compressor, you may remove the seal without draining the oil; if it does, the oil must be drained from the crankcase. The seal parts are taken out next. Be sure to mark the seal parts so that they are reinstalled correctly. Frequently, you will find the seal parts are attached to a flange that must be pried out very carefully.

Do not pump down the compressor if you have a bad leak or suspect the seal is broken because to do so would allow air and moisture to be drawn into the system.

In this case, close the service valves, relieve the internal pressure of the compressor, drain the oil, and leave the drain open. Now proceed as before.

Insure that all parts are cleaned and the sealing surfaces lapped to each other. You may find some seals are molded synthetic rubber gaskets instead of metal-to-metal. When a new seal is installed, all parts are coated with clear oil and special care is exercised in aligning and replacing the unit. If the seal is to function efficiently, a critical spring tension must be maintained on the sealing surface.

> Note: Always consult the TM's and manufacturer's instructions prior to making repairs to a compressor.

Pistons, pins, bearings, crankshafts, cylinders, block, etc. in compressors will seldom become damaged or give you trouble unless they are abused. A refrigerating compressor is seldom subject to a wide variation of loads and pressures. It is used to pump clean, cool refrigerant gas at a constant head pressure. Therefore, the component parts of a refrigerating compressor will usually provide long and trouble free service. Any work that must be done on component parts (other than valves and shaft seals) is accomplished by methods very similar to those used in automotive engine repair. If you have to work on a compressor, remember to keep all parts perfectly clean and free from moisture. Also, carefully mark all parts so that they can be properly reassembled. After repairs are complete, the compressor should be tested. Air must be purged from the compressor and oil replaced in the crankcase. Run the compressor for about an hour to make sure that the pistons and bearings are functioning free.

Now that we have covered open type compressors, let's take a look at hermetic compressor testing and replacement.

Although a hermetic compressor is relatively trouble free, there will be occasions when testing and possible replacement will be necessary. Pistons will hang up or become frozen, valves will crack or break, and internal motor circuits will develop shorts or opens. Because these internal problems just mentioned will necessitate the replacement of the compressor, it is very imperative that you are sure that the problems are internal and are not caused by external failures such as problems with the control circuits, switches, and external wiring.

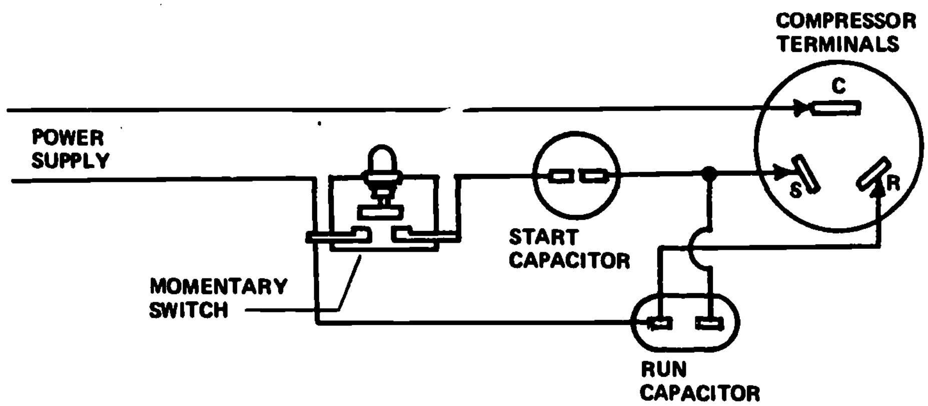


Fig 4-13. Test hookup to test compressor.

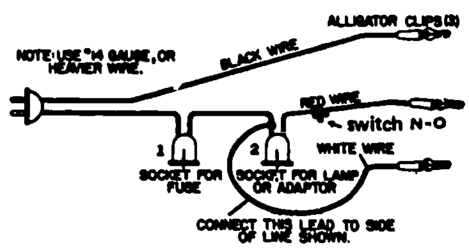


Fig 4-14. Constructing test cord.

A rather simple test hookup that can be assembled in your shop and used to check a compressor motor (capacitor start/induction run or capacitor start/capacitor run) is illustrated in figure 4-13 and figure 4-14. It consists of a starting capacitor, a running capacitor and a simple switch.

To employ this test hookup, first remove all wires from the compressor terminals. Connect the test hookup to the starting (S), running (R), and common (C) terminals as shown in

> Note: Be sure to tag each wire to insure that they can be correctly reconnected to the terminals of the compressor.

figure 4-13. Now plug the test cord circuit into the power supply and immediately close the switch for 1 to 2 seconds (holding the switch closed for a longer period of time may result in the starting winding being burned out), then open the switch. Upon the switch being opened the compressor motor should continue to run if it is not defective. If the compressor motor fails to run then the compressor unit must be replaced.

