CSA Unit 13 : Controls

Chapter 1
Fundamentals of Controls

A gas technician/fitter regularly encounters numerous types of controls. The fundamentals of operating these controls are also numerous. Knowing how controls work, where they are applied, and how they interact with other controls is important to understanding overall systems.

MK Created by Mike Kapin

Purpose and Objectives

Purpose

A gas technician/fitter regularly encounters numerous types of controls. The fundamentals of operating these controls are also numerous. Knowing how controls work, where they are applied, and how they interact with other controls is important to understanding overall systems.

Objectives

At the end of this chapter, you will be able to:

- describe control concepts and components
- explain the basic control system
- describe operating controllers
- describe electronic sensors and operating controllers
- describe electronic control concepts
- describe limit and safety controllers
- describe combustion and safety controls
- describe ignition control modules
- describe integrated appliance control modules
- describe building management systems and communication protocols
- describe valves and regulators

Terminology in Gas Controls

Algorithm

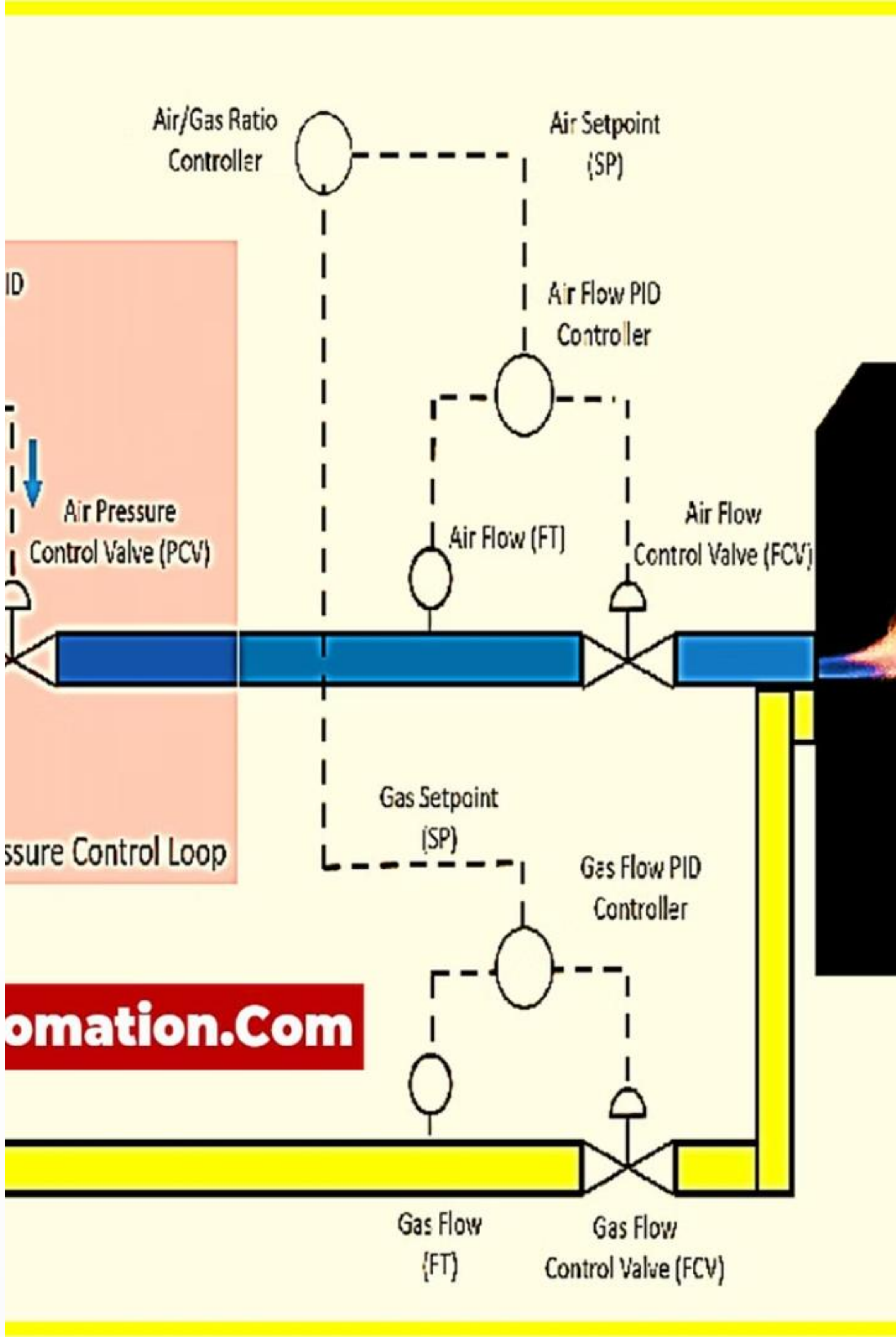
A set of electronic instructions pre-programmed into the microprocessor of an electronic controller. The microprocessor uses the algorithm to perform calculations with converted digital data received from system sensors.

Analogue signal

Has an arrangement of values, which could be measuring temperature, pressure, humidity, flow, light levels, etc., over any given time period.

Digital signal

One of two values they are also called binary, as their information consists of nothing but zeroes and ones. Examples include open/closed, start/stop, on/off, yes/no.



More Control System Terminology

Building management system (BMS/BAS/EMS)

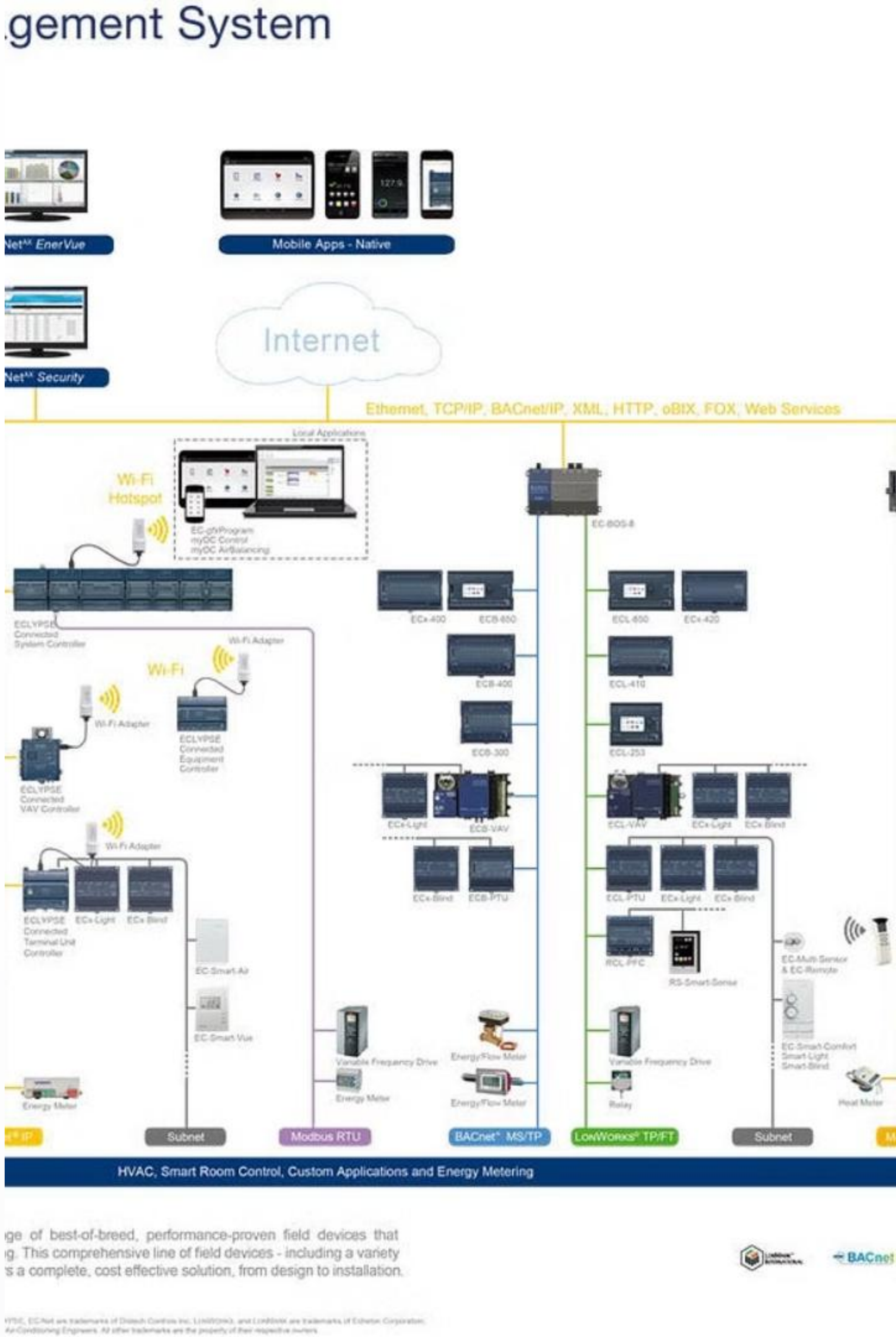
The main building HVAC and energy control system designed to maximize energy performance as well as provide an optimal environment to the occupants in the area. The BMS uses a main network to connect to multiple areas or system controllers.

Direct digital control (DDC)

A term used in building automation for the concept of reading sensor data, processing the data in the digital domain, and controlling heating, ventilation, and air conditioning (HVAC) equipment. A DDC controller converts analogue signals to digital and back as needed.

Dual in-line package switch (DIP switch)

A manual electric switch that is packaged with others in a group.



Flame Control Terminology

1. **Flame failure response time**

   The time it takes for the flame sensor circuits to react to a flame failure and de-energize the main gas valve.

2. **Flame safeguard control (FSG)**

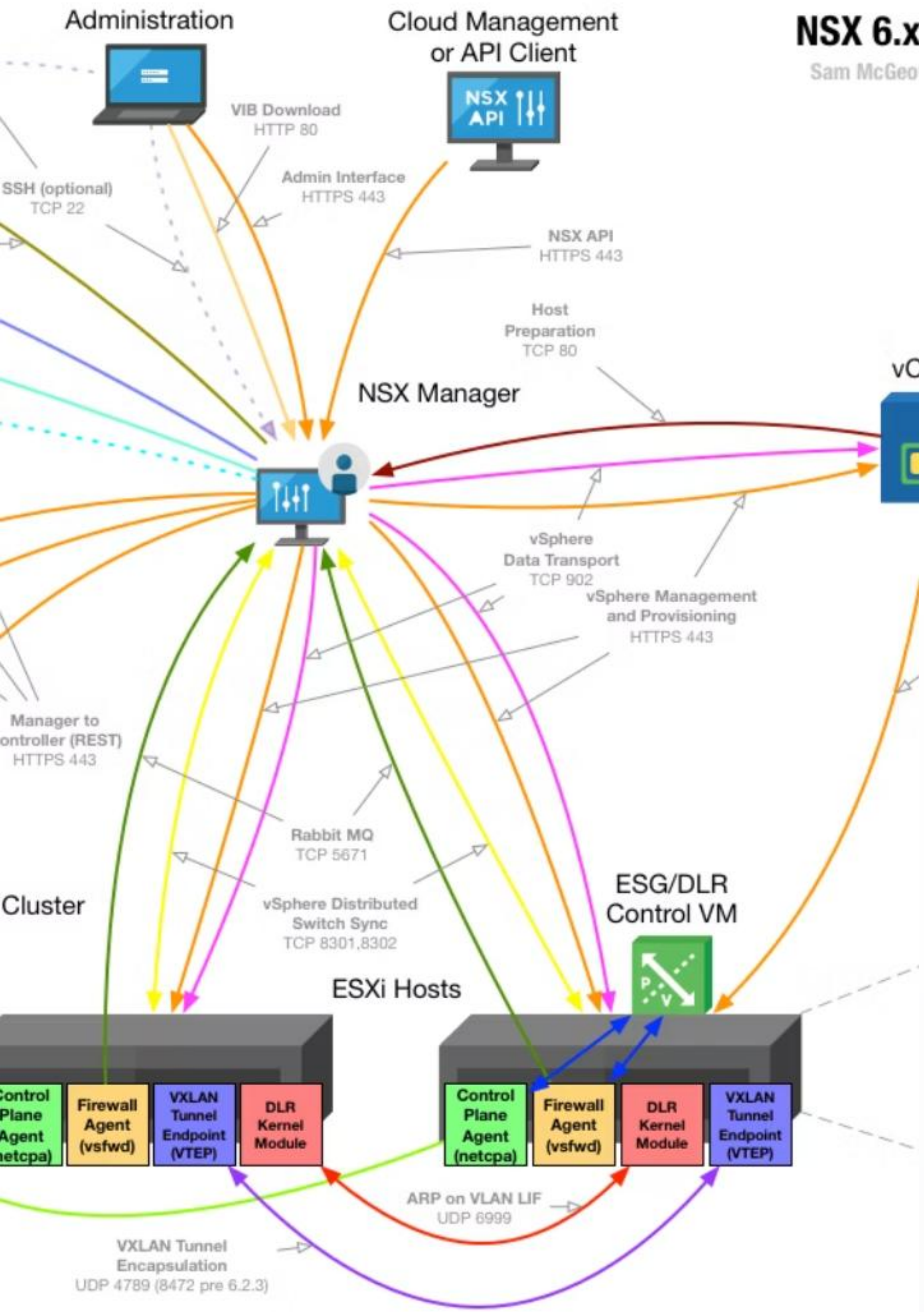
   The central controller over the safe supply of gas and air to the burner(s).

3. **Trial for ignition**

   The period of time allowed to establish ignition. For modules that are part of a 100% safe system, the trial for ignition period is stated on the module.

4. **Lockout**

   The expiration of the ignition time with a control module, which then requires a manual reset to restart the ignition sequence.



Network and Communication Terminology

Input/Output (I/O)

Commonly used to refer to the different signals or control points connected to the controller. The reference to I/O lets an installer know there are field connections required.

Local area network (LAN)

A network that interconnects computers within a limited area such as a residence, school, laboratory, university campus, and office building.

Local operating network (LON)

A networking platform specifically created to address the needs of control applications, built on a protocol for networking devices over media.

Network protocols

A set of rules and conventions for communication between network devices. Standardized network protocols provide a common language for network devices.

Wireless Communication Terminology

Wireless communication

The transfer of information or power between two or more points using radio waves.

Wide-area network (WAN)

Any telecommunications network or computer network that extends over a large geographical distance.

Wireless local area network (WLAN)

A computer network that links two or more devices over a short distance using a wireless distribution method.

Wireless personal area network (WPAN)

A PAN carried over a low-powered, short distance wireless network technology.

Control Concepts: Thermal Expansion of Solids

Principles of Thermal Expansion

Control systems used in the gas industry use the physical characteristics of solids, liquids, and gases to expand and contract and to conduct or resist electricity as a means of regulating the burner system. For example, physical characteristics associated with the expansion of solids and liquids, electromagnetism, the thermoelectric effect, and electricity are all used in varying capacities.

Metals expand when heated and contract when cooled. The principle of the thermal expansion of solids is used for several control devices that regulate temperature change.

Temperature Disc

The temperature snap disc (Klixon®) responds to temperature changes by moving from a concave to convex shape, touching electrical contacts and completing a circuit. The temperature disc can be used in the thermal relay.

Bimetallic Strip Operation

How Bimetallic Strips Work

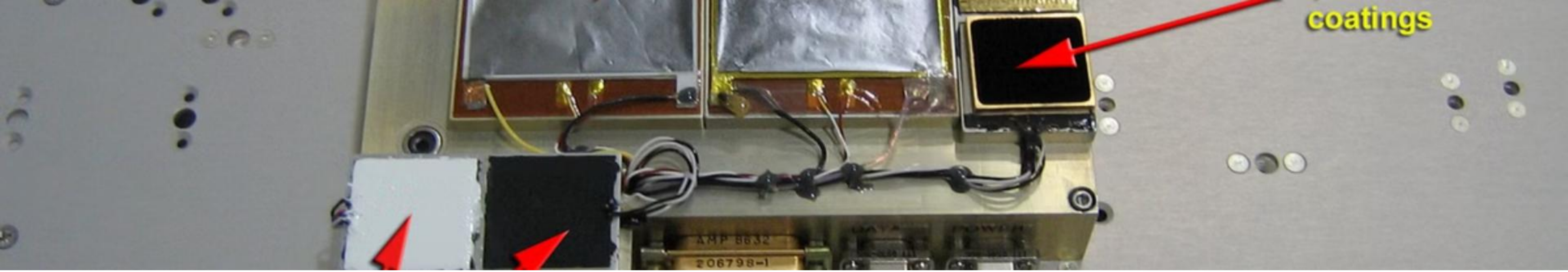
The bimetallic strip operates on the fact that not all metals expand at the same rate. This device uses the warping action created when two dissimilar metals having different coefficients of expansion are welded together at one end and exposed to temperature change.

Movement Mechanism

Since one end of the bimetallic strip is anchored solidly, the free end moves up or down with an increase or decrease in temperature. The resulting curling or bending is used to control the opening or closing of electrical contacts.

Applications

The functions of the bimetallic strip can be tied in with a change in voltage by wrapping a heat resistive wire around the strip. When voltage is applied, the current drawn by the wire will create heat, causing the bimetal to warp and open/close electrical contacts.



Rod and Tube Control Device

Construction

The rod and tube control device works on the principle that some metals expand more quickly than others. The sensing portion is constructed of copper tube that has a high expansion/contraction rate.

Components

The copper tube encases an invar rod, a metal alloy with a low expansion/contraction rate. The invar rod and copper tube are welded together at the far end.

Operation

The expansion and contraction of the copper tube effectively moves the invar rod back and forth, opening and closing a switch.

Thermal Expansion of Liquids

Liquid Expansion Principle

Like solids, liquids expand when heated and contract when cooled. When liquid is sealed in a narrow tube (called a capillary), the force created by the liquid expanding within the capillary is used to operate an electrical switch or control mechanism.

Sealed Bellows

In the sealed bellows control device, liquid inside a bulb at one end of the capillary tube senses the temperature of the surrounding atmosphere and expands or contracts. At the other end of the capillary tube an attached bellows reacts to the pressure within the capillary by expanding or contracting.

Applications

The action of the bellows is used to operate a switching device completing or interrupting an electrical circuit, or a mechanism that controls the gas valve outlet modulating the gas supply to the main burner.

Liquid Fill Types for Sealed Bellows

Fluid Fill

Sealed bellows used to operate thermostats may have a temperature limit of 650°F (343°C) and usually contain a fluid similar to a light oil. The expansion or contraction of this type of fill is quite linear and gives a smooth operation of the thermostat.

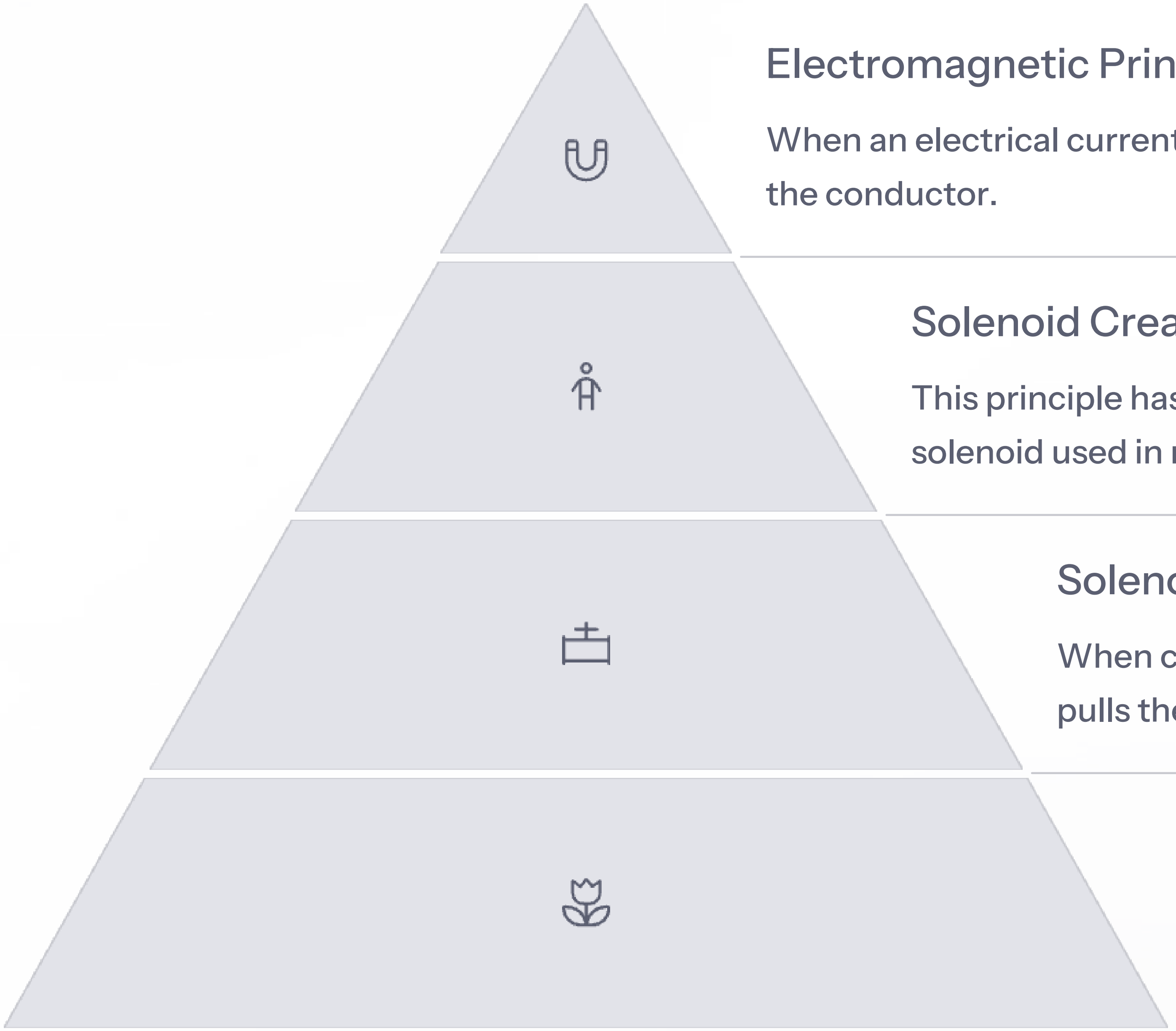
Always check the manufacturer's specification for recommended temperature and pressure limits.

Mercury

For high temperatures, such as 3000°F (1648°C) reached in pilot safety controls, the bulb must be filled with mercury. The expansion of the mercury is smooth up to approximately 650°F (343°C), at which point the mercury vaporizes (boils).

With vapourization, a rapid expansion takes place, giving the control "snap action". Similarly, upon cooling, there is a rapid contraction as the vapour condenses to a liquid.

Electro-magnetism in Controls



Electromagnetic Principle

When an electrical current is passed through a metal rod (conductor), a magnetic field surrounds the conductor.

Solenoid Creation

This principle has been used in creating the electromagnet, which forms the basis for the solenoid used in many control devices.

Solenoid Operation

When current runs through the solenoid coil, it creates a magnetic force that pulls the armature into the center of the coil.

Return Mechanism

When the circuit is opened, the magnetic field dies, and the armature returns to its original position, often with the assistance of a spring.

Thermoelectric Effect

Thermoelectric Principle

The thermoelectric effect of producing electricity by heat is used for the thermocouple and thermopile.

Thermocouple Construction

A thermocouple consists of a bimetallic strip joined at one end (called the hot junction).

Voltage Generation

When the hot junction is heated, a direct current (DC) voltage is generated across to the other two ends of the strips (the cold junction).

The thermocouple is used to prove the pilot flame. If it goes out, the thermocouple prevents the main gas valve from opening. The magnitude of the voltage across to the cold junction depends on the two materials of the bimetallic strip and the temperature difference between the hot and cold junctions.

Thermocouple Output and Applications

Thermocouple Output

The output of a single thermocouple is very small - 20 to 30 millivolts (mV) [1000 mV = 1 volt (V)].

Thermopile Creation

Placing a number of single thermocouples in series electrically can create a device known as a thermopile, which generates hundreds of millivolts.

Flame Proving

The thermocouple is used to prove the pilot flame. If it goes out, the thermocouple prevents the main gas valve from opening.

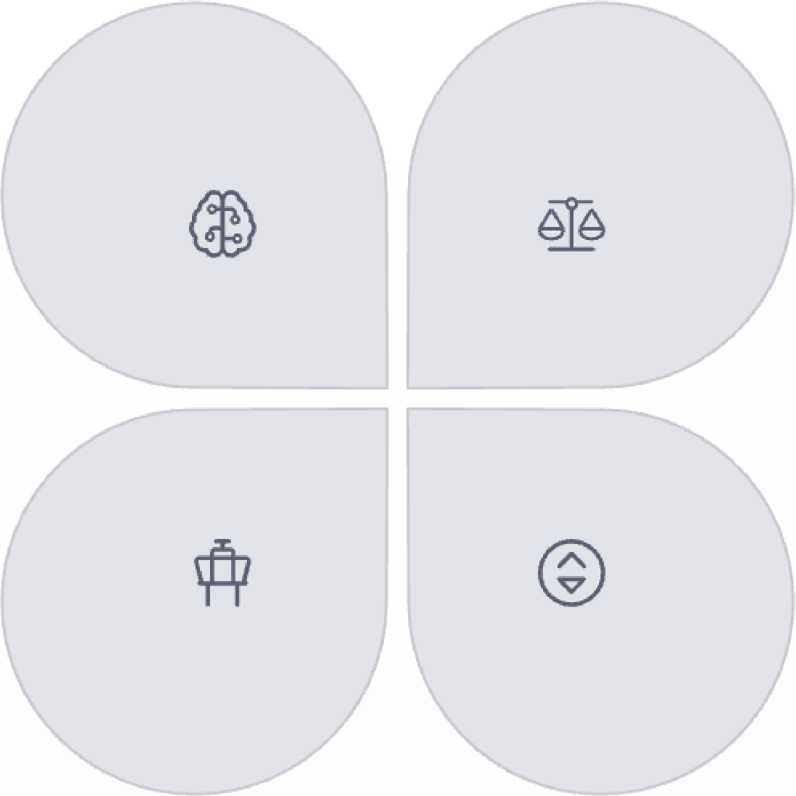
Wheatstone Bridge Principle

Circuit Principle

Electrical circuitry has used resistors (R) in many applications to control the flow of current in systems for many years.

Balance State

When the ratio of R1 to R2 is the same as the ratio of R3 to R4, the circuit is in balance (i.e., there is no current flow between A and B).



Control Function

The circuit remains energized until the resistance of the sensor (R4) changes sufficiently to rebalance the ratio between R1/R2 and R3/R4.

Thermostat Application

Used in some electronic thermostat controls for water heaters. When the thermostat dial (R3) is set to a given temperature, an imbalance occurs, allowing current to flow.

Semiconductors and Solid-State Electronics

Solid-State Devices

Solid-state electronic devices are made up of solid components that do not move. Semiconductors are the materials used to make the electronic components used in solid-state circuitry.

Electronic controls, as they are most commonly referred to, are now replacing most electromechanical controls. Electronic controls have led to more accurate, compact, flexible, and, in many cases, less expensive controls.

Integrated Circuit Boards

Most semiconductor devices are used to create the control circuits that are found embedded within the integrated circuit boards of the appliance. These circuit boards or controllers may have hundreds of electronic components, and they would typically be repaired by replacing the complete controller.

Transistors

Function

A transistor is a semiconductor device used for switching or amplifying signals and electrical power.

