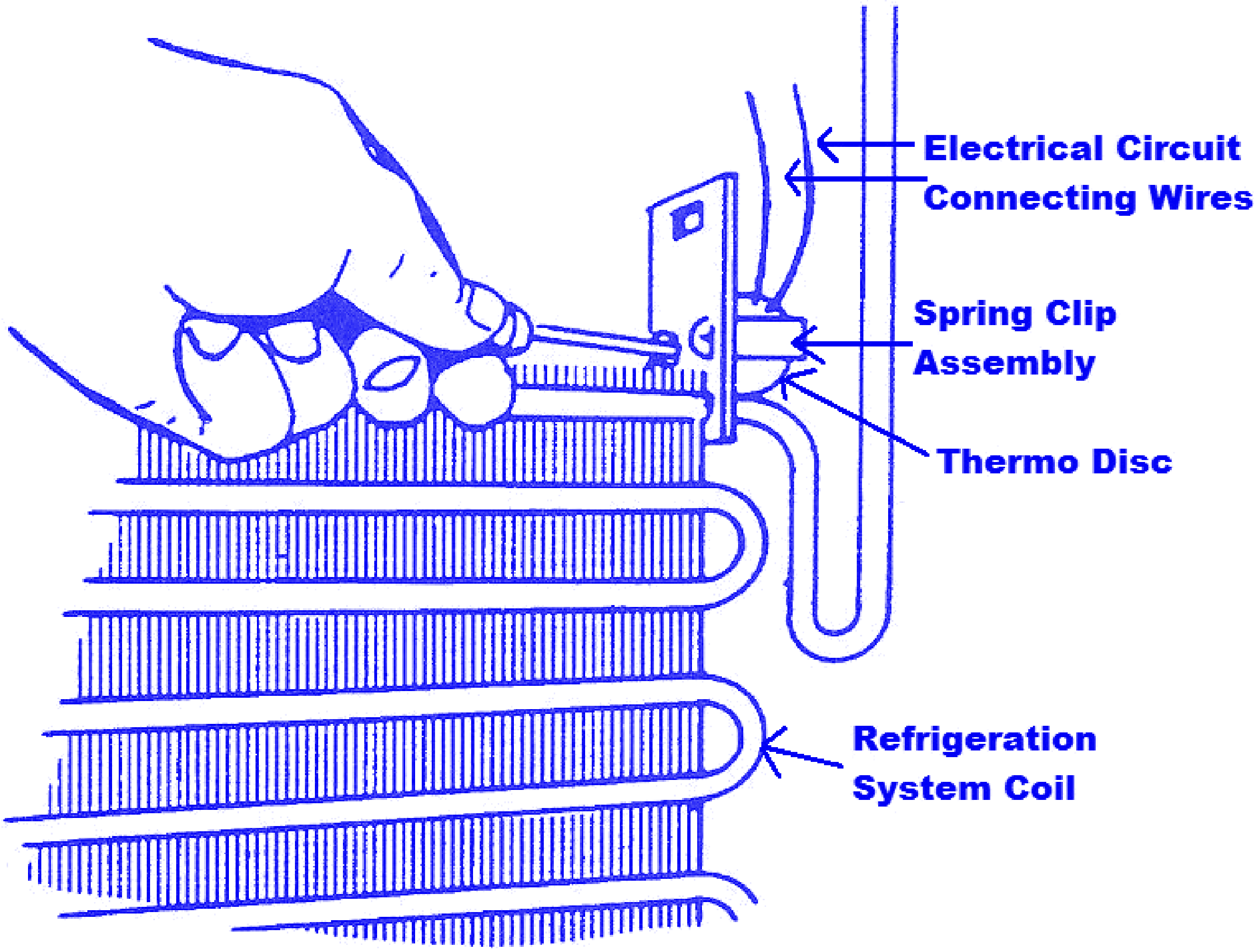
Volume 1

Major Appliances

Troubleshooting, Servicing & Installing

Jim Johnson



esco press

Electrical & Refrigeration Fundamentals

Major Appliances Troubleshooting, Servicing & Installing Volume 1

Electrical & Refrigeration Fundamentals

Jim Johnson

esco press

Library of Congress Cataloging-in-publication Data

Johnson, Jim

Major Appliances: Troubleshooting, Servicing & Installing
Volume 1: Electrical & Refrigeration Fundamentals

ISBN-13: 978-1-937659-22-6

PO Box 2259
Green Valley, AZ 85622-2259

Notice To The Reader

The author and publisher do not warrant or guarantee any of the products described herein. The author and publisher do not assume, and expressly disclaims, any obligation to obtain and include any information other than that provided by the manufacturer.

The reader is expressly warned to consider and adopt all safety precautions that might be indicated by the activities indicated herein and to avoid all potential hazards. By following the instructions described herein, the reader willingly assumes all risks in connection with such instructions.

The author and publisher make no representations or warranties of any kind, including but not limited to, the warranties of fitness for particular purpose or merchantability, nor are any such representations implied with respect to the material set forth herein, and the author and publisher take no responsibility with respect to such material.

Major Appliances
Troubleshooting, Servicing & Installing Volume 1
Electrical & Refrigeration Fundamentals

CONTENTS

Preface

The major appliance industry has a shortage of qualified technicians. The key word is *qualified*. As in any craft, there will be people who will be "working at it" but their performance will be below industry standards.

In addition, many states and cities have licensing and certification requirements for major appliance technicians and responsible associations and regulatory agencies consider certification and training a necessity to ensure industry growth and ensure customer satisfaction. Credentials such as these are apart from the certification required by the EPA for refrigerant handling.

The philosophy behind this text is that one cannot be an effective appliance service technician if basic concepts are not fully understood. Everyone understands that electricity makes an appliance work. However, if technicians don't understand where electricity comes from and how it does its job, it affects their ability to troubleshoot a problem in an electrical circuit. Likewise, in order to effectively evaluate the performance of a refrigeration system, a grasp of the fundamental concepts of the simple "mysteries" of heat transfer is necessary.

Vocational instructors have long recognized that eliminating the mysteries behind basic concepts is the foundation of technical education, and that a confident, able technician can only emerge after this has been accomplished. For this reason, this text provides a simple and direct approach to the fundamentals of electricity and refrigeration related to the operating functions of refrigerators, freezers, room air conditioners, washing machines, clothes dryers, dishwashers, gas and electric ranges, and microwave ovens.

ACKNOWLEDGEMENTS

Thanks To:

Renee Tomlinson and Marlena Stavropoulos for their help in developing this updated version of the original text; Bobby from Authorized Technical Services in Tucson for providing parts for photos, Fluke Corporation and Fieldpiece instruments for images from their user manuals; and to the students in my trade school classes, and technicians who have attended my workshops and were not afraid to ask questions.

Dedication:

First, to my wife Peggy Lee, who has been with me through all of the ups and downs and twists and turns of my personal and professional life for 52 years.

Second, this book is dedicated to the memory of Chuck Johnson. His career in the appliance business began at a time when “servicemen” ran calls for a buck-and-a-half, and one of the fundamental skills necessary was the ability to adjust the latch on a refrigerator door, to a time when “technicians” had to learn to troubleshoot electronic controls.

Major Appliances
Troubleshooting, Servicing & Installing
Volume 1

LIST OF ILLUSTRATIONS

CHAPTER
1

Electrical Fundamentals

Figure 1-10: Conductors, semiconductors, and insulators differ in their atomic structure. A conductor atom (a) has only one valence electron, a semiconductor atom, (b) will have up to 4 valence electrons and an insulator atom, (c) contains up to 8 valence electrons.

Figure 1-11: The atomic structure of a material dictates whether it will be a good conductor of electrical energy or if it will be an effective insulator.

CHAPTER
2

Alternating Current Fundamentals Terms & Definitions

Figure 2-1: An elementary AC generator in which the conductor is fixed, and the magnets are allowed to spin around a conductor.

Figure 2-2: The sine wave illustrates one 360° rotation of an AC generator.

Figure 2-3: Because of the higher elevation of tank A, a greater level of pressure is produced at the outlet although the same diameter pipe is used for both tanks.

Figure 2-4: A clamp-type meter is used to check the current draw of electrical components in appliances.

Figure 2-5: The Ohm's Law memory circle can be used to simplify the formulas used to illustrate the relationship between voltage, current, and resistance.

Figure 2-6: If any two values are known, the third value can be determined through Ohm's Law.

CHAPTER 3

Electrical Distribution Systems

Figure 3-1: A typical generator found in an electric plant. Most electrical generating stations use many such generators to supply power to a service area.

Figure 3-2: A simplified illustration of a transformer. Note the difference in the number of turns of wire in each winding.

Figure 3-3: A simplified version of a step-down transformer. Note the sine wave symbol at the left, indicating that the energy source is alternating current, and the symbol at the right, indicating voltage being delivered.

Figure 3-4: An electrical distribution system. You can trace electrical energy from the point of origin, through a substation, and finally to the consumer. This network of wiring and transformers is referred to as a grid.

Figure 3-5: Four types of main disconnect panels found in residential and commercial buildings. The most common power supply system for major appliance service technicians is panel D.

Figure 3-6: A cartridge and plug fuse panel found in older homes, and a circuit breaker panel used in most residences today. The circuit breaker panel will contain single-pole and two-pole breakers.

Figure 3-7: Single-pole and two-pole breakers in a residential distribution panel.

CHAPTER 4

Operating Components In Major Appliances

Figure 4-1: An elementary electric motor. The magnetic field set up by the stator winding causes the rotor to spin.