If the motor runs but the compressor valves are broken or cracked, little or no cooling will occur in the evaporator and little or no heating of the condenser. Once the unit is started, the voltage will drop to an abnormally low reading. The pump will need no balance time after it is stopped. Also, little or no capillary feed noise will be heard.

Symptoms of an overcharge of oil that are very noticeable are: excessive compressor noise and vibration, low capacity, and continuous high voltage. To remedy this situation, the compressor should be replaced. If the proper procedures are followed some oil may be removed depending on the amount of overcharge. Follow the instruction contained in the appropriate TM and/or manufacturer's publication.

In the event that the hermetic compressor unit must be replaced, it should be replaced with a new or factory rebuilt one.

When replacing hermetic units, it should be remembered that electric wiring, thermostatic switches, relays, and motor starter are not considered parts of the sealed unit and therefore must be removed from the old unit and remounted on the new one. Due to the sealed compressor operating at higher speeds than an open type, the valves, pistons, and valve orifices are much smaller than in an open type. Consequently, great care must be exercised when installing a hermetic unit to insure that any foreign matter is kept from entering the unit when it is open during installation. The following procedure is employed to remove and replace a hermetic compressor.

- Using a pair of side-cutting pliers, cut the discharge line in half, allowing the unit charge to escape into the atmosphere. To prevent the possibility of oil being blown around, place a cloth over the pliers as the cut is made.

  Note: If the escaping refrigerant has a burned odor, a shorted stator is indicated and the condenser and evaporator should also be replaced.

- While the refrigerant is escaping, remove the compressor terminal cover and the relay bracket mounting screws.
- Remove the electrical leads from the compressor terminals (if not previously removed during diagnosis). Lift away this electrical assembly. Tag the electrical leads for reference when reconnecting them.
- Remove the compressor holddown bolts.
- Cut the suction line near the compressor with the side cutters. Again, place a cloth over the cut to catch any oil that may escape.
- Lift the old unit off the base. Pinch the discharge and suction tubes several times with pliers and then bend the tube ends over. This is done to prevent any oil loss and keeps foreign matter out of the compressor if it is to be rebuilt.
- Check the tubing on the new compressor and on the unit to determine where it should be cut. Then, with a tubing cutter, cut all tube ends. Leave about two inches of straight tubing so that fittings may be installed.
- Transfer the rubber grommets or vibration isolators from the old compressor to the new one and lift the new compressor into place in the unit's base.

  Note: Inspect the rubber grommets or vibration isolators for defects. If they are found to be defective, in any way, replace them.

- Assemble the proper fittings on the tube ends.
- Install a tee assembly in the suction line. Insure that the leg of the tee is pointing in such a direction that a flare nut can be connected later for recharging.
- Install a tee assembly in the discharge line. Insure that the cap seal and bonnet are tight.
- Reassemble the electrical connections and the compressors mounting washers and nuts.
- After insuring that all connections are properly made and tight, check the unit for leaks. Repair any leaks that are found.
- Lastly, recharge the system with the proper and correct amount of refrigerant.
- Place the unit into operation and observe for proper operation.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. When testing for leaking valves, the maximum allowable discharge pressure drop is

   a. 2 psig per minute.
   b. 3 psig per minute.
   c. 4 psig per minute.
   d. 5 psig per minute.

2. In testing the compressor valve, you turn the flywheel very slowly. In the process, you notice that the pressure rises slowly or it rises and falls. What should this indicate to you?

   a. The discharge valve is leaking.
   b. There are leaks past the piston or piston rings.
   c. The head gasket is leaking.
   d. All of the above

3. To what extent do you disassemble the compressor to facilitate repairs?

   ____

4. What precautions must be taken when reassembling the compressor that has been repaired?

   ____

   ____

5. What are the two problems most often encountered with crankcase seals?

   a. ____

   b. ____

6. What are two types of oil seals used most often in compressors today?

   a. ____

   b. ____

7. If the seal is to function efficiently, what must be maintained on the sealing surfaces?

   ____

8. What is the best method of leak detection for leaking seals?

   ____

Work Unit 4-3. CONDENSERS AND EVAPORATORS

SPECIFY THE CLEANING REQUIREMENTS OF AIR-COOLED CONDENSERS.

STATE PROCEDURES FOR CLEANING SCALE FROM WATER-COOLED CONDENSERS.

STATE CLEANING REQUIREMENTS AND ITEMS TO CHECK RELATING TO DRY TYPE EVAPORATORS.