Operation

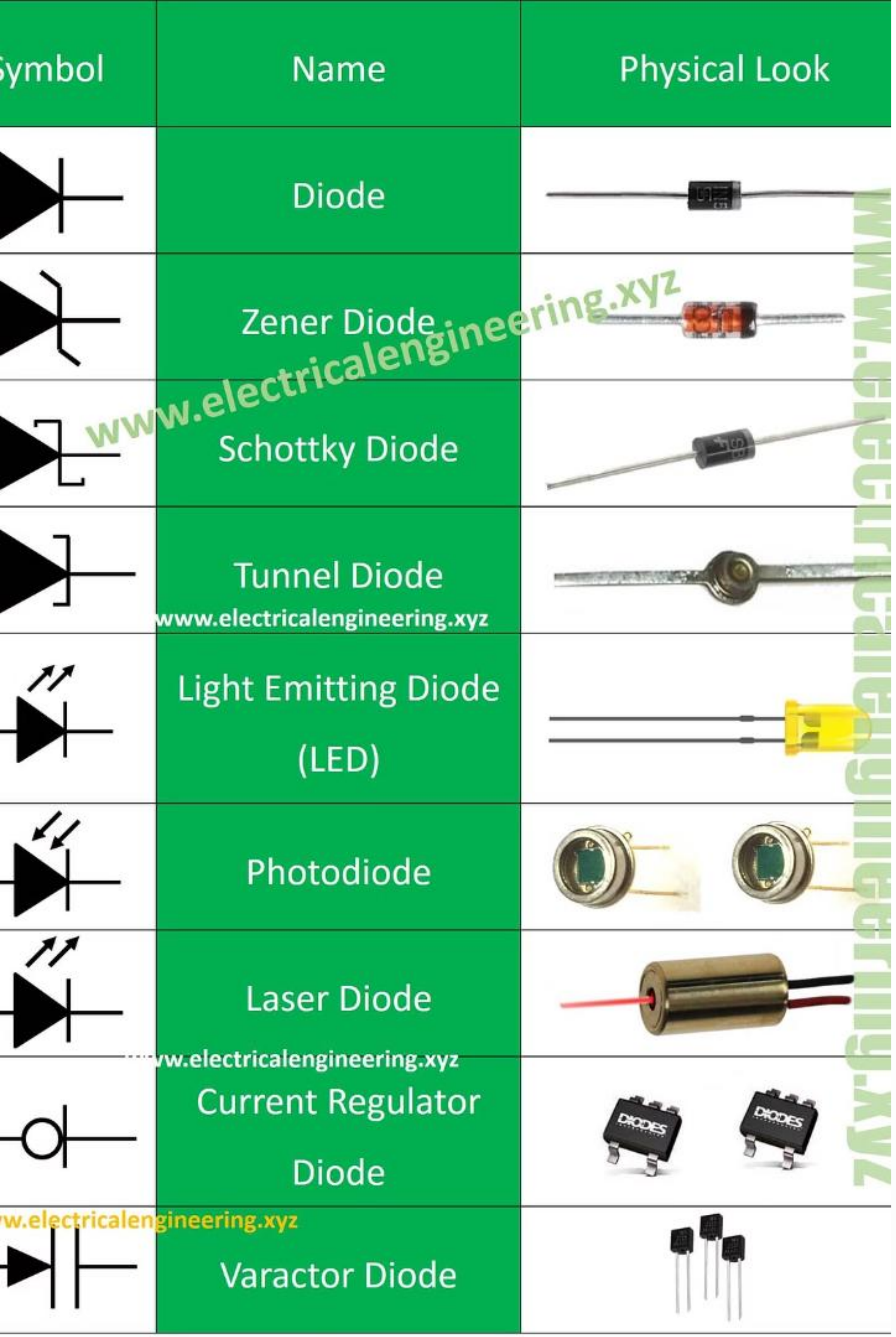
When a small amount of voltage is applied to the Base (B), it allows current to flow from the collector (C) to the emitter (E).

Amplification

The transistor is also what makes amplifiers work. Instead of being simply on or off, it can also be anywhere in between.

Control Capability

The circuit applied to the base can control how big a portion of the main current is going to flow through, thereby amplifying a signal.



Diodes

Function

Semiconductor materials are used to make diodes. The diode allows the passage of current in only one direction (forward biased, anode to cathode).

Applications

This device is used for various purposes such as a switch within control modules, the light-emitting diode, and photodiodes.

Circuit Integration

Diodes are fundamental components in electronic control circuits, providing one-way gates for electrical current.

Thyristors

Thyristor Basics

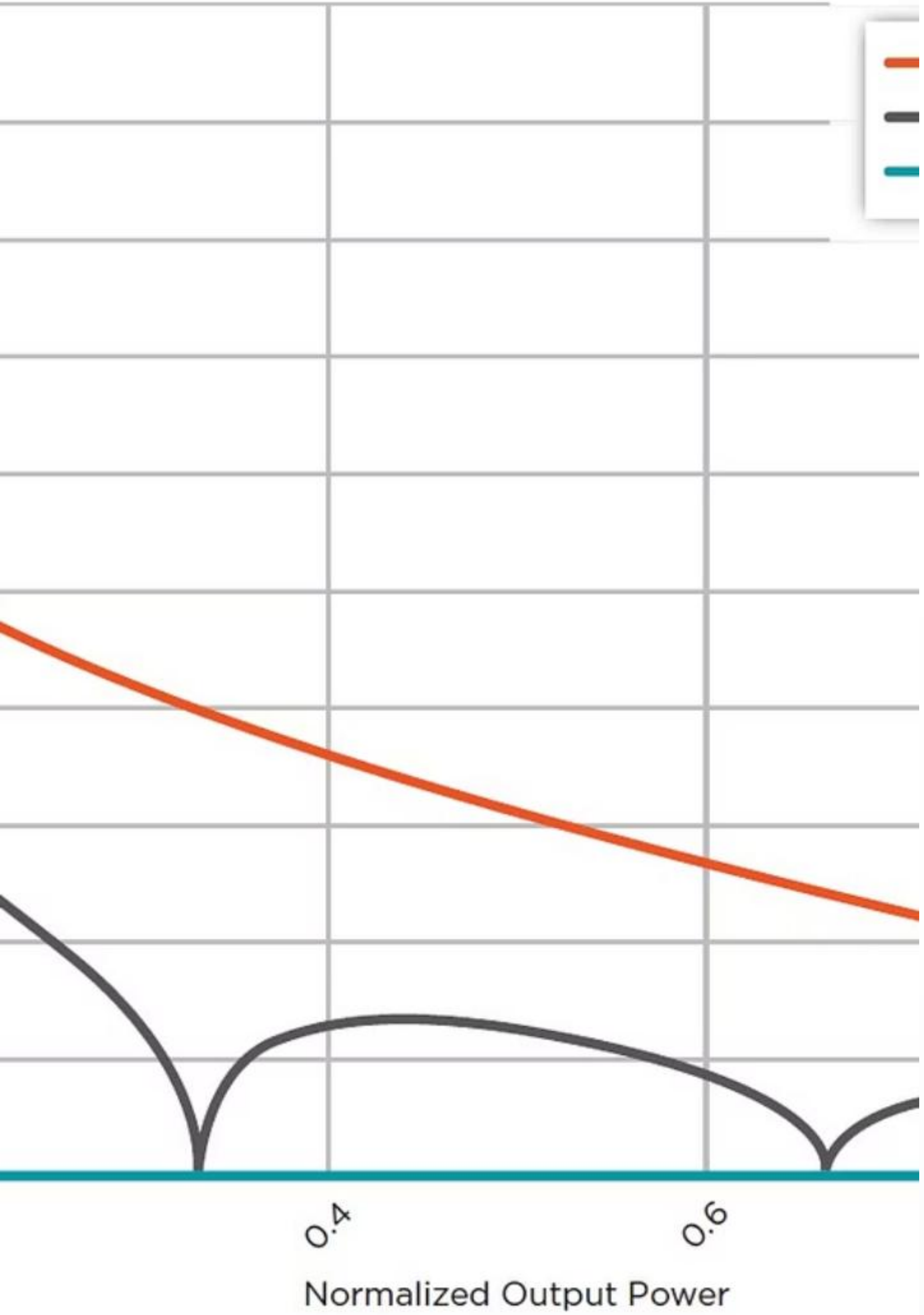
Thyristors are like diodes with additional layers of semiconductor materials and additional control terminals. Initially, thyristors block current until a separate control current activates them.

Comparison to Transistors

Similar to a transistor, the thyristor is ideal as an electronic relay in that a small voltage induced current can control a much larger voltage and current. A thyristor is different from a transistor as it only needs a pulse signal to make it conduct and, thereafter, remains conducting.

Types of Thyristors

The three basic types of thyristors are: SCRs (silicon-controlled rectifiers), DIACs (diode for alternating current), and TRIACs (triode for alternating current).



SCR (Silicon-Controlled Rectifier)

SCR Definition

The term is an acronym for silicon-controlled rectifier. In the off state, the SCR is blocking current in both directions until it receives trigger current at the gate terminal.

Triggering

Once triggered, the SCR will then allow only forward biased flow until it turns off.

Applications

SCRs are commonly used in power control applications where precise switching of high currents is required.

TRIAC (Triode for Alternating Current)

TRIAC Operation

The TRIAC operates like the SCR, but can conduct current in both directions when triggered. The term is an acronym for triode for alternating current.

Bidirectional Capability

Its bidirectionality makes it convenient for use as electronic relays in AC applications.

TRIACs are commonly used in light dimmers, speed controls for electric motors, and other applications where control of alternating current is needed.

DIAC (Diode for Alternating Current)

2

DIAC Definition

DIAC is another member of the thyristor family. The term is an acronym for diode for alternating current.

Initial State

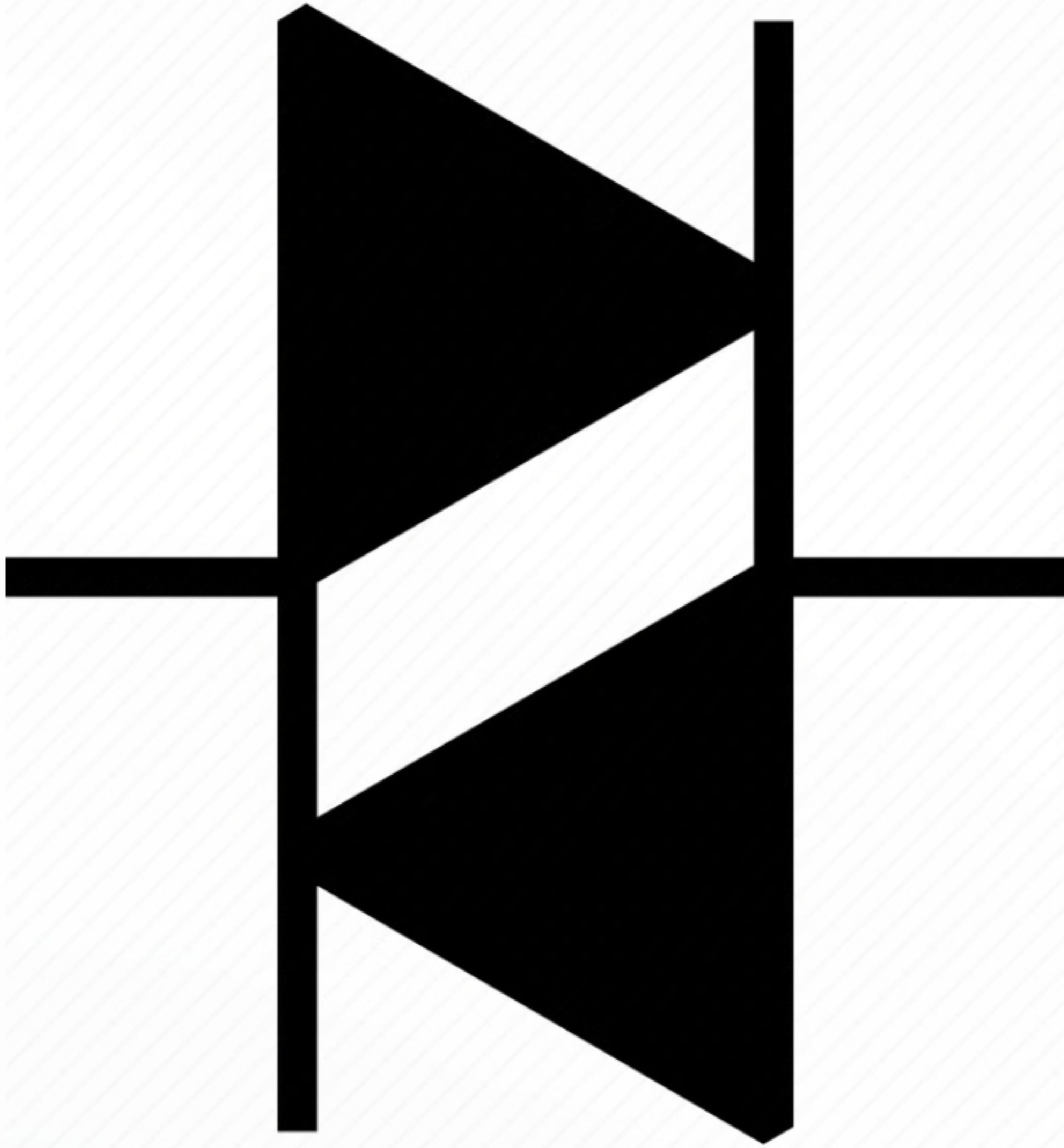
Initially, a DIAC is in a high resistance non-conducting state.

Activation

Bidirectional current is triggered once a high enough voltage (breakover voltage) is applied across the two terminals.

Operation

DIACs have no gate electrode as they are activated by a breakover voltage of approximately 30 V and remain in conduction until the holding current drops below a specific value.



Thermistors

Function

Thermistors are widely used for temperature measurement and sensing. A thermistor is a resistance thermometer as it changes its electrical resistance with a change in temperature.

Sensitivity

These devices are designed to give a large change in resistance with only a small change in temperature.

Metal Properties

Typically, the electrical resistance of metals increases when heated. Some metals, however, have the opposite effect and are used in control situations when more current is required when the metal is heated.

Construction

Thermistors are made of semiconductive material designed to operate the circuit current flow within specified temperature ranges.

Types of Thermistors

Positive Temperature Coefficient (PTC)

A PTC thermistor increases resistance with a temperature increase.

PTC thermistors are often used in self-regulating heating elements, current-limiting devices, and temperature sensors where increasing resistance with temperature is desired.

Negative Temperature Coefficient (NTC)

An NTC decreases its resistance with an increase in temperature.

NTC thermistors are commonly used in temperature measurement applications, temperature compensation circuits, and inrush current limiters where decreasing resistance with temperature is beneficial.

Thermistors come in many different operating ranges and are referenced by their resistance at 25°C. For example, a 10K has an operating range of -55-150°C and has a resistance of 10 kilohm (KΩ) @ 25°C.

The Basic Control System

The function of a control system is to operate gas-fired equipment in response to variable conditions. For example, in a residential heating system, the control system helps ensure safe firing of the furnace in response to variable room temperatures. Likewise, in a commercial boiler, the control system fires the burner in response to the condition of the controlled variable (e.g., a hot water boiler operator responds to water temperature; a steam boiler operator responds to steam pressure).

Control System Purpose

There are as many different control systems as there are controls, but all systems have certain functional similarities - certain parts perform similar tasks.

System Integration

Although control sections are often shown separately for purposes of discussion, actual hookups of control systems are complicated by the fact that several functions may be combined in a single control, additional features may be performed by the control system, and more than one limit or controller may be used.

Four Basic Sections of a Control System

Operating Controllers

Respond to changes in the controlled variable (temperature, pressure, etc.) and make or break a circuit. Examples: thermostats, operating aquastats, and operating pressure controls.

Limit and Safety Controllers

Take the command away from the operating controls when continued operation would cause an unsafe situation. Examples: low-water cut-off switches, high-limit aquastats, high limit pressure controls, and flow switches.

Combustion Safety Control

Monitors the flame initiation and allows the gas to flow only if a stable flame is initiated and maintained. Examples: flame sensors and air-proving switches.

Ignition Control Module

Sequences the safe light-up of the burner system (providing the limit controls indicate a safe condition). Examples: intermittent pilot, direct spark ignition, hot surface ignition control modules, and flame safeguard controls.

Operating Controllers and Sensors

Electromechanical vs. Electronic

Electromechanical operating controllers respond to changes in the controlled variable by making or breaking a circuit, whereas sensors monitor the variable for an electronic controller, which will take the appropriate action.

Modern Control Systems

Most new or replacement operating controls are of the digital electronic type and sometimes require an additional power supply and more wiring. Many of the most recent controls have advanced features enabling them to have displays and programming capabilities.

Due to the wide variance in control types, installation, operation, and programming, it is not possible to go into detail regarding any one control.

Thermostats

Thermostat Function

Thermostats can sense the temperature of the air or other mediums in a controlled area and translate this information into on/off switching of the heating or cooling equipment or modulation according to the demand.

Load Switching Ability

Thermostat may be rated for direct switching of line voltage, low voltage, or millivoltage loads.

Purpose Variations

Thermostat may be heating only, cooling only, or heating/cooling combined. They may also perform any number of auxiliary functions.

Thermostat Operation with Mercury Bulb

Room Cooling

As the room cools, the bimetal strip contracts and moves the glass bulb.

Circuit Completion

The mercury in the bulb moves and engulfs the two contacts, completing a circuit.

Valve Activation

This closes the control module circuit and energizes the main gas valve.

Temperature Rise

As the room temperature rises to meet the setpoint, the bimetal strip expands, moving the glass bulb in the opposite direction.

Circuit Breaking

The mercury rolls to the opposite end and breaks the control module circuit. The gas supply to the main burner is shut off.

Attention: New thermostats do not contain mercury. When replacing older thermostats, be sure to handle them carefully to avoid breaking the glass bulb. Mercury is dangerous to the environment! It is important to properly recycle devices that contain mercury.

Room Thermostat with Bimetal Sensor

1 Temperature Drop

As the temperature of the bimetallic sensor drops, the bimetal bends as one of its metals tries to contract more than the other, and the right end of the bimetal slowly rises.

2 Contact Closure

When the switch contacts are almost closed, the magnet quickly pulls them together to make a good contact.

3 Valve Opening

When the contact points come together, the automatic gas valve is powered and opens, allowing gas to flow to the burner.

4 Temperature Rise

As the room temperature around the thermostat rises, the bimetal begins to bend slowly downward.

5 Contact Breaking

Initially, the magnet holds the contact together until the bimetal has bent enough to overcome the pull of the magnet, then the contacts break free cleanly.

6 Gas Shutoff

As soon as the contact points separate, the gas supply to the appliance is automatically turned off.

Digital Thermostats

Electronic Operation

Modern thermostats use electronic circuitry, instead of bimetal strips and contacts, to control circuit operation. Digital thermostats use a thermistor to measure temperature. When the thermistor's electrical resistance changes with temperature, the microcontroller converts that number to an actual temperature reading.

Power Sources

Digital thermostats are usually powered one of three ways:

- A power circuit operates from the 24 V AC supply and battery is used to provide back-up during power failures.
- A rechargeable battery operates the thermostat, charging when the thermostat is not calling and discharging while the thermostat is calling.
- A non-rechargeable battery always powers the thermostat. Battery life is typically one to two years.

Programmable Thermostats

Definition

The term programmable thermostat generally means a thermostat that can be set to operate at different temperature settings at different times. They range in complexity from units that use a simple time clock to units that are operated by integrated circuits.

Energy Savings

The programmable thermostat can reduce energy consumption by maintaining a desired temperature only during the hours the dwelling is occupied. The temperature can be maintained at an uncomfortable level the rest of the time, which permits the heating unit to operate much less often.

Programming Considerations

Each thermostat has specific programming instructions and is configured to the application it is being used on. Unfortunately, due to human error in using these devices, many programmable thermostats result in more energy use than the basic manual thermostat.

Smart Thermostats

Wi-Fi Connectivity

Smart thermostats are Wi-Fi-enabled thermostats with many of the same options as programmable thermostats, with the additional capability to self-learn.

Remote Control

The thermostat may communicate with other smart devices to receive remote commands or voice commands.

Location Services

Smart thermostats can identify your location and adjust settings accordingly.

Self-Learning

The device learns people's schedule and habits to modify settings automatically.

Temperature Swing

Understanding Temperature Swing

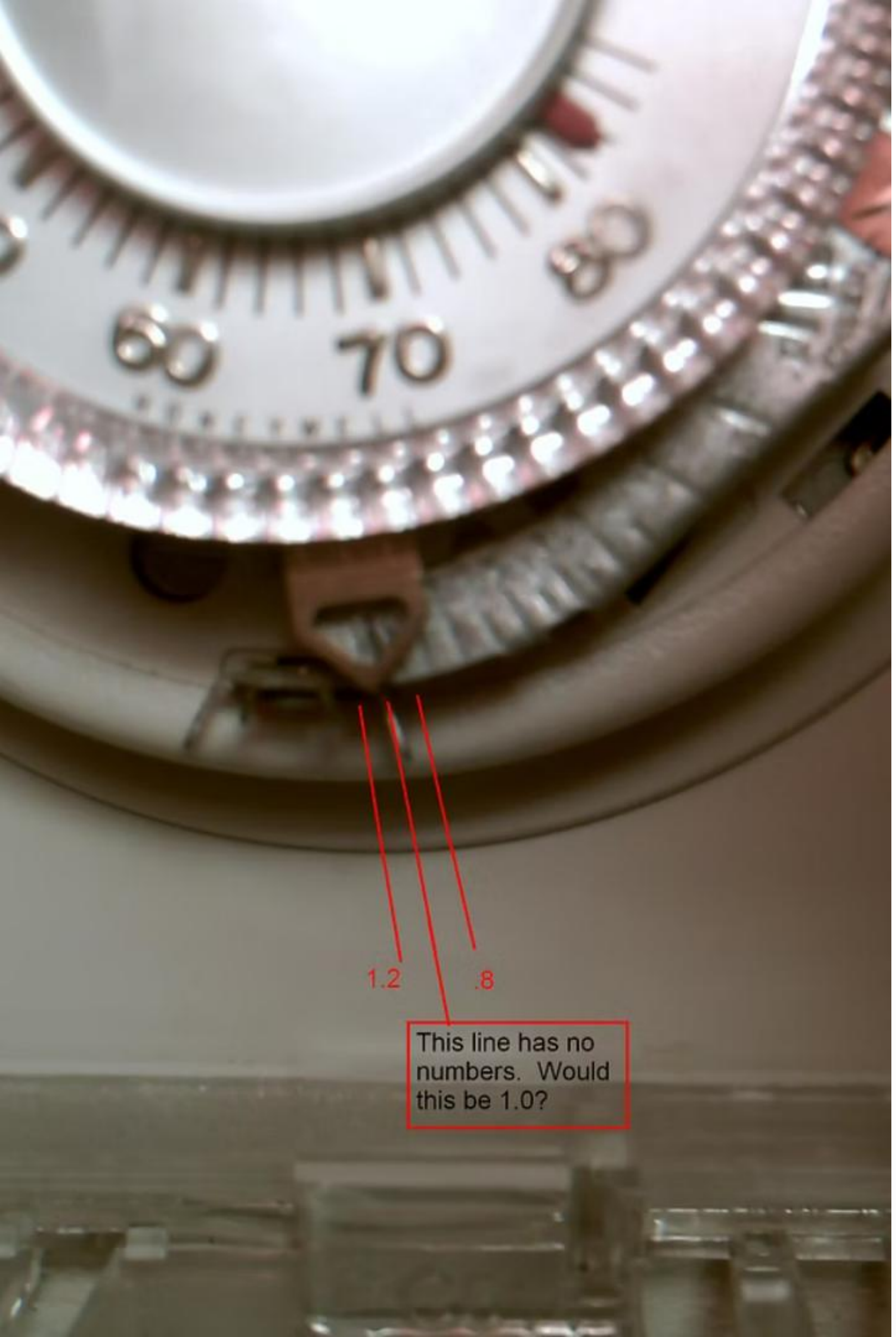
Temperature swing, also known as operating differential, is the difference between the highest and lowest temperatures obtained in a room. Wide temperature swings from the setpoint reduce the comfort level.

For illustrative purposes, the temperature swing has been exaggerated in the diagram. In this diagram, the thermostat has a pre-set differential between the contacts making and breaking 3°F.

System Overshoot

Consider a mid-efficient gas furnace that operates at a relatively high combustion chamber temperature. The thermostat contacts are open and the burner has stopped. The blower continues to run for a few minutes to cool down the furnace and dissipate the residual heat. This causes system overshoot where the building temperature rises above the comfort point.

When the system cycles on, a similar situation occurs as the burner must first warm up the heat exchanger before the blower can come on and deliver heat to the room.



Heat Anticipators

Purpose

Old-style mechanical thermostats use a heat anticipator to cut off the furnace early and let the blower dissipate the residual heat and reduce the system overshoot.

Operation

The anticipator is a small resistive heater in the thermostat itself, which heats when the system is on. The heat it produces raises the internal thermostat temperature slightly faster than the surrounding room temperature.

Function

This causes the thermostat to shut off the heating system sooner than it would if affected by room temperature only. In other words, the thermostat "anticipates" the need to shut off the heating system.

Advantages of Heat Anticipators

Overshoot Compensation

It compensates for overshoot by shutting off the heating equipment before the actual room temperature reaches the shut-off point. This permits the residual heat delivered by the system to carry the room temperature up to this point.

Cycling Rate

It has the effect of increasing the cycling rate since the "on" time of the burner is reduced.

Mechanical Lag Compensation

It compensates for the mechanical lag of the thermostat by moving the temperature of the bimetal element through its operating range at a faster rate.

Setting the Adjustable Heat Anticipator

Purpose

The purpose of the adjustable anticipator, which is installed in the thermostat, is to provide a single thermostat that matches almost any type of gas valve or heating control system load.

Current Dependency

Heat anticipators are dependent on current flow. The current flow, in turn, is determined by the amperage draw of the relay, gas valve, etc., in the primary heating system.

Cycle Rate

For older-style furnaces with a heat operated fan switch (less than 90% efficient), the thermostat should cause the furnace to cycle about four or five times per hour.

Adjustment

Should a longer or shorter cycle be required, further adjustment of the heat anticipator would be necessary to obtain the correct cycle rate of the furnace. Each type of thermostat has a different method to set the heat anticipator. Read the manufacturer's instructions and set as directed.

Millivolt Systems and Electronic Anticipation

Millivolt Systems

Because of the small voltage developed by a self-generating system, the anticipator must be small so as not to create too great a voltage drop. Also, because the anticipator produces a very small amount of heat, it must be placed against the bimetallic.

Thermostats for millivolt circuits are specifically manufactured and are for use with 750 mV systems only.

Electronic Anticipation Methods

Solid-state electronics technology uses a number of methods such as using variable speed fan motors and adjusting water temperature and flow rates for hydronic systems to increase temperature control accuracy.

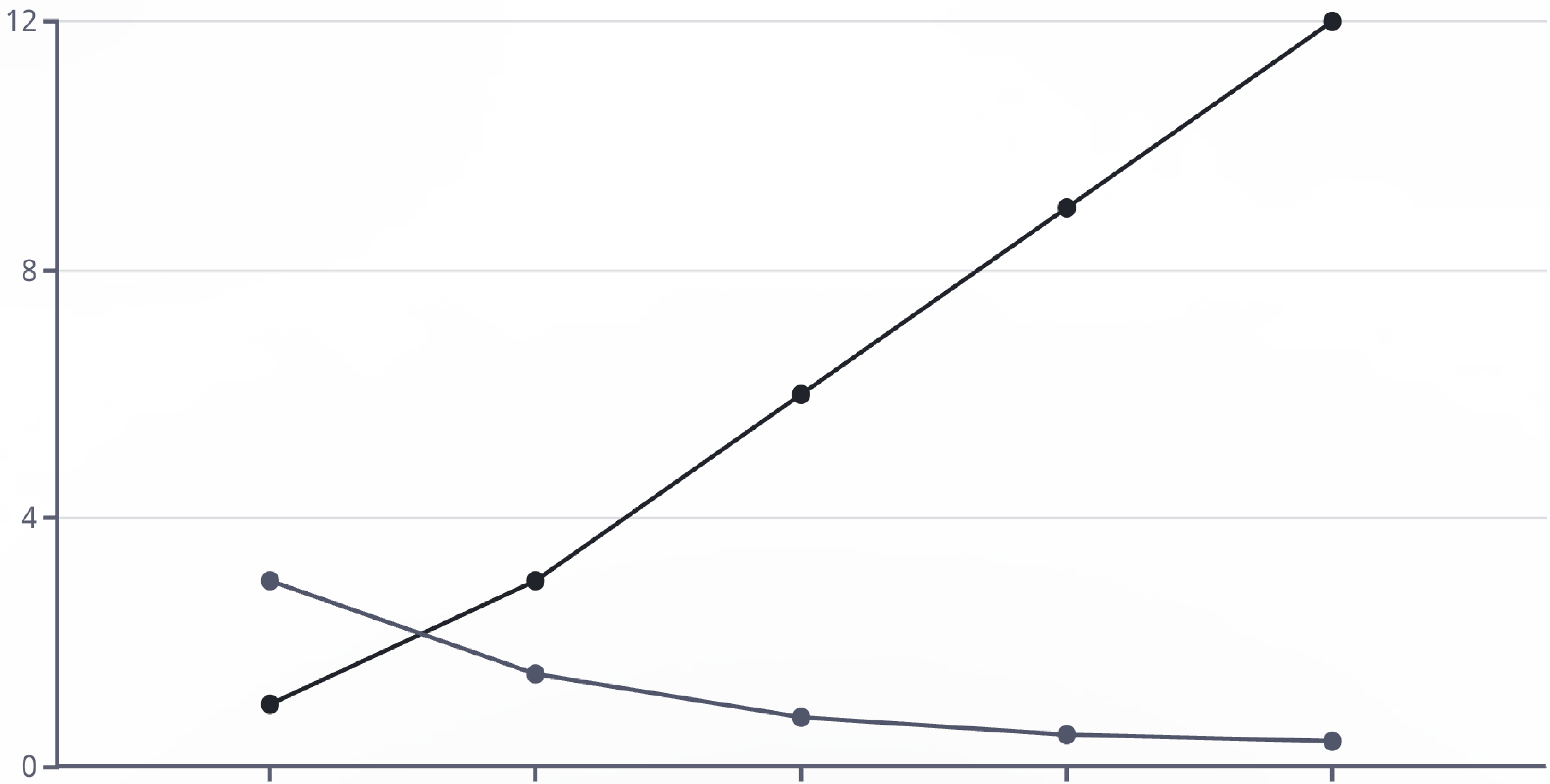
Like mechanical thermostats, electronic thermostats can also be used to control temperature swing by adjusting the cycle rate.

