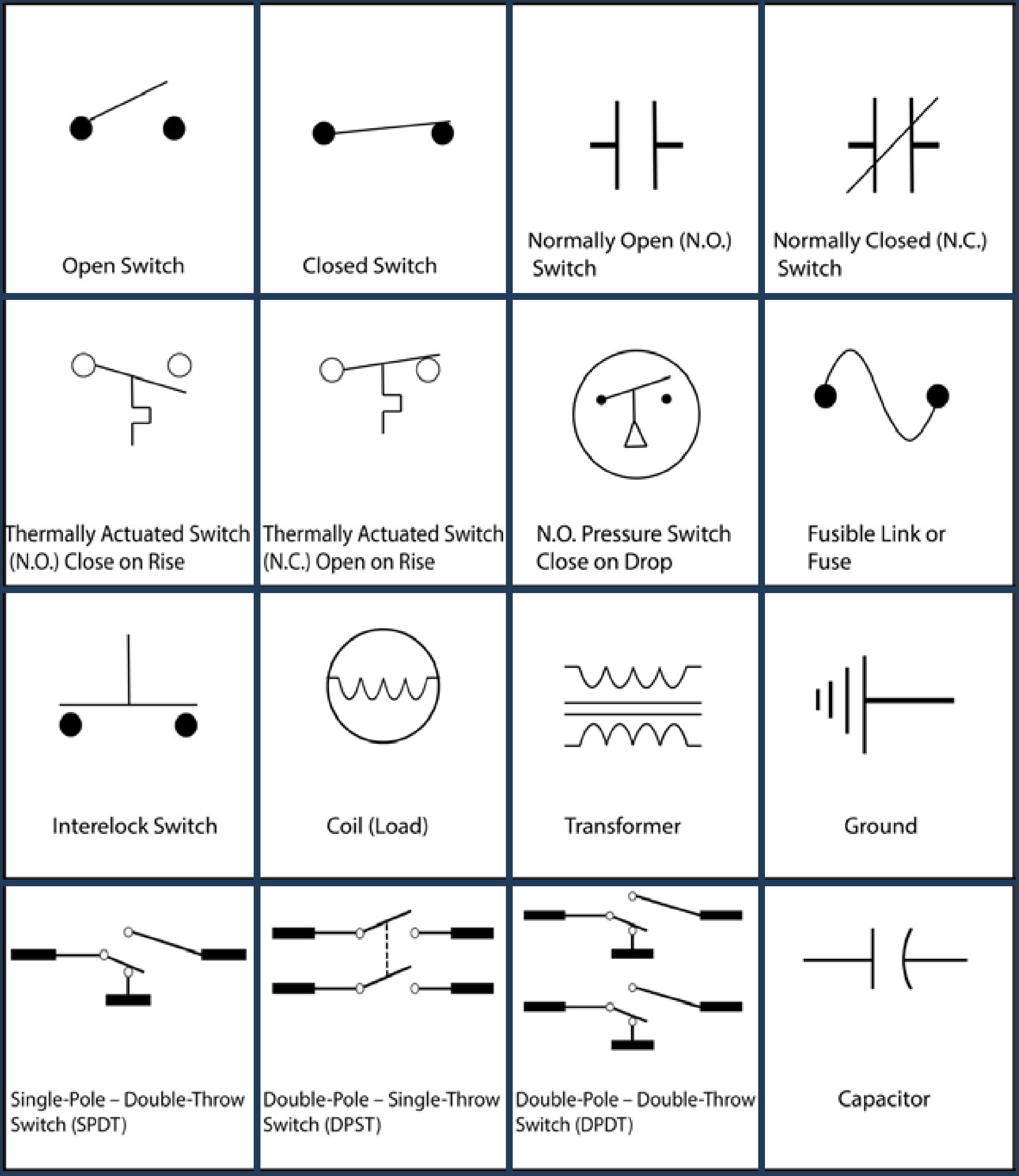
Open Switch
Closed Switch
Normally Open (N.O.) Switch
Normally Closed (N.C.) Switch
Thermally Actuated Switch (N.O.) Close on Rise
Thermally Actuated Switch (N.C.) Open on Rise
N.O. Pressure Switch Close on Drop
Fusible Link or Fuse
Interelock Switch
Coil (Load)
Transformer
Ground
Single-Pole – Double-Throw Switch (SPDT)
Double-Pole – Single-Throw Switch (DPST)
Double-Pole – Double-Throw Switch (DPDT)
Capacitor

Figure 1

GAS-FIRED FURNACE WIRING DIAGRAMS and SEQUENCE of OPERATIONS

LEARN THE FUNDAMENTALS OF SCHEMATICS

TEXT AND GRAPHICS COURTESY OF ESCO

Wiring diagrams are an important tool for technicians as they aid in troubleshooting and provide an understanding of how a particular appliance should operate. There are a few different ignition systems found in gas furnaces and a wiring diagram can help to determine the sequence of operations for the unit. As emerging technology finds its way into the HVACR field, the ability to read, interpret, and comprehend electrical schematics is a requirement in the field. This article will review pictorial and schematic diagrams, as well as the sequence of operations for ignition systems used with gas furnaces.

A wiring diagram is provided with every gas furnace and can usually be found on the inside of the blower compartment door. The diagram is a pictorial representation of the electrical circuits found in the furnace. Most furnaces include both a connection diagram and a schematic diagram. System components are usually represented by symbols which can vary from one diagram to the next. There is also a legend to identify the components, which can vary amongst manufacturers. Figure 1 is a sample chart of symbols used with the schematics presented in this article. Learning how wiring diagrams are drawn can aid in understanding the sequence of operations for a furnace or boiler.