The devices that pass air over air-cooled condensers have an effect much like that of a vacuum cleaner. The fans and flues draw dust or dirt particles from the air and deposit them on the condenser, where they prevent the rapid transfer of heat from the surface to the condensing medium. When the gases within the condenser are permitted to reach too high a temperature, the oil that circulates throughout the entire system also becomes heated and may carbonize. A great part of this carbonized oil will adhere to the inside walls of the condenser, where it will retard rapid heat transfer from the hot gases to the condenser tubes. If the condenser has become very dirty on the outside surface, it will usually be nearly as dirty on the inside because of the carbonized oil clinging to the inner walls.

Therefore, to return a dirty condenser to its original efficiency, the inside surface as well as the outside surface of the condenser must be cleaned. Ordinary brushes and mild soap solutions will remove the usual dust and dirt deposited on air-cooled condensers. However, in some places, such as bakery shops, small particles of sugar, flour, and grease may have been deposited on the condenser. These materials cannot be removed with brushes and ordinary cleaning fluids. They usually require alkalign or acid solutions to remove them from the metal surface of the condenser. A good alkalign solution may be made by mixing 1/2 lb of trisodium phosphate in 1 gallon of water. After using any of these solutions, rinse the condenser thoroughly with clear, warm water.

The removal of carbon from the internal surface of the condenser presents another problem. There is more danger in using a solution that only loosens or partially removes this carbon deposit than in using a solution that does not remove any of it. The most satisfactory method to clean the inside of the condensers is with superheated steam. The superheated steam will remove all the loosened material from the inside of the condensers, and it will prevent formation of any oxide or other material on the interior walls.

The only precaution necessary in the use of superheated steam is to be sure that the temperature of the steam is not above the melting point of any of the materials from which the condenser is constructed. This applies particularly to the solder used to connect the discharge line, the receiver line, and the return line.

Water-cooled condensers accumulate scale on their internal surfaces. This scale must be removed. Scale can be removed either mechanically or chemically. Where possible, mechanical removal is preferred over chemical removal since chemicals often attack the metal and weaken it. This is particularly apt to happen when chemicals are mixed without very careful measurements.

The scale in condenser tubes may be either thick or thin, and it may be either easy or difficult to remove. Scale is usually removed by the use of steel brushes attached to the end of rods. Similar to the bore brush and cleaning rod used to clean your rifle bore. Except the ones required to clean condenser tubes are larger and longer. After the condenser has been drained, the water connections and pass heads are removed. Be careful not to use suitable cement to hold them in place during assembly. The shell side of the gasket should be coated with an oil-graphite mixture to prevent damage at the next disassembly.

Heavy scale requires that a small brush be used first. Brush size is then increased progressively in diameter until the final cleaning is made with the same size as the condenser tubes. No attempt should be made to drive a rod through a tube since a large solid piece of scale on one side of the tube would possibly defect the rod causing it to puncture the other side of the condenser tube.

Tubes may also be cleaned with a tube cleaner that is either turned by hand or with a large portable electric drill. Tube cleaners have water connections, so a flow of water can be used to flush out the particles loosened during cleaning. Another device that can be used is a flue cleaner. Flue cleaners are made from two to four pieces of spring steel twisted in a spiral shape and are normally used to clean fire tubes on boilers. However, a flue cleaner of the proper size is convenient to remove scale and other deposits that form in water-cooled condenser tubes. They should be rotated, preferably with a large portable drill, while being pushed through the condenser tubes. Water should be flushed through the tubes at the same time to wash away particles loosened by the flue cleaner. After the cleaning, tubes should be oiled by drawing an oil-soaked cloth through them to prevent oxidation. However, this oil film is soon washed off after water starts to circulate within the tubes.

Chemical cleaning is done with acid. The preferred acids are hydrochloric and sulfanic. The acids should have an inhibitor added before cleaning begins to prevent the acid from attacking the metal being cleaned. The acid solution may be passed through the condenser by either of two methods: gravity or forced through by a pump. Be sure to use all necessary personal protective equipment and follow prescribed safety precautions when handling acids and other chemicals during cleaning.

There are two methods used to clean dry-type evaporators when they become dirty, one is with a stiff fiber brush and by the use of compressed air. When using compressed air it is best to direct the compressed air through the evaporation in the opposite direction to the normal flow of the refrigerant. When the evaporator tubes are cleaned, insure that you also clean the evaporator drain pan and flush the drain pan line.

In order for an evaporator of this type to properly remove heat, you must periodically check the evaporator for adequate pressure and ice accumulation, and you must insure that there is proper airflow over the coils.