Cycle Rate in Digital Thermostats

6	3	9
Standard CPH	High-Efficiency	Electric Heat
Typical cycles per hour for standard systems	Recommended CPH for condensing furnaces	Standard CPH for electric heat furnaces

Digital electronic thermostats use a cycles-per-hour (CPH) method of anticipation that differs from earlier electromechanical thermostats. A cycle is burner on-time plus off-time. Divide a 60-minute hour by six cycles and you get 10 minutes for each cycle. That means the equipment can come on every 10 minutes if there's a need for heat. Typical cycle rates are from 1 to 12 CPH heat/cooling applications. Most electronic thermostats come out of the box set for 5 or 6 CPH.

CPH Settings and Temperature Differential



Multi-stage Thermostats

Multi-stage Furnaces

Modern multi-stage furnaces can increase efficiency and comfort since lower settings may be adequate to meet the building demands most of the time.

Thermostat Function

Multi-stage thermostats are used to switch the heating or cooling equipment between the various stages.

Staging Methods

Manufacturers use setpoint staging, time-based staging, or rate-of-change staging to initiate different stages.

Types of Multi-stage Systems

Two-stage Systems

The first stage is usually about 65% capacity, while the second stage is 100% capacity.

Thermostats designed for two-stage furnaces must activate different circuits on the furnace to initiate the two different firing rates or stages. These units have terminals to accommodate two heating wires, W1 and W2, as well as two AC wires, Y1 and Y2, plus power, fan, common wire, and possibly additional functions.

Variable Capacity Systems

Variable capacity systems operate at any percentage of capacity between about 40% and 100%.

Thermostats designed for variable capacity systems sends a modulating signal to the furnace control indicating the necessary firing rate. Fully modulating thermostats are typically manufacturer specified as they need to match the equipment controller.

Note: Two stage furnaces have optional settings to allow customers to use an existing single stage thermostat. The furnace controller has a second stage delay DIP switch, which needs to be set up for the desired time delay or rate of change option.

Thermostat Location

Level Installation

Be sure that magnetic switch thermostats are level when installed. Use a spirit level to check.

Room Selection

Install the thermostat in a room that is subjected to the average temperature of the dwelling.

Height Placement

Place where it will be exposed to normal air circulation, approximately 5 feet from the floor.

Avoid Interference

Install where it is not subjected to the artificial effects of internal heat or cold, such as television sets, lamps, direct sun, cold air return, etc.

Wall Selection

Mount on an inside wall, away from stairways or corners because they affect the circulation of air.

Wireless Thermostats

Wireless Communication

Wireless thermostats use low-energy radio waves such as Z-Wave or Zigbee to create a WPAN for communicating.

Multiple Sensors

Can communicate with additional wireless sensors and/or separate zone thermostats.

Interface Module

Uses a wireless interface module mounted at the heating equipment that can act as a central hub.

Connectivity

The interface module can provide Wi-Fi and internet connectivity.

Wireless Thermostat Network

Battery Life

By using extremely low energy radio/wireless protocols, the devices achieve very good battery life, up to several years.

Message Targeting

Only the intended device acts upon the message.

Signal Range

The devices can transmit information much farther than the 10-20 meters range of the device signal.

Mesh Network

The devices all link up to form a mesh network that can pass the message along to any other device within range.

Fan Switch

Historical Context

The fan switch discussed here is old technology but worth mentioning briefly to understand the purpose of the operating control in the fan circuit.

Construction

Fan switches were a normally open (NO) bimetal switch. They were used to bring on the air circulating fan after the furnace was warmed up to the "fan-on" setpoint.

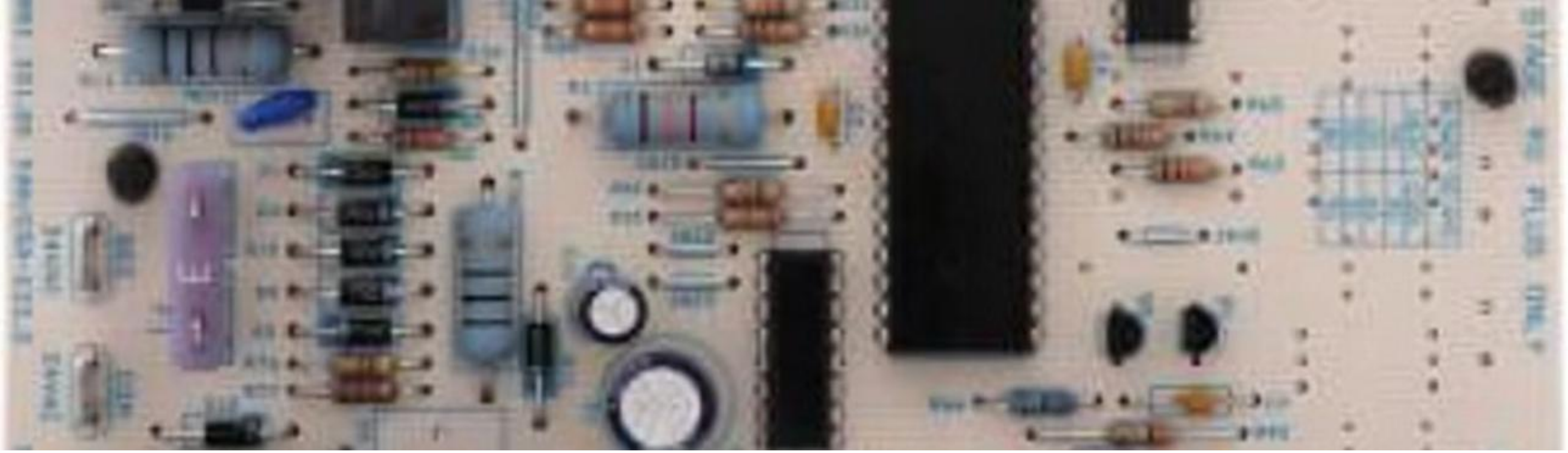
Cooling Function

They also allowed the fan to continue to run after the burner had shut off until the heat exchanger was cooled to the "fan-off" setpoint.

4

Independent Circuit

The fan control circuit runs independent of thermostat and burner controls.



Modern Fan Control

Integrated Control

On modern furnaces, the fan switch is one of many solid-state components within an integrated furnace control, and it is less easily identified within a fan circuit.

Time Delay Relays

The fan on and off switching is activated by time delay relays contained within the furnace controller activated by the call for heat or summer circulation from the thermostat.

Circuit Concept

The separate fan circuit concept is still relevant. The fan switch would still exist, although it would not be heat-activated as shown in older wiring schematics.

Boiler Water Temperature Control

Hydronic Heating Systems

Hydronic space heating systems use hot water boilers as the energy source. These boilers can vary from conventional high mass boilers that operate at a set temperature of approximately 180°F to low mass modulating condensing boilers that can change the firing rate as well as the water temperature settings to maximize efficiency.

Control Methods

The water temperature is controlled with electromechanical operating aquastats on conventional boilers, while modern boilers use temperature sensors to send information to a microprocessor-based controller.

The controller compares the boiler water information with other sensor feedback before it takes actions such as starting the boiler, modulating the firing rate, and even changing the water setpoint temperature.

Aquastats

Operation

Electromechanical aquastats contain a sealed bellows that operate on the liquid expansion principle. The operating aquastat is a normally closed switch that controls the temperature of the water inside the boiler.

Temperature Control

If the aquastat is set for 180°F (82°C), the contacts will remain closed until the water reaches this temperature. At this point, the contacts open and cut off power to the main gas valve.

Differential

The water cools several degrees before the contacts close again. The amount of temperature drop before the contact make again is determined by the differential setting. Aquastats may come with a temperature differential that is fixed, for example 10°F (6°C) or adjustable between 5°F and 30°F (3-17°C).

Types of Aquastats

Direct Mounted

Direct-mounted aquastats use an immersion well that is threaded into the water space of the boiler or the run of a tee. This allows for the replacement of the aquastat without draining the water.

Remote Bulb

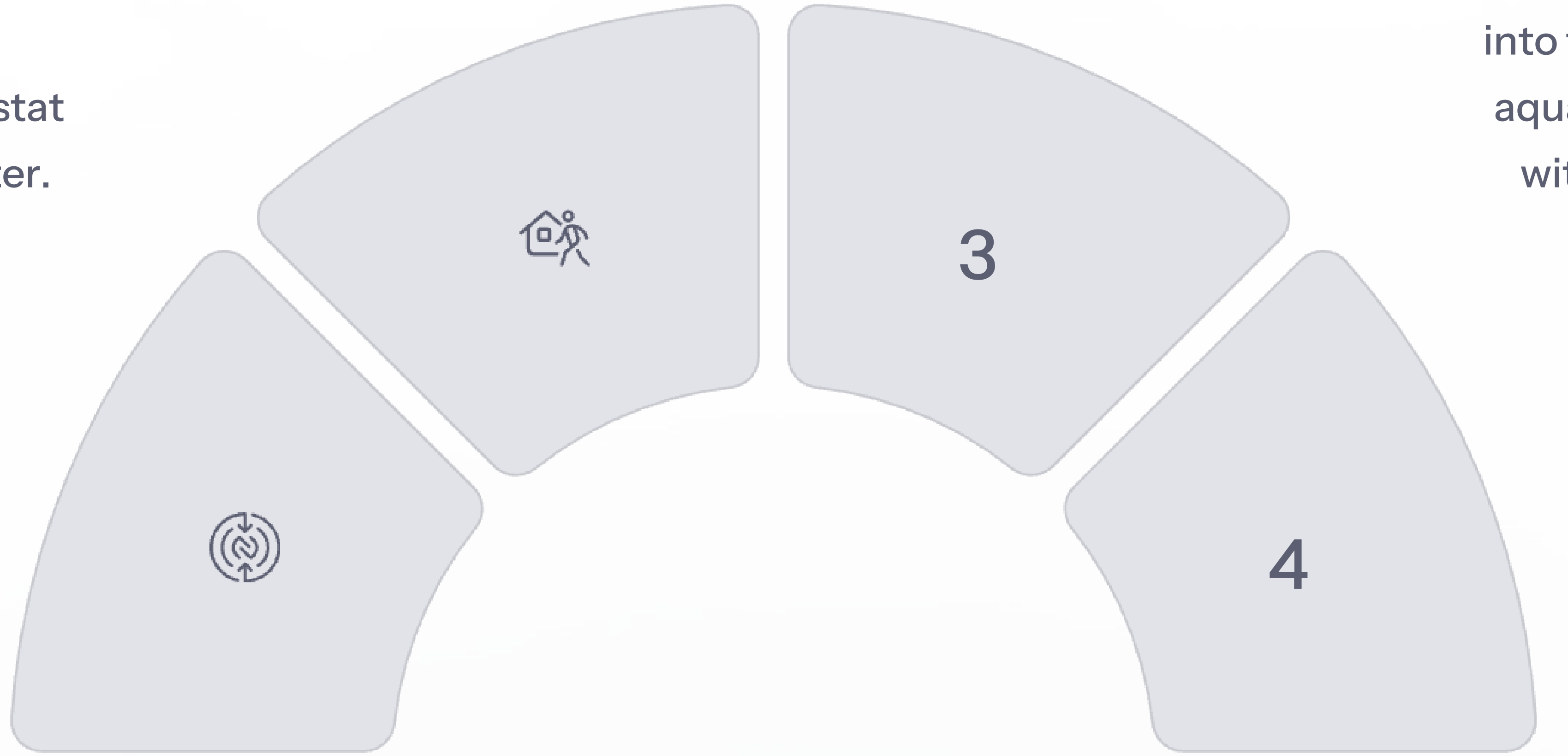
Remote bulb aquastats have the flexibility of mounting at a different location than the sensing bulb.

Surface Mounted

Strap on style aquastat gets mounted onto the surface of a tank or pipe.

Installation

Thermal conductive paste is applied to the outside of the sensing bulb prior to inserting it and the short capillary tube into the well. The case of the aquastat is then connected with the adapter screws.



Operating Sensors in Modern Boilers

Electronic Controllers

Modern modulating condensing boilers have electronic controllers that integrate multiple control functions, not one unit. This controller process information from multiple temperature sensors.

Thermistor Operation

These sensors use thermistors, which create a variable current in the sensing circuit that corresponds to the temperature. This sensing circuit amperage change results from the change in resistance of the thermistor.

Similar to the operating aquastat, the operating thermistor is placed in a location that senses the highest boiler water temperature.

-5	23	42,326.00	95	203	786.6
0	32	32,650.00	100	212	678.6
5	41	25,391.00	105	221	587.6
10	50	19,899.00	110	230	510.6
15	59	15,711.00	115	239	445.2

NTC Thermistor Resistance Values

Temperature (°F)	Temperature (°C)	Resistance (Ω)
-50	-46	490,813
0	-18	85,362
50	10	19,900
100	38	5,828
150	66	2,045
200	93	829
225	107	553

This table shows temperature and resistance values of a typical NTC 10 kΩ thermistor. As temperature increases, the resistance decreases in a non-linear relationship.

Boiler Steam Pressure Control

Steam Production

As steam gets used for the process, the steam boiler will need to fire and produce more steam. The steam boiler controls monitor the steam pressure in the upper steam chamber to determine when the boiler needs to fire.

Control Types

Just as was identified with the hot water boilers, the operation can be done with electromechanical controls or electronic sensors.

Pressure Monitoring

The operating pressure control (pressuretrol) is a pressure activated switch. As steam pressure in the boiler rises and reaches the setpoint of the pressure control, the switch contacts open and de-energizes the power to the main gas valve.

Operating Pressuretrol

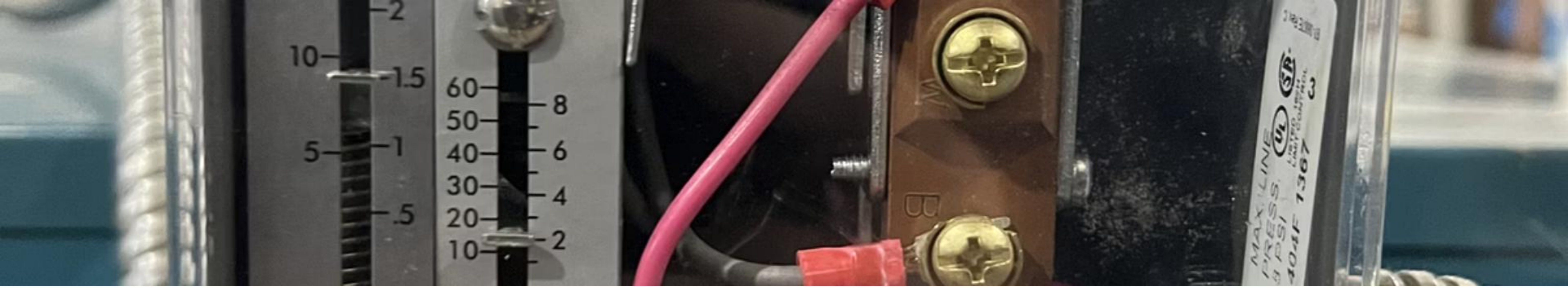
Connection Method

The pressuretrol is connected to the upper steam space of the boiler with pipe and fittings. A siphon loop is used to help protect the control from direct contact with the steam as condensate will collect inside the coil and create separation.

Pressure Sensing

The internal diaphragm assembly, which will create the movement to activate the contacts, will sense the pressure.

For example, if the main setting is approximately 5 pounds per square inch gauge (psig) [34 kilopascal (kPa)], the contacts stay closed until the steam pressure reaches 5 psig (34 kPa). Once it has reached this pressure, the contacts open and cuts off power to the main gas valve.



Pressuretrol Settings

5	1.5	3.5
Main Setting (psig)	Differential (psig)	Cut-in Pressure (psig)
Cut-out pressure when contacts open	Pressure drop before contacts close	Pressure when contacts close again

The contacts close again when the steam pressure reduces by the differential setting, in this case, down to approximately 3.5 psig (24 kPa).

The main (cut-out) and differential on the operating pressure control are adjustable.

Red Seal Alignment

CSA Gas Trade Unit	2014 Red Seal Block	2014 Red Seal Task	Title
11	A	Task 1	Performs safety-related functions
12	A	Task 2	Maintains and uses tools and equipment
13	A	Task 3	Plans and prepares for installation, service and maintenance
14	B	Task 4	Fits tube and tubing for gas piping systems
15	B	Task 5	Fits plastic pipe for gas piping systems
16	B	Task 6	Fits steel pipe for gas piping systems

This table shows the alignment between CSA Gas Trade Units and the 2014 Red Seal certification tasks and blocks.

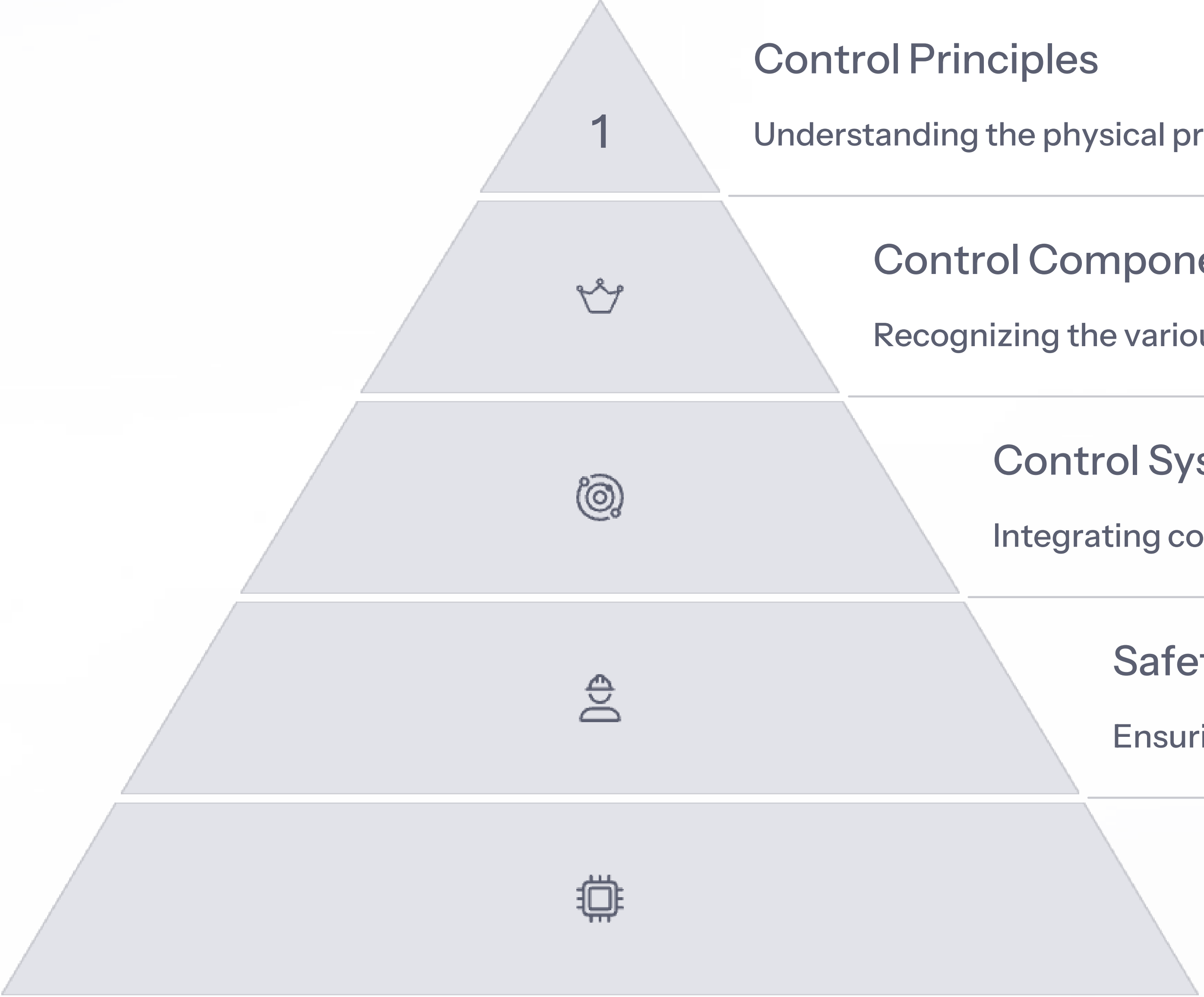
Red Seal Alignment Continued

CSA Gas Trade Unit	2014 Red Seal Block	2014 Red Seal Task	Title
17	C	Task 7	Installs venting
18	C	Task 8	Installs air supply system
19	C	Task 9	Installs draft control systems
20	D	Task 10	Selects and installs electronic components
21	D	Task 11	Selects and installs electrical components
22	D	Task 12	Installs automation and instrumentation control systems

Red Seal Alignment Final Section

CSA Gas Trade Unit	2014 Red Seal Block	2014 Red Seal Task	Title
23	E	Task 13	Installs gas-fired system piping and equipment
24	E	Task 14	Installs gas-fired system components
-	E	Task 15	Installs propane storage and handling systems
-	F	Task 16	Tests gas-fired systems
-	F	Task 17	Commissions gas-fired systems
-	G	Task 18-20	Maintains, repairs, and decommissions gas-fired systems

Summary of Control Fundamentals



Control Principles

Understanding the physical principles that make controls work

Control Components

Recognizing the various components and their functions

Control Systems

Integrating components into functional control systems

Safety Controls

Ensuring safe operation of gas-fired equipment

Advanced Technology

Adapting to new electronic and smart control systems

Gas technicians must understand the fundamentals of controls to properly install, maintain, and troubleshoot gas-fired equipment. From basic principles of thermal expansion to advanced electronic controls, this knowledge forms the foundation for safe and efficient system operation.

Industrial Boiler Control Systems

This section explores the various control systems used in industrial boilers, including pressure transmitters, system control concepts, and safety mechanisms that ensure proper operation and prevent hazardous conditions.

Operating Pressure Transmitters

What are Pressure Transmitters?

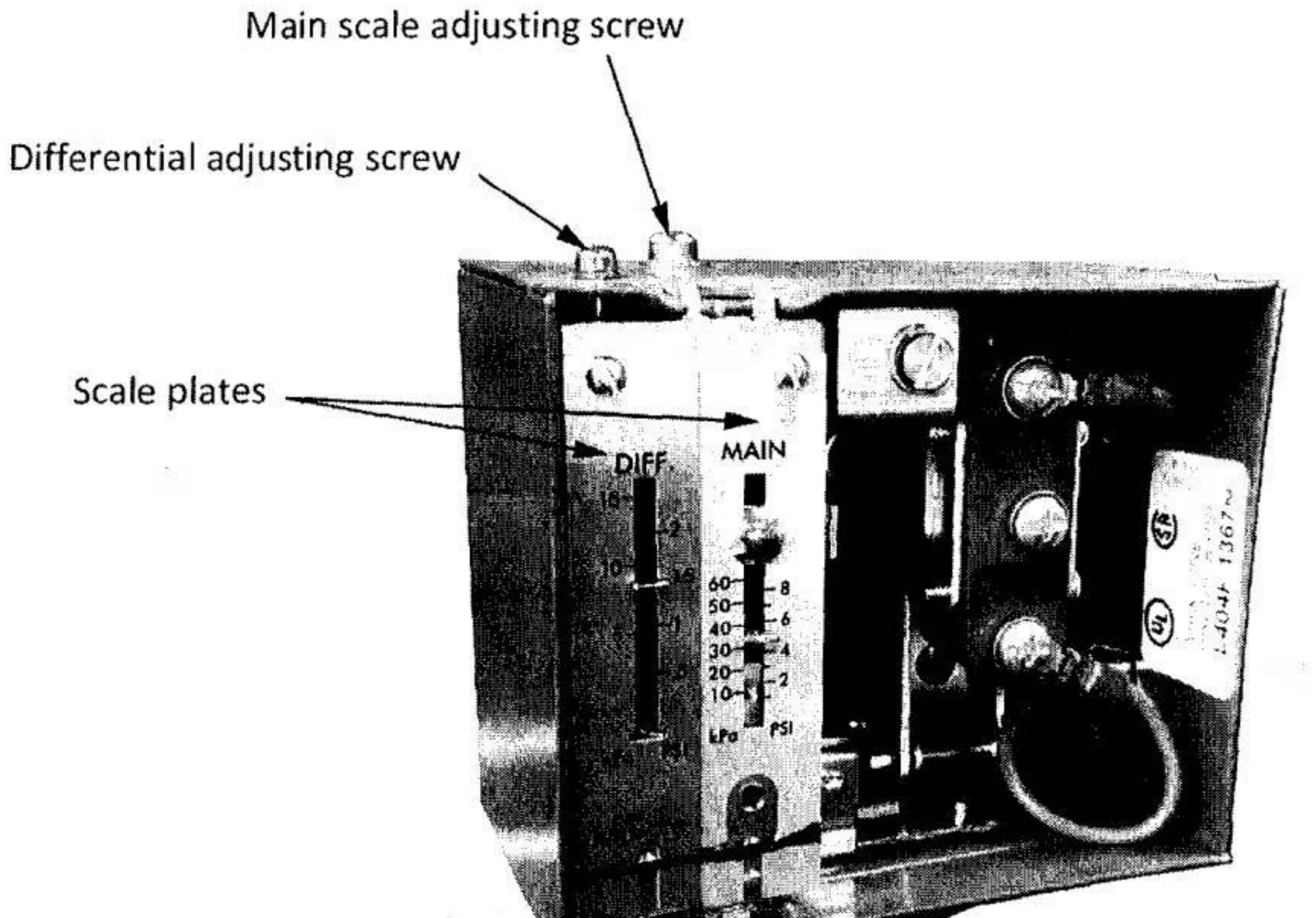
Industrial boilers may have remote electronic controllers that will require local sensors rather than electrometrical operating controls. Pressure transmitters or transducers convert an applied pressure into a measurable electrical signal.