Figure 4-2: When a conductor cuts the lines of force of a magnet, a current flows through the conductor.

Figure 4-3: As current flows through a conductor, a magnetic field is set up around the conductor.

Figure 4-4: The conductor that makes up the windings of a motor is insulated with a very thin, strong insulating material.

Figure 4-5: A washing machine motor is designed to start and run under a heavy load. It employs a motor pulley for the belt that operates appliance in agitate/tumble and spin modes.

Figure 4-6: An evaporator fan motor from a frost-free refrigerator is one example of a low torque motor. Note the rust from operation in a wet environment.

Figure 4-6: The blade connected to the low torque motor mounted behind the panel circulates air over a heating element in a convection oven.

Figure 4-7: This low torque motor operates a squirrel cage blower that cools a *magnetron tube* in a microwave oven, and also employs a propeller type cooling fan blade to prevent overheating of its motor windings.

Figure 4-8: This double shaft, low torque motor is used in a clothes dryer. A pulley on one side drives the belt that moves the drum and a blower assembly on the other side forces air through the dryer heat source. The motor windings are operated by a *centrifugal switch*.

Figure 4-9: This illustration shows a stall-type motor which is used to operate the mechanism that harvests the cubes from a mold. It is designed to stall and maintain pressure while in the process of ejecting cubes.

Figure 4-10: In some applications, a dishwasher may employ a motor similar to a washing machine motor to operate the pump during wash and drain cycles, while in other situations, a separate drain pump motor, such as the one shown here, may be employed.

Figure 4-11: Inside this transparent refrigeration system compressor case with the dome removed, you can see the spring-mounted motor assembly, and the refrigeration system piston pump assembly.

Figure 4-12: An example of a condenser fan motor used in refrigerators and freezers.

Figure 4-13: A solenoid-operated water valve. The types of mounting brackets and fittings used will vary depending on the application of the valve. The valve shown here operates on 120 VAC, has one solenoid coil, and is used in the water dispensing system to an ice maker.

Figure 4-14: A dual water solenoid assembly in a refrigerator. To simplify service procedures, manufacturers may design the assembly with different sized water outlet connections.

Figure 4-15: A standard dual solenoid water valve is employed in a washing machine to allow either cold water only, hot water only, or a mixture of cold and hot to flow.

Figure 4-16: In some washing machines, a sensor is used to control the temperature of water flow according to the settings selected via an electronic control system.

Figure 4-17: Surface elements for electric ranges are manufactured in a variety of configurations and wattage ratings. When replacing and element such as this, an exact replacement should be used.

Figure 4-18: When replacing a bake or broil element in an electric range, it is critical that the configuration and wattage rating of the replacement component is the same as the original in order to ensure proper operation of the appliance.

Figure 4-19: A Cal-rod type element consists of a resistive conductor surrounded by a heat conductive material, wrapped in a metallic outer shell.

Figure 4-20: Some examples of the different configuration of defrost heaters that technicians encounter in servicing appliances. When replacing a defrost heater, it is critical to use an exact replacement to ensure proper operation of the appliance.

Figure 4-21: A Nichrome wire is another type of heating element used in major appliances. When used as a defrost heater in a refrigerator, the heating element is contained in a glass tube. Manufacturers often warn technicians to use care in handling this type of element during installation due to the fact that touching the glass could shorten the life of the replacement element.

Figure 4-22: With the sheet metal enclosure separated, the Nichrome wire, which is black because it has been in service, is visible. The ceramic insulator that allows for the 240-volt terminal connection is at the bottom left. Several insulators are also used to suspend the element inside the enclosure.

Figure 4-23: One example of a Nichrome wire element and the insulating material that is positioned under the smooth top of an electric range.

Figure 4-24: Low wattage heaters that prevent refrigerant cabinet sweating keep drain troughs from freezing and keep ice dispensing systems free of frost vary in their design according to their application. In some cases, technicians may use a kit form of heater and tape to custom fit a replacement.

Figure 4-25: A segment of a heater for a drain trough positioned under a coil in a frost-free refrigerator. When a freeze cycle is initiated after a defrost cycle, water can remain in the drain. The heater in this application ensures that any water remaining in the drain will evaporate rather than freeze and clog the drain.

CHAPTER
5

Switches In Major Appliance Circuits

Figure 5-1: A simple electrical circuit. A switch allows current to pass when it is in the closed position, and the load performs useful work when electrical energy is applied.

Figure 5-2: When a refrigerator cold control is in an open position, no current will pass to the compressor and other cooling mode operating components in a refrigerator.

Figure 5-3: When a refrigerator cold control is in a closed position, the compressor and other cooling mode operating components will be energized.

Figure 5-4: An electromechanically operated refrigerator thermostat employs a bellows and spring system. The capillary tube of the control senses temperature and creates pressure to overcome or surrender to spring pressure to open and close the control contacts.

Figure 5-5: An electronic control system of a refrigerator, often referred to as a Mother Board. The board connects to all the wiring harness systems in the refrigerator to monitor functions and control temperature.

Figure 5-6: In this example, a mounting opening allows attachment of this thermistor to an interior cabinet location when the device is designed to sense air temperature.

Figure 5-7: A thermistor that is designed to sense the temperature of a refrigeration system coil can be positioned on a tube of the coil with a clip assembly.

Figure 5-8: Entering the diagnostic mode of an electronic control system to check the condition of the thermistors requires a specific procedure outlined in the manufacturer's equipment service manual. The procedure varies, depending on the manufacturer and the specific model of the appliance.

Figure 5-9: In addition to checking the condition of the thermistors, other factors relative to the operation of the refrigerator can be checked when the appliance is in the diagnostic mode.

Figure 5-10: This chart shows the change in resistance of a thermistor relative to a change in temperature. When the temperature of an NTC thermistor goes up, the resistance of the device goes down.

Figure 5-11: When two dissimilar metals inside a bimetal switch react to temperature, it makes or breaks a circuit to a load.

Figure 5-12: A bimetal switch of this type is commonly located near the heat source of a clothes dryer, making and breaking to regulate temperature.

Figure 5-13: A bimetal switch from a mold type ice maker. A mastic paste is applied to ensure good contact between the ice maker mold assembly and the thermos disc. When this device is chilled to a temperature of near 0° F, it closes, allowing the initiation of the ice maker harvest cycle. During the harvest mode, the switch is warmed by the ice maker mold heater, causing it to open and break the electrical circuit.

Figure 5-14: One example of a bimetal switch employed as a defrost termination is a thermostat in a refrigerator. A device such as this is located near the refrigeration coil that is warmed in a defrost mode by a heating element. Replacing the switch in this example requires the removal of a spring clip that holds it in place.

Figure 5-15: This defrost termination thermostat opens at 90°F. Depending on the design of the refrigerator, a defrost thermostat may open as low as 45°F.

Figure 5-16: A plunger type refrigerator door switch. Figure 5-17: A rocker type refrigerator door switch. Figure 5-18: An interlock switch.

Figure 5-19: An electromechanical washing machine timer. When the motor turns the escapement, the leaf switches inside the timer make and break circuits to various components within the machine.

Figure 5-20: One example of a frost-free refrigerator defrost timer in which the motor, switching contacts, and gear assemblies are encased in plastic. The wire harness connections are shown on the left.

Figure 5-21: An electromechanical defrost timer uses a cam and gear assembly to initiate and terminate defrost and run modes of a frost-free refrigerator.

Figure 5-22: One example of an electronic defrost control, often referred to as an ADC (Adaptive Defrost Control).

Figure 5-23: A current relay, overload protector, and compressor connecting terminals.

Figure 5-24: A PTC relay designed to operate a refrigerator compressor. A device of this type is commonly used in conjunction with a run capacitor.

CHAPTER 6

Refrigeration Fundamentals

Figure 6-1: Heat transfer by conduction occurs through a solid material, such as copper tubing. With one end of the tubing placed in a flame, the heat will, in time, travel the length of the tubing.

Figure 6-2: An illustration of the components of a refrigeration system from a fundamental perspective. These components work together to accomplish heat transfer by creating a pressure differential and allowing for the change of state of the refrigerant in the system.

Figure 6-3: One example of a temperature/pressure chart that shows how temperature affects the pressure of refrigerants.

Figure 6-4: This illustration shows the direction of refrigerant flow along with the fundamental components of the system. Also shown is the change of state of the refrigerant that accomplishes the absorption and rejection of heat.

Figure 6-5: This illustration shows the configuration for a side-by-side refrigerator/freezer sealed system. In addition to accomplishing the transfer of heat to preserve food, this manufacturer has also designed the system to allow one loop of condenser tubing to keep the cabinet from sweating.

Figure 6-6: A finned evaporator is positioned in the freezer section of a frost-free side-by-side refrigerator/freezer. The drain trough catches the defrost water and allows it to drain out of the cabinet assembly.

Figure 6-7: One type of fan cooled condenser found in refrigerators is compact with steel tubing integrated to a steel plate. A fan is mounted on one end of the assembly to allow cooling.

Figure 6-8: In this example, the forced air condenser tubing is integrated into a steel wire assembly and positioned under the refrigerator cabinet. In this case, air flows not only through the condenser tubing but also across the drain pan to aid in evaporation of defrost water.

Figure 6-9: A room air conditioner employs one fan motor to operate an indoor section blower and an outdoor section fan to circulate air through the condenser coil in the outdoor section and evaporator in the indoor section.

Figure 6-10: Steel condenser tubing is soldered to the inside of the outer cabinet section of a chest freezer. This type of sealed system may employ an oil cooling loop as part of the condenser.