Ideally, evaporator pressure should be measured at the inlet, just after the metering device, as well as the outlet. Most systems do not have fittings at these locations to take pressure readings. However, you can check the pressure by reading the low-side pressure gauge when the compressor is running and then reading it again just as the compressor stops. The sharp rise in the pressure is the pressure drop. A pressure drop of 2 to 3 psi is tolerable.

Frost on the evaporator acts as an insulation, thus reducing the ability to absorb heat. If frost or ice is found near the TEV, it usually indicates too great a superheat setting along with low suction pressure. Spotty frost on the evaporator coils usually means uneven airflow over the evaporator or that some defrost elements are not functioning if the unit is so equipped.

Insufficient air passing over the evaporator reduces suction pressure and tends to ice up the evaporator. The cause can usually be traced to dirty evaporator coils, a dirty filter, or the placing of boxes and foodstuff in such a manner as to restrict the flow of air.

The evaporator itself very seldom causes any trouble. Problems with the evaporator can usually be corrected by adjusting, repairing, or replacing system components and controls that directly affect the refrigerant's action in the evaporator or those that keep its evaporator free from excessive frost buildup. Those components and controls are the metering device, defrost controls, and fans or blowers (if it is a forced correction type evaporator). Problems with the evaporator itself are usually caused by leaks due to corrosion or a puncture due to abuse. If an evaporator becomes corroded, it is best to replace it. If a leak develops through abuse, it can be soldered in all cases except when the evaporator is made of aluminum. If an evaporator is made of aluminum it can be repaired by using epoxy cement (follow directions for individual brand used). If problems with evaporators do not result from leaks or corrosion and do not result from inoperative system components and controls, then it is stopped up from oil carbonization. At this point, a decision must be made to attempt to clean it or to simply replace it.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. Why do air-cooled condensers require cleaning?

____

____

2. What should you use to clean a condenser?

____

____

3. What precautions should you use in steam cleaning the inside of air-cooled condensers?

____

____

4. In what two ways can scale in water-cooled condensers tubes be removed?

   a. ____

   b. ____

5. State the procedures for mechanically cleaning water cooled-condenser tubes?

____

____

6. What two devices besides brushes can be used for cleaning condenser tubes?

a. ______________________________

b. ______________________________

7. What are the preferred acids for chemical removal of seals?

a. ______________________________

b. ______________________________

8. State the purpose of adding an inhibitor to acids before using them to remove seals.

____

____

9. What are two methods of passing acid solutions through the tubes of a water-cooled condenser?

a. ______________________________

b. ______________________________

10. State how to direct compressed air to clean dry-type evaporators.

____

11. State how to check the pressure drop in the low side of the system using a single gauge.

____

____

12. You find an evaporator with spotty frost accumulation. What is the cause of this condition?

____

____

13. How does a dirty evaporator coil affect the system's low-side pressure?

____

____

Work Unit 4-4. AUTOMATIC CONTROLS

STATE GENERAL ADJUSTMENTS THAT ARE MADE TO AUTOMATIC CONTROLS.

Exact procedures in adjusting the various automatic controls used in different systems will vary with each switch design. All that can be accomplished in this work unit is to give you some general rules to follow for adjusting and servicing typical controls. First and foremost, always consult the TM's for the particular system before attempting to service or adjust any controls.

Cycling or motor control switches start the compressor when temperature and low-side pressure rise to a predetermined level and stop the compressor when temperature and pressure fall to another level that is determined by a range setting. It is a general rule that operating pressures or temperatures are lowered by decreasing the spring tension of a control unit and raised by increasing the spring tension. Some cycling control devices are provided with a differential adjustment that is used to set the difference between the cut-in and cut-out points.

The range and differential of a low-side pressure control may be adjusted in the following manner:

- Attach a compound gauge to the suction service valve.

- Set the range adjustment for the lowest pressure and the differential adjustment for the largest difference.

- Start the compressor and operate it until the compound gauge shows the desired pressure or vacuum for cut-in or starting the compressor in normal operation.

- Slowly change the range adjustment until the control cuts out the compressor.

- Move the range adjustment slowly in the opposite direction until the control cuts in (starts) the compressor. This sets the cut-in point.

- Let the compressor run until the gauge shows the pressure at which cut-out is desired.

- Adjust the differential slowly until the control cuts-out (stops compressor). This sets the cut-out point.

- Let the system operate normally through at least one or two complete cycles, and on the next cycle note the gauge readings at which cut-out and cut-in occurs. It is possible that slight adjustments will have to be made.