Components

A pressure transmitter consists of two parts:

- an elastic material, which deforms when exposed to a pressurized medium
- an electrical device, which detects the deformation

Figure 1-31
Pressuretrol settings
Courtesy of Camosun College, Rodney Lidstone, licenced under CC BY



How Pressure Transmitters Work

Flexible Diaphragm Design

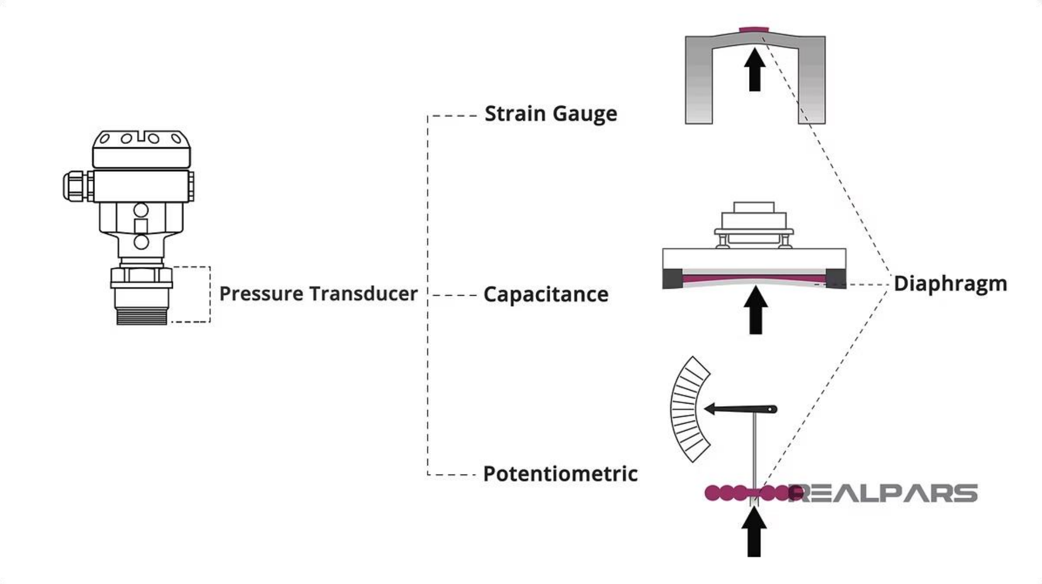
One of the most common methods is to form the elastic material into a thin flexible diagram. The electrical device then detects this deformation and converts it into a proportional electrical signal.

Signal Conversion

When pressure is applied to the diaphragm, it flexes in proportion to the pressure. This mechanical movement is detected by the electrical component and converted into a signal that can be read by the control system.

Applications

These transmitters are essential for monitoring boiler pressure and providing feedback to control systems, ensuring safe and efficient operation of industrial boilers.



System Control Concepts

Primary Control Types

The two primary control concepts are either:

- on/off control used with electromechanical controllers
- closed-loop control used with sensors and a microprocessor-based controller

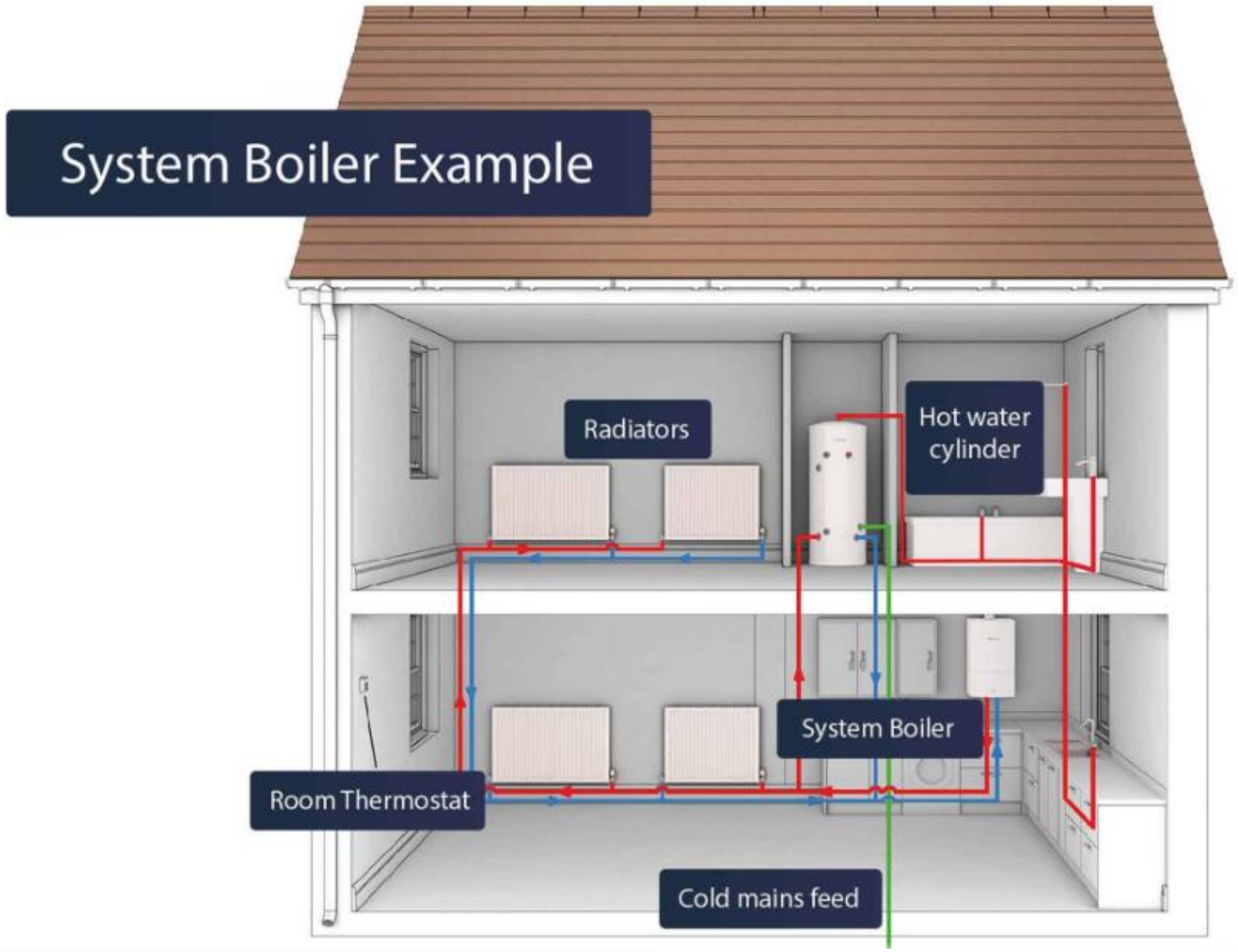
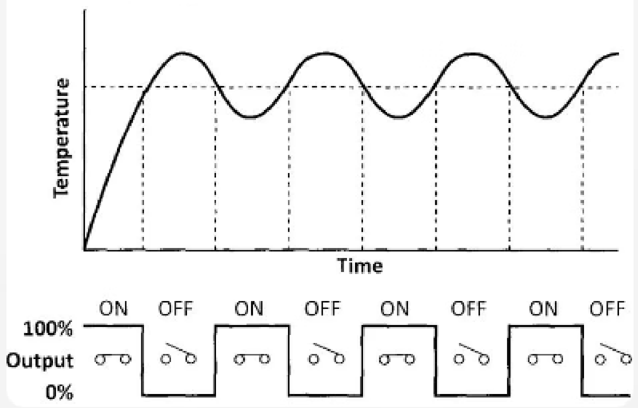


Figure 1-33
Basic on/off control deadband



On/Off Control Systems

Electromechanical Measurement

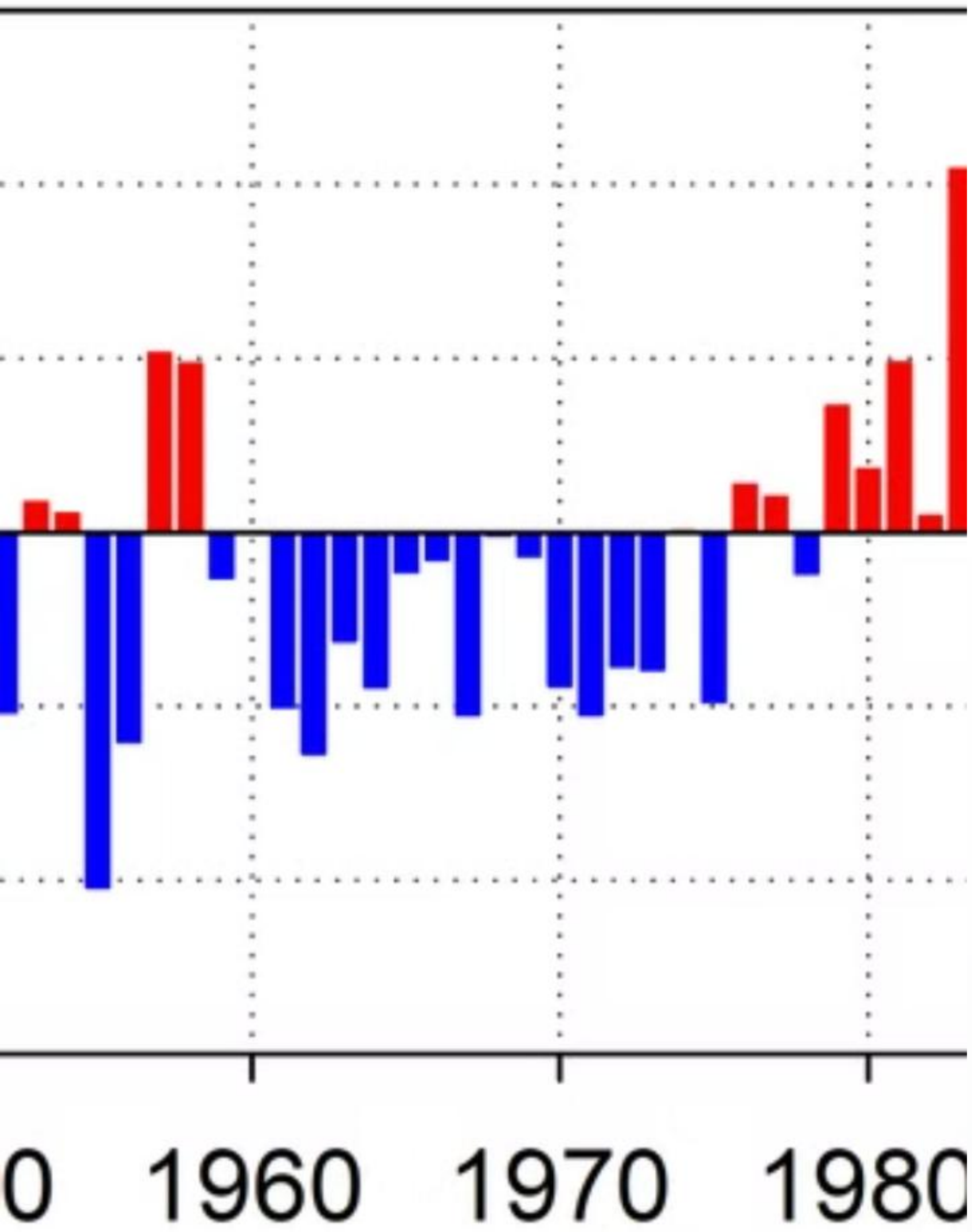
When electromechanical devices measure the controlled variables (air temperature, water temperature, etc.), they directly act upon a set of electrical contacts.

Built-in Logic

They were called controllers as they would be installed directly into an electrical circuit that would be energizing or de-energizing a load or relay. The control sequencing and logic is built into the circuitry.

Deadband Effect

On/off is a very simple form of control, but its outcome will have swings over and under the desired setpoint (deadband).



Limitations of On/Off Control

Binary Operation

The equipment is only running at either 100% on or off

Temperature Swings

Creates temperature fluctuations above and below the setpoint

Differential Requirement

The electromechanical controller itself has to have a differential designed into it

Rapid Cycling Risk

Without differential, contacts would be rapid firing constantly

Electronic Control Systems

Sensor-Based

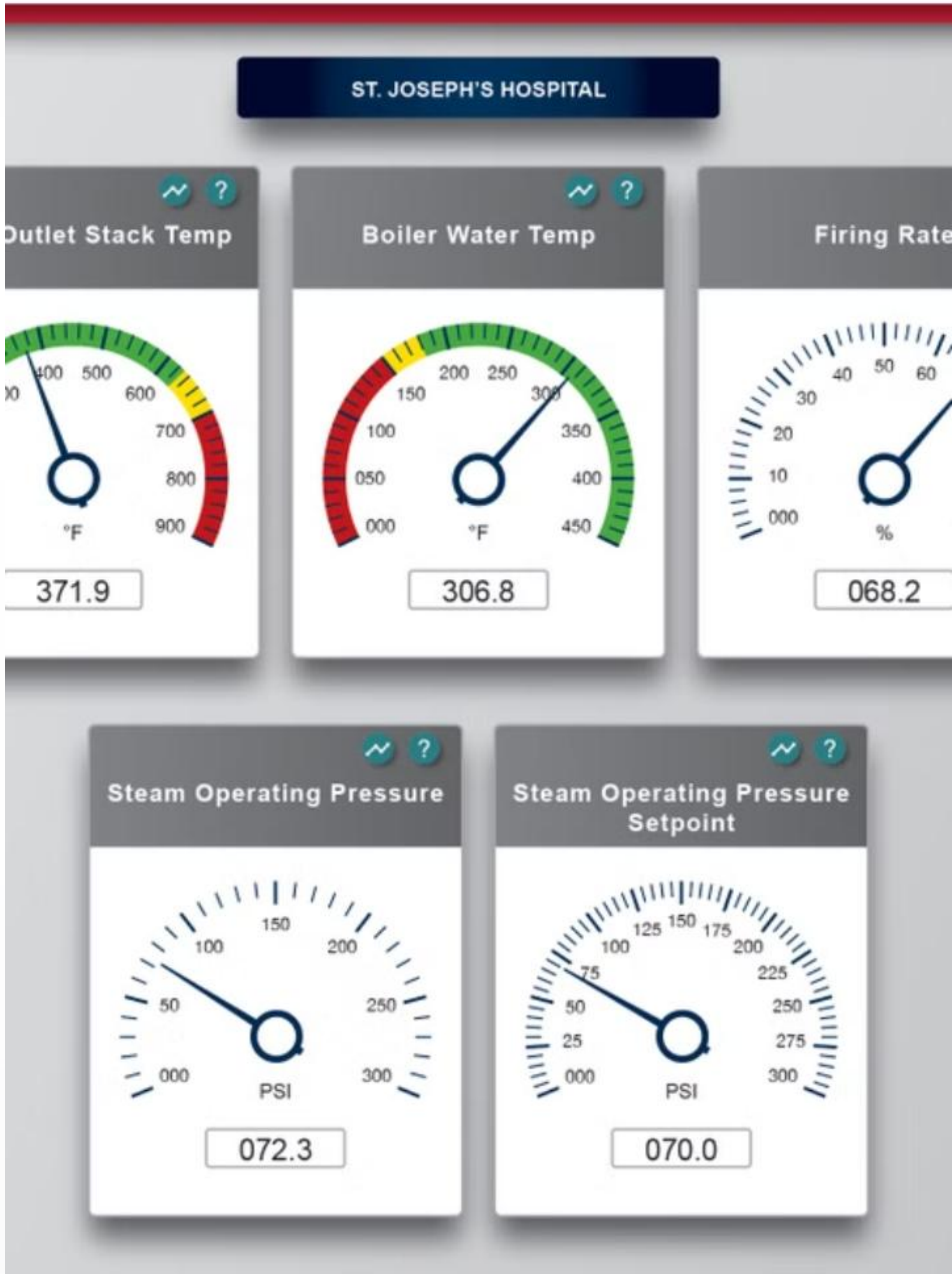
The electronic devices introduced are mostly sensors that would be measuring the controlled variable and communicating that information to a master controller.

Integrated Controls

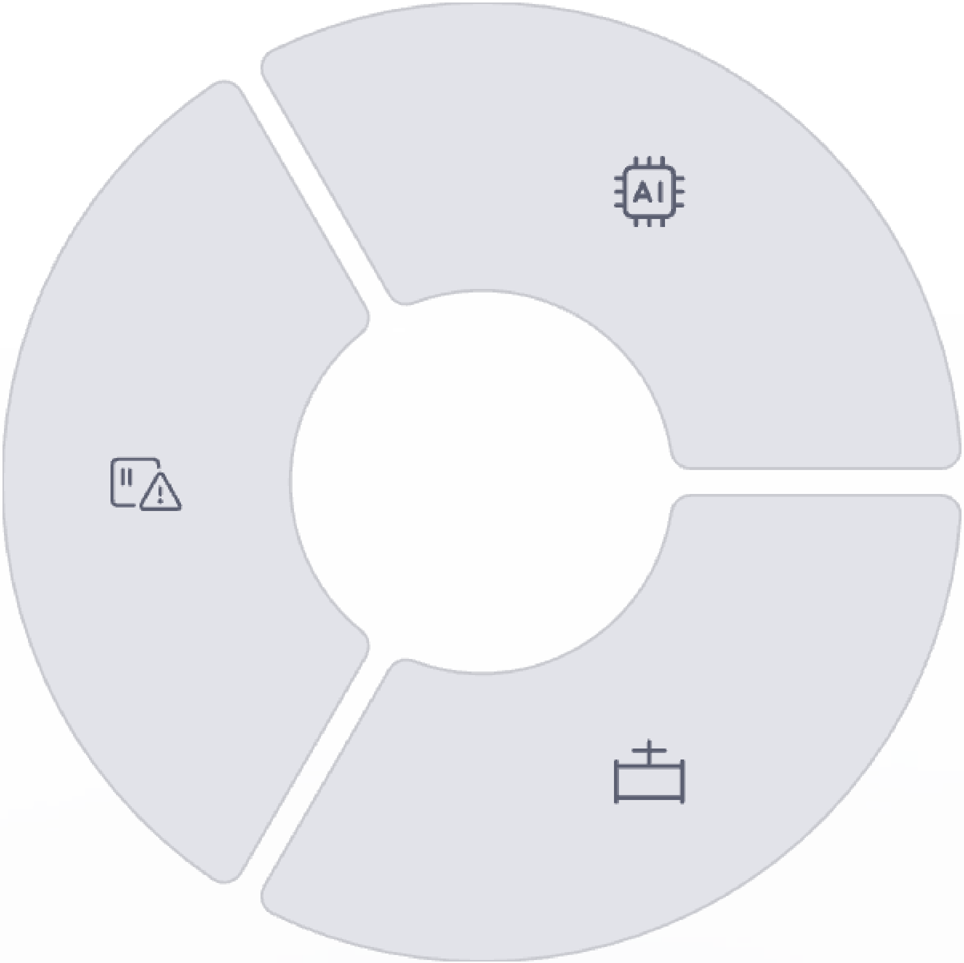
Example of these controllers are integrated furnace controls and integrated boiler controls. They are referred to as "integrated" because they can combine two or more functions to become more effective.

Variable Operation

Modulating boilers and multistage furnaces can vary their firing rate based on feedback that the controller gets from its various internal and remote sensors.



Components of Electronic Control Systems



Controller

The brain of the system that processes sensor data and makes decisions

Sensors

Devices that measure variables like temperature, pressure, and flow

Control Devices

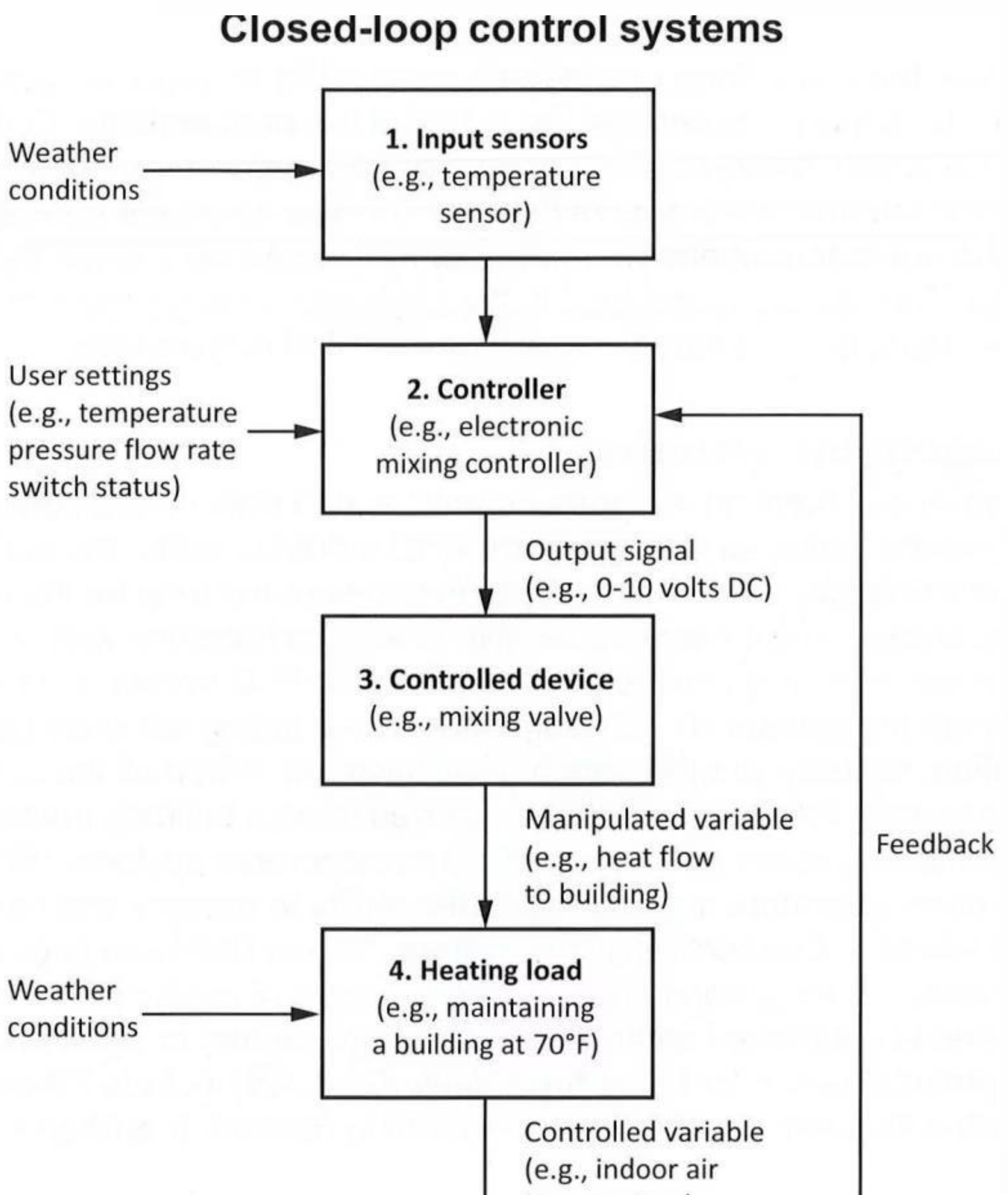
Components that execute the controller's commands, such as valves and motors

Closed-Loop Control Systems

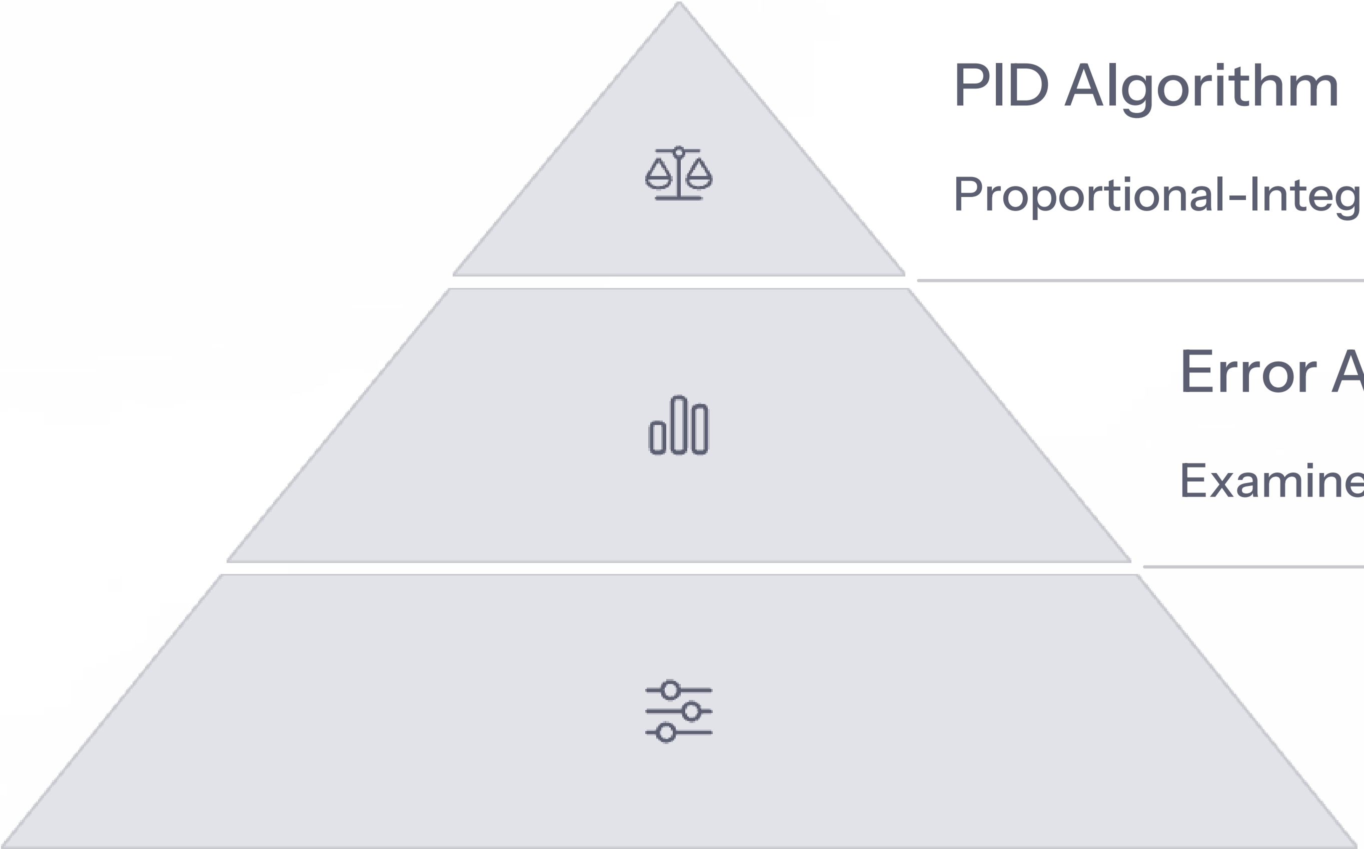
Feedback-Based Operation

A closed-loop control system can make adjustments to the manipulated variable (e.g., boiler supply water temperature) based on feedback it receives from sensors in the controlled variable (e.g., indoor air).

This enables a heating system to modulate its input and more closely match the load requirement to avoid the overshoot and undershoot inherent with an on/off control system.



PID Control



PID Algorithm

Proportional-Integral-Derivative control

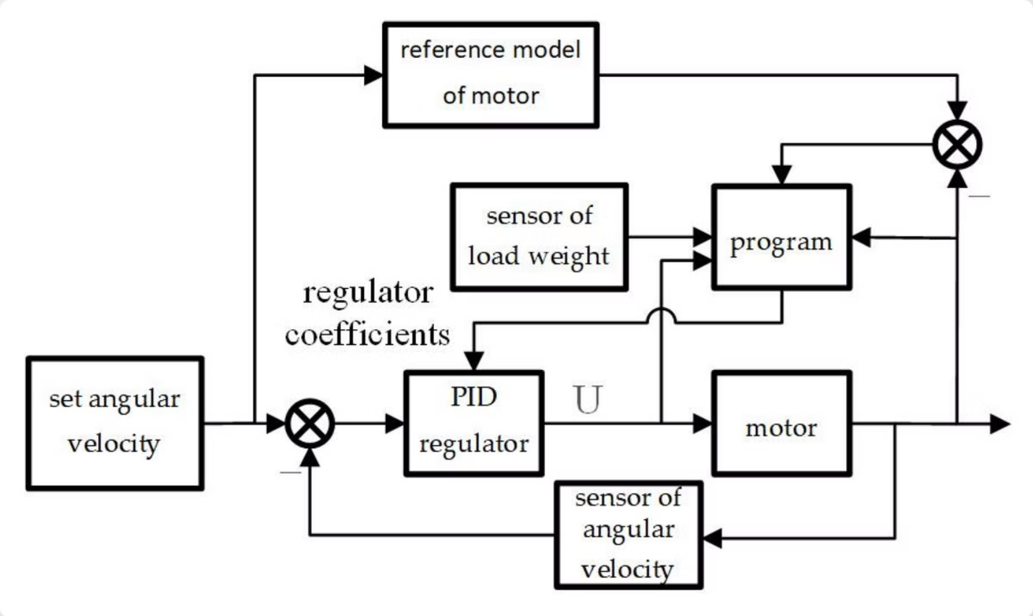
Error Analysis

Examines difference between target and measured values

Continuous Adjustment

Makes precise adjustments to maintain optimal operation

When the controller receives feedback from the sensors, it compares the information with the setpoint value and makes adjustments. For example, the boiler may modulate its firing rate to better match the demand. The adjustments that the controller makes are based on a stored set of instructions (algorithm). One of the most common control processing algorithms used is called proportional-integral-derivative control (PID).