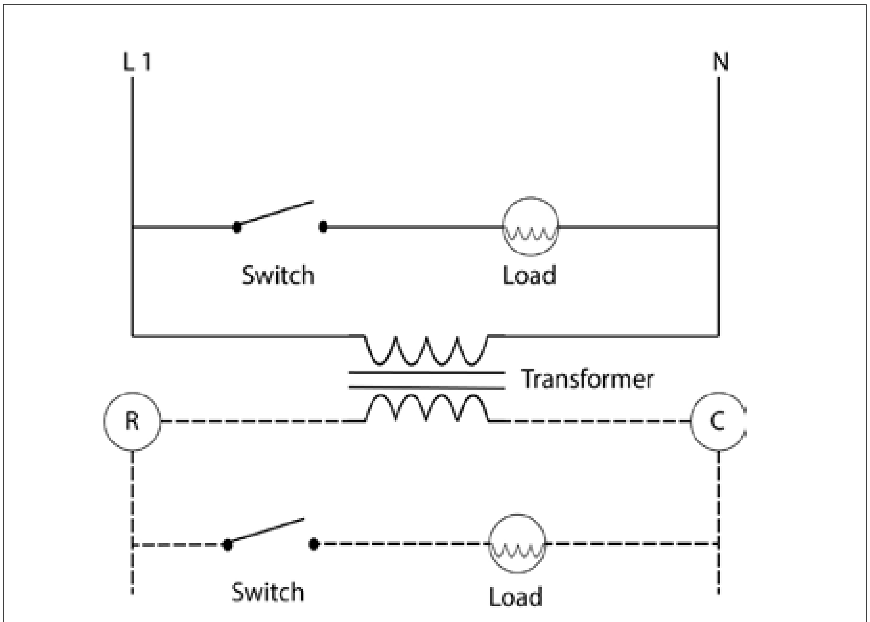

Figure 2

Schematic Diagram

A schematic diagram, commonly referred to as a ladder diagram, is drawn similar to an actual ladder. The vertical legs on the top left and right side represent the source voltage. The individual circuits and their components are represented on horizontal lines like the rungs of a ladder. In the center of the diagram is the control voltage transformer, dividing the diagram into two halves. The upper portion contains all of the line voltage circuits and the lower portion contains all of the low-voltage circuits. Figure 2, is a sample ladder diagram, depicting the electrical circuits including voltage sources, switches, and loads.

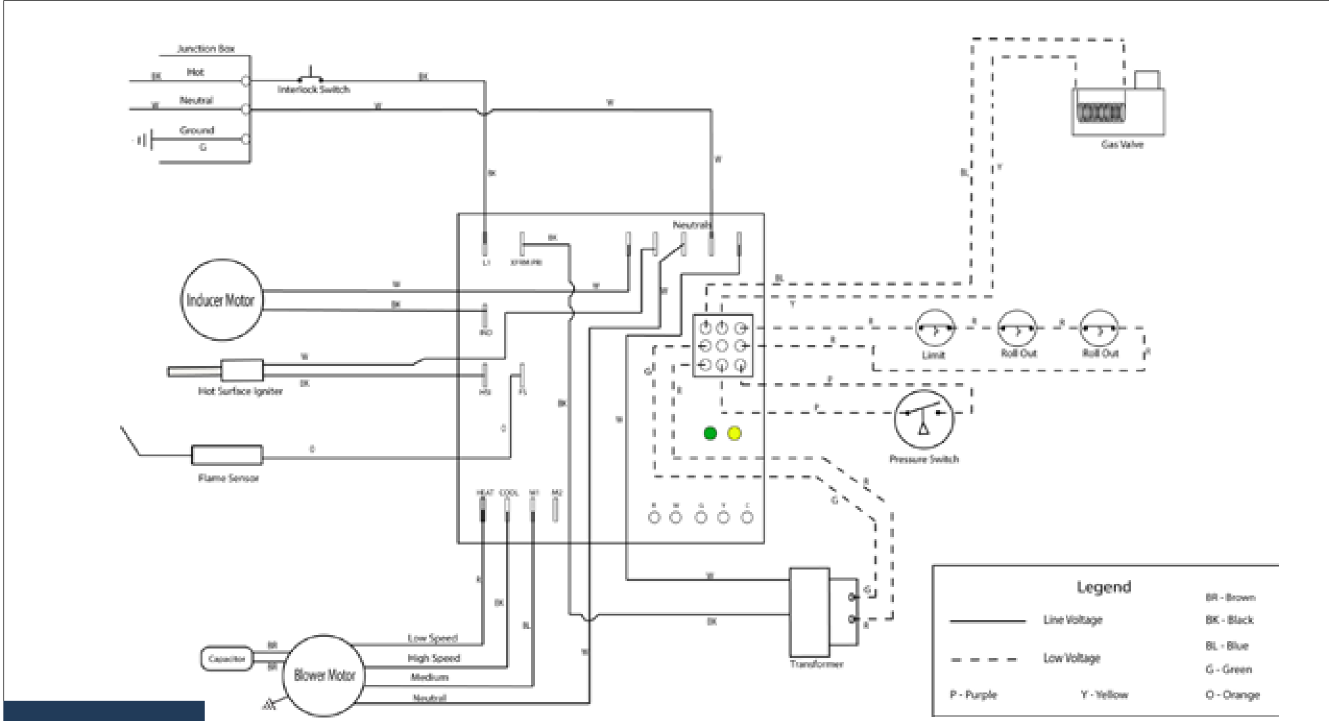

Figure 3

A connection diagram is a pictorial representation of the system components and how they are connected. It does not indicate the physical location of the components in the furnace, only their electrical connections. Connection diagrams do not typically use as many symbols as schematic diagrams. The legend indicates the type or look of the lines used on the diagram to indicate line voltage, low-voltage, or field connections. Figure 3 is an example of a connection diagram for a direct hot surface ignition furnace with an integrated furnace control.

Sequence of Operations

Every gas-burning appliance follows a specific sequence of operations which helps ensure safe ignition and operation. This article reviews continuous ignition, intermittent ignition, and direct ignition furnaces. It explains various ignition controls used for each type of ignition system and the wiring diagrams for each.

Continuous Ignition

A continuous ignition furnace (standing or constant pilot) has a pilot flame that must be lit manually. Once lit, the pilot stays on indefinitely, whether there is a call for heat or not. A transformer supplies a 24V control voltage to a thermostat which is used to control the system. Figures 4 and 5 should be referred to when reviewing the ignition sequence of a standing pilot furnace.

