Major Appliances
Troubleshooting, Servicing & Installing
Jim Johnson

Volume 1

Electrical & Refrigeration Fundamentals
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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.
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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 turn 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.

![Diagram of generating station](image)

**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 flow (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 flow, and we refer to the material as a "good conductor of electricity," there is still some resistance to the flow 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:
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.
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)

When an electronic control system is 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.](image)

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.](image)
**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.](image)

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.
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.
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