Components of PID Logic

Proportional

Output varies in proportion to how much error exists (e.g., how far is the boiler water temperature from the setpoint)

Integral

Examines the duration over which the error occurs (e.g., how long has the temperature been below the setpoint)

Derivative

Measures how fast the error is changing. This adjusts the reaction time

Outdoor Reset Control

Weather-Based Adjustment

Outdoor reset is when the controller calculates the system water temperature setpoint by monitoring weather conditions. The controller lowers boiler water temperature when the outdoor temperature is warmer and increases it when the outdoor temperature is colder.

Benefits

- Improved energy efficiency
- Better comfort control
- Reduced temperature swings
- Required by energy conservation regulations in many areas

Building Management Systems

Integrated Control

Today, many gas appliances have an integrate control located right on the equipment. These may include sensor (I/O) connections, as well as internal PID modules within the control board.

Larger Systems

On larger commercial, institutional, and industrial systems, the control loop for the gas equipment is only one piece of the puzzle, and it needs to be able to work in harmony with other HVAC equipment.

On these systems, it is common to use a DOC or PLC system to communicate, operate, and coordinate the various HVAC equipment.

BMS Components and Functions

Comprehensive System

When all the systems are tied into the building's main network (Primary Bus), this is referred to as a building management system (BMS), building automation system (BAS), or energy management systems (EMS).

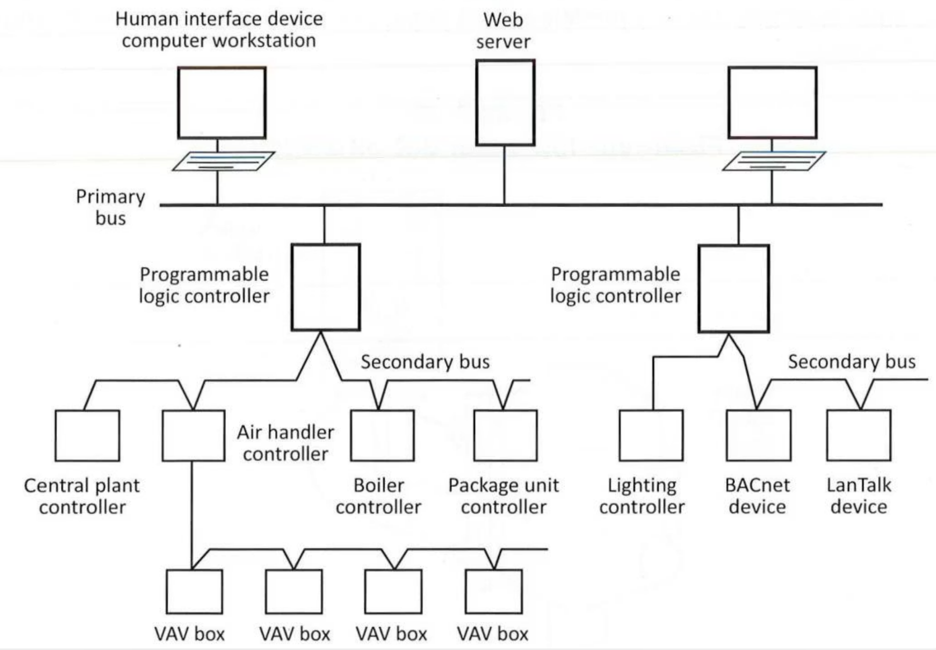
Remote Access

This type of system gives operators and managers the ability to monitor and control remotely from any networked location.

System Benefits

Connecting all the systems to one BMS can improve occupant comfort, system efficiency, energy consumption, and life cycle of equipment.

Figure 1-35
BMS/BAS/EMS



BMS Communication Protocols

Ethernet

Standard networking protocol used for local area networks (LANs)

BACnet

Building Automation and Control Network - a data communication protocol for building automation

LonWorks

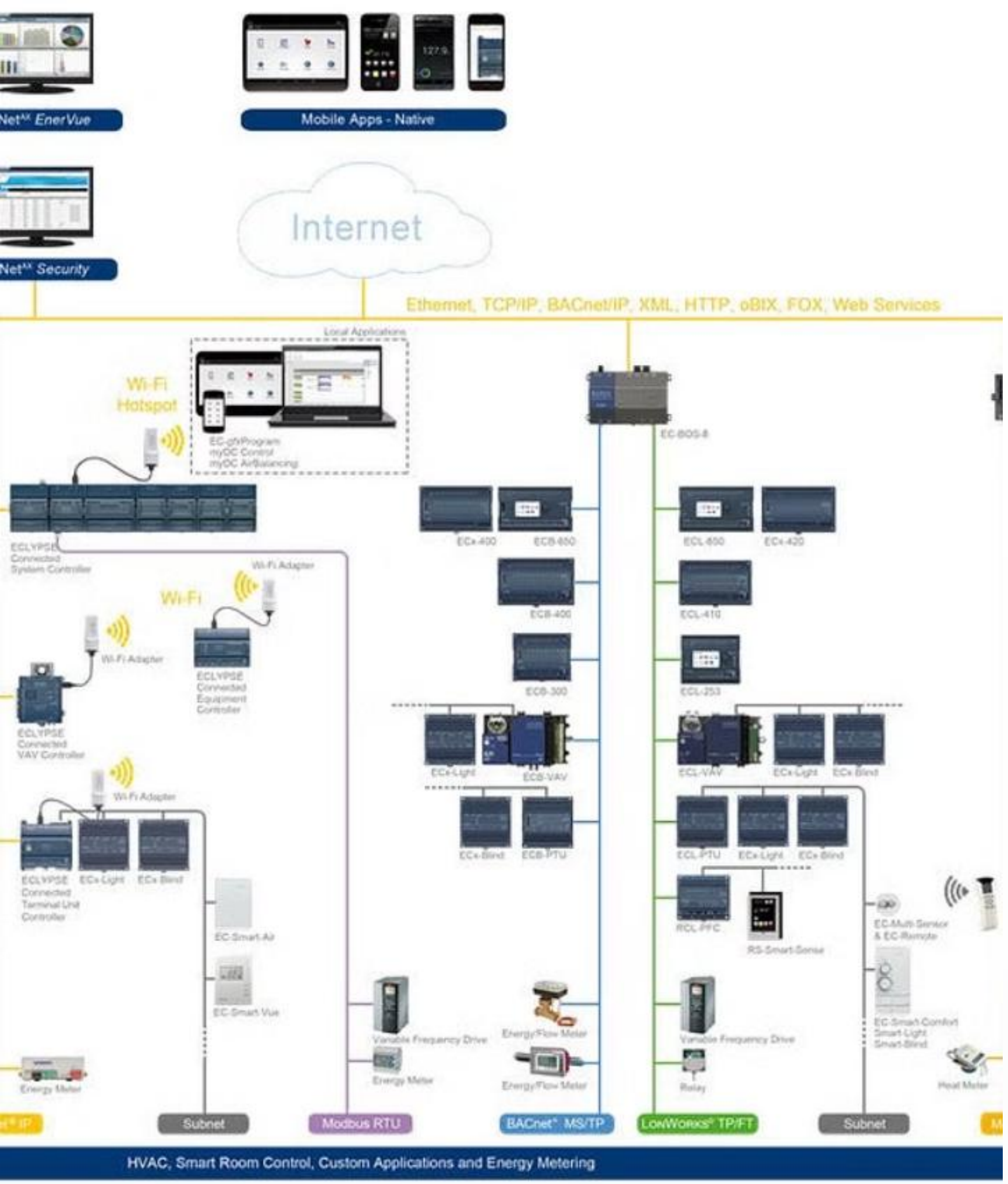
Local operating network - a networking platform specifically created to address control applications

Modbus

A serial communications protocol originally published for use with programmable logic controllers (PLCs)

KNX

A standardized, OSI-based network communications protocol for intelligent buildings gement System



ge of best-of-breed, performance-proven field devices that
g. This comprehensive line of field devices - including a variety
s a complete, cost effective solution, from design to installation.

BMS Integration Considerations

Override Functions

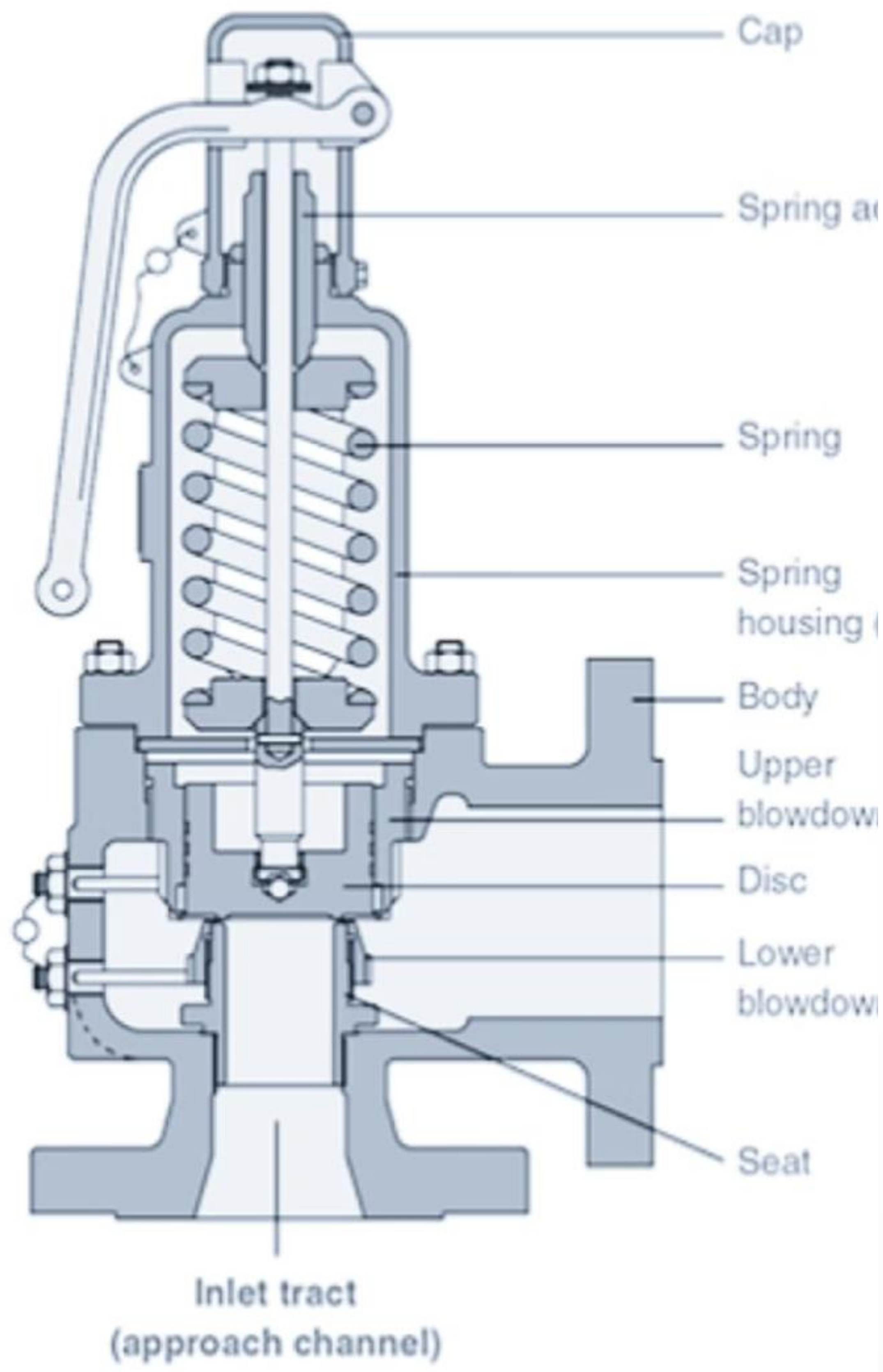
Building management systems may use the DOC or PLC to control the equipment firing rate and the outdoor reset functions. In these cases, it may be necessary to override these functions within the appliance's internal controller.

DIP Switch Settings

Could entail specific settings on the appliance DIP switches and I/O connections as well as a network protocol interface module.

Follow Manufacturer Instructions

Be sure to follow the manufactures instructions for setting up the appliance onto a BMS.



Limit and Safety Controllers

Purpose

Limit and safety controls include all the interlocking controls to ensure that the burner cannot operate unless all associated functions to the burner are normal.

Protection

In addition to the standard pressure and temperature safety limit controls used for the protection of the fired equipment, there are several other controls used as limits or interlocks.

Function

These safety systems monitor various aspects of boiler operation and shut down the system if dangerous conditions are detected.

Low-Water Cut-Off Switch

Function

The low-water cut-off switch actuates in response to fluid movement. If the water level in the boiler falls below the minimum level, the low-water cut-off switch opens its contacts and cuts off power to the main gas valve.

The Boiler and Pressure Vessel code lists when and where low water cut-offs are required.

Types

There are two basic types of low-water cut-off switches:

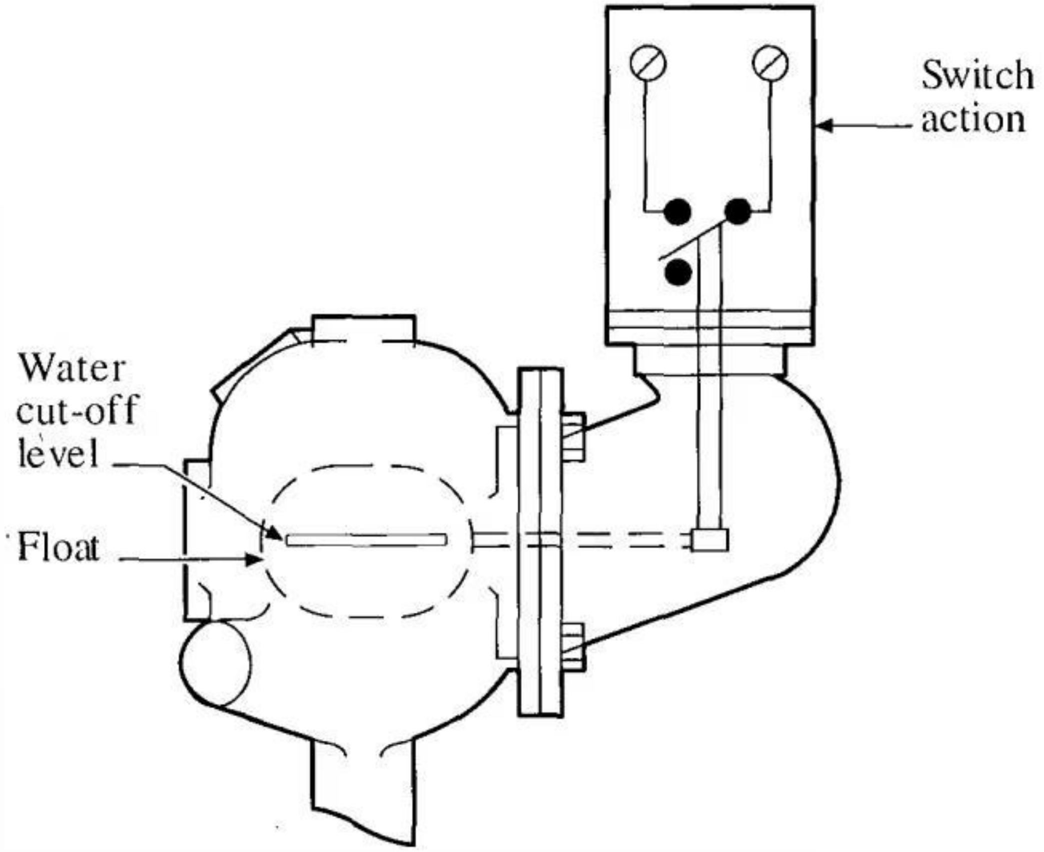
- float type
- probe type

Figure 1-36
Float-type low water cut-off switch

Float-Type Low-Water Cut-Off

Operation

The float type is a normally open switch that is held close by the float on top of the water. If the water level falls below a predetermined point, the float mechanism lowers and breaks the electrical contact.



Probe-Type Low-Water Cut-Off

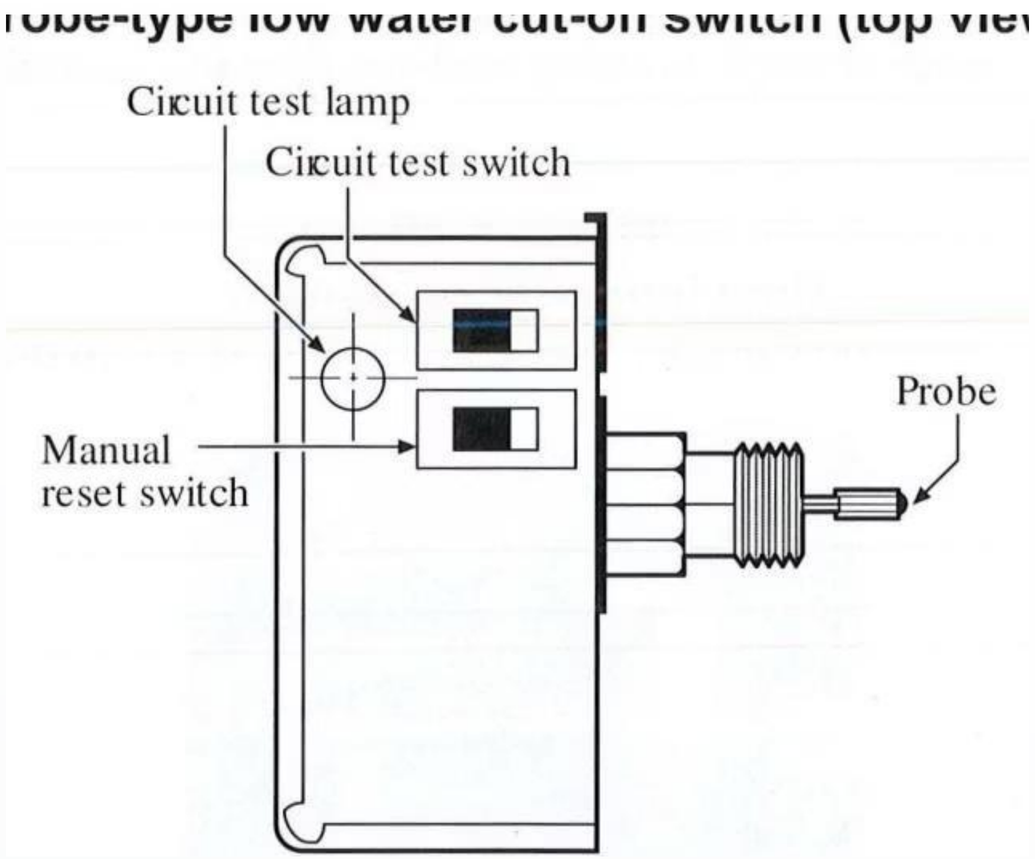
Operation

The probe type is a normally open switch. It has an electronic circuitry that uses boiler water to conduct current between the terminals on the end of the probes.

There are multiple and single probe types. The single probe type is most common in commercial and residential applications.

Circuit Breaking

On the single probe type, if the water falls below the level of the probe, the electronic circuit between the terminal and the boiler shell or piping is broken. In response to no circuit, the low water cut-off switch opens, cutting off power to the main gas valve.



High Limit Aquastat

Function

The high limit aquastat is similar to the operating aquastat but is adjusted to a higher water temperature setting [commonly 200°F (93°C)]. It serves as a backup safety switch in case the operating aquastat fails.

Manual Reset

Some models are equipped with a manual reset device. For example, if the water temperature reaches 200°F (93°C) and the contacts open, the switch must be manually reset to close to encourage the operator to check the system and remedy the situation rather than continually resetting the high limit.

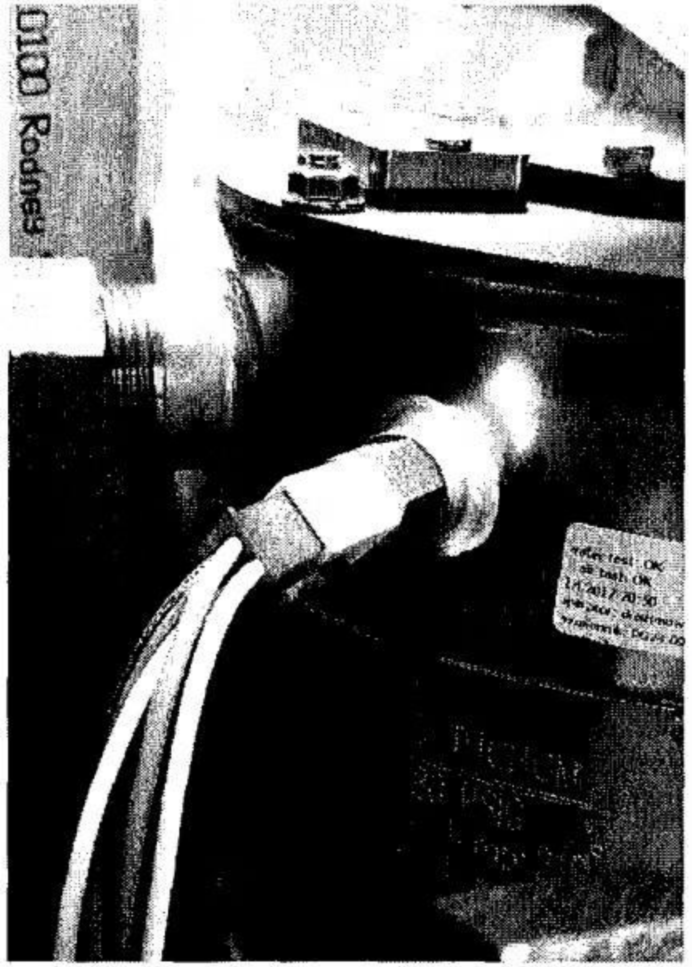
Dual Temperature Sensors

Combined Components

The two aquastats can be mounted side by side. In some cases, they are consolidated into one component, even sharing a single sensing element.

Dual Sensor Design

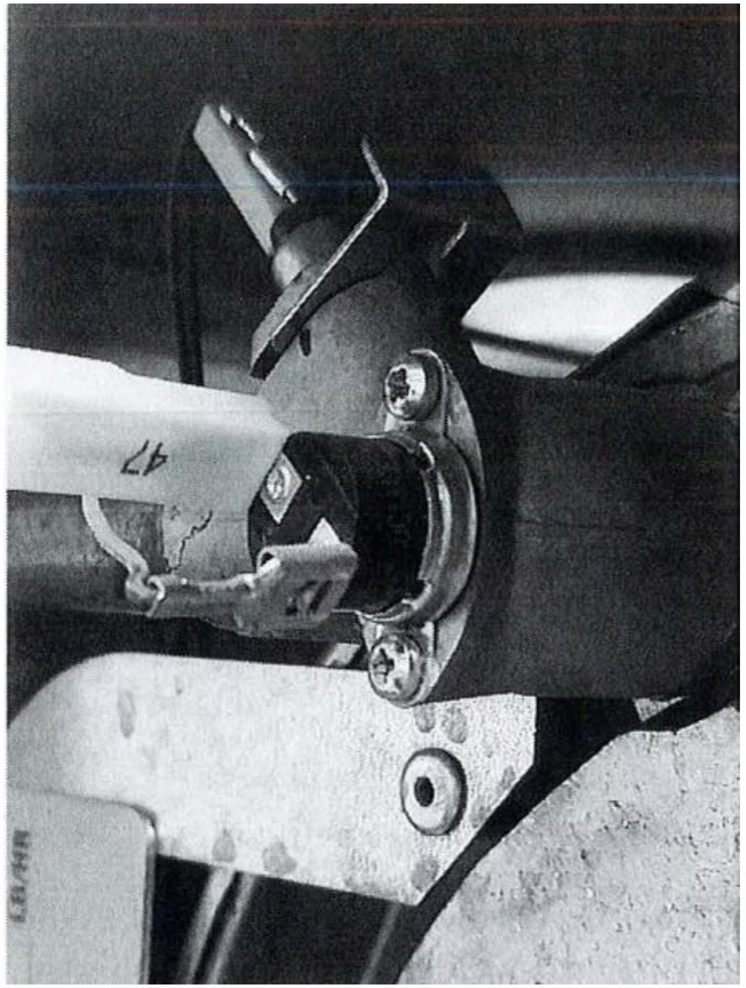
In the image, you can see four wires coming from this sensor well as a single housing contains both the operating and high limit thermistor type sensors.



Snap Disc Boiler High Limits

Surface Mount Design

Another common style of boiler high limit is the non-adjustable surface mount snap disc type. Notice that they must be in contact with a flat surface to get maximum contact.



Flow Switch

Function

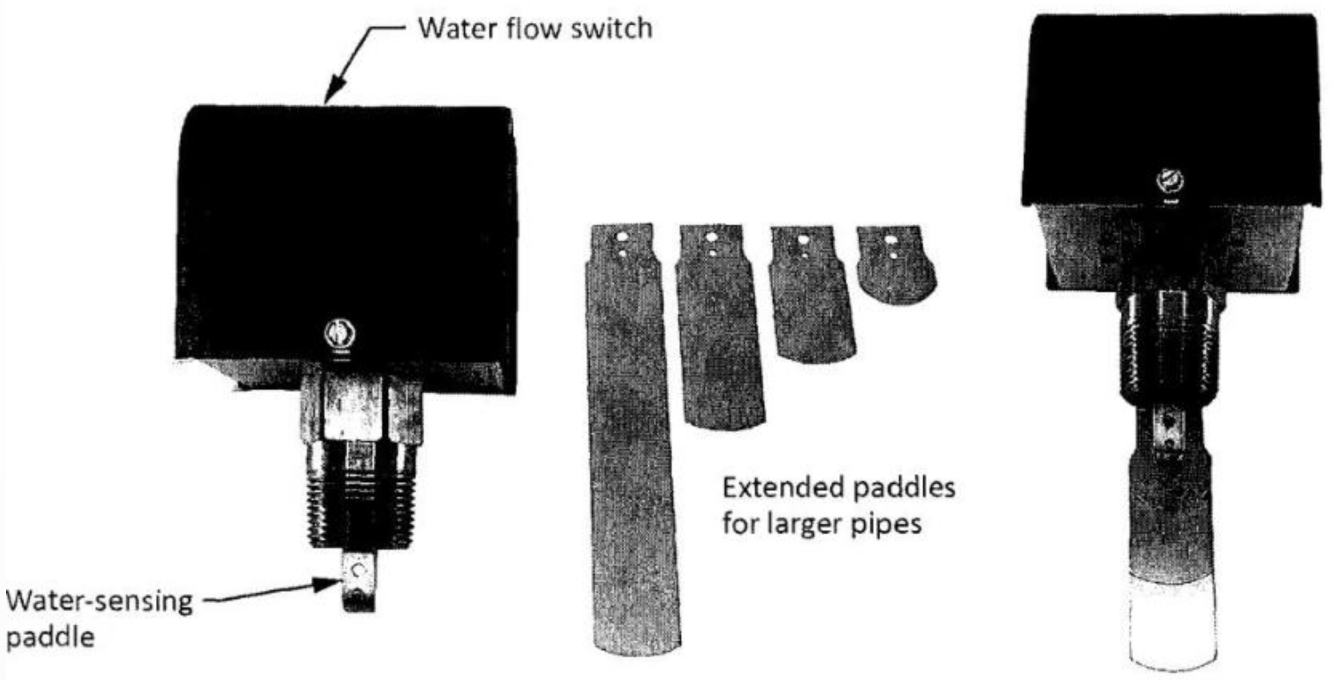
Flow switches actuate in response to water movement. They ensure that the pumps are circulating water in the piping system and the boiler before the main burner can fire.

Boilers that require flow switches have small water capacities, and their water may turn to steam if the flow of water is inadequate.

Installation

Flow switches come with various paddle lengths for different pipe sizes. Be sure to read the installation instructions carefully because some paddle sizes may need to be stacked to create a stiffer paddle or trimmed.