Figure 6-11: Aluminum evaporator tubing is soldered to the outside of the inner cabinet section of a chest freezer.

Figure 6-12: This illustration shows the sealed system components of an upright manual defrost freezer. Note that there is an oil cooling loop of condenser tubing located in the crankcase of the compressor. The evaporator tubing, in addition to providing cooling, functions as shelving.

Figure 6-13: An oil cooling loop is a pass of tubing that rests in the oil in a compressor crankcase.

Figure 6-14: When an appliance sealed system employs an oil cooling loop the Initial Discharge Line is routed to a pass of tubing to allow the dissipation of heat.

Figure 6-15: One example of a frost-free upright freezer sealed system. Here, a finned evaporator is used in conjunction with a static condenser.

Figure 6-16: In a dual evaporator refrigeration system, a 3-way valve controls refrigerant flow to one evaporator at a time, or to both evaporators simultaneously, depending on the information that the appliance electronic control system provides. In this example refrigerant is being supplied to both evaporators.

Figure 6-17: A device known as a 3-way valve is employed in a dual evaporator refrigeration system. Refrigerant enters the valve from the liquid line and exits from the fresh food and freezer compartment capillary tube connections.

Figure 6-18: A partial temperature/pressure chart that shows refrigerants that are considered to be low and medium pressure.

Figure 6-19: This illustration shows the air flow pattern in a side-by-side refrigerator/freezer. With the evaporator located in the freezer section, a temperature of 0 to 5 degrees can be achieved. A percentage of air from the freezer circulates into the fresh food section through a damper control. A cold control in the fresh food section cycles the refrigeration system off and on.

Figure 6-20: In this example of a top mount refrigerator, air flow is supplied to the fresh food section through a duct in the rear of the cabinet and the air is returned through what is known as a *mullion* section of the cabinet.

Figure 6-21: When condenser tubing is spot welded to the inside of an outer cabinet, the performance of the refrigeration system can be affected by excessive ambient temperature.

CHAPTER
7

Using Test Equipment In Appliance Servicing

Figure 7-1: One example of a digital multi-meter that is capable of accomplishing the necessary electrical testing in appliances, as well as checking temperature. In this case, the device is set to check *resistance* or *continuity*.

Figure 7-2: This digital multi-meter, like the one shown in Figure 7-1, is also capable of all electrical checks necessary in appliance servicing and testing temperature, however its specific method of operation is different.

Figure 7-3: Meter leads are color coded black and red to ensure proper connections when testing components and circuits. Alligator clips are frequently available as an option and may be attachable to the meter or the main leads in a variety of ways.

Figure 7-4: This particular model of meter employs multiple connecting ports and specific dial settings for specific functions.

Figure 7-5: A type K thermocouple is used in a digital multi-meter to accomplish temperature measurements.

Figure 7-6: This meter employs two dial settings, and a SELECT switch is used to toggle from one function to another.

Figure 7-7: In a standard 120-volt receptacle, neutral is larger of the two blade openings for connecting an appliance power cord. When a receptacle of this type is grounded, it's referred to as three-prong receptacle. In very old homes with outdated wiring systems, a technician may encounter a two-prong receptacle, which means the receptacle is not grounded.

Figure 7-8: When inserting the leads of a meter into the hot and ground connections, the display should show 120-volts.

Figure 7-9: When inserting meter leads into the neutral and ground connections of a receptacle, a reading of 0-volts is one indicator that the receptacle is properly wired.

Figure 7-10: This illustration shows a digital meter being used to check the potential voltage in a receptacle (a no-load reading), and the display is showing precisely 119.5-volts. One reason it is important for appliance technicians to understand the value of obtaining an exact voltage reading is a concept known as voltage drop.

Figure 7-11: When a 120-volt appliance is connected to a duplex outlet, and operating, (a load reading) inserting meter test probes will check the receptacle for voltage drop.

Figure 7-12: An electric dryer may be connected to a 3-wire, 30-amp receptacle, depending on the age of the building. This type of connection was permitted prior to the 1996 NEC.

Figure 7-13: A 3-wire, 50-amp receptacle that was permitted for electric ranges prior to the 1996 NEC. In an electric range, the 240-volt power supply is required for the operation of the heating elements, while oven lights, and in some cases, signal lights, operate on 120-volts. In some older equipment, a clock may operate on 120-volts.

Figure 7-14: The 1996 NEC required that 30 ampere electric dryer receptacles be a 4-wire configuration with an "L" shaped slot for neutral and a horseshoe shaped slot for ground.

Figure 7-15: A 50 ampere, 4-wire receptacle for an electric range connection. This type of receptacle was required by the 1996 NEC.

Figure 7-16: One example of a 3-wire, 240-volt connecting pigtail for an electric dryer that would be found on appliances installed prior to the 1996 NEC. Note the "L" shaped neutral connection blade, two 240-volt connecting blades, and the three terminal connections that are designed to connect to a terminal block on the appliance.

Figure 7-17: A three-wire pigtail connection to an electric dryer terminal block. The neutral terminal is located in the middle of the block and the two hot wires are commonly identified L1 and L2.

Figure 7-18: An illustration from a manufacturer's service manual showing the installation of a pigtail to a terminal block. This example is for an electric range installation.

Figure 7-19: In this four-wire pigtail connection, the ground wire is connected directly to the oven cabinet.

Figure 7-20: Potential voltage in this circuit, with the switch in an open position, would be read with a voltmeter at points 1 (power entering a switch) and 2 (the neutral connection to the light).

Figure 7-21: With the switch in a closed position, there is now applied voltage to the light at points A and B.

Figure 7-22: Potential voltage is present at the L2 connection to the Broil Element and at the P1 connection on the Electronic Oven Control.

Figure 7-23: When a switching assembly inside the Electronic Oven Control closes, the circuit to the bake element is complete.

Figure 7-24: One example of a digital multi-meter that, when an "amp clamp" is attached, can be used to check current draw in a circuit.

Figure 7-25: A sample of a manufacturer's wiring schematic for a frost-free refrigerator. Note that terminal 2 of the defrost timer is connected to a yellow wire, which is connected to the defrost heater.

Figure 7-26: Consulting the manufacturer's information that shows the physical location of components and the electrical wiring harness, shows the technician where a particular check for current draw can be accomplished.

Figure 7-27: After opening the spring-loaded jaw of the ammeter to place it around a wire, be sure that the wire is positioned properly in the jaw in order to obtain an accurate reading.

Figure 7-28: In this illustration, the process of checking a 240-volt heating element is shown with the amp clamp positioned around one wire connected to the component.

Figure 7-29: An illustration from a manufacturer's instruction manual showing the procedure for setting the device to check resistance and continuity. The concept shown here is that testing a load that has not failed will show a given resistance, and also that checking a closed switch should show a fraction of an ohm while checking an open switch will allow the display to show "OL", designating Open Line, a condition also known as Infinity.

Figure 7-30: This segment of a clothes dryer wiring diagram shows the relationship between the drive motor of the appliance and the switches that are wired in series with the motor windings and other devices in the appliance. (Note: Complete diagram in Figure 7-31)

Figure 7-31: One example of an electric clothes dryer wiring diagram. In addition to the motor switches discussed in Figure 7-30, other switches wired in series with loads are shown.

Figure 7-32: In this example, the test equipment is set to a proper range in order to accurately read the resistance of the fan motor, in this case 22.6 Ohms.

Figure 7-33: A door switch that has three terminal connections: Common, Normally Open, and Normally Closed.

Figure 7-34: A simplified schematic diagram for a microwave oven. Two door switches known as a Primary and Secondary Interlock (N.O.) are employed to confirm that the oven door is closed, along with an Interlock Monitor Switch (N.C.).

Figure 7-35: This microwave oven interlock switch is a normally open device. When the actuator is at rest, testing between the COM and N.O terminals will show infinity, when the actuator is pressed, the meter display will show continuity.

Figure 7-36: When a switch is in the open position, the display on this device shows "OL", Open Line, also known as a reading of infinity.

Figure 7-37: When the actuator of an N.O. switch is pressed, the display will show a fraction of an Ohm (continuity) if the switch is operating properly. This particular switch is showing 0.3 Ohms in the closed position.

Figure 7-38: When testing a bi-metal type switch when it is cool, the meter should display continuity, which can be shown as a fraction of an Ohm.

Figure 7-39: A capacitor under test and showing 12.2 microfarads. If this reading was within the manufacturer's specifications, the device would be good.

Figure 7-40: When performing sealed system evaluation and repairs on appliances, a gauge set is connected in order to read pressure and vacuum.

Figure 7-41: A temporary piercing type valve consists of a clamp assembly that is fastened to the refrigeration system tubing, a piercing assembly, and a piston.

Figure 7-42: Installation of a permanent access valves requires brazing the assembly on to the refrigeration system tubing.

Figure 7-43: A replacement filter/drier with a built-in access valve. This component is installed on the liquid line in the process of repairing a sealed system, and, with the capillary tube metering device inserted into the assembly at the other end, the joints are soldered.

Figure 7-44: The low side gauge connected to the suction side of the refrigeration system measures both a positive pressure and a negative pressure.

Figure 7-45: The high-side gauge reads pressure and shows temperature. In this example, R-404a is the innermost scale shown in red numbers, R-22 is shown in green, and R-410a is shown in red with white numbers.

1.1 PRODUCING ELECTRICITY

Electrical energy begins at a generating station and, in simple terms, is defined as a form of energy that performs useful work when converted to light, heat, or mechanical energy. This definition should be easy for us to accept because we see it in action every day when we tum on a light, use a toaster, operate an automatic laundry equipment, cook with an electric range or microwave oven, or allow electricity to make our lives easier in many different ways. The first question is, "How is it produced?"