The procedures used to adjust a temperature or thermostatic type of cycling control is very similar to that used to adjust a pressure control. However, instead of using a compound gauge, you would use a thermometer at the place where the temperature control sensing bulb is located. Remember that a temperature control should always start the compressor when the sensing bulb is warmed by hand. If it does not, the bulb and bellows have lost their charge. Before attempting any repairs or adjustments of a temperature-type cycling control, make sure that the sensing bulb is properly mounted. Normally, with this type of control, the range is adjusted before the differential is changed. Only in unusual cases will the differential sometimes have to be changed to accommodate different types of service. You should also remember that when you adjust this type of control, the range adjusted will affect the differential and vice versa. Once you have completed adjustments, and have observed temperatures and pressures and found them to be right, check that all locking nuts or screws are tight.

Since the exact methods, pressures, and temperatures used in setting automatic control devices differ depending on the characteristics and type of service of the individual system, only some general examples can be given here. Again, it must be mentioned that you must consult the TM's and manufacturer's directions for detailed operation and repair of individual system controls.

High pressure cut-out switches are usually a type of switch that is installed as a safety device. The cut-out is determined by the manufacturer and is stated in the operating instructions. These switches will cut out at a certain pressure and cut back in at another lower temperature. Some high pressure cutouts do not cut in automatically, but are equipped with a reset button that must be pushed manually. Sometimes this type of switch is mounted in the same housing as the suction pressure control switch.

Suction pressure control switches stop and start the compressor according to the demand for refrigerant in the evaporator coil. The suction pressure control should be set at a suction pressure that corresponds to a temperature that is a few degrees colder than the temperature to be maintained in the evaporator.

<u>Example</u>:

If the evaporator was required to maintain a temperature of 34°F and the refrigerant used in the system is R-12, by consulting the refrigerant chart for R-12, the suction pressure control should be set between 31.7 and 26.8 psig.

Thermostatic switches control solenoid valves that feed the liquid refrigerant to the evaporator. These controls open the solenoid at a predetermined temperature and close at a lower predetermined temperature. It is a good practice to set the cut-in point 2° to 3°F higher than what is required.

EXERCISE: Answer the following questions and check your responses against those listed at the end of this study unit.

1. When setting a pressure type control, how do you initially set the range and the differential?

   ____

2. You can determine whether a temperature control's bulb and bellows have lost their charge by watching to see if the switch mechanism activates when you ____________

   ____

SUMMARY REVIEW

In this study unit, you have learned to repair components of the refrigeration system. This study unit alone will not make you an expert refrigeration technician, however, if you apply the procedures and guidelines outlined in this study unit and the rest of this course, along with on-the-job training, you will become more proficient.

Answers to Study Unit #4 Exercises

Work Unit 4-1.

1. a. Overload
   b. Loss of power
   c. Driven machine blocked
   d. Worn bearings
   e. Bad connection
2. An ammeter
3. By using a soldering gun to restore the circuit
4. By disconnecting the motor from the lead and rotating the rotor shaft of the motor by hand
5. By adding fiber space washers
6. At any point between the power source and the rotor
7. In order to determine whether a ground exists in the motor or on the conduit
8. Continuity across any two conductors
9. The motor will slow down under load; it will have low starting torque and signs of overheating.
10. a
11. a
12. c
13. c
14. e
15. a
16. d
17. b
18. d
19. a
20. e
21. e

Work Unit 4-2.

1. b
2. d
3. Remove only those components necessary to faciliate repairs.
4. Be careful not to mar or scratch the gasket sealing surfaces.
5. a. Squeaky noise caused by a dry seal
   b. Leaky seal caused by a scored seal surface
6. a. Bellows seal
   b. Rotary seals
7. Critical spring tension
8. Soap solution

Work Unit 4-3.

1. Because the dust and dirt particles deposit on the condenser and prevent the rapid transfer of heat
2. Use soap solutions and brushes on the outside and superheat steam on the inside.
3. Do not allow the temperature of the steam to rise above the melting point of any of the material that the condenser is constructed of.
4. a. Mechanically
   b. Chemically
5. After the condenser is drained, the water connections pass heads are removed carefully so as not to damage the jackets. Heavy scale requires the use of a small steel brush attached to the end of the cleaning rod. Brush size is increased in size as scale is removed until the brush matches inside size of the tube. After cleaning, tubes should be flushed and oiled by drawing an oil soaked cloth through them. Install pass heads but coat shell side of gasket with an oil-graphite mixture to prevent damage at next disassembly.
6. a. Tube cleaners
   b. Flue cleaners
7. a. Hydrochloric
   b. Sulfanic
8. To prevent the acid from attacking the metal
9. a. Gravity
   b. Forced circulation
10. Direct the compressed air opposite to the normal airflow.
11. Check the pressure by reading the low-side pressure gauge when the compressor is running, and then read it again just as the compressor stops. The sharp rise in pressure is the pressure drop.
12. Uneven airflow or some defrost elements are not working.
13. Reduces suction pressure and tends to ice up the evaporator.