→When a thermostat initiates a call for heat, it sends a 24V signal to the furnace from the W terminal.

→The 24V signal travels through a series of normally closed safety switches, terminating at the gas valve. The safety switches may vary from one model to the next. A limit switch is standard on all units. Roll outs, a vent switch, or an auxiliary limit switch may be featured in different models.

→When the gas valve is energized, it opens, allowing a flow of gas to the burners which are ignited by the pilot.

→The combustion gases cause the heat exchanger to rise to a predetermined temperature. When this temperature is reached, a thermally actuated

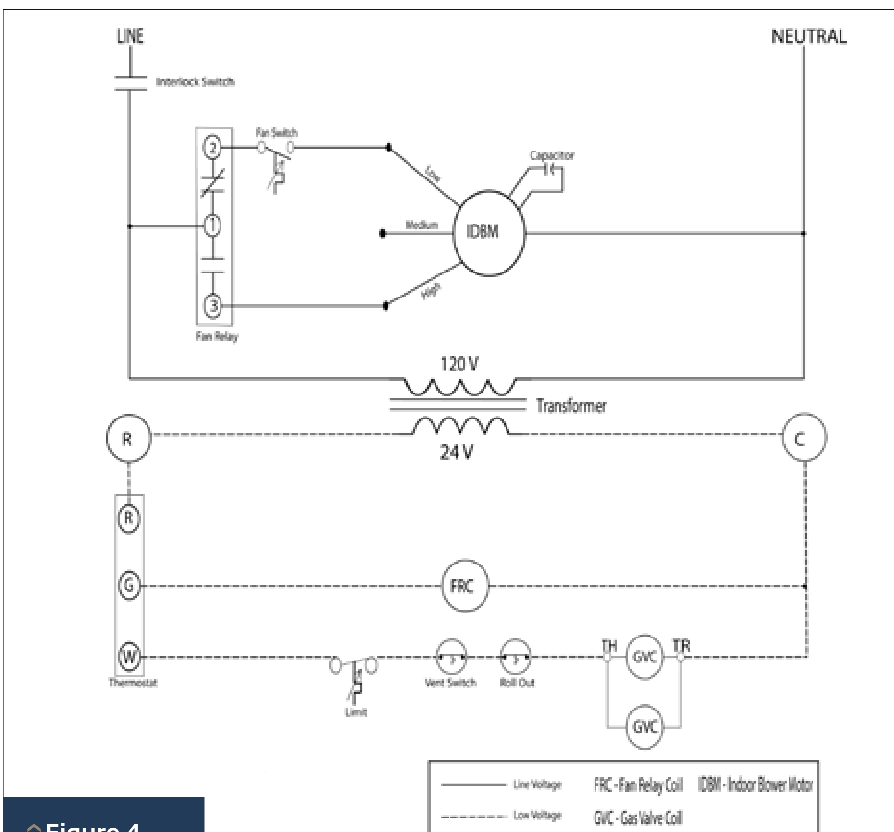

Figure 4

fan switch will close and energize the blower motor.

→When the thermostat is satisfied, the contacts open terminating the 24V signal to the furnace's gas valve. The gas valve closes, extinguishing the burner flame. However, the pilot light remains burning.

→The blower motor runs until the heat exchanger cools to a predetermined temperature and the fan switch opens de-energizing the blower motor.

Intermittent Ignition

Intermittent ignition furnaces will light a pilot with an electronic igniter each time there is a call for heat. Once the thermostat is satisfied, the main burners and pilot are both turned off. The two most common intermittent ignition systems are intermittent spark and intermittent hot surface igniter (HSI). These systems utilize non-integrated controls for burner function. Intermittent spark ignition systems use a spark from a transformer, rated between 7,500 -15,000 volts, to light the pilot which then ignites the main burners. Intermittent HSI systems usually use a small, 24V hot surface igniter to light a pilot.

Non-integrated controls are responsible for control aspects such as the burner function of a furnace or boiler. In an intermittent ignition system, they are responsible for lighting a pilot, sensing the pilot, de-activating the ignition device, and lighting the main burners. Some systems may incorporate two or more controls that work together to act as an integrated control system. While most non- integrated control modules follow the ignition sequences mentioned above, they may differ in other operational aspects such as: lockout control, retry procedure, and igniter timing sequence.

Lockout

The term lockout refers to a control's reaction to a flame detection failure. Depending on the design and programing of the control, the lockout can be a soft lockout or a hard lockout. In a soft lockout, the control closes the gas valve and, after a preprogramed time delay, will try to reignite the burner. If the flame fails again, a second soft lockout occurs. After the delay, a third attempt to ignite the burner takes place.

If the flame fails to ignite, the control initiates a hard lockout. A hard lockout will result in the complete shutdown of the control with no further attempts at ignition.The hard lockout requires the control to be reset (powered off and then back on) before another trial for ignition can proceed. The number of retries and length of the delays prior to hard lockout depends on the control's programing, which varies by manufacturer.

Continuous Retry

Modules can be programmed for a continuous trial for ignition. When the ignition sequence is initiated, the control will attempt to light the furnace, usually for 90 seconds. If ignition is not achieved, the module will close the gas valve and begin a delay, allowing any residual gas to be evacuated from the heat exchanger. After the delay, the control module will try for ignition again. It will continue until ignition is achieved or the call for heat has been terminated. This type of control is usually found in outdoor intermittent spark ignition furnaces.

Ignition Timing Sequence

Ignition timing varies greatly due to the different types of igniters and ignition modules in use today.

Typically, spark igniters are energized for 90 seconds or until ignition is achieved. Hot surface ignition modules will use 15, 30, or 45 second delays to allow for igniter warm up. The time allowed to detect ignition before a lockout or retry is initiated also varies. It is important to refer to the manufacturer's literature for the exact timing sequence.