It's common knowledge that the electricity we use to operate appliances comes from a power plant and that a generator is used to produce the energy, but the answer involves a bit more than saying, "It comes from a generating station."

It will help you to view the electrical generating station as nothing more than a factory that takes a raw material, such as coal or oil, or employs a *hydroelectric* or nuclear process, and changes the chemical or kinetic energy into another form of energy: electricity. Figure 1-1 illustrates, in its simplest form, the process of converting chemical energy into electrical energy. You'll note that, as you trace the process we are showing in this example from its beginning (a mine supplying coal) to its end, the energy takes six different forms.

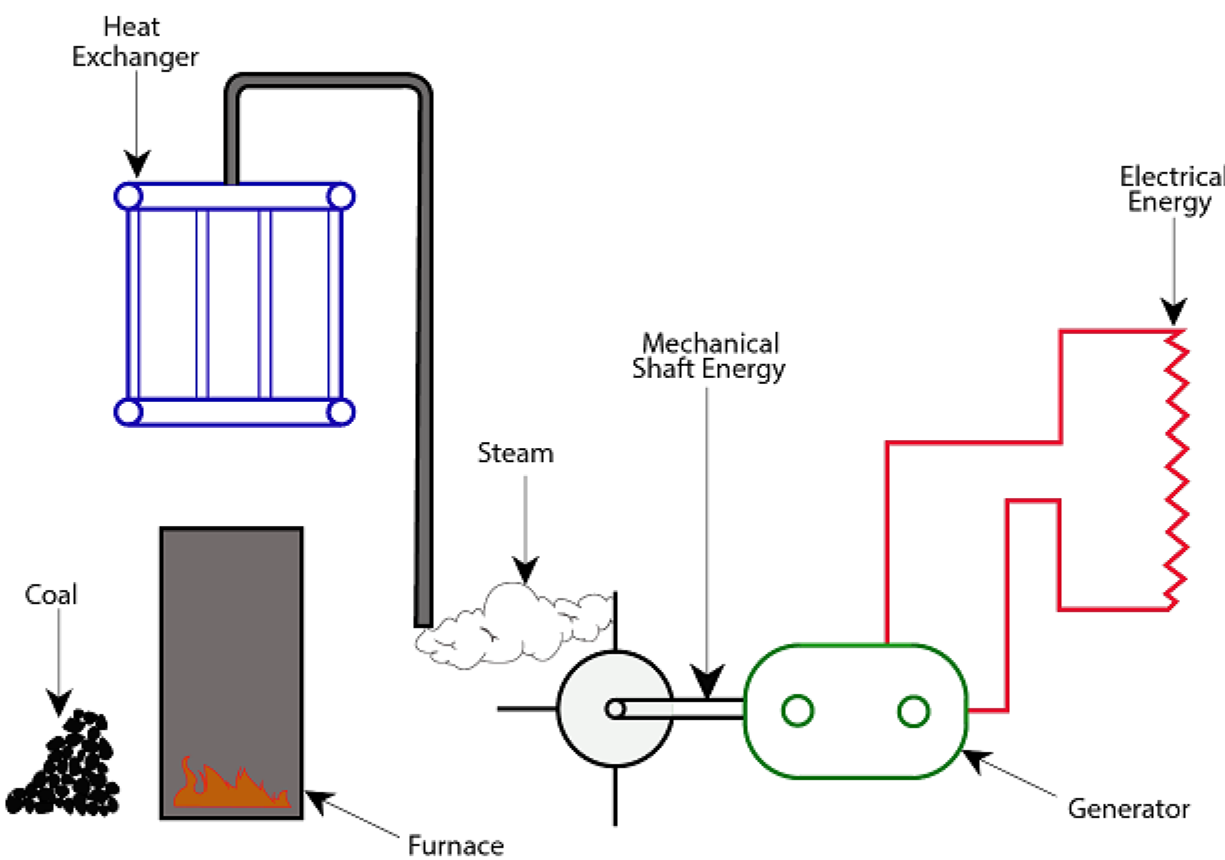


Figure 1-1: Converting chemical energy into heat energy, which creates steam. The high-pressure steam spins the turbine and mechanical shaft energy turns the generator.

Referring to the chart in Figure 1-11:

Mica is an effective ________________________________ material.

Silicon is a ____.

Copper is an effective ____ of electricity.

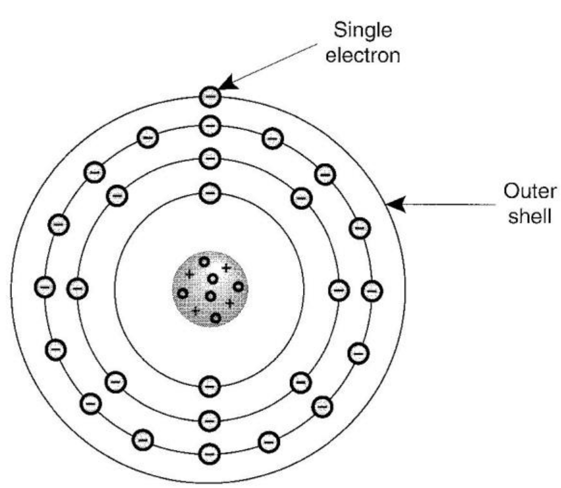
The single electron that is furthest from the nucleus of the atom and can be easily knocked out of orbit is referred to as a:

____ electron.

An insulator can have up to _______ valence electrons.

A silver atom contains ________ orbits which are known as shells of electrons.

The illustration below illustrates the atomic structure of a _________________________ atom.



CHAPTER TWO

Alternating Current Fundamentals, Terms and Definitions

LEARNING OBJECTIVES

After studying this Chapter, you will be able to:

1. Define the method through which alternating current is generated.
2. Define the terms volt, ampere, resistance, and watt.
3. Understand how Ohm's law is used to solve electrical problems and illustrate the relationship between the three basic electrical units: current, voltage, and resistance.
4. Understand how the cost of electrical power is calculated and follow the steps necessary to calculate the cost of operating an appliance.

2.1 ALTERNATING CURRENT

When working as an appliance service technician, a good habit to develop is that of looking for the manufacturer's equipment information tag as you begin servicing the refrigerator, washing machine, or whatever it is you happen to be repairing. Experienced techs consult the tag for the model and serial number (especially if the appliance is under warranty) and look for the operating data of the item.

From an electrical perspective, one piece of information you'll encounter on the model tag relates specifically to the type of energy used to power the appliance. Terms such as 120 VAC or 240 VAC tell you the specific level and type of energy that must be applied for the appliance to operate properly. VAC is an abbreviation for *Volts Alternating Current*, and the numbers preceding the abbreviation tell you the proper voltage necessary for a specific piece of equipment.

A refrigerator, for example, since it operates through a power cord that is plugged into a standard wall outlet, (the same receptacle into which you could plug a table lamp or an electric drill) it will operate on 120 VAC. In some cases, you may find this level of voltage referred to as 115 VAC or 110 VAC. From this perspective, it doesn’t matter which number is discussed.

The variable in voltages you may encounter in a given situation are related to the specific level at which a particular generating station delivers energy, and the previously mentioned refrigerator can operate normally at all of the voltages we have listed here.

Checking for proper current draw of a component can be accomplished with a clamp-type meter such as the one shown in Figure 2-4.

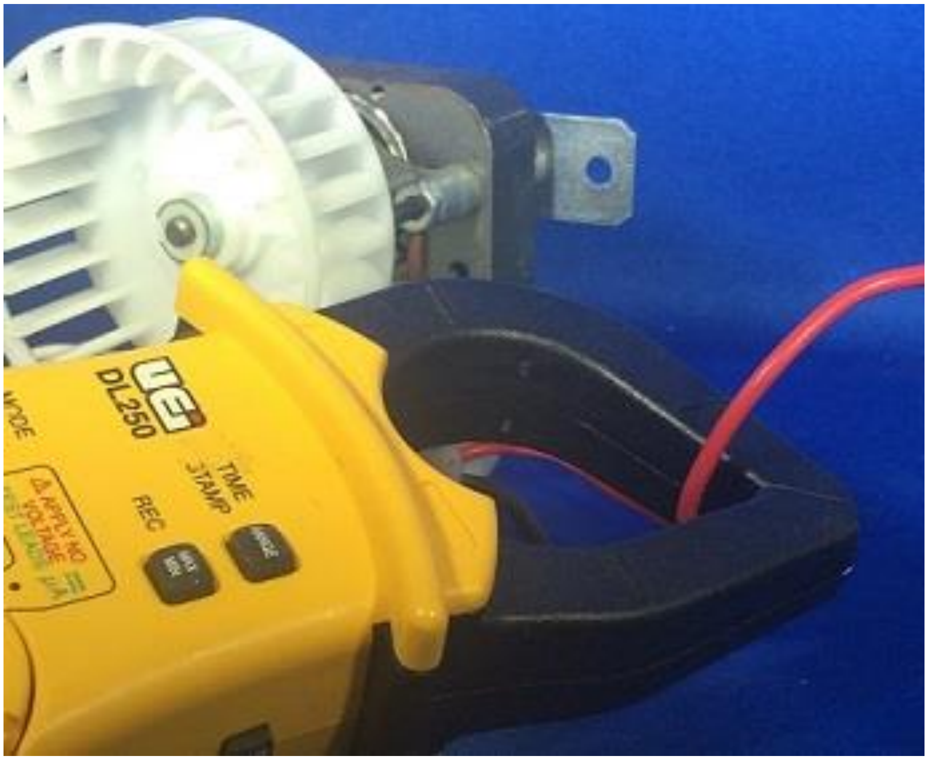


Figure 2-4: A clamp-type meter is used to check the current draw of electrical components in appliances.