Work Unit 4-4.

1. Lowest pressure and largest difference
2. warm the bulb by hand

REFRIGERATION SERVICING

REVIEW LESSON

Instructions: This review lesson is designed to aid you in preparing for your final exam. You should try to complete this lesson without the aid of reference materials, but if you do not know an answer, look it up and remember what it is. The enclosed answer sheet must be filled out according to the instructions on its reverse side and mailed to MCI using the envelope provided. The questions you miss will be listed with references on a feedback sheet (MCI-R69) which will be mailed to your commanding officer with your final exam. You should study the reference material for the questions you missed before taking the final exam.

A. Multiple Choice: Select the ONE answer that BEST completes the statement or answers the question. After the corresponding number on the answer sheet, blacken the appropriate circle.

Value: 1 point each

1. Identify what you must consult prior to the installation of refrigeration equipment?

   a. Unit SOP
   b. MCO 4700-15/1E
   c. A technical publication
   d. TM 4700-15/1E

2. What are four common steps for the proper installation of refrigeration equipment?

   a. Leveling, correct electrical power, good ventilation, and good drainage
   b. Leveling, correct electrical power, good equipment, and good drainage
   c. Leveling, correct location, good ventilation, and new equipment
   d. Leveling, correct location, proper equipment, and good drainage

3. What are the four services performed by the operator on refrigeration equipment?

   a. Before operation, during operation, after operation, and yearly operation
   b. Weekly, yearly, bi-monthly, and quarterly
   c. Before, during, after operation and quarterly PM
   d. Bi-weekly, monthly, quarterly, and yearly

4. Identify four common critical inspection points of refrigeration equipment.

   a. Condenser fins, evaporator, electrical contacts and connection, and metering devices
   b. Condenser fins, evaporator, electrical contacts and connections, and filters
   c. Condenser fins, metering devices, evaporators, and filters
   d Metering devices, evaporators, electrical contacts and filters

5. Wet insulation in the walls of a refrigeration cabinet can be detected by

   a. feeling the outside of the cabinet for cold spots.
   b. removing the interior panels to expose the installation.
   c. noting the buildup of frost inside the cabinet.
   d. checking the outside of the wood cabinet for condensation.

6. After the water system of an ice-making machine has been chemically cleaned, the cleaner should be drained and the machine flushed with

   a. fresh water only.
   b. a sodium bicarbonate solution.
   c. a citric acid solution.
   d. a saltwater solution.

7. The clearance between the cutter blades and drum on a rotating drum ice-flaking machine should be set

   a. cold to prevent damage when the machine is off.
   b. cold to insure proper removal of ice flakes.
   c. warm because clearance increases during operation.
   d. either warm or cold since the clearance does not change.

8. The two operating pressures that you should observe in diagnosing refrigeration troubles are

   a. suction and head pressure.
   b. suction and liquid pressure.
   c. liquid and gas pressure.
   d. head and gas pressure.

9. A low charge of refrigerant, an obstructed liquid line, a motor control out of adjustment, or not enough air passing over the evaporator will cause ______________ in a system.

a. high head pressure
b. high suction pressure
c. low head pressure
d. low suction pressure

10. An inefficient compressor, a cooling medium too cold, a low charge, or too much cooling medium will cause ________________ in the refrigeration system.

a. high head pressure
b. low head pressure
c. high suction pressure
d. low suction pressure

11. While trouble-shooting a system with an air-cooled condenser, you determine that the head pressure is high and a definite temperature drop can be felt at the liquid level on the condenser return bends during operation. What is the cause and remedy?

a. There are noncondensables in the system; purge the system.
b. There is restricted air flow; clean the coils.
c. There are dirty filters; clean the filters.
d. There is refrigerant overcharge; bleed off the excess refrigerant.

12. Noise, failure to pump properly, and overheating are three of the four problems that you may encounter in either open or hermetic compressors. What is the fourth problem?

a. Floodback
b. Oil traps
c. Mechanical seizure
d. Burnout

13. A compressor that is low on oil or out of oil indicates a lubrication failure which could be caused by which of the following?

a. Frosting or icing of the coil
b. A plugged drier
c. Refrigerant floodback to the compressor during operation due to a bad expansion valve or poor bulb location
d. Rattling of the compressor on startup

14. The three problems most commonly blamed on expansion valves are

a. overheating, improper superheat, and low oil charge.
b. overfeeding, underfeeding, and improper superheat.
c. overfeeding, underfeeding, and erratic operation.
d. low suction pressure, low oil charge, and excessive refrigerant charge.