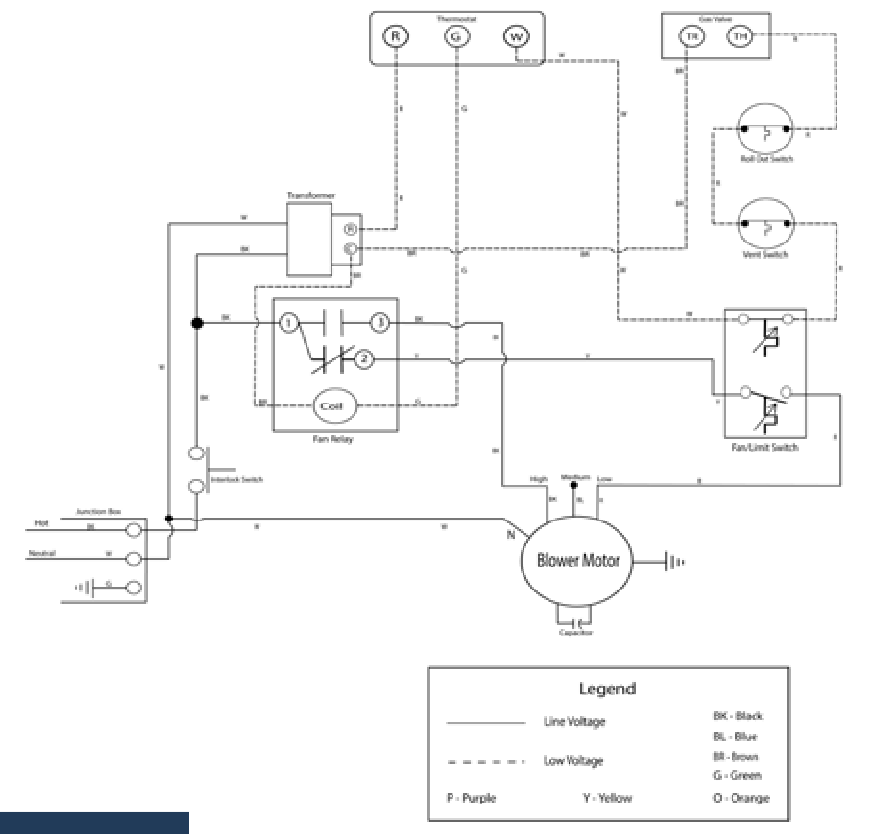

Figure 5

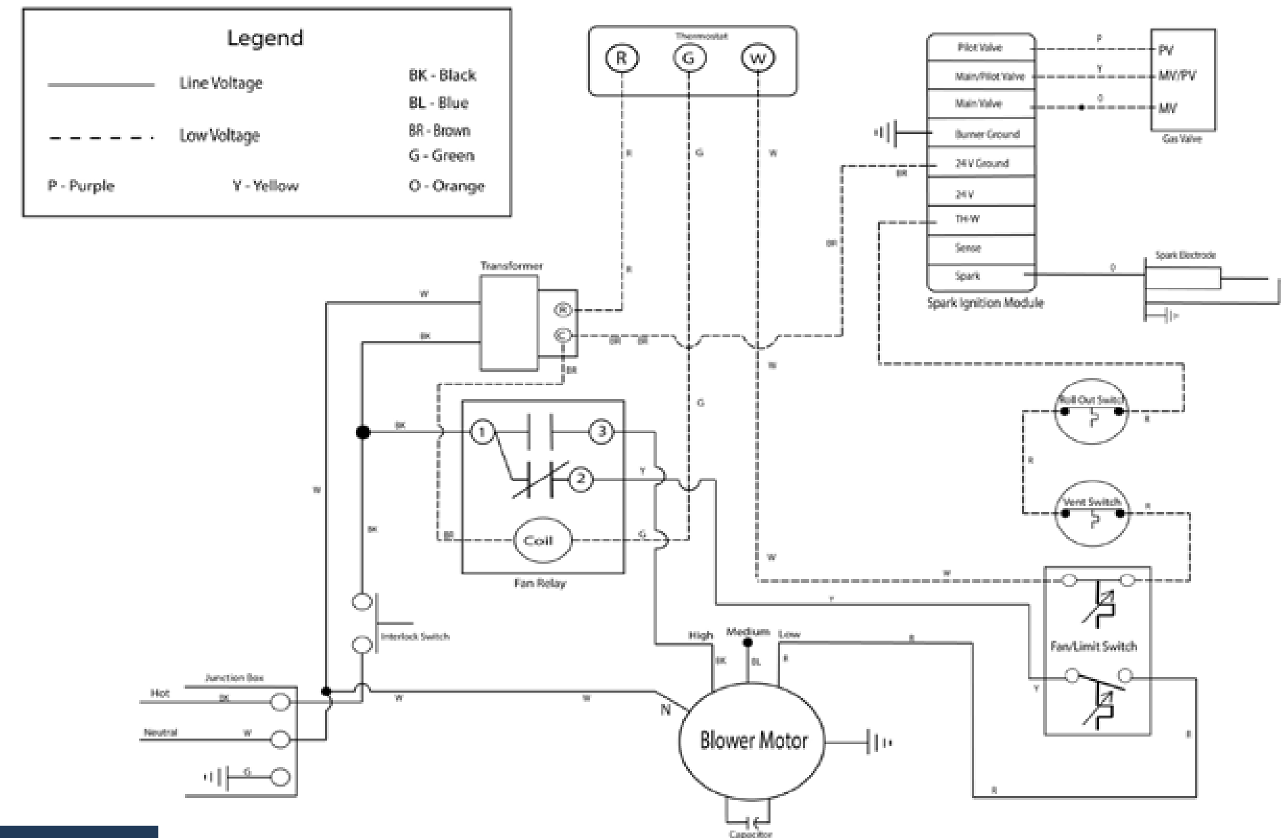

Figure 6

Non-integrated controls require a 24V input signal from the thermostat to initiate the ignition sequence. Refer to Figure 6 while reviewing the ignition sequence of these systems. A general ignition sequence for intermittent control modules is as follows:

→Lighting the pilot. A 24V signal is sent to the gas valve at its pilot valve terminals, typically PV (pilot valve) and MV/PV or C (common terminal), which triggers the flow of pilot gas. At the same time, voltage is sent to the igniter creating a spark to ignite the pilot.