In this example, the clamp of a test meter is positioned around a wire connected to a refrigerator evaporator fan motor. This allows the meter to measure the current draw of the motor based on the concept discussed earlier regarding an electromagnetic field existing around a conductor when there is electron flow in the conductor.

2.4 RESISTANCE

The opposition to current f1ow (the flow of electrons along a conductor) is referred to as resistance. There is some resistance in all conductors. Even if the atomic makeup of a material allows electrical energy to f1ow, and we refer to the material as a "good conductor of electricity," there is still some resistance to the f1ow of electrons.

An electrical component in an appliance, such as a heating element or a motor winding, will also have a designed level of resistance that allows the component to accomplish its task of providing heat or mechanical energy. This degree of resistance is measured in *Ohms*.

Figure 3-5 offers a simplified illustration of the variations in electrical energy supplied to the main electrical panel of a building.

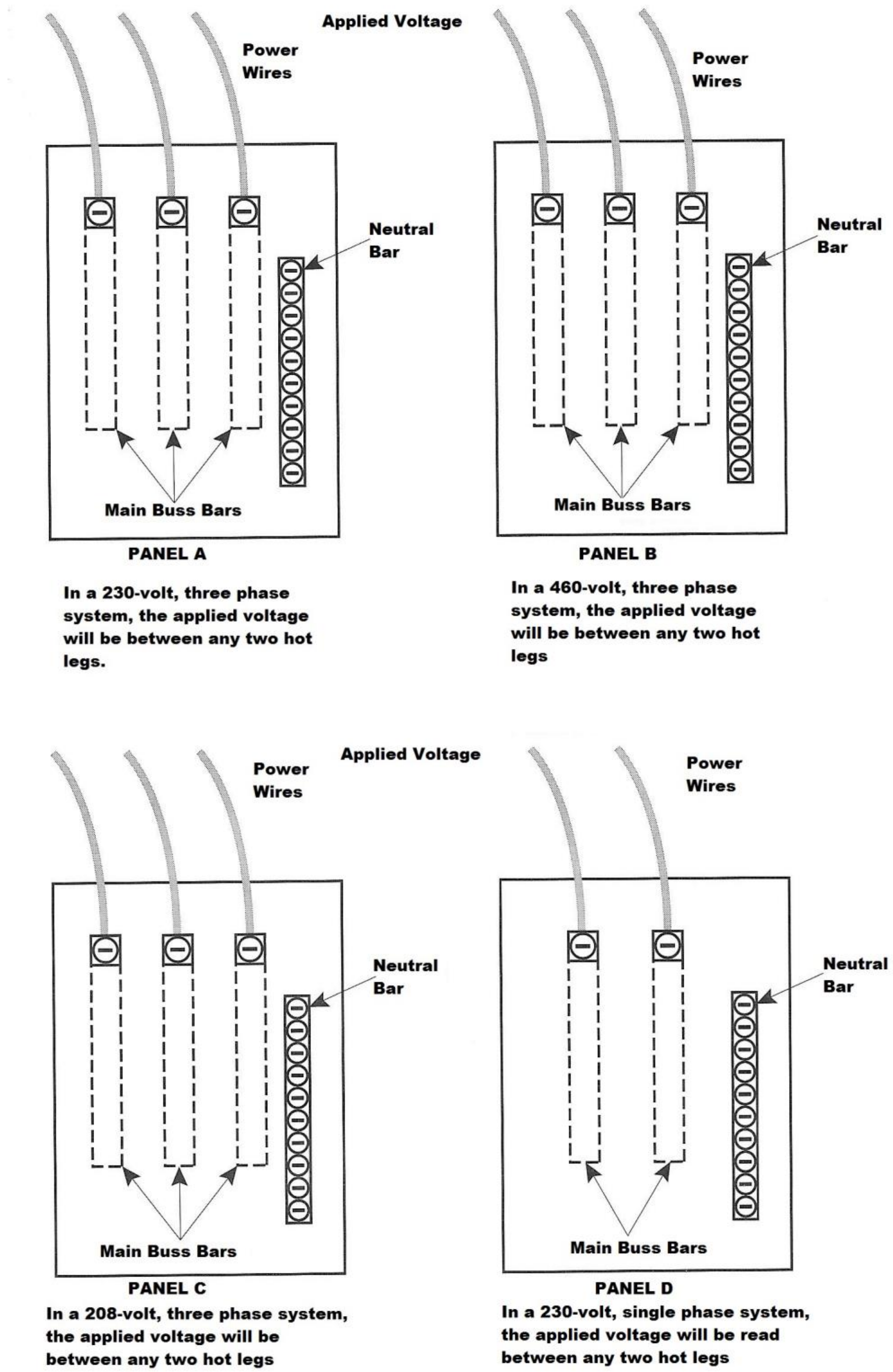


Figure 3-5: Four types of main disconnect panels found in residential and commercial buildings. The most common power supply system for major appliance service technicians is panel D.

Explain what would occur if a poor connection at a circuit breaker did not allow the full voltage to be applied to a refrigerator circuit.

____

____

____

The definition of the term "phase" relative to electrical circuits is:

____

____

In a 460-volt, three-phase system the applied voltage will be read:

____

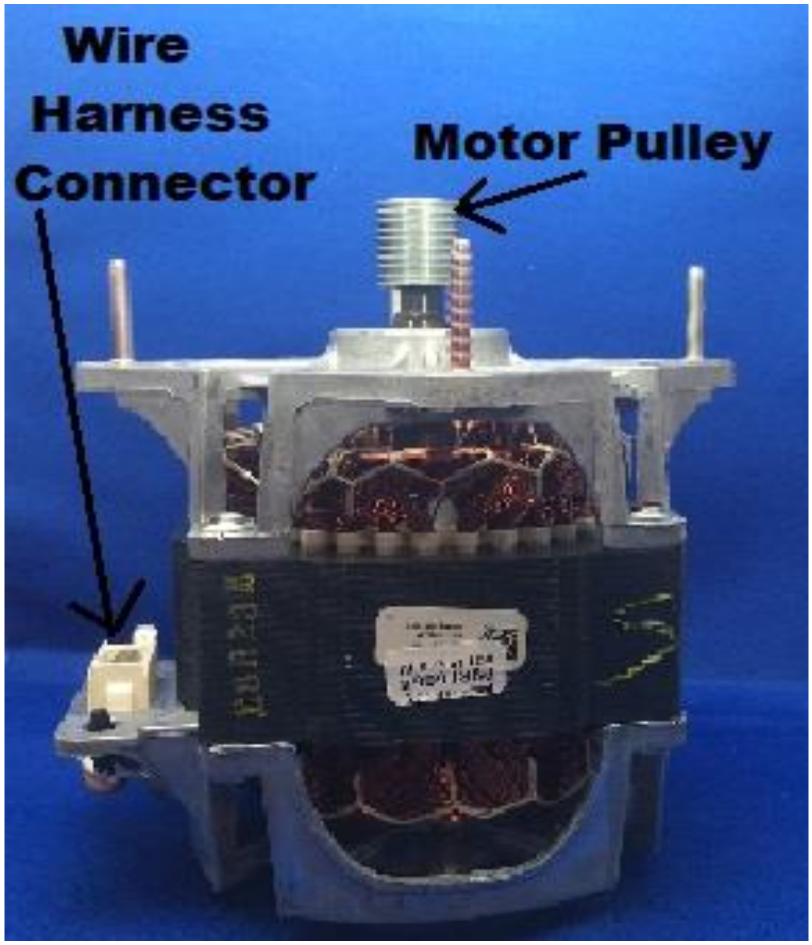


Figure 4-5: A washing machine motor is designed to start and run under a heavy load. It employs a motor pulley for the belt that operates the appliance in agitate/tumble and spin modes.

Another type of motor you'll encounter when working as an appliance technician is the shaded pole motor. This motor is much smaller, and because of different construction methods, has a very low starting and running torque. A shaded pole motor is commonly used to circulate air flow inside a frost-free refrigerator, cool off the condenser coil on a refrigerator, or circulate necessary air in cooking equipment.

Single phase window and *wall-through* air conditioning units will commonly employ *PSC (Permanent Split Capacitor),* their compressor motors, and in some cases the motors that are employed for air flow in these units. Run capacitors, devices that are designed to make a motor run more efficiently, may also be used in the operation of some refrigerator and freezer compressors. Very small induction-type motors are used to operate ice makers in refrigerators or to operate *electromechanical* timing devices in automatic washers, clothes dryers, microwave ovens, and refrigerators. The following illustrations (Figures 4-6 through 4-13) show a variety of motors used in appliances.

4.3 SOLENOIDS

A common application for a solenoid is to operate a water valve. One example of this is shown in Figure 4-14, a valve used in the water dispensing system in a refrigerator. This type of device also uses an electrically energized coil of wire to create an electromagnet. Unlike a motor, however, the electromagnetic field does not spin a rotor, but instead causes a rod placed in the center of the solenoid to shift position, overcoming spring pressure that keeps the valve closed, creating an opening that will allow water to flow.