Figure 1-41
Flow switch that senses water flow
Image courtesy of Terry Bell

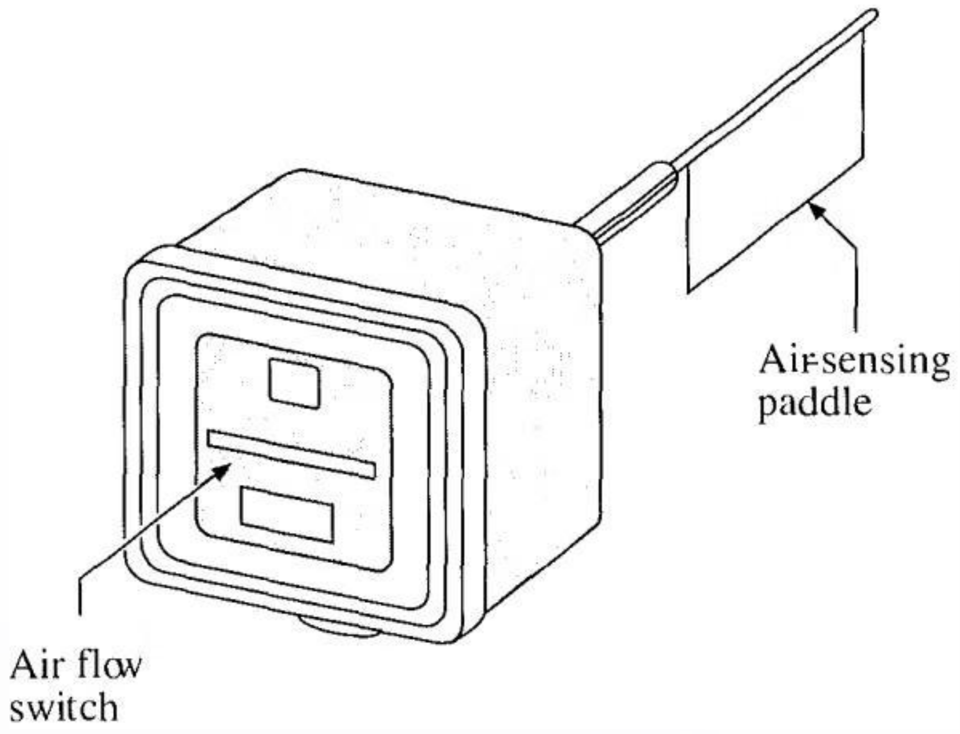


Sail Switch

Air Flow Detection

Flow switches can also be designed to detect air movement. These are called sail switches.

A common application of a sail switch is proving air flow for burner systems.



High-Limit Switch

Function

The high-limit switch actuates in response to an excessive rise in air temperature. It is a normally closed switch that opens the control circuit if overheating occurs.

Common Type

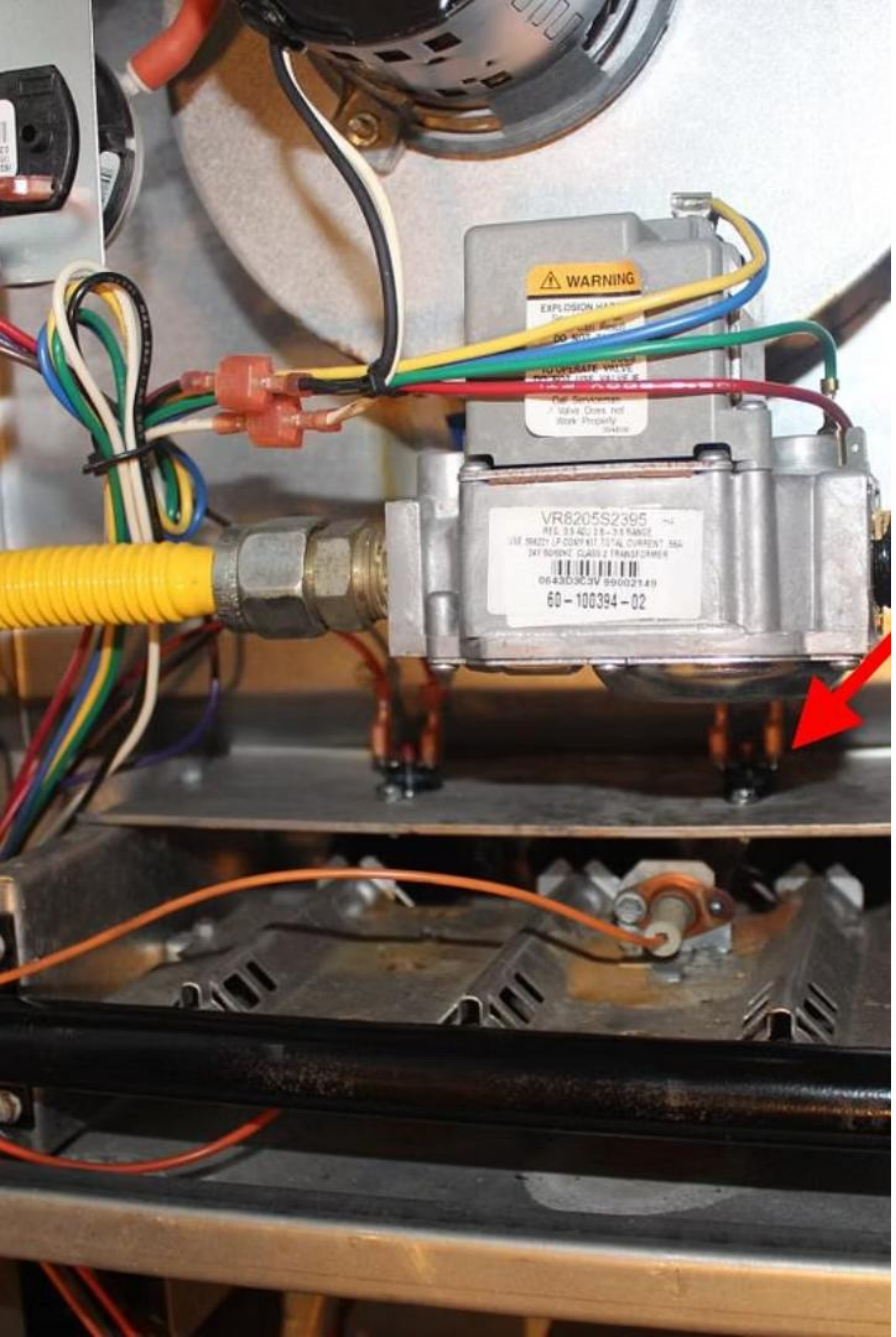
The snap disc temperature sensing switch is commonly used on many small appliances as a limit switch. The sensing element may extend into the air stream by employing an extended snap disc thermostat limit switch.

Extended Snap Disc Thermostat

Design

The extended snap disc thermostat has a sensing element that protrudes into the air stream for more accurate temperature measurement.

Figure 1-44
Extended snap disc thermostat limit switch
Image courtesy of Terry Bell



High-Limit Switch Operation

Location

A common location for a high-limit switch on a forced warm-air furnace is next to the heat exchanger.

Temperature Response

If the temperature of the heat exchanger reaches around 200°F (93°C) - the normal setpoint for the high limit - the heat-sensitive bi metal will warp and break the control circuit.

Automatic Reset

Once the temperature lowers to around 175°F (79°C), the contacts will automatically reset. In this case, the differential between the opening and closing temperature settings is 25°F (14°C).

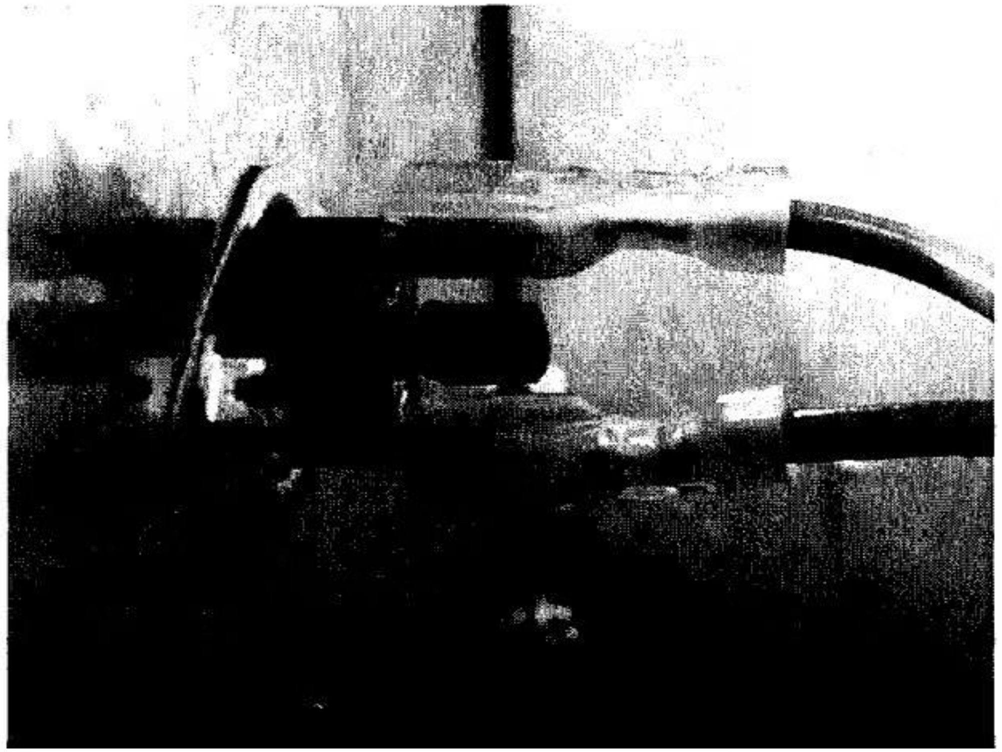
Fixed Settings

The setpoint and differential are usually not adjustable as these are determined by the manufacturer for the unit.

Flame Rollout Switch

Safety Application

The snap disc type of high-limit switch is often used as a flame roll-out switch for various applications. It also includes a small manual reset button between the electrical connections.

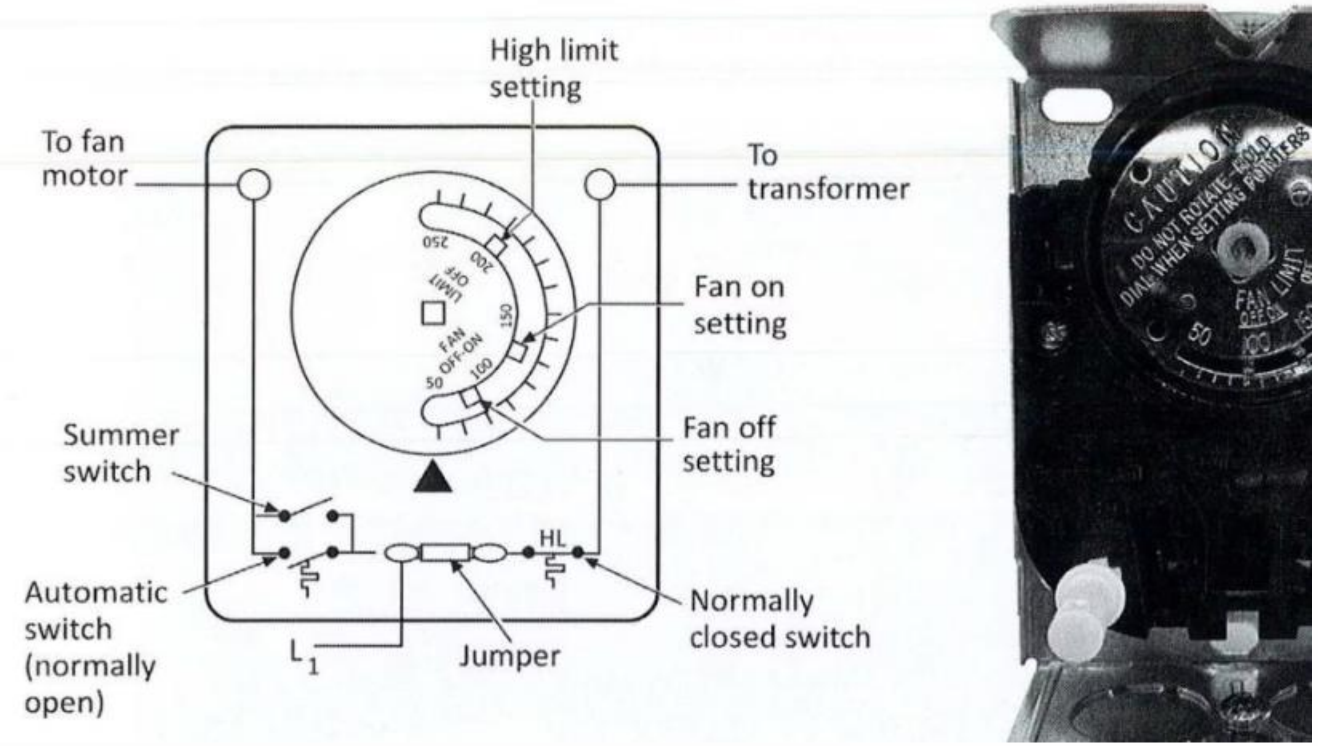


Combination High-Limit/Fan Control Switch

Consolidated Design

Multiple controls or sensors may be consolidated into one component. The combination high-limit/fan control is an older-style electrometrical control that contains a normally open fan switch on the left side and a normally closed high-limit switch on the right side and also shares the same bi metal helical sensing element.

Combination high-limit/fan control
Image courtesy of Terry Bell



Operation of Combination Control

Temperature Rise

As the temperature rises, the bimetal strip first closes the fan switch and starts the blower

Overheating Condition

If an overheating condition occurs due to insufficient air flow, the bi metal strip will continue to warp

Limit Activation

When the limit cut-out temperature is reached [around 200°F (93°C)], the limit switch opens

Fan Operation

The fan continues to run until the fan switch cools and opens

High-Limit Pressure Control

Function

A high-limit pressure control (pressuretrol) works similarly to an operating pressure control except that it is adjusted to a higher pressure setting.

Notice the high limit looks similar to the operating controller, but it does not have a differential setting; instead, it has a manual reset push button.

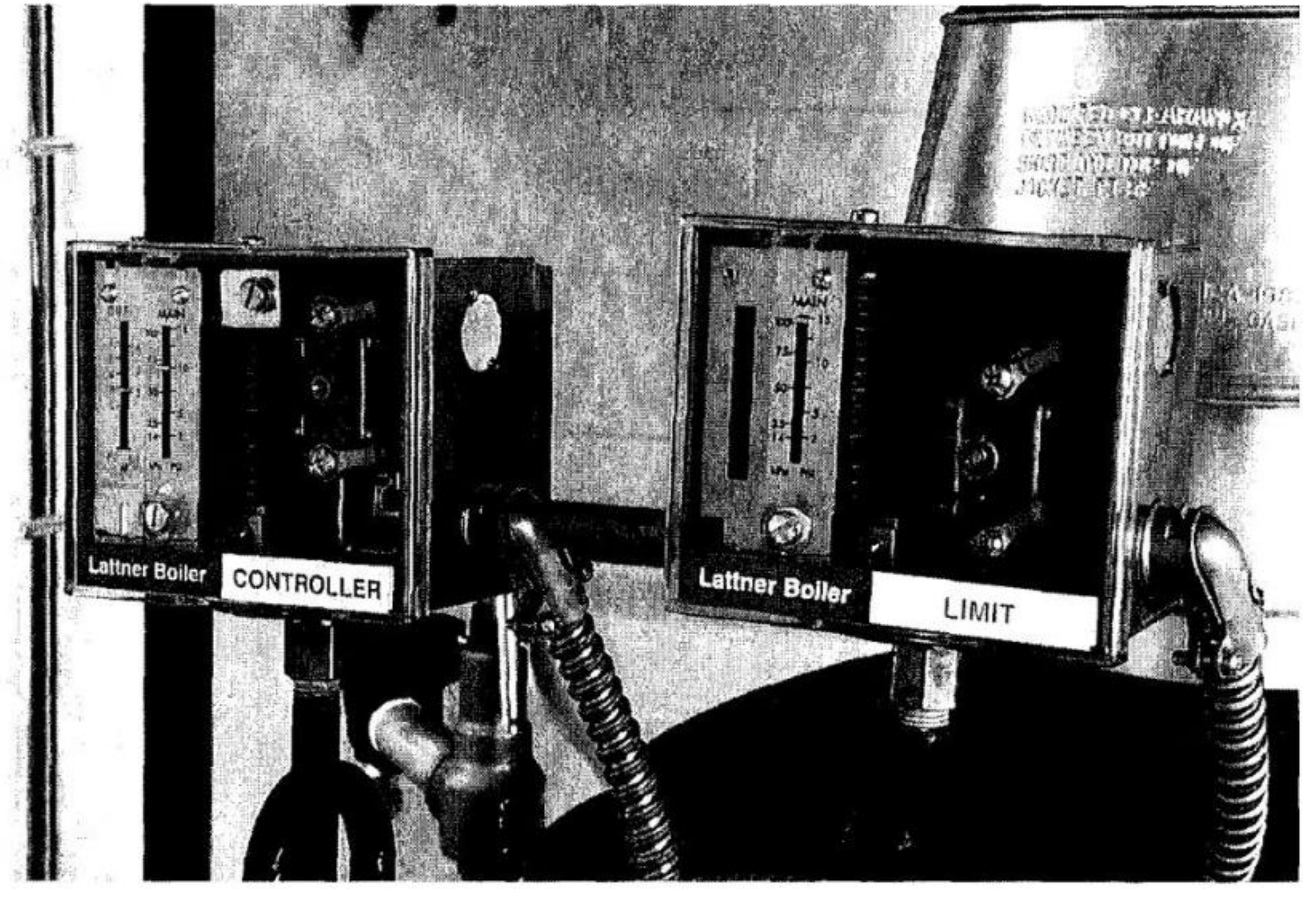
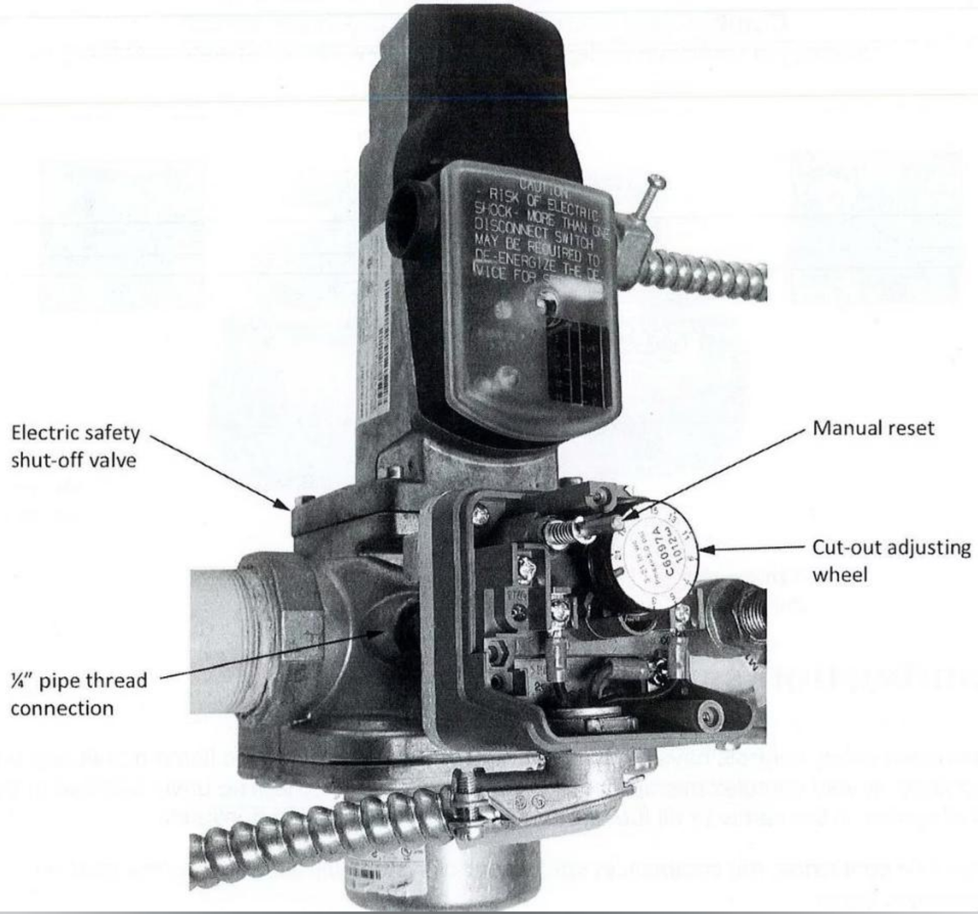


Figure 1-49
Gas pressure switch
Courtesy of Camosun College, Rodney Lidstone, licenced under CC BY



Gas-Pressure Switches

Code Requirement

Gas-pressure switches are required by code on burner systems that operate with gas pressures greater than 1/2 psig (3.5 kPa).

Safety Function

They automatically de-energize the gas valve(s), shutting off the gas supply to the burner in the event of an overpressure or an under pressure condition in the burner valve train assembly.

Specialized Equipment

Gas pressure switches differ from other pressure switches in that they are specifically approved to be used with combustible gases and are not interchangeable with non-approved controls.

Verification

Always confirm the application with the manufacturer's literature.

Types of Gas Pressure Switches

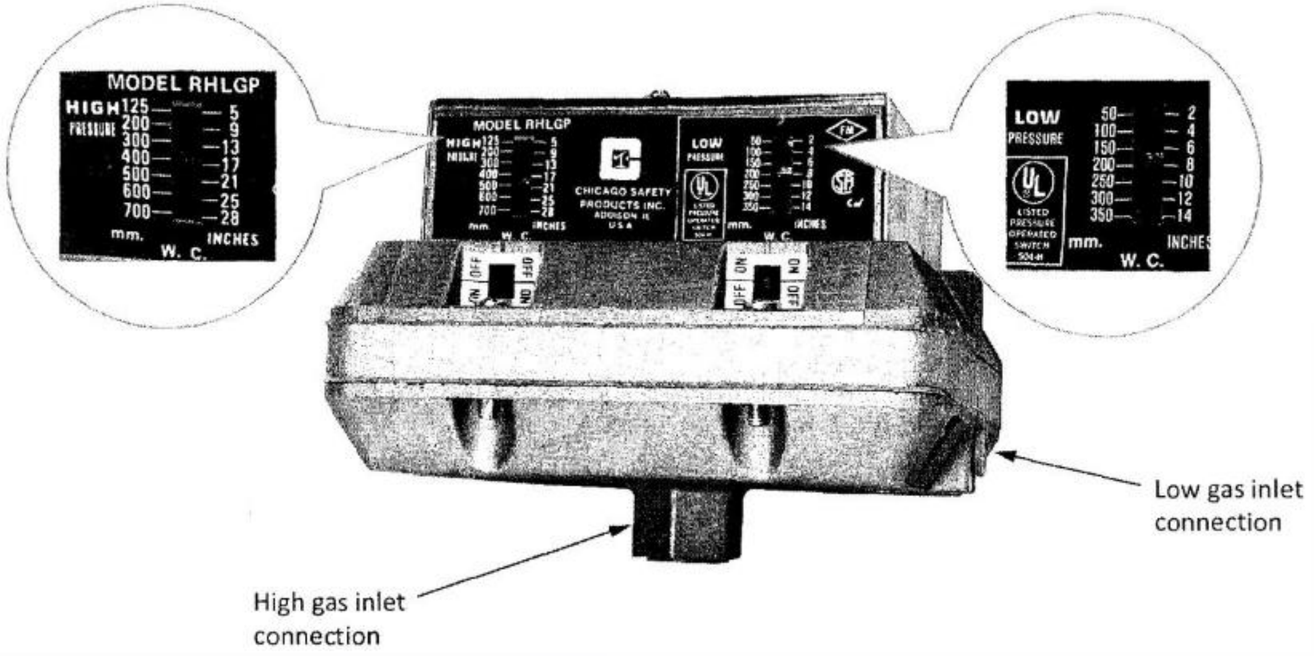
Type	Operation	CSA B149.3 Requirement
Low gas-pressure switch	Are reverse acting (RA) in that they open if gas pressure falls below the setpoint of the appliance pressure regulator	The switch opens if the pressure drops to 50% of the regulator setpoint.
High gas-pressure switch	Are direct acting (DA) in that they open when gas pressure exceeds the outlet pressure of the appliance regulator	The switch opens when the appliance regulator setpoint is exceeded by 25% or more.

Combination Gas Pressure Switch

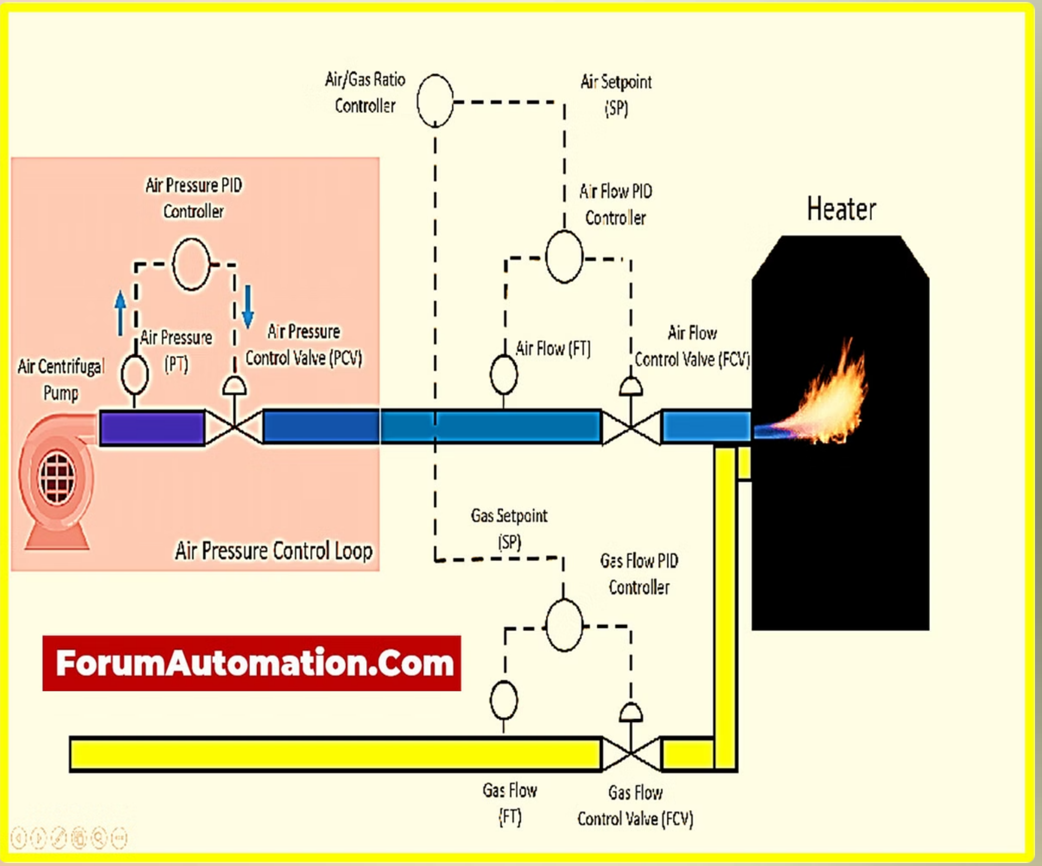
Combined Function

As with many other controls, both the high and the low pressure switches may be combined in a single unit.

Closer inspection of the settings shows that this combination switch is set up to protect an appliance operating with a maximum inlet gas pressure of 1/2 psig (14 inches w.c.) and a minimum of 1/4 psig (7 inches w.c.).



Combustion Safety Controls



Evolution

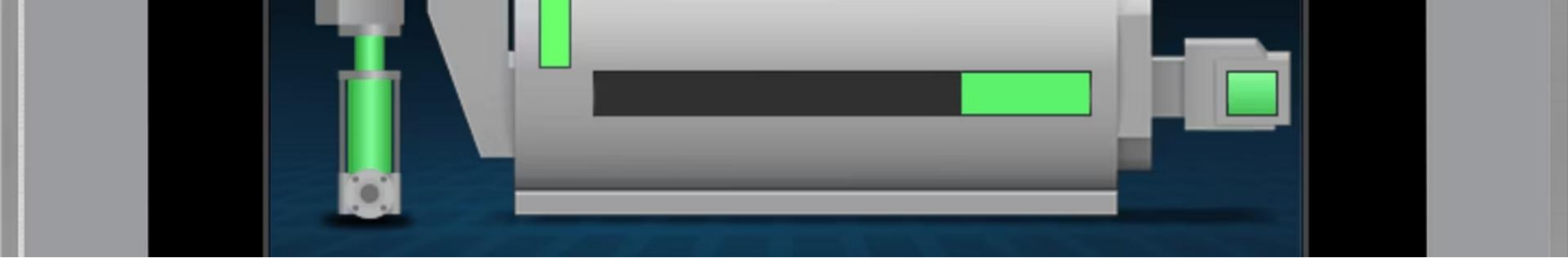
Combustion safety controls have evolved over the years from very basic flame monitoring and supervision to very complex microprocessor-based control systems.