→Sense the pilot, turn off the ignition source. Spark systems usually use the spark electrode as a flame sensing device. They monitor the flame current through a grounded wire connected to the burners. Some models may use a flame sensor to detect the flame. In all systems, it is the pilot flame being sensed, not the main burners. Once the pilot flame is sensed, the igniter is de-energized, and the ignition sequence continues.

→Lighting the main burners. Upon sensing the presence of a pilot flame, the control module will send a 24V signal to the gas valve terminals responsible for main burner operation, usually MV (main valve) and MV/PV or C (common terminal).

→Blower motor is energized. Once the heat exchanger reaches a predetermined temperature or time delay, the fan switch will energize the blower motor.

In some furnaces, two control modules function together to create an integrated control system. A non-integrated module handles the burner sequence allowing a separate control to handle the other furnace functions. The controls communicate with each other, with a 24V signal, to create a seamless ignition sequence.

These systems typically follow a combination of the sequences mentioned above with slight variations.

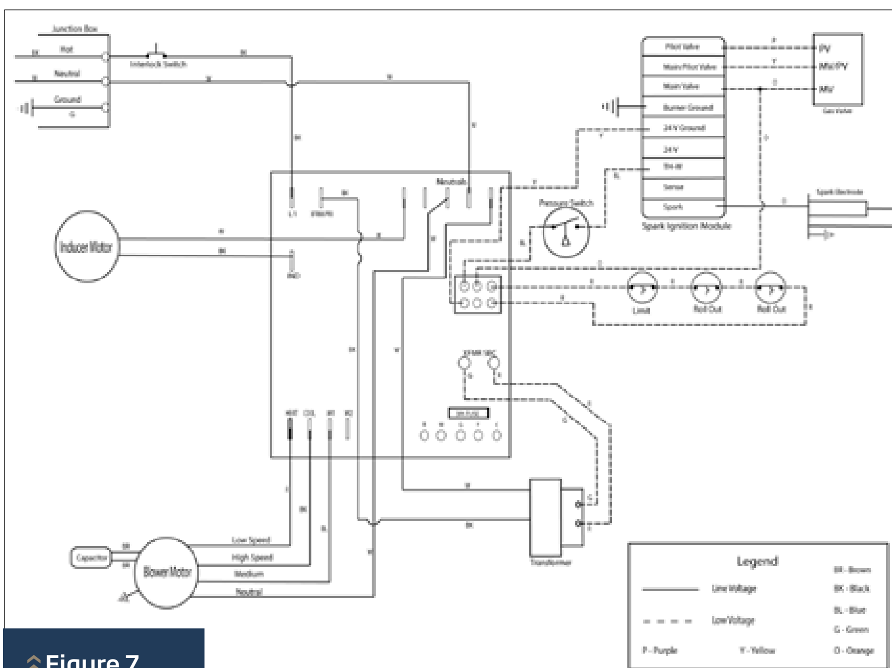

Figure 7

The most common of these ignition systems are intermittent spark ignition and intermittent hot surface ignition, sometimes referred to as a Smart Valve. The following is a typical ignition sequence for these systems, refer to Figures 7 and 8. For this text, the main control module will be referred to as the primary control and the igniter/gas valve control will be referred to as the secondary control.

→Thermostat calls for heat. The thermostat sends a 24V signal to the primary control module, usually to the W terminal on the control, to start the ignition sequence.

→Induced draft motor is energized. When the primary control receives an input from the thermostat, it will react by sending a 120V signal to the induced draft motor. The motor purges the heat exchangers of any residual flue gas from the previous cycle, called pre-purge, and creates a slight vacuum in the exchanger.

→Safety switch(es) verified. One or more, normally open, negative pressure, safety switches will close with suction or vacuum created by the induced draft motor. When the switch closes, it will send a 24V signal to the secondary control module indicating that it has closed, and the sequence can continue.

→Lighting the pilot. The secondary control sends a 24V signal to the gas valve at its pilot terminals, which triggers the flow of pilot gas. Simultaneously, voltage is sent to the spark igniter or 24V hot surface igniter. The hot surface igniter requires a warm up period before the pilot gas flows.

→Sensing the pilot, turn off the ignition source. Spark systems usually use the spark electrode as a flame sensing device. They monitor the flame current through a grounded wire connected to the burners. Some models may use a flame sensor to detect the flame. In all systems, it is the pilot flame being sensed, not the main burners. Once the pilot flame is proved, the igniter is de-energized, and the ignition sequence continues.

→Lighting the main burners. Once the pilot has been established, the control module will send a 24V signal to the gas valve terminals responsible for main burner operation. At the same time, a 24V signal is sent back to the primary module to initiate the blower on delay.

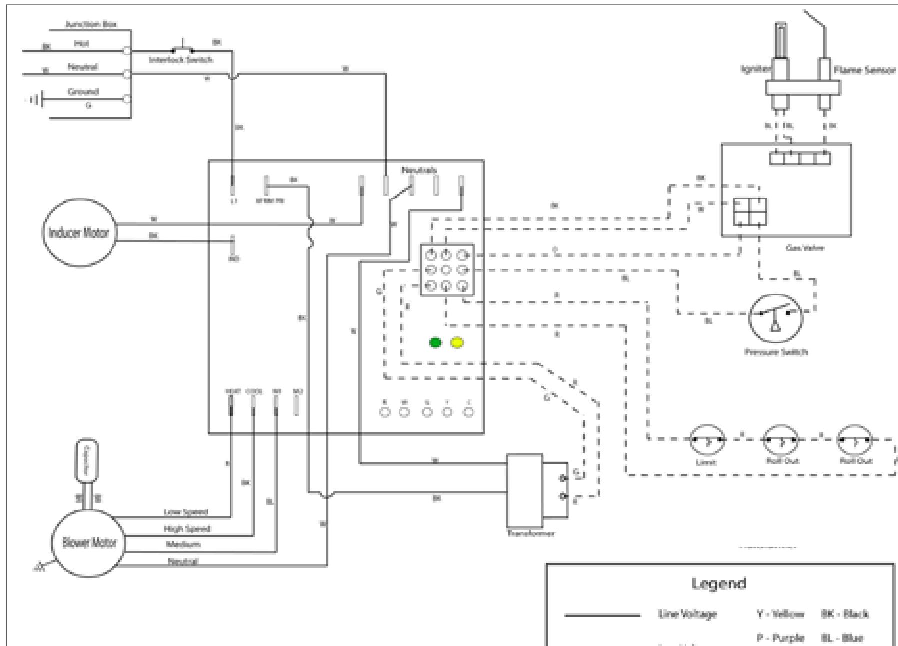

Figure 8

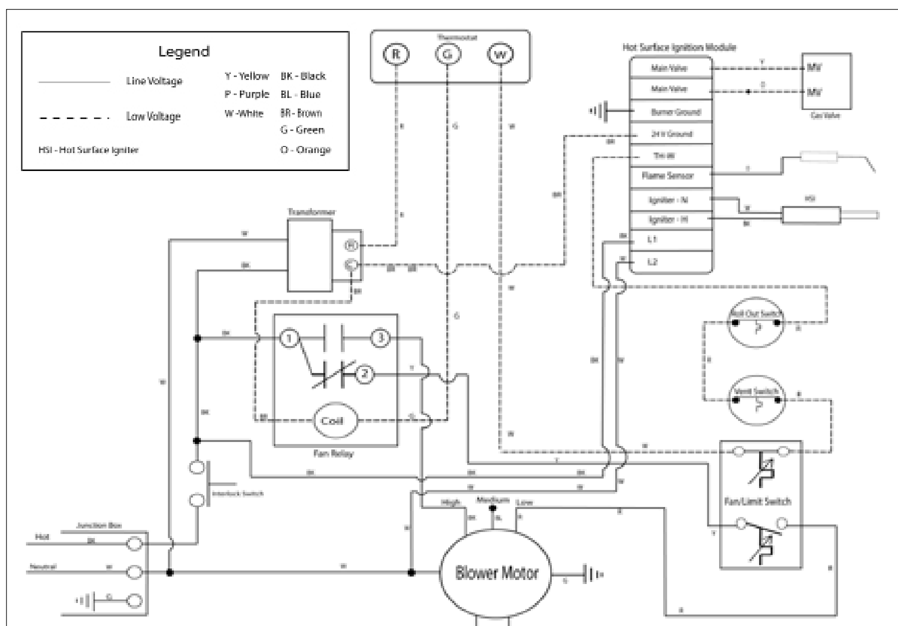

Figure 9

→Blower motor is energized. Once the primary module receives the 24V signal, a timer is started that allows time for the heat exchanger to heat up, referred to as blower on delay. Once the delay time is reached, the primary module will send a 120V signal to energize the blower motor.

In either system, when the call for heat is satisfied, the blower off delay begins. The blower motor continues to run to clear the heat exchanger of any remaining heat and circulate it into the space being heated. The module may contain small DIP switches or a jumper for adjusting the fan delays.

Direct Ignition

Direct ignition furnaces utilize an electronic igniter, spark or hot surface, to ignite the main burners. There is no pilot flame in the ignition sequence. They also have a flame sensor that is used to prove burner ignition. Direct ignition systems can incorporate either non-integrated or integrated controls.

Non-integrated controls in direct ignition systems are primarily hot surface ignition, although they could also

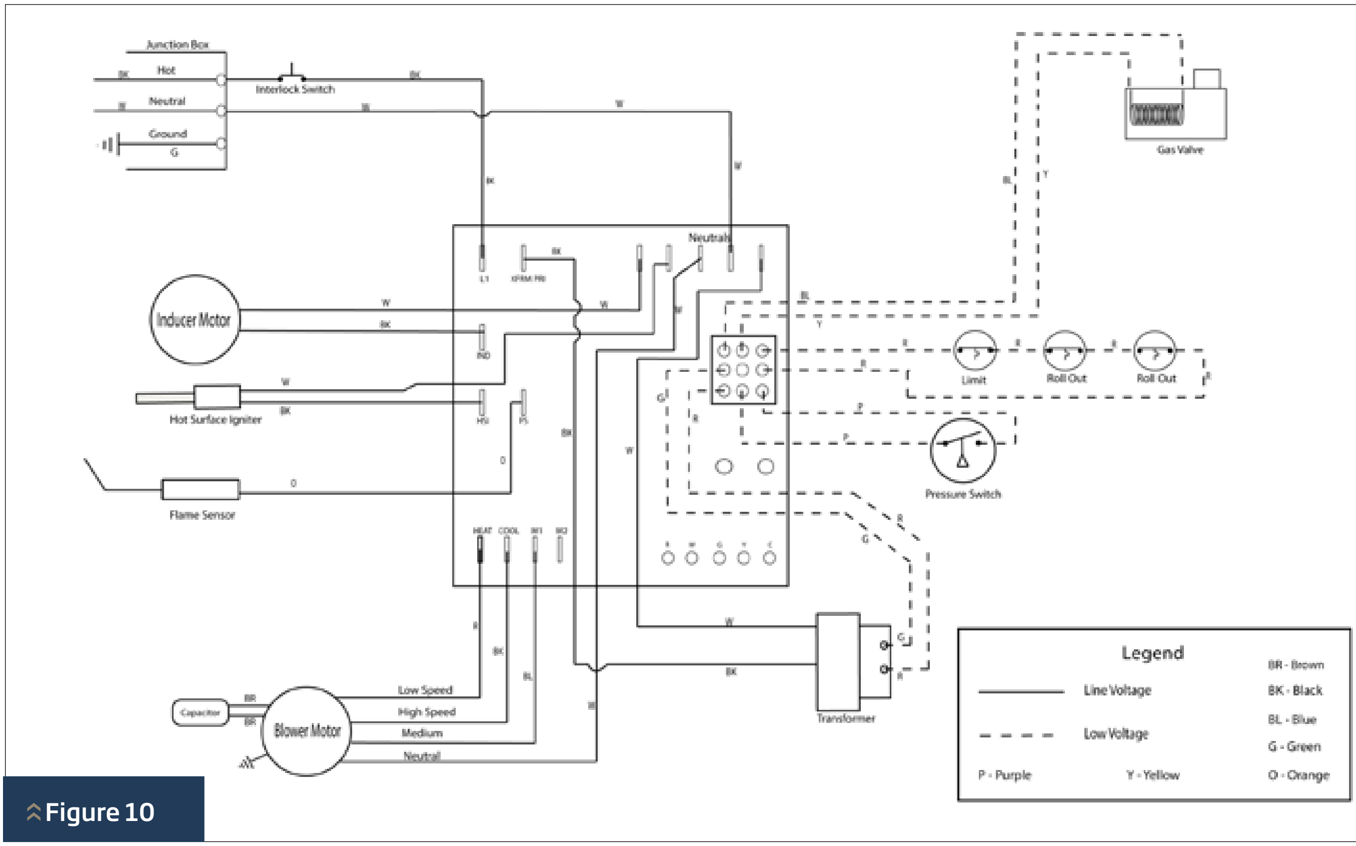

Figure 10

be direct spark ignition. The following is a typical ignition sequence for a direct, hot surface, ignition system, Figure 9, using a non-integrated control module.

→Energize the igniter. The control module will send voltage to the igniter, normally a 120V hot surface igniter.

→Turning on the gas to the burners. After a preprogrammed delay to allow for the igniter to reach ignition temperature, a 24V signal is sent to the gas valve allowing a flow of gas to the main burner.

→Sensing the flame, turn off the igniter. Upon ignition, a flame sensor relays a signal in (DC) Microamps to the control module. The module will then de-energize the igniter and continue the flow of gas.

→Blower motor is energized. When the heat exchanger reaches a predetermined temperature, the fan switch will close energizing the blower motor.

Integrated control modules are used to control all the components in the furnace or boiler. They are circuit boards programmed by the manufacturer to perform all the functions required of the furnace. All the electrical components are connected to the control module through a series of plugs, harnesses, and electrical connectors. At first glance, these circuit boards seem complicated due to the number of wires and components used. A schematic is vital to understanding the wiring and operation of the furnace.

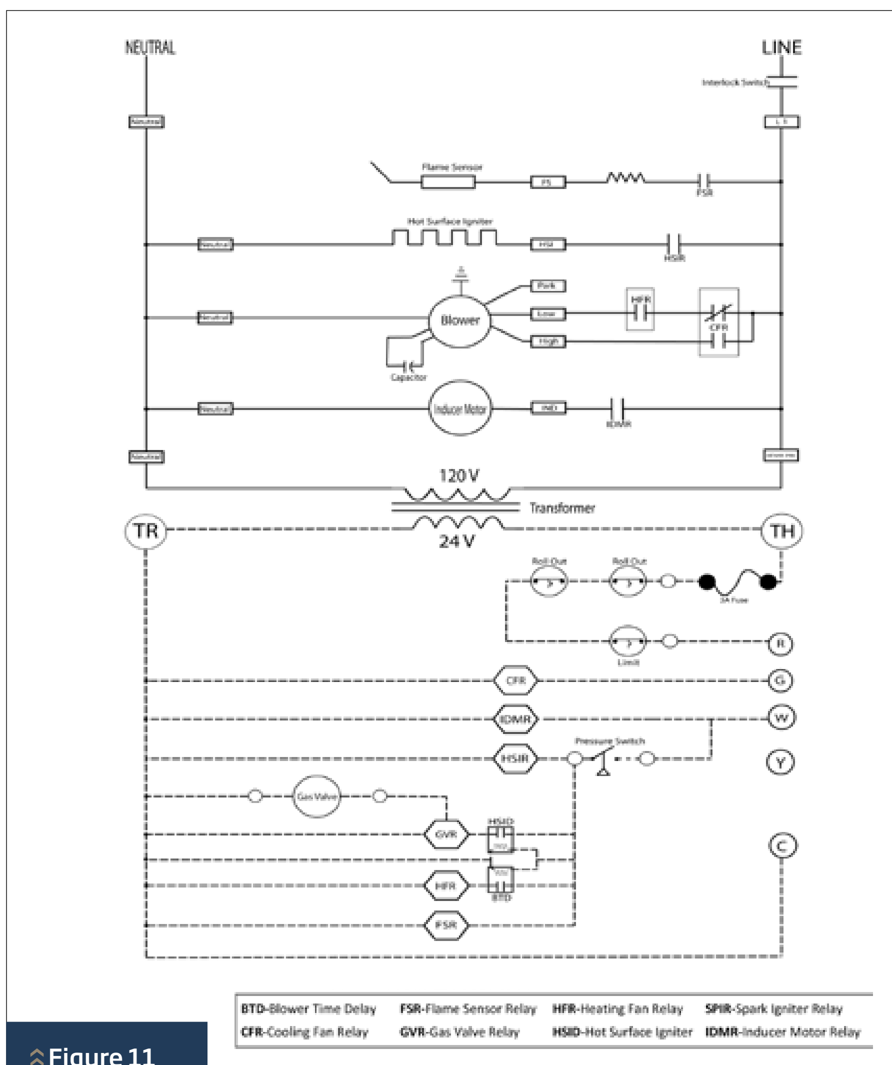

Figure 11

Integrated furnace controls (IFCs) rely on a series of inputs throughout the ignition sequence to turn components on or off. These types of controls may incorporate safety circuits that are constantly being monitored by the IFC and may not be a part of the ignition sequence. An open safety circuit would prevent the control from initiating the ignition sequence and may also turn on the furnace blower motor, induced draft motor, or both.

Direct spark ignition and direct hot surface ignition systems commonly incorporate integrated control modules. These modules are not interchangeable from one ignition system to another because they are engineered and programmed for a specific furnace. The best source of information on a specific control module's ignition sequence is the manufacturer's literature.

The following is a typical sequence of operations for these types of systems using an integrated furnace control, Figures 10 through 13:

→Thermostat calls for heat. The thermostat sends a 24V signal to the control module, to the W terminal on the control, to start the ignition sequence.

→Induced draft motor is energized. When the control receives the input from the thermostat, it will react by sending a 120V signal to the induced draft motor. The motor purges the heat exchangers of any residual flue gas from the previous cycle. This pre-purge cycle creates a slight vacuum in the exchangers.

→Safety switch(es) verified. A normally open negative pressure safety switch, or switches, will close with the vacuum created by the induced draft motor. When the switch closes, it will send a 24V signal back to the control module indicating that it has closed, and that the sequence can continue.

→Igniter is energized. Receiving a signal from the negative pressure switch, the control will send a 120V signal to a hot surface igniter, or high voltage to a spark igniter. In hot surface ignition models, a timer is started to allow time for the igniter to achieve ignition temperature. Delay times vary from one model to the next. Refer to the manufacturer's literature for additional information.

→Gas valve is energized. After the igniter is energized, the module will send a 24V signal to the gas valve to allow a flow of gas to the burner. During this step, the ignition control allows a brief period, typically four seconds, for a flame sensor to detect ignition using a (DC) microamp signal. If the flame is detected, the module will de-energize the igniter and continue the sequence. If a flame is not detected, it will start the process all over, after a delay, to allow any residual gas to be evacuated. After a predetermined number of unsuccessful tries, the control will go into a lockout.

→Blower motor is energized. Once a flame is detected, a timer is started that allows time for the heat exchanger to warm up, referred to as blower on delay. Once the delay time is reached, the module will send a 120V signal to the blower motor.

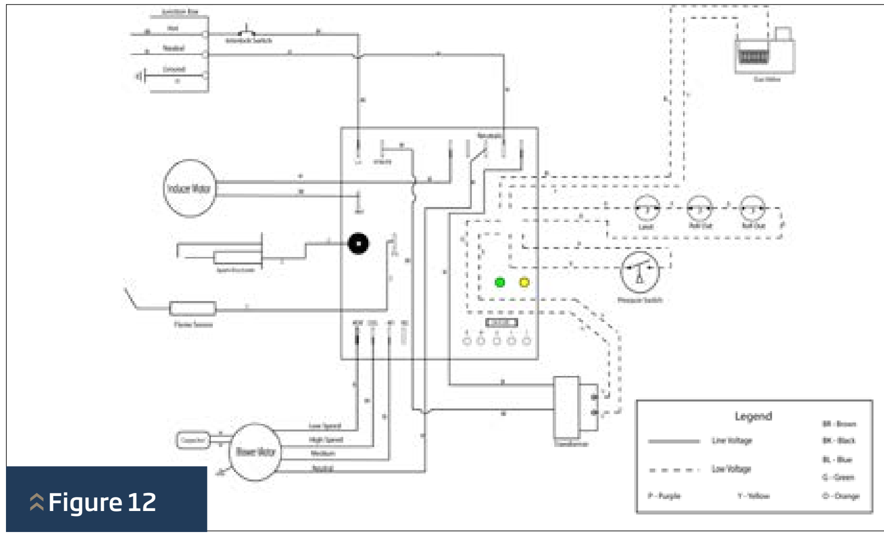

Figure 12

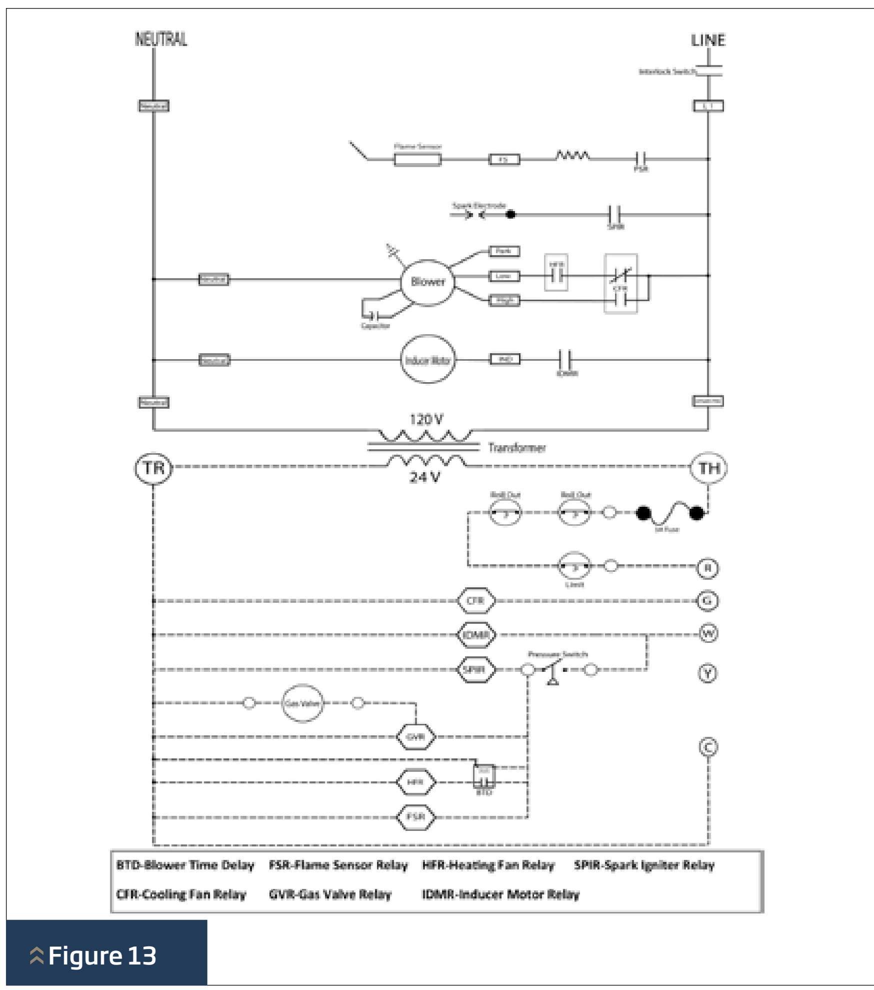

Figure 13

This article is excerpted from the book Gas Heating: Furnaces, Boilers, Controls and Components. *The primary author is Jason Obrzut, CMHE, from ESCO Institute, and four additional contributing authors.*