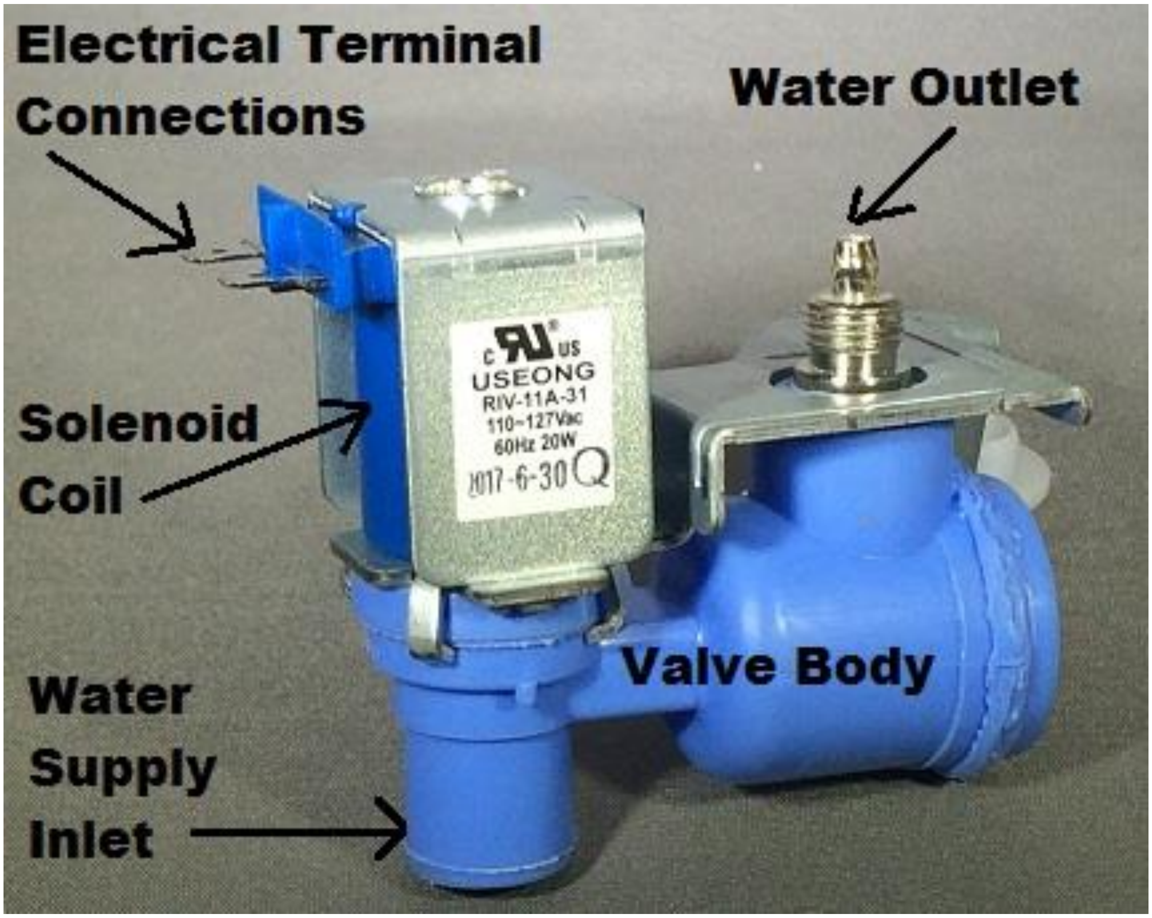


Figure 4-14: A solenoid-operated water valve. The types of mounting brackets and fittings used will vary depending on the application of the valve. The valve shown here operates on 120 VAC, has one solenoid coil, and is used in the water dispensing system to an ice maker.

A single solenoid-operated valve will be found in a refrigerator equipped with an ice maker. Energizing the solenoid coil for a brief period of time allows a small amount of water to flow into the ice maker assembly. In refrigerators that have both an ice maker and water dispensing system, two separate valves or a two-solenoid valve may be employed. One solenoid will control the flow to the ice maker, and the other solenoid or separate valve will control the flow of water from the dispensing system. Figure 4-15 shows one example of a dual valve assembly in a refrigerator.

CHAPTER FIVE

Switches in Major Appliance Electrical Circuits

LEARNING OBJECTIVES

After studying this Chapter, you will be able to:

1. Identify the different types of switches used in appliance electrical circuits.
2. Explain the fundamental difference between electromechanical and solid-state switches used in major appliances.

Up to this point, our discussion has centered on the fundamentals of electricity and electrical components in appliances that use electrical energy to perform useful work. A component of this description is referred to as a *load*, a device to which we apply energy and the end result of that process is the production of heat, light, or mechanical energy. In this chapter, we'll discuss components that are not loads, but *switches*. Switches don't use electrical energy; they allow a complete circuit to the loads that perform work.

5.1 SWITCH FUNDAMENTALS

We use switches to make or break a circuit (energize and de-energize) a load. This is done according to how much heat we want from an electric oven bake element, surface unit, gas burner in an oven, or the amount of cooling we want from a refrigerator, freezer, room air conditioner, or the length of a cycle desired in laundry equipment or other appliance. Thermostats (sometimes referred to as *cold controls* when we're talking about refrigerators instead of ovens), motor starting relays, pressure-sensing devices, water temperature selectors, bimetal devices, and timers, are all a switch in one form or another.

Switches classified as electromechanical in nature have been, and still are, in use in all the forms we mentioned above. In some appliances, the classification of switch is electronic, which means that it is a device that doesn't have moving parts as electromechanical devices do, but, instead, accomplishes switching in a different manner, such as increasing or decreasing resistance, to make or break a circuit.

And, while switches of all types may seem to be complex and confusing as a concept new to you, the principle behind their use is no more complicated than the application of the simple light switch and bulb circuit shown in Figure 5-1.

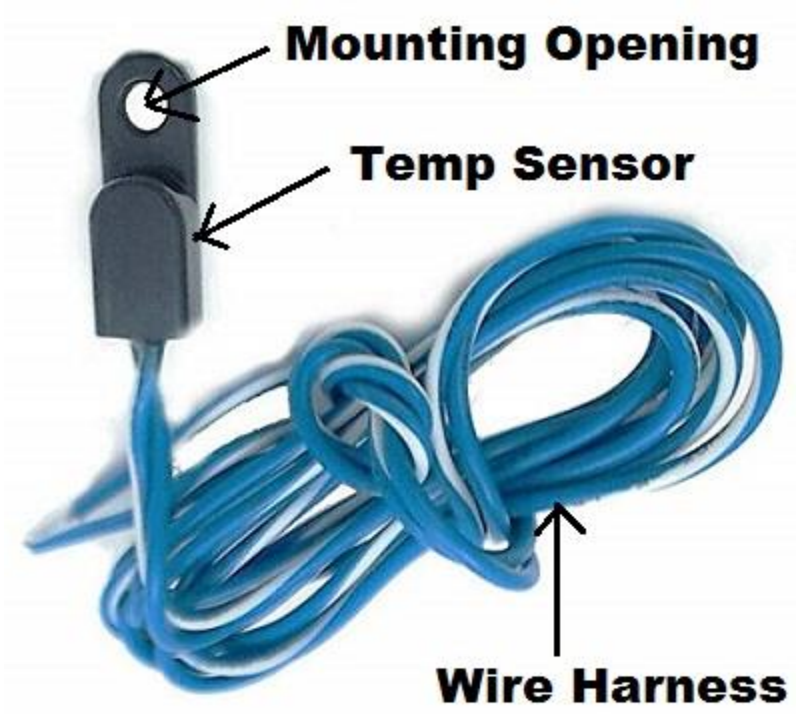


Figure 5-6: In this example, a mounting opening allows attachment of this thermistor to an interior cabinet location when the device is designed to sense air temperature.

In some cases, an air temperature sensing thermistor may be held in place by a cover or silicone rather than a mounting opening. Also, in some situations, a thermistor is designed to sense the temperature of a refrigeration system coil and employs a clip assembly to allow attachment to a tube. (See Figure 5-7)

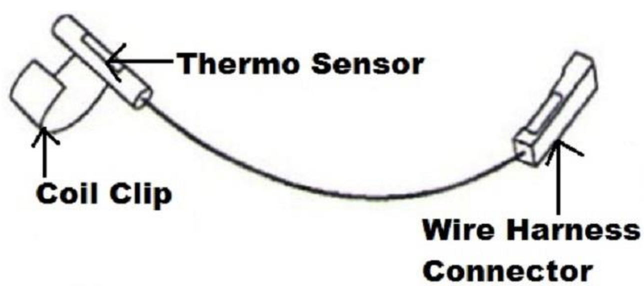


Figure 5-7: A thermistor that is designed to sense the temperature of a refrigeration system coil can be positioned on a tube of the coil with a clip assembly.

When an electronic control system in employed in the operation of a refrigerator, a common practice is to follow specific manufacturer instructions to use the appliance touchpad in order to initiate a diagnostic mode that allows for the evaluation of thermistors while they are connected to the wiring harness and the refrigerator is operating. One example of a manufacturer's procedure for diagnostic mode initiation is shown in Figure 5-8.

A wide range of timers are also used in clothes dryers, dishwashers, gas and electric ranges, and microwave ovens.

When used as a control in a frost-free refrigerator, the electromechanical timer has two cycles, run and defrost. Referred to as the defrost timer by many manufacturers, it maintains a run cycle most of the time, then enters the defrost cycle for a comparatively short period of time. Depending on the make and model of the refrigerator, defrost cycle lengths may vary from a minimum of 14 minutes to a maximum of 28 minutes. Figure 5-20 shows one example of an electromechanical refrigerator defrost timer.

Figure 5-20: One example of a frost-free refrigerator defrost timer in which the motor, switching contacts, and gear assemblies are encased in plastic. The wire harness connections are shown on the left.