15. Bubbles in the sight glass indicate either a(n) ____________ in the system or a(n) ____________ due to restriction liquid lift, or an undersized liquid line.

a. shortage of refrigerant; pressure drop
b. pressure increase; plugged drier
c. dirty condenser; valve set too low
d. very light load; shortage of refrigerant

16. Identify the most common cause of leaks in the refrigeration system.

a. Faulty equipment
b. Faulty tools
c. Poor workmanship
d. Inexperienced personnel

17. Identify the method of leak detection which not only indicates a leak but gives its exact location.

a. Special method
b. Positive method
c. Nonpositive method
d. Combination special and nonpositive method

18. Identify the special method of leak detection.

a. Soap solution
b. Halide torch
c. Electronic leak detector
d. Oil solution

19. If a heater element will not come up to its proper temperature the most probable cause is

a. an open circuit.
b. a short to ground.
c. a cross short.
d. insufficient power.

20. You suspect that a short to ground has occurred. The instrument that you will select to locate this trouble is the

a. voltmeter.
b. clamp-on-ammeter.
c. ohmmeter.
d. wheatstone bridge.

21. The type of trouble that can be located with either the voltmeter or ohmmeter is

a. insufficient power.
b. a cross short.
c. an open circuit.
d. a short to ground.

22. Which common electrical problem found in refrigeration systems, at times, may be extremely difficult to locate?

a. Improperly made connections
b. Defective timers
c. Loose connections
d. Bad relays

23. If you were to come upon a unit that was not operating and you suspected an electrical problem, what is the first thing you should check?

a. Check to see if the unit is connected and turned on.
b. Check the suction and head pressure.
c. Check the motor for a burned starting winding.
d. Check the sight glass for bubbles.

24. The first step in locating an open circuit is to

a. select the meter to use.
b. perform a visual inspection.
c. perform an operational check.
d. isolate the circuit.

25. When trouble-shooting a shorted circuit, it is necessary to shut-off circuit power and

a. isolate the circuit.
b. use a voltmeter.
c. use a ammeter.
d. close the control device.

26. A solid short circuit will normally be the

a. hardest short to find.
b. most destructive type of short.
c. control device.
d. unit of resistance.

27. A short that comes and goes is called a

a. short to ground.
b. cross short.
c. partial short.
d. floating short.

28. A transformer-rectifier that has been used to supply 24 volts d.c. to a system is inoperative. The input voltage is 120 volts a.c. and the output voltage is zero. What type of trouble is indicated?

a. Improper power
b. Short to ground
c. Cross short
d. Open circuit

29. Prior to removing a malfuctioning relay for replacement, you should

a. make a wiring sketch.
b. turn the power on.
c. connect the new relay.
d. disconnect all motors.

30. When making minor repairs to electrical circuits or units, terminal loops should

a. be installed so that they will close as the terminal is tightened.
b. be installed black to silver, white to gold.
c. not be used.
d. be at least 3 inches long.

31. Fuse clips for ferrule fuses must

a. be installed vertically.
b. be tight and clean.
c. not exceed 120 volts, 10 amps.
d. be hermetically sealed.

32. If a motor fails to start, the most likely trouble is a(n)

a. open circuit.
b. defective switch.
c. short to ground.
d. cross short.

33. A motor connected to a load will not come up to speed. With the load disconnected, the motor operates normally. The trouble most likely is

a. an open circuit.
b. the load.
c. a short to ground.
d. a cross short.

34. Referring to question #32. What meter would you use to check the problem?

a. An ohmmeter
b. An ammeter
c. A voltmeter
d. A wheatstone bridge

35. What are the gases called that remain in a gaseous state after the refrigerant liquefies?

a. Halogen gases
b. Ammonia gases
c. Condensable gases
d. Noncondensable gases

36. In testing a system for noncondensable gases, what is the maximum allowable pressure difference between the pressure within the condenser and the pressure corresponding to the temperature of the refrigerant being used?

a. 5 psig
b. 6 psig
c. 10 psig
d. 15 psig

37. The purging of a system should continue until the _______________ drops to the proper point corresponding to the temperature of the refrigerant.

a. suction pressure
b. temperature
c. head pressure
d. air pressure

38. The two main categories of service valves are

a. two- and three-way types.
b. one- and three-way types.
c. one- and two-way types.
d. front and back seat types.

39. Which port in the three-port two-way valve is always open?

a. Gauge port
b. Line port
c. Compressor port
d. Charging port

40. If you have a leaky valve that is caused by a faulty seat what should be done?

a. Repair the seat.
b. Replace the seat.
c. Replace the valve.
d. Tighten the valve so it will not leak.

41. To insure a tight, dry system before charging what should be accomplished after the system has been opened?

a. Evacuation
b. Purging
c. Pressurizing the system
d. Charging the unit

42. Of the two methods of evacuation, which is the preferred method?

a. Purging
b. Triple
c. Deep vacuum
d. Single-stage

43. Which of the two methods of evacuation will not remove all of the moisture?

a. Single-stage
b. Two-stage
c. Deep vacuum
d. Triple

44. The procedure used to save the refrigerant in the system and prevent air from entering is called

a. evacuation.
b. pump down.
c. charging.
d. purging.

45. Once the bar gauge manifold is installed, what is the next step in the procedure to pump a unit down?

a. Frontseat the suction and discharge service valves.
b. Set the low pressure control at 3 psig.
c. Start the compressor.
d. Close the King valve.

46. What is the purpose of loosening the flare nut on the suction service valve with the valve frontseated?

a. To allow air to escape
b. To prevent excessive pressure buildup
c. To prevent excessive foaming of the oil
d. To allow excess oil to be purged

47. The most common method of determining the charge in small systems is by

a. a frost line.
b. pressure determination.
c. a charging cylinder.
d. weighting the charge.

48. In which method of charging is the refrigerant added in liquid form?

a. Low-side charging
b. Plug method
c. Siphon method
d. High-side charging

49. Identify the procedure that is used in high-side charging.

a. Keep the refrigernt drum in an up right position.
b. Invert the refrigerant drum or service cylinder and support it securely.
c. Insure that only gas is allowed to enter the system.
d. Allow a few seconds for the compressor to draw the remaining refrigerant from the line.

50. In which method of determining the proper oil charge should the system be allowed to operate for a period of time before the final determination is made?

a. Measured
b. Weighted
c. Dip stick
d. Sight glass

51. Which method of determining the oil charge is used primarily with a small vertical shafted hermetic compressor

a. Measured
b. Weighted
c. Dip stick
d. Sight glass

52. Oil is normally introduced into a refrigeration system by either the

a. oil plug method or high-side charging.
b. low-side vacuum method or high-side charging.
c. oil plug method or low-side vacuum.
d. oil plug method or pour-in method.

53. In adding oil by the vacuum method, the unit is operated until the compound gauge registers a ________________ inch vacuum.

a. 2
b. 10
c. 15
d. 20

54. In the oil plug method of adding oil, the compressor is started and you slowly frontseat the suction service valve until a pressure of approximately ______ psig is reached.

a. 2
b. 4
c. 6
d. 8

55. After attaching a compound gauge to the low-side of the system, you start the compressor and gradually frontseat the suction service valve until the pressure in the crankcase drops to _____ psi before removing the oil plug.

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

56. Which of the following is NOT a precaution to be taken in charging and removing refrigerant oil?

a. Pressure must be controlled when the crankcase is opened to the atmosphere.
b. Do not add more than 1 pint of oil at a time.
c. System overcharging should be avoided.
d. Use only clean, dry oil.

57. If a normally operating motor suddenly stops, you should

a. disconnect the motor from the load.
b. let it cool and try to reset the overload.
c. disconnect the motor leads.
d. open the circuit protective device.

58. What occurs in a shorted circuit?

a. The voltage will read higher than normal.
b. The current will read lower than normal.
c. The resistance will read higher than normal.
d. The resistance will read lower than normal.

59. The most probable cause of excessive noise when a motor operates is

a. insecure mountings.
b. improper ventilation.
c. poor conductors.
d. a deficient voltage supply.

60. The maximum allowable discharge pressure drop when testing for leaking compressor valves is

a. 2 psig per minute.
b. 3 psig per minute.
c. 4 psig per minute.
d. 5 psig per minute.

61. What should be indicated by the compressor pressure rising slowly or it rising and falling as you turn the flywheel very slowly by hand?

a. That there are leaks past the piston or piston rings
b. That the discharge valve is leaking
c. That the head gasket is leaking
d. All of the above

62. To facilitate repairs to a compressor you should

a. remove all components.
b. remove only those components necessary to facilitate repairs.
c. replace the complete unit.
d. call a compressor mechanic.

63. Identify the precautions that you must take when installing or removing gaskets.

a. Use the old gasket and oil it good.
b. Insure they are dry and scarred.
c. Insure the gasket is installed right side up.
d. Be careful not to mar or scratch the gasket sealing surfaces.

64. Squeaky noise caused by a dry crankshaft seal is one of two problems most often encountered with crankshaft seals. Identify the second problem.

a. An improper seal
b. A seal installed backwards
c. A leaky seal caused by a scored seal surface
d. Using improper oil