Purpose

The basic purpose of the control system is the same for all fuel systems: to safely operate the appliance.

Function

Under safe conditions, the combustion safety control system will allow the burner start-up sequence to begin.



Evolution of Combustion Controls

1

Simple Thermocouple

Early systems used basic thermocouples that monitored the pilot flame

2

Electronic Ignition Control

Advanced to modules that monitor the flame and sequence the burner cycle

3

Flame Safeguard Systems

Evolved to FSG control systems that control all processes of burner operation

4

Integrated Management

Modern systems feature manufacturer-specific integrated burner management and control systems

Flame Sensors

Purpose

Flame sensors are designed to detect the presence of a flame, whether it be the pilot flame or the main burner.

Operation

If the flame is not detected, the flame sensor fails to send a flame signal to the control module/system.

More complex systems are examined in the Gas Trade Training: Advanced program above 400k BTU series.

Flame Rod Detectors

Common Detection Method

Flame rod detectors are the most common flame-sensing devices.

Types

There are two basic types of flame rod detection systems:

- flame conductivity
- flame rectification

They work on the principle of flame ionization, whereby the heat from the flame causes air molecules in and around the flame envelope to collide so forcibly as to propel some electrons out of their atoms, thus producing ions and free electron.

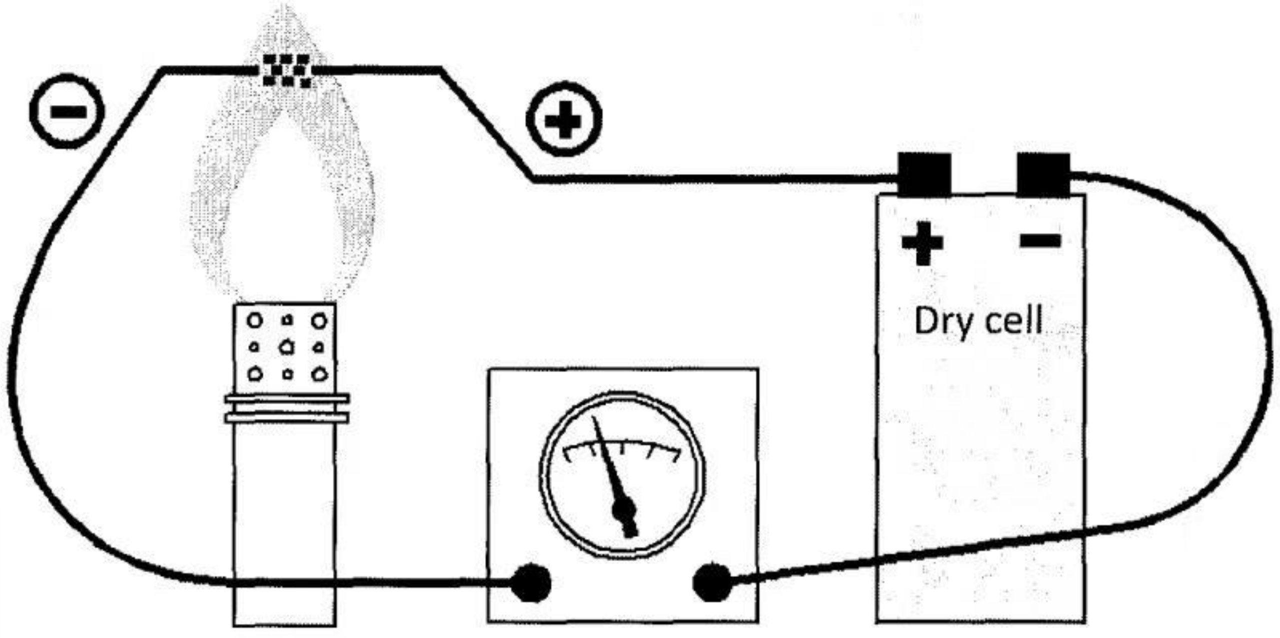
Flame Conductivity System

Operation

For a conductivity system, two flame rods (electrodes) are placed in the flame, and when an AC voltage is applied across the electrodes, an equal current can be conducted through the flame between the two rods. Since electricity consists of electrons moving from atom to atom, the ions in the flame conduct the movement of these electrons.

Limitation

Because the flame current in a conductivity system is AC, this system cannot differentiate between a leakage current and an actual flame current. It is possible for the system to falsely indicate the presence of a flame (with possibly dangerous results) if the flame electrode is shorted to ground through a leakage circuit with about the same resistance as the flame.



Flame Rectification System

Design Difference

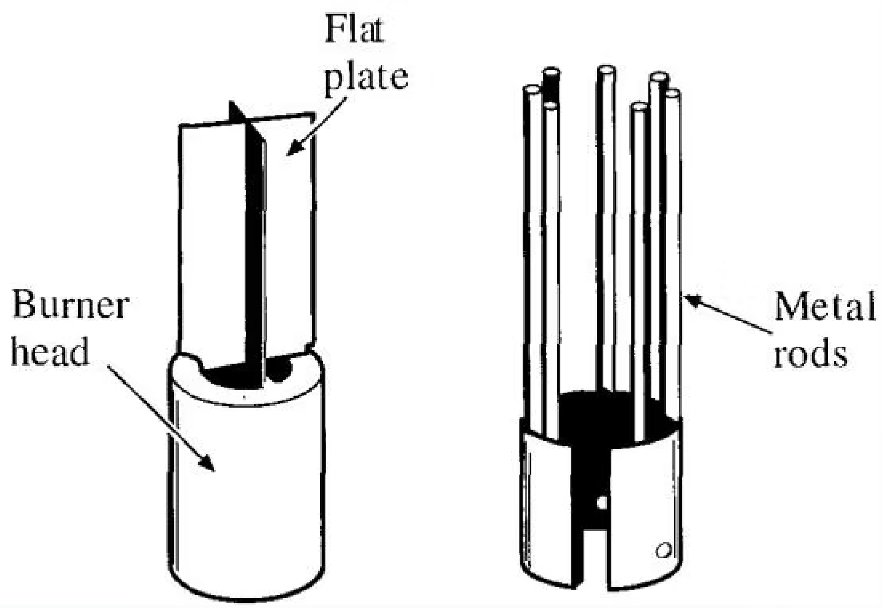
The flame rectification system also uses two electrodes, but with one important difference - the ground electrode is always designed to be much larger than the flame electrode (flame rod).

The amount of current conducted through the flame depends on the relative size of the flame rods. In this system, the ground electrode (usually the burner head) is much larger than the flame electrode.

Size Ratio

To ensure adequate flame rectification, maintain a minimum ratio of 4:1 between grounding area and the flame rod. This means that the grounding area must be four times the size of the flame rod.

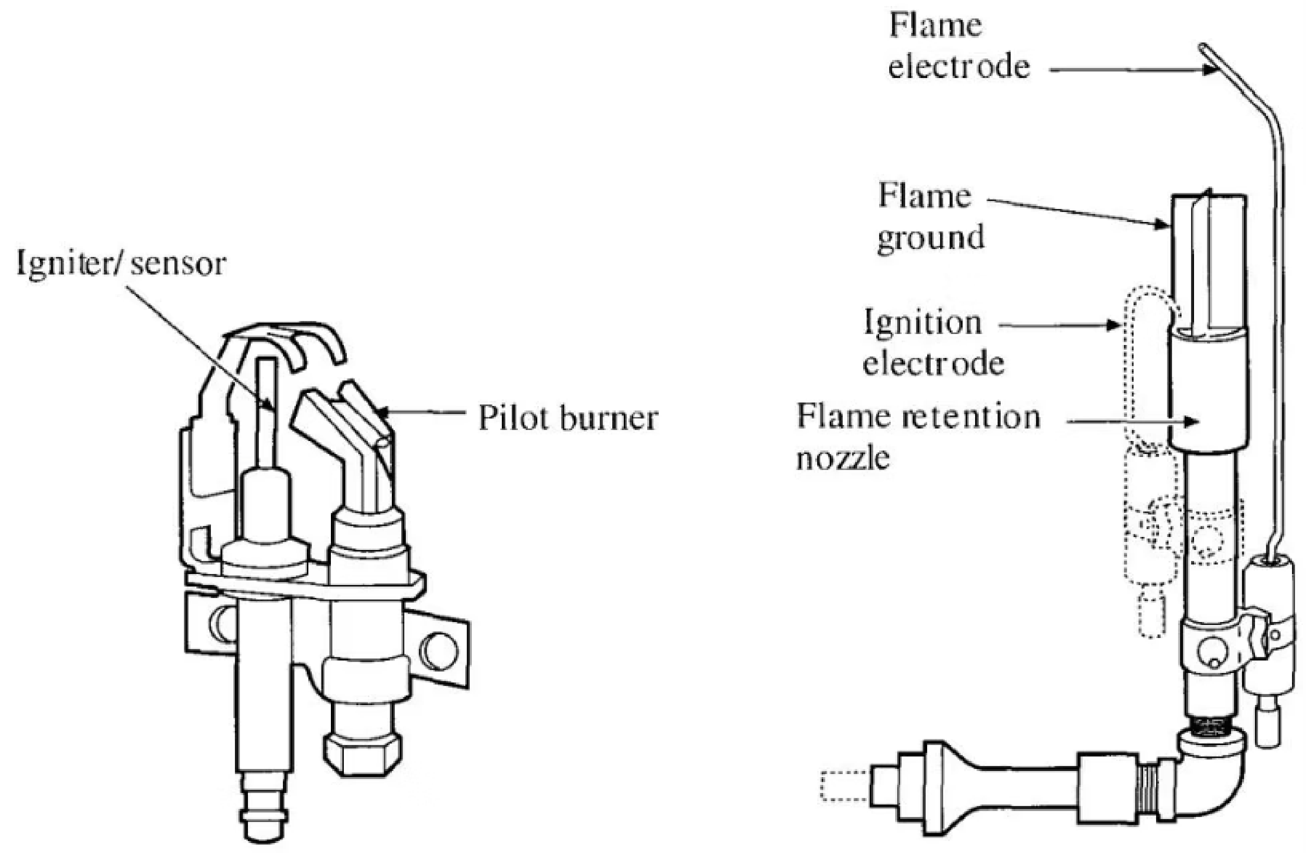
In some cases, additional metal rods or plates are added to the burner to increase the grounding surface area.



Flame Rod Materials

High Temperature Materials

The typical flame rod is made from Kanthal®, a high temperature alloy capable of withstanding temperatures up to 2462°F (1350°C), or Globar®, a ceramic material having a maximum operating temperature of 2600°F (1425°C).



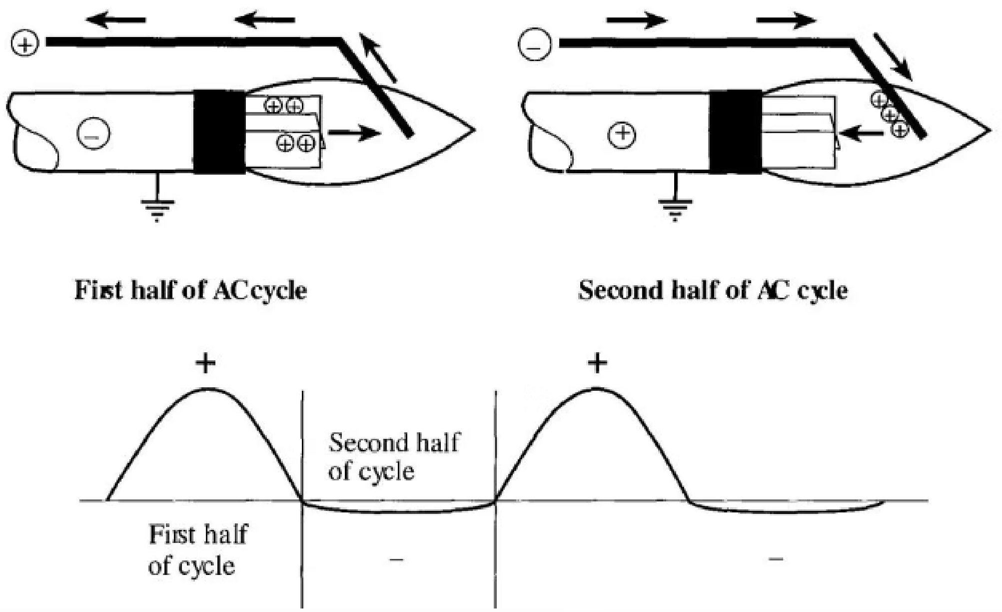
Typical flame rod setup for both residential and large applications.

Flame Rectification Operation

Principle

Although powered by an AC source, the size difference between the burner head and the flame rod creates a pulsating current that can be read by a DC microammeter.

Figure 1-54
Current flow in a flame rectification system
Any short circuit of the flame rod to ground would create an equal AC signal This would be identified by flame safeguard control and would be rejected.



Flame Rectification Cycle

First Half of Cycle

1. AC voltage is supplied across the two electrodes. The flame rod is positive, and the grounding area is negative.

2. Positively charged ions flow to the grounding area. Since the grounding area is large, it holds many electrons.

3. Positively charged ions pull a high stream of electrons into the flame. This results in a high current flowing from the grounding area to the flame rod during the first half of the cycle.

Second Half of Cycle

In the second half of the cycle, the reverse process occurs, but the flame rod cannot hold as many electrons and the resulting current is weaker.

Resultant Current

The resultant current acts like a pulsating DC. The flame signal in a rectified system should be steady and can be measured with a DC microammeter.

Optical Flame Sensors

Flame Radiation

A flame radiates energy in the form of waves that produce heat and light. Only approximately 6% of the radiation is visible to the eye; the majority (90%) of the heat occurs at the infrared end of the spectrum, while a small percentage (3%) occurs at the ultraviolet end of the light spectrum.

Figure 1-55
Approximate breakdown of light emitted by flame

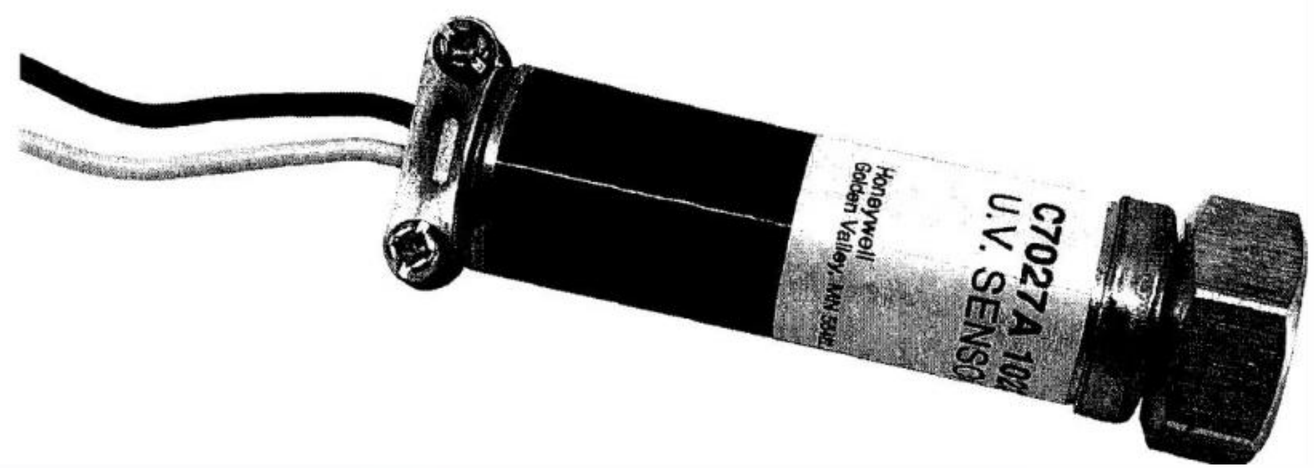
Ultraviolet Flame Sensor

Construction

An ultraviolet sensing tube can detect the radiant energy in a flame. This tube consists of quartz and filled with inert gas.

Operation

Two AC-energized electrodes within the tube will, upon detection of ultraviolet radiation, create electrical pulsations. These pulsations are used to signal the control module that ultraviolet radiation has been detected, thus proving the pilot flame.



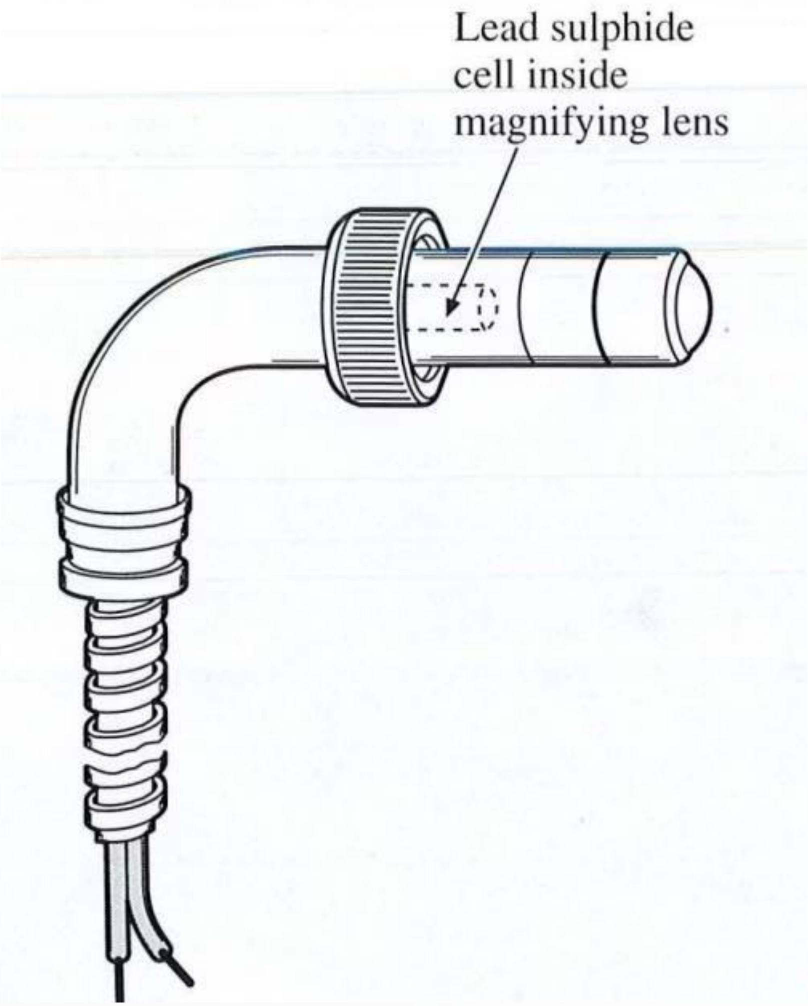
Infrared Flame Sensor

Main Element

The main element of the infrared sensor is a lead sulphide cell that is used as an electrical switch. The lead sulphide material is in itself a semiconductor, but when exposed to infrared radiation, it loses its resistance and allows free movement of electricity.

Application

When installed in the control circuit and (sighted) at the infrared part of the pilot flame, the lead sulphide cell will energize the circuit only if it detects infrared radiation, proving the pilot flame.



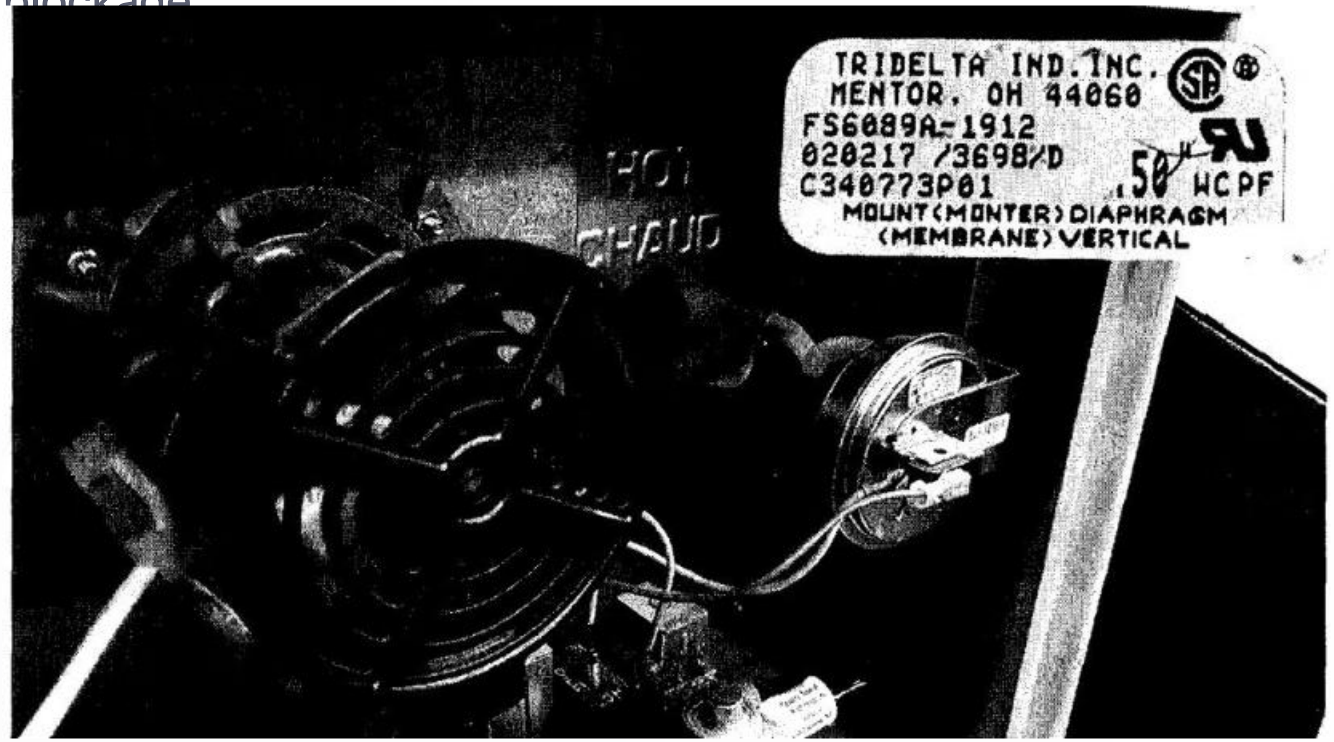
Air-Proving Switch

Function

Air-proving switches interlock the burner fan operation with the flame safeguard control. They are used to sense combustion air or flue gas flow on any appliance that incorporates a fan or blower.

Design

Essentially, air-proving switches are sensitive diaphragm-operated pressure switches used to sense positive, negative, or differential air pressure changes at specific location on the gas appliance to confirm air flow or alternately to indicate a blockage



Pressure Switch Operation

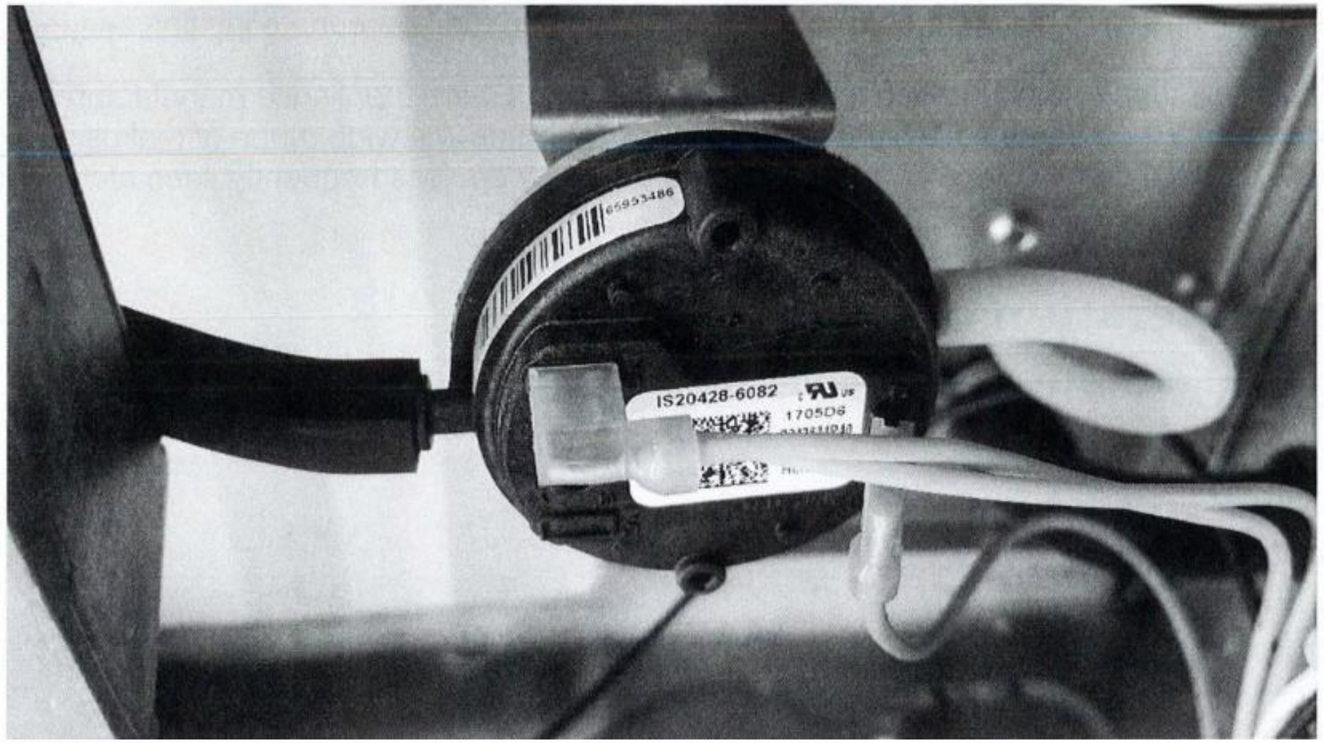
Single Sensing Design

The pressure switch shown has a single sensing hose connected to the negative side of the induced vent blower, requiring at least a 0.50 inch w.c. pressure fall (WCPF) to complete the control circuit.

A pressure switch used to sense a positive pressure would be labelled w.c. pressure rise (WCPR).

Differential Design

On high-efficiency condensing furnaces, the switch will have two hose connections to measure pressure difference - one for sensing the pressure at the burner enclosure and the other for sensing proper venting pressure at the draft inducer/condensate collector box.



Variable Capacity Applications

Multiple Pressure Switches

On variable capacity appliances, there will be multiple pressure switches with different pressure set points that correspond with the pressures created by the fan at different firing rates.

Calibrated Setpoints

Each pressure switch is calibrated to activate at a specific pressure level corresponding to a particular firing rate.

Safety Function

These switches ensure that proper air flow is maintained at each operating level, preventing unsafe combustion conditions.

Ignition Control Modules

Function

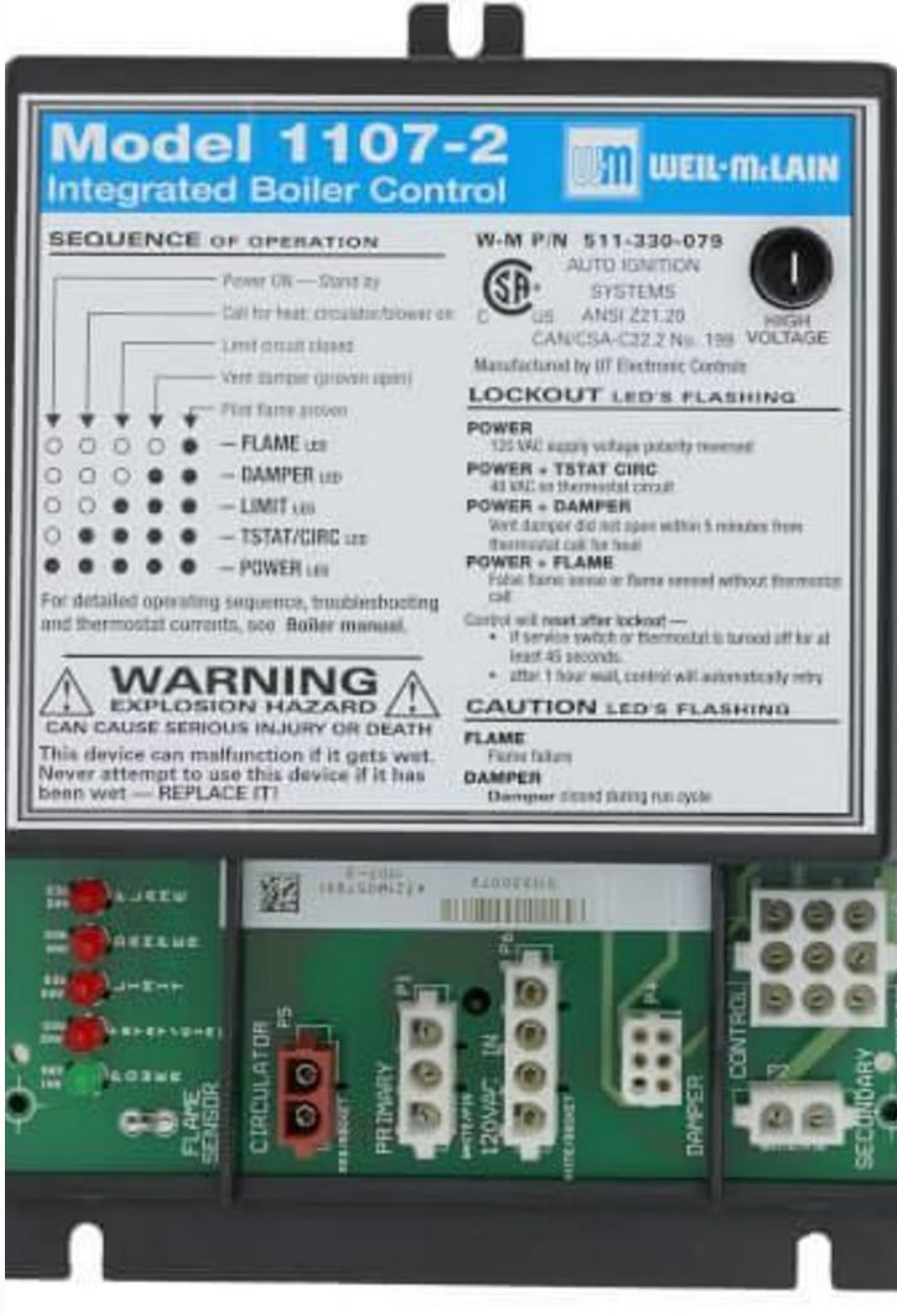
Control modules provide ignition and main flame failure protection for automatically ignited gas burners.

Operation

In conjunction with limit and operating controls and interlock devices, these controls automatically sequence with solid-state logic the burner/blower motor, ignition, and main fuel valves.

Cycling

The control cycles automatically when the operating controls close and after a power shutdown. They must be manually reset after a safety shutdown.



Evolution of Electronic Ignition

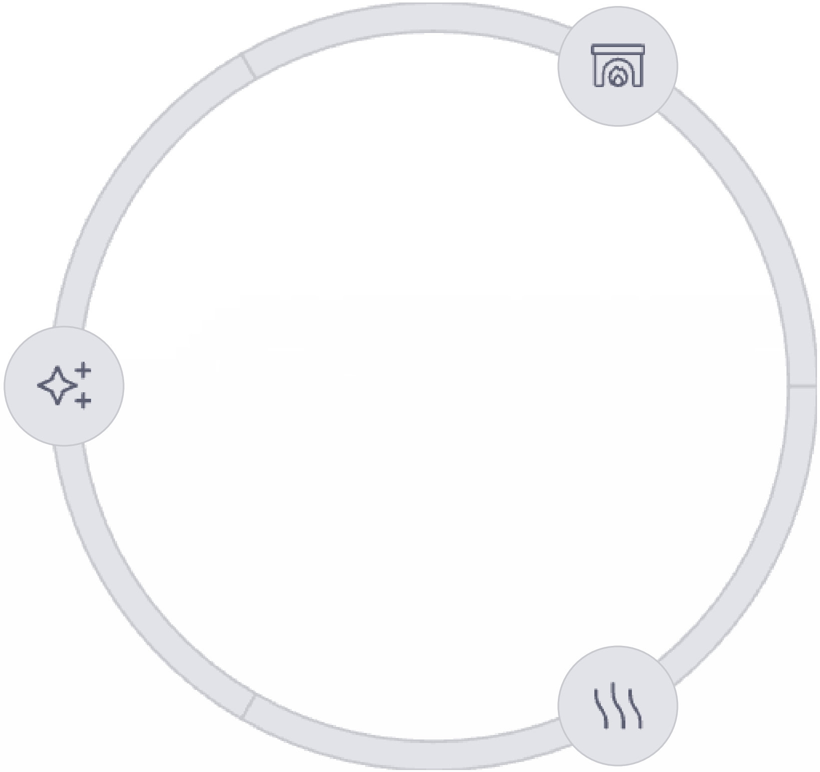
Original Design Purpose

Control systems with electronic ignition were originally designed for rooftop units, infrared heaters, and other gas-fired appliances where access to the pilot was difficult or where environmental factors such as wind and rain caused frequent pilot outages that involved expensive service calls.

Pilot Relight Kits

Pilot relight kits are flame sensors/igniters in one unit that, upon a flame failure, begin to spark in order to relight the pilot. This unit continues to spark for a predetermined amount of time until the pilot relights or the control module goes into lockout.

Types of Control Systems



Direct Spark Ignition

Uses a spark to directly ignite the main burner without a pilot

Intermittent Pilot

Uses a spark to ignite a pilot flame, which then ignites the main burner

Hot Surface Ignition

Uses an electrically heated element to ignite the gas

Manufacturers make several models of each type, depending on the specific sequence of operation required. Instead of a dedicated ignition control module, many appliances will have an integrated control board to manage all of the electronic components, including the appropriate ignition sequence.

Integrated Control Boards

Modern Approach

Instead of a dedicated ignition control module, many appliances will have an integrated control board to manage all of the electronic components, including the appropriate ignition sequence.

Flame Safeguard Controllers

On inputs less than 400,000 British thermal units per hour (Btu/h), appliance manufacturers may also choose to use a flame safeguard controller, which comes in a wide range of makes and models.

Basic Operation of Ignition Systems

2

Heat Call

On a call for heat, the thermostat energizes the control module

Sequencing

The control module then sequences the safe light-up of the burner system

Safety Check

Performs a safe start check

Ignition

Ignites the flame and powers the gas valves

Monitoring

Proves presence of flame and monitors during the run cycle

Cycle Completion

Thermostat Satisfaction

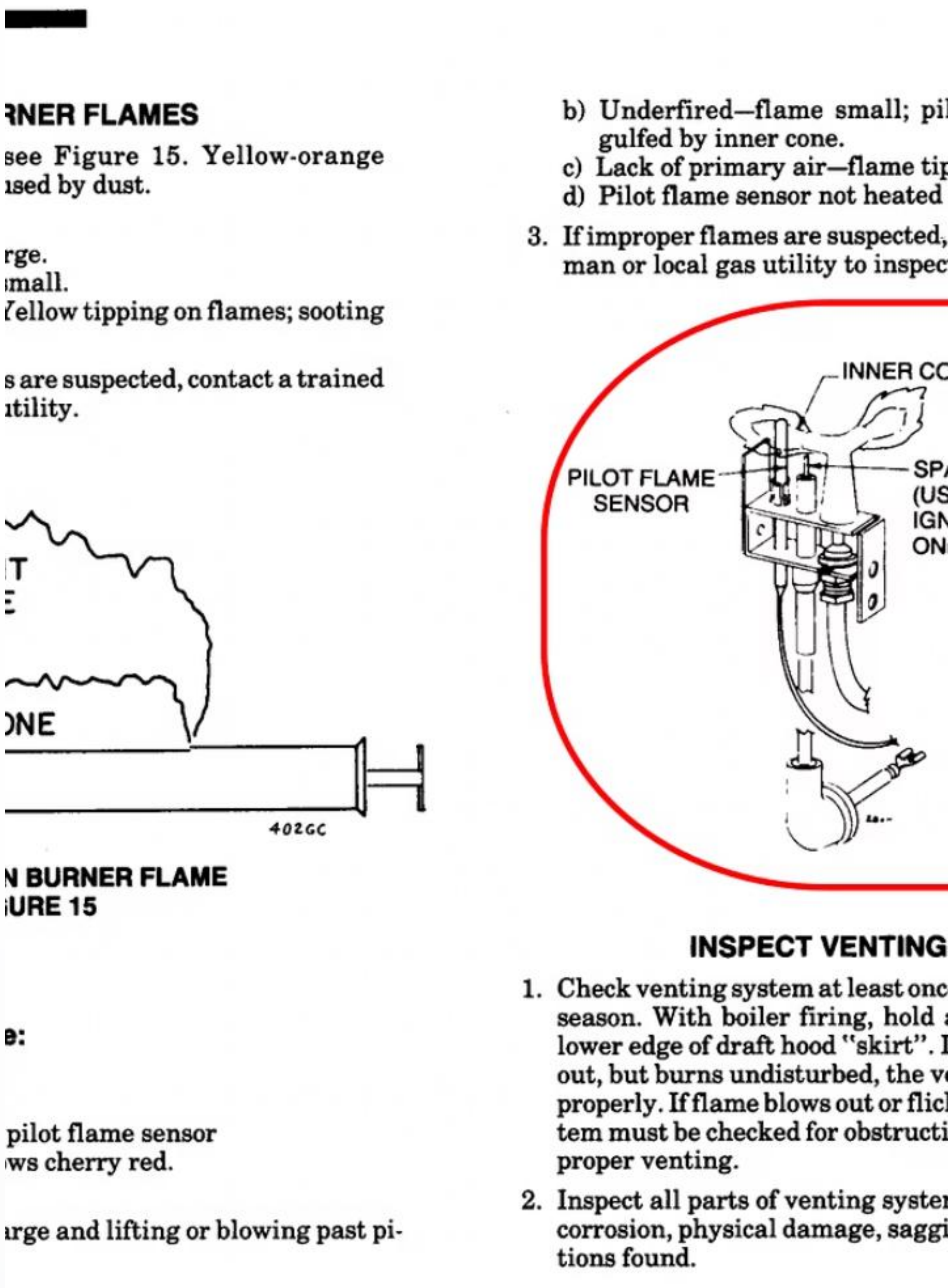
When the call for heat is satisfied, the thermostat de-energizes the control module.

Valve Shutdown

The control module then de-energizes both the pilot and main gas valves.

Ready State

The system returns to standby mode, ready for the next call for heat.


RNER FLAMES
see Figure 15. Yellow-orange
ised by dust.

rge.
small.
Yellow tipping on flames; sooting

s are suspected, contact a trained
utility.

N BURNER FLAME
URE 15

e:

pilot flame sensor
ws cherry red.

arge and lifting or blowing past pi-

b) Underfired—flame small; pi
gulfed by inner cone.
c) Lack of primary air—flame tip
d) Pilot flame sensor not heated

3. If improper flames are suspected,
man or local gas utility to inspec

INSPECT VENTING

1. Check venting system at least onc
season. With boiler firing, hold
lower edge of draft hood "skirt". I
out, but burns undisturbed, the v
properly. If flame blows out or flic
tem must be checked for obstructi
proper venting.
2. Inspect all parts of venting syste
corrosion, physical damage, saggi
tions found.

Ignition Control Terminology

Term	Definition
Trial for ignition	The period of time allowed to establish ignition. For modules that are part of a 100% safe system, the trial for ignition period is stated on the module. Modules that are part of a non-100% system energize the pilot valve and source of ignition until the flame is established.
Lockout	What happens to the control module if the trial for ignition time expires. The module then requires a manual reset to restart the ignition sequence, accomplished either by depressing a reset button on the control module or by turning the thermostat to its lowest setting, depending on the make and model.

Lockout Reset Procedure

De-energize Control

Turning the thermostat to its lowest setting de-energizes the control module.

Wait Period

After a predetermined period (usually 1 to 3 minutes), the control module resets.

Re-energize

The control can be energized by turning the thermostat back to its setting.

Lockout Indicators

Visual Indicators

Depending on the control and how it is wired, a visual (flashing LED) alarm accompanies lockout mode to indicate that there has been an ignition or flame failure.

- Different flash patterns may indicate specific fault codes
- Some systems use colored LEDs to indicate different states
- Modern systems may display numeric codes on a digital display

Audio Indicators

Some systems also include audio alarms that sound when a lockout condition occurs.

- Beeping patterns may indicate different fault types
- Volume and duration may vary by manufacturer
- Some systems allow for remote audio alarms

Boiler Control System Summary

Sensing Components

From pressure transmitters to flame sensors, modern boilers use a variety of sensing devices to monitor operating conditions.

Safety Controls

Multiple safety systems including high-limit switches, low-water cut-offs, and pressure controls work together to prevent hazardous conditions.

Control Logic

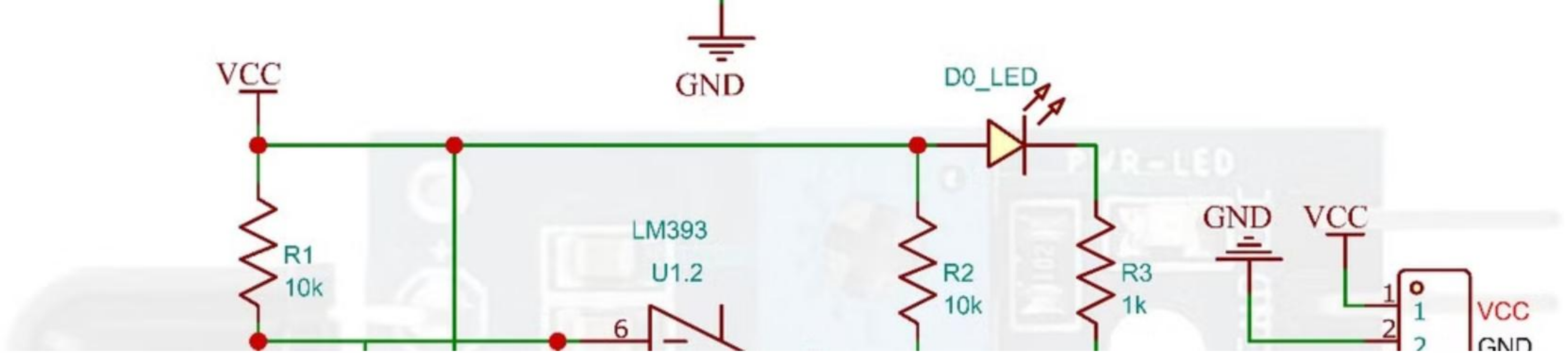
Advanced control systems use PID algorithms and closed-loop feedback to maintain optimal operation and efficiency.

Integration

Modern boilers can be integrated into building management systems for comprehensive monitoring and control of all building systems.

Gas Appliance Control Systems

This presentation explores the various control systems used in gas appliances, including flame failure response mechanisms, ignition control modules, and valve systems that ensure safe and efficient operation.



Flame Failure Response Time

Definition

The time it takes the flame sensor circuits to react to a flame failure and de-energize the main gas valve

Control Module Response

Some control modules go directly into lockout on a flame failure, while others recycle the trial for ignition.

Intermittent Pilot Control Module

Call for Heat

On a call for heat by the control circuit, the control module sequences the safe light-up of the pilot flame and then the main burner.

Operation

The pilot flame ignites and operates only during main burner operation.

Shutdown

When the call for heat is satisfied, the pilot and main gas valves are shut off.

INTERMITTENT CONTROL SYSTEM WIRING DIAGRAM

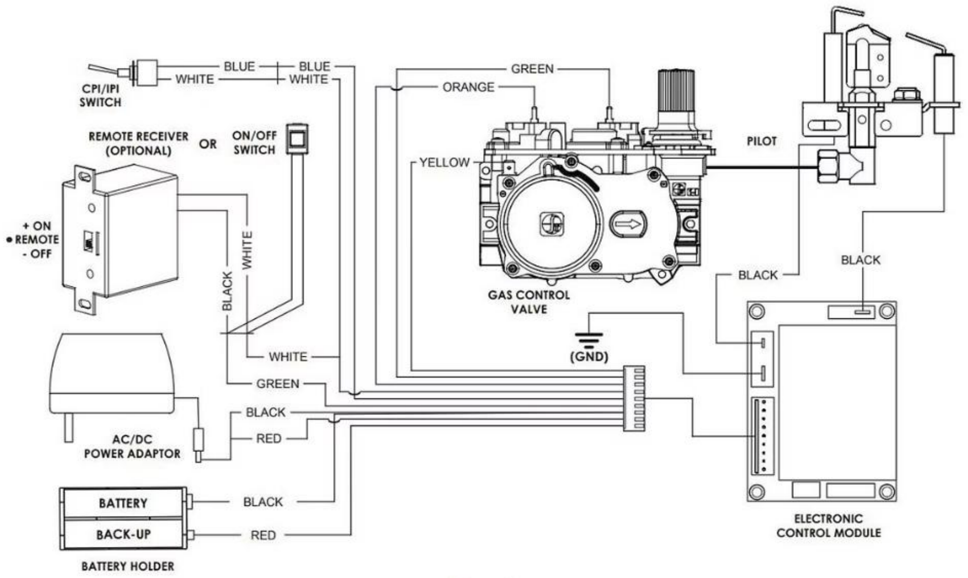


Figure 24

Intermittent Pilot Control Module Terminals

Terminal Layout

The terminals on the control module connect to the control circuit, the main and pilot valves, and the igniter-sensor.

Each manufacturer of an intermittent pilot control module designs a different terminal layout. However, all types have terminals for input power, main and pilot gas valves, ground, and the igniter sensor.

Redundant Gas Valve

The redundant gas valve has two internal valve seats for extra safety.

This valve can be set up to operate separately for an intermittent pilot system or simultaneously for non-pilot systems such as direct spark ignition or hot surface ignition.

Figure 1-60
Intermittent pilot control module with combination igniter-sensor and redundant gas valve

Intermittent Pilot Control Module Components

Control Circuit

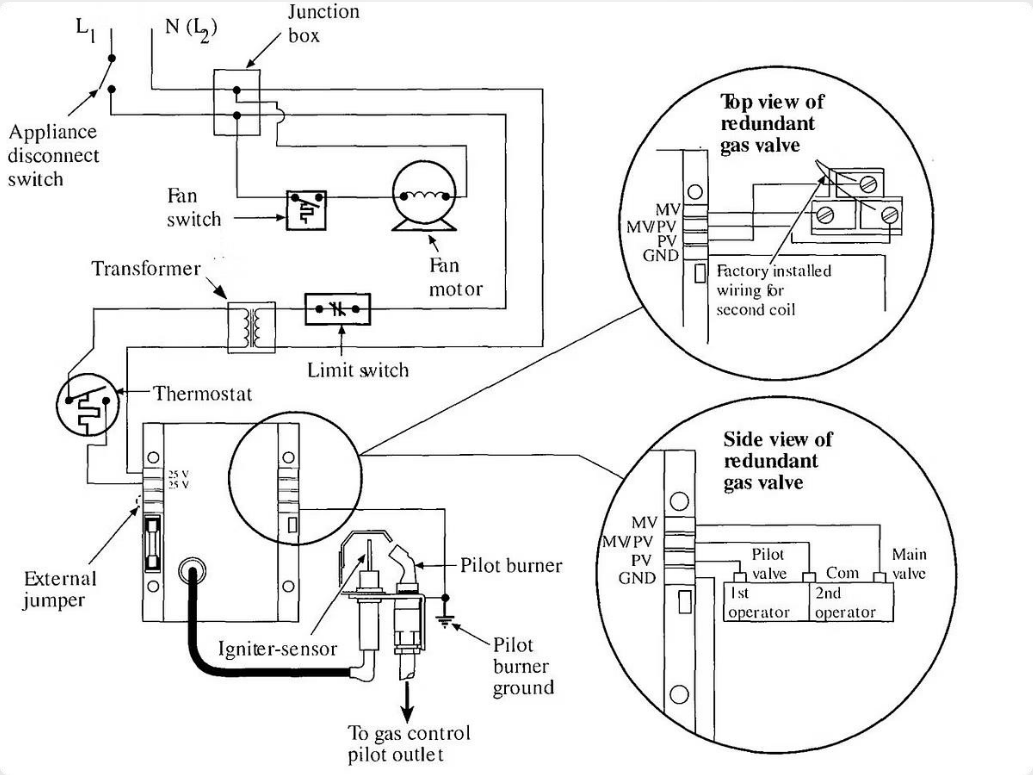
The control module is energized when the control circuit is complete.

Thermostat

On a call for heat, the thermostat contacts close to complete the control circuit.

Voltage

The control circuit energizes the control module through the terminals labelled "25V."



Intermittent Pilot Control Module Operation

Safe Start Check

Energizes the flame sensor and performs a safe start check; if false signal exists, it does not energize the igniter.

Ignition Sequence

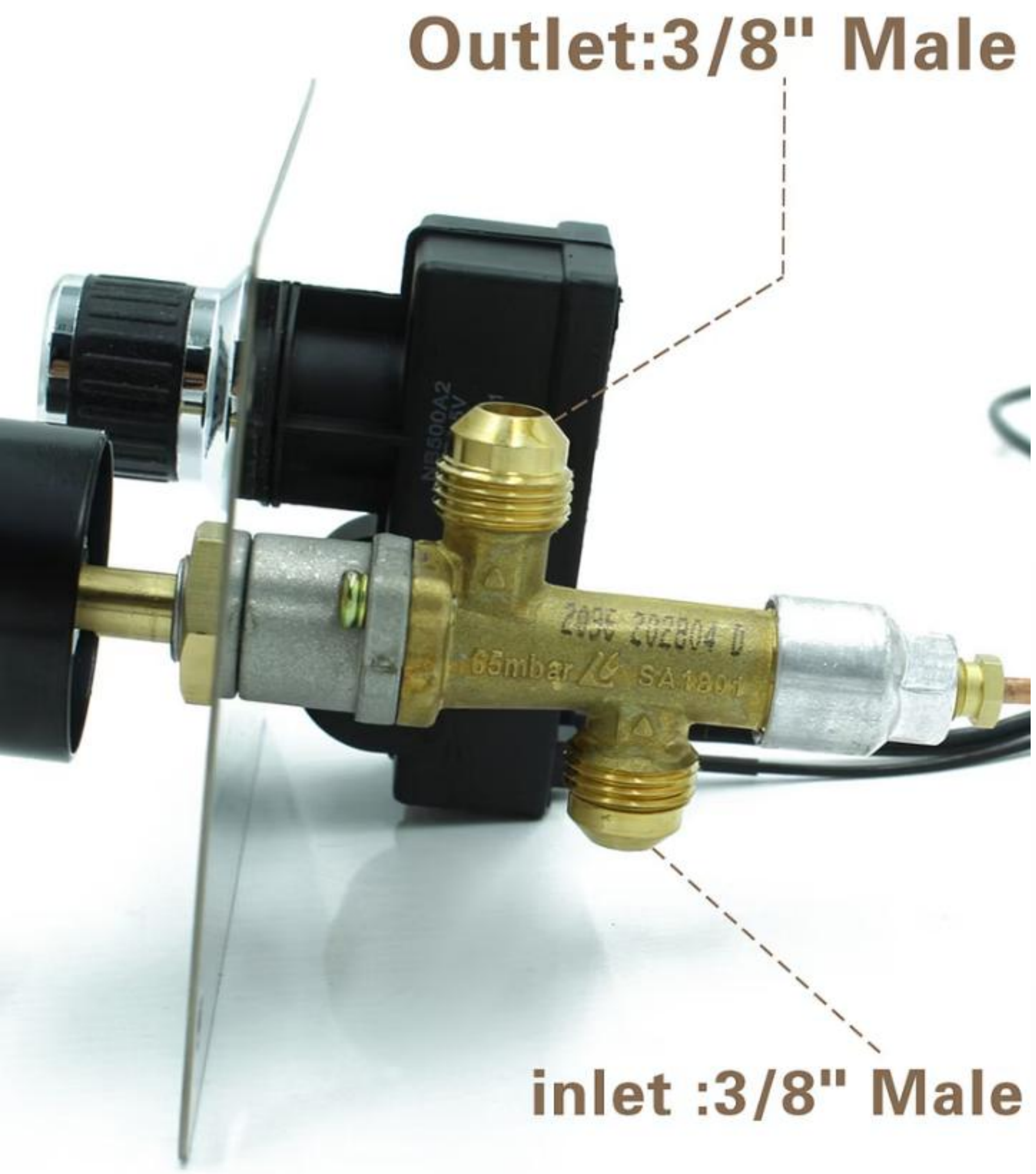
Energizes the igniter, then energizes the pilot valve through terminal marked "PV", and lights the pilot flame with the igniter.

Flame Proving

Proves the flame with the flame sensor, de-energizes the igniter, and energizes the main gas valve through the terminal marked "MV".

Monitoring

Monitors the pilot flame, through the flame sensor, during the entire run cycle of the main burner.



Flame Failure Response

Flame Failure

If flame failure occurs, the control module responds immediately

Valve Shutdown

De-energizes the main gas valve

Reignition

Re-energizes the igniter

Safety Lockout

On 100% safe systems, if unable to relight within trial period, control module goes into lockout

Non-100% Safe Systems

Continuous Operation

For non-100% safe systems, the spark generator remains energized indefinitely or until a pilot flame is finally established.

Safety Concerns

This approach presents potential safety issues as unburned gas could accumulate if ignition fails to occur.

Modern Standards

Most modern systems incorporate lockout features to prevent continuous attempts at ignition when conditions are unsafe.

Direct Spark Ignition Control Module

Operating Principle

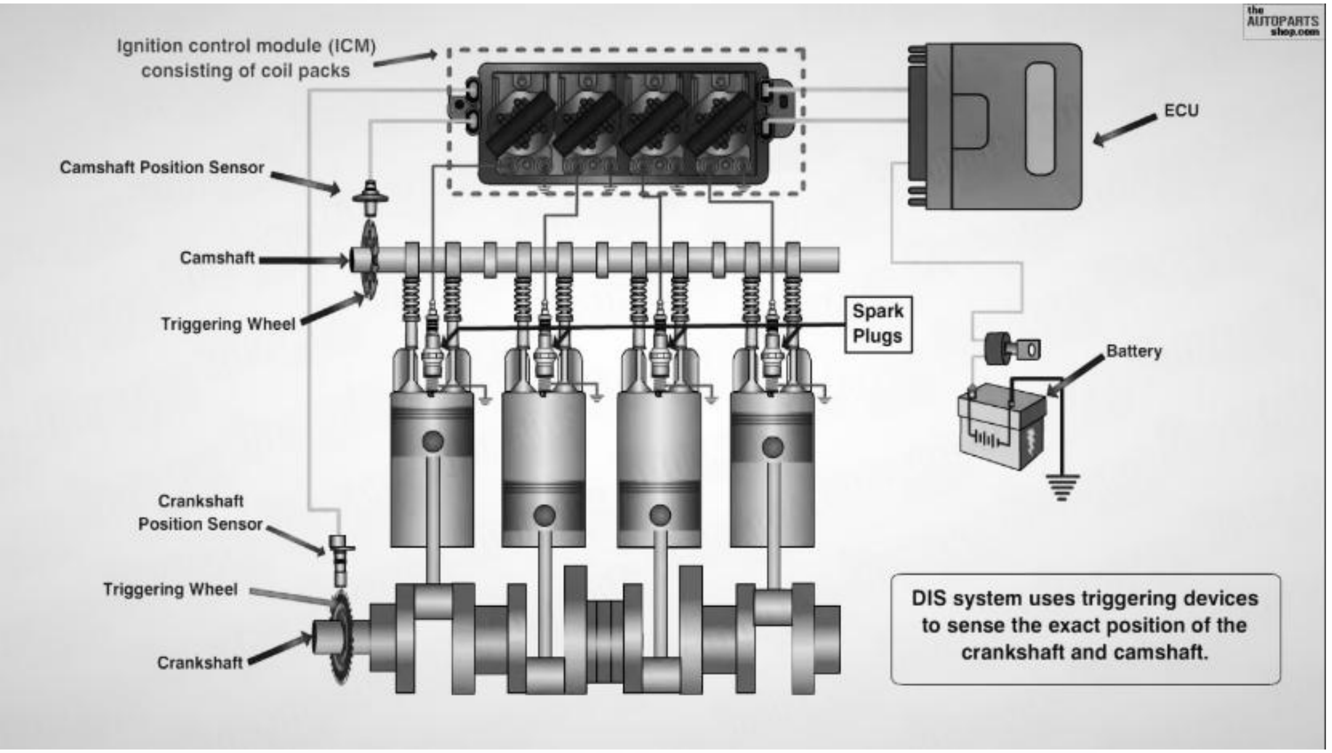
Direct spark ignition systems operate on a slightly different principle from the intermittent pilot system.