In some cases, the motor of a defrost timer is exterior mounted to the case. Regardless of the construction method, the terminal arrangement that connects to the wiring harness is consistent, allowing an electrical circuit to the timer motor, the run components of the refrigerator, and the defrost system. Figure 5-21 shows one example of timer terminal identification.

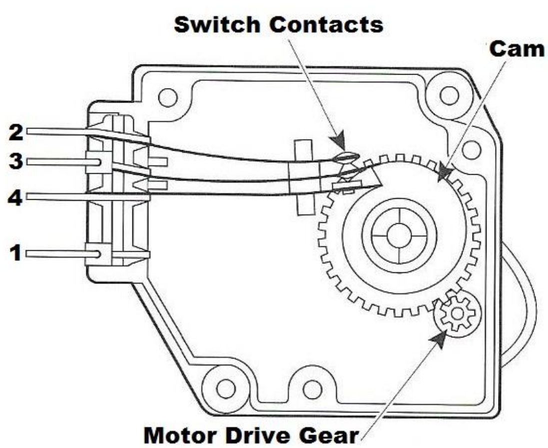


Figure 5-21: An electromechanical defrost timer uses a cam and gear assembly to initiate and terminate defrost and run modes of a frost-free refrigerator.

Convection

The movement of heat through a fluid is called convection. This term is important in the explanation of refrigeration fundamentals for two reasons: First, it explains another method of heat movement into the refrigerator cabinet (moisture in the air carries some of the heat). Second, it explains why a liquid, such as a pitcher of juice, is chilled when it is placed warm into the refrigerator and is cooled by the surrounding air. Convection is also at work when heat is transferred into or out of the chemicals that we use inside the coils of the refrigeration system in the refrigeration process.

Conduction

The movement of heat through a solid material is known as conduction. This is simply illustrated by putting one end of metal tubing in contact with a fire. (See Figure 6-1) If you were to leave it in this position for a given period of time, then touch the end of the tubing that was not in the fire, you would feel the heat from the fire because it traveled through the solid material from the contact end to the end you touched.

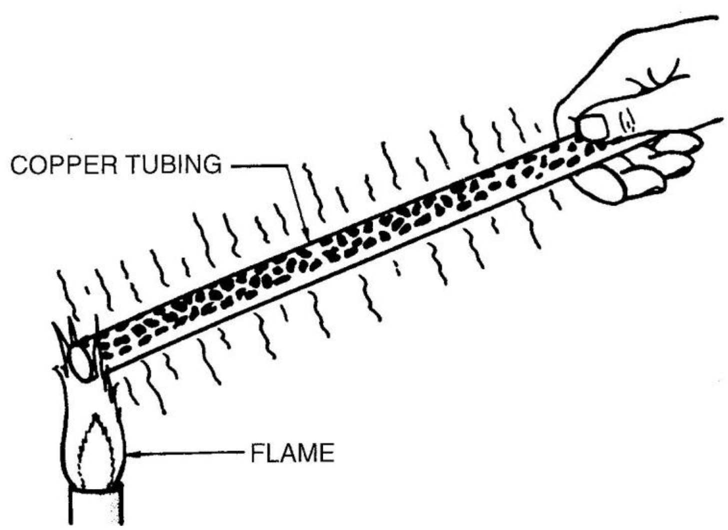


Figure 6-1: Heat transfer by conduction occurs through a solid material, such as copper tubing. With one end of the tubing placed in a flame, the heat will, in time, travel the length of the tubing.

Conduction is the process by which the heat moves through glass or metal containers into the cooler surrounding air in the refrigerator. Another illustration of conduction is heat passing through metal tubing that makes up the refrigeration system coils.

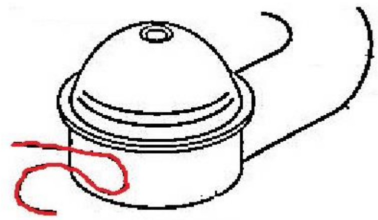


Figure 6-13: An oil cooling loop is a pass of tubing that rests in the oil in a compressor crankcase.

To understand how an oil cooling loop functions, trace the flow of refrigerant from what is considered to be the Initial Discharge Line, on through the Yoder Loop, and back to the crankcase of the compressor.

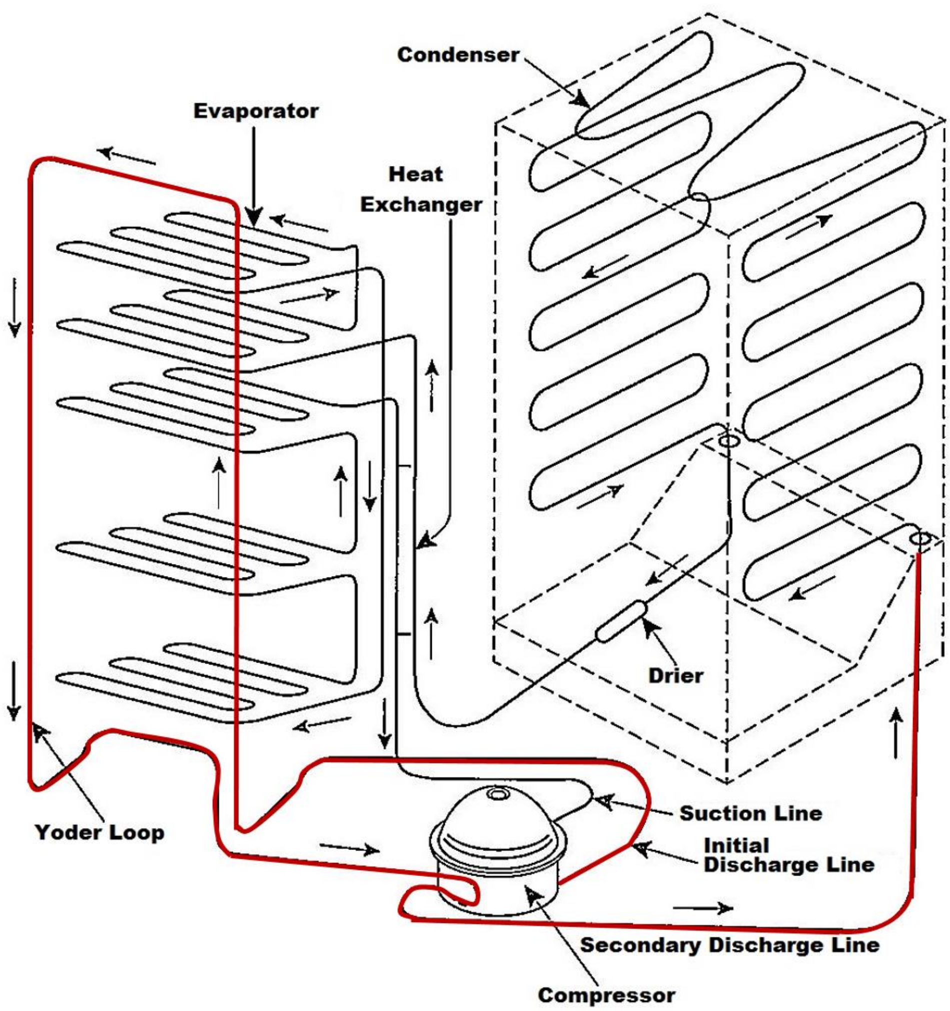


Figure 6-14: When an appliance sealed system employs an oil cooling loop the Initial Discharge Line is routed to a pass of tubing to allow the dissipation of heat.

7.1 MULTI-METER FUNDAMENTALS

Figure 7-1: One example of a digital multi-meter that is capable of accomplishing the necessary electrical testing in appliances, as well as checking temperature. In this case, the device is set to check *resistance* or *continuity*.

When technicians new to the appliance industry begin learning about test instruments, they are often of the opinion that while a device is complex, once the use of one type of multi-meter is mastered, specific information about how the equipment is used will apply to all types of electrical meters.

Experienced technicians, however, also know that with each make and model of a digital multi-meter, there is a learning curve.

It's common for an appliance technician to accomplish 5 to 6 completed calls in a normal workday when considering travel time, diagnostic procedures, and part replacement. In the course of that day, the chances of finding the same problem twice are slim. On one call, you may have to determine whether the voltage from a receptacle is correct. On your next service call, you may have to test a control on an appliance that is "sitting dead" and use an ohmmeter to find out if the device is capable of allowing current to pass.

On your next call, you may have to test a motor on a washing machine to make sure it is drawing proper current, and you'll use an ammeter. And, to round out your day, you may have to test an oven for correct temperature or troubleshoot the high voltage section of a microwave oven, which means you may use a multi-meter for these tasks or perhaps a specific test device designed for only one type of testing process.

Thus far, we've only covered multi-meters very briefly. The reality of test equipment is that there are more different brands, types, and combinations of meters and gauges on the market than there are different brands of major appliances, and selecting the meters you prefer to use is a matter of personal preference and individual experience.

As we cover specific test procedures in this chapter, keep in mind that the examples shown may apply in general terms to more than one type of device, but not every device you may encounter. When considering multi-meters from a safety perspective, technicians should always use meters that are known as a Category III device with a 600-Volt rating.

7.2 CHECKING VOLTAGE WITH A MULTI-METER

When using a multi-meter to check voltage related to appliances, there are two fundamental voltage systems for technicians to consider:

1. Testing for AC (Alternating Current) voltage applied to appliance equipment and checking for voltage applied to components within an appliance that operates on AC voltage, such as motors, solenoids, and heating elements.

2. Testing for DC (Direct Current) voltage applied to components within appliances, such as control boards or other specific components that operate on direct current.

And, when learning about voltage, two categories that can be considered about it are:

1. Potential Voltage: Voltage that is present in a circuit, but no work is being performed in the circuit.

2. Applied Voltage: Voltage that can be measured and applied to the wiring connections of a component.

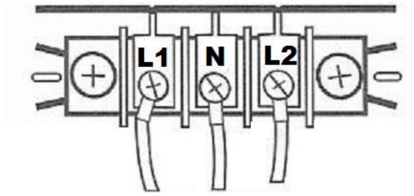


Figure 7-17: A three-wire pigtail connection to an electric dryer terminal block. The neutral terminal is located in the middle of the block, and the two hot wires are commonly identified L1 and L2.

When checking a 240-volt appliance power supply for voltage drop the test can be accomplished at the pigtail connections of the terminal block. Since a terminal block may be constructed with threaded studs and nuts to allow connection of the pigtail or screws, it will be more convenient to use alligator clips rather than standard meter probes to make the connection.

Once a base voltage has been accomplished by connecting a voltmeter to the L1 and L2 terminals with the appliance not operating, initiating a cycle that ensures operation of the heating element will allow for a second voltage test. With both voltage tests accomplished, you can determine if the voltage drop in the circuit is beyond the NEC standard maximum of 3%. Figure 7-18 shows another example of a three terminal block connection.

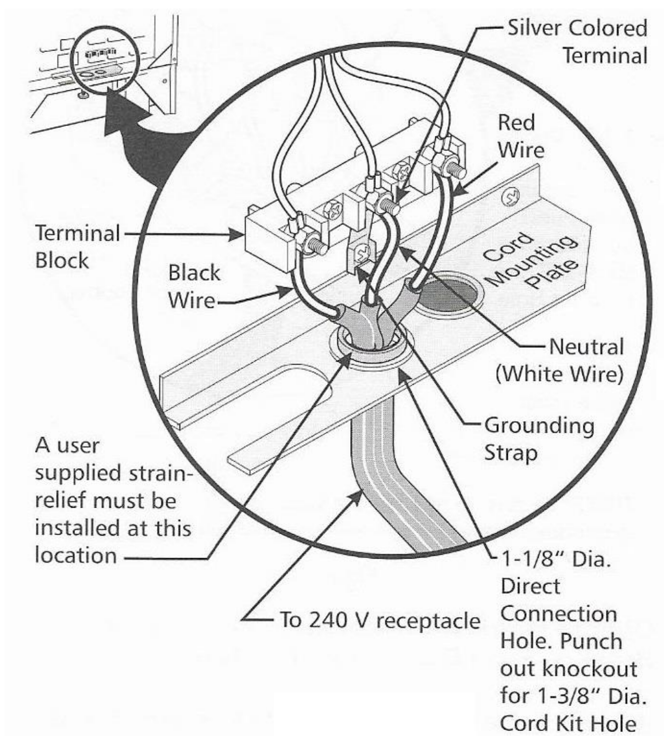


Figure 7-18: An illustration from a manufacturer's service manual showing the installation of a pigtail to a terminal block. This example is for an electric range installation.

When using test equipment to check the resistance of a load, or the continuity of a switch, the power supply to the appliance must be disconnected, and the component needs to be isolated from other devices in the wiring harness in order to obtain an accurate reading. It is also good practice to use alligator clips when possible to ensure a good connection to the device terminals.

In the illustration below, the fan motor being tested has a resistance of 22.6 Ω.

Figure 7-32: In this example, the test equipment is set to a proper range in order to accurately read the resistance of the fan motor, in this case 22.6 Ohms.

When checking a load such as a motor, solenoid coil, or heating element, there are two aspects of the test to consider. One, is that you may need to determine what the exact resistance is supposed to be by consulting the manufacturer's specifications (on the equipment diagram or in the service manual). The other is to understand that in some cases, general knowledge regarding what is considered normal may be the only information you need to determine whether a component has failed or not.

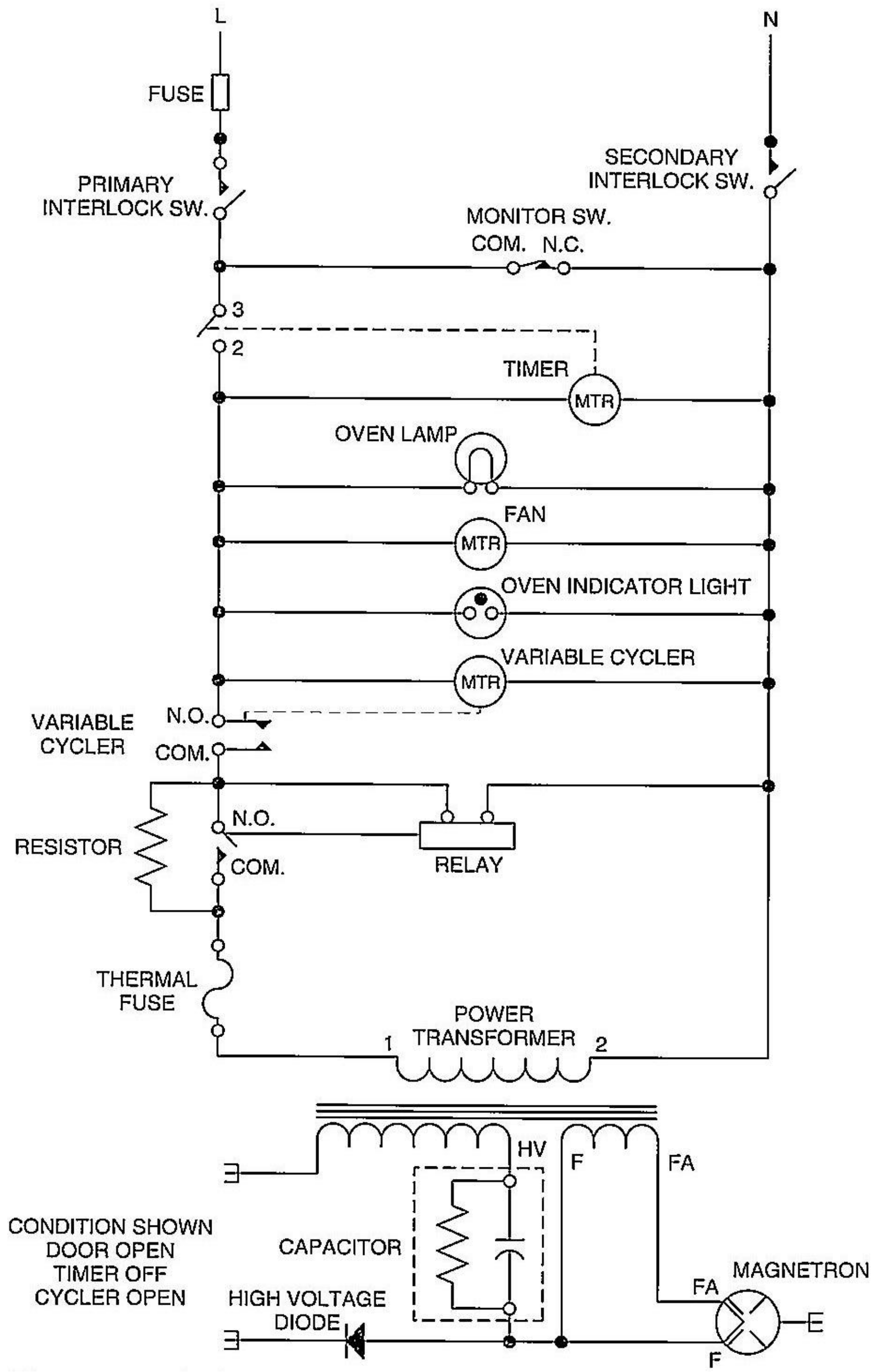


Figure 7-34: A simplified schematic diagram for a microwave oven. Two door switches known as a Primary and Secondary Interlock (N.O.) are employed to confirm that the oven door is closed, along with an Interlock Monitor Switch (N.C.).

To ensure safe operation of a microwave oven, the normally closed Interlock Monitor Switch must open properly to allow operation. In the event that this switch does not open properly, the fuse on the line side of the power supply will open immediately.

Volume 1

Major Appliances

Troubleshooting, Servicing & Installing

Jim Johnson

Jim Johnson has been a full-time technician, as well as a full-time trade school and community college instructor and administrator, working in and around the refrigeration, HVACR, appliance, and facility maintenance fields since 1973. He has facilitated hundreds of training seminars, workshops and classes in the HVACR electrical and refrigeration areas alone, as well as many other workshops in other technical and non-technical areas.

His background includes a satellite training network for HVACR and appliance technicians, and the development and presentation of more than 75 video training programs. He has authored five textbooks and 10 technician handbooks.

He has been a columnist for trade magazines for more than 20 years, including Indoor Comfort News, RSES Journal, ACHR News, ACHR News Extra Edition, HVACR Today, and Marcone World Magazine, providing monthly troubleshooting features and more than 500 feature articles.

He is a member of RSES, Certified as a Residential and Light Commercial Air Balancing and Diagnostic Technician, and is certified in heat pumps. He also holds multiple certifications in combustion analysis and carbon monoxide safety. He is a registered proctor for NATE exams, and his workshops, HVAC training videos, and e-book CD’s not only provide a simplified approach to learning about troubleshooting and servicing heating and air conditioning equipment, they also serve as an effective preparation for NATE certification exams.

ISBN-13: 978-1-937659-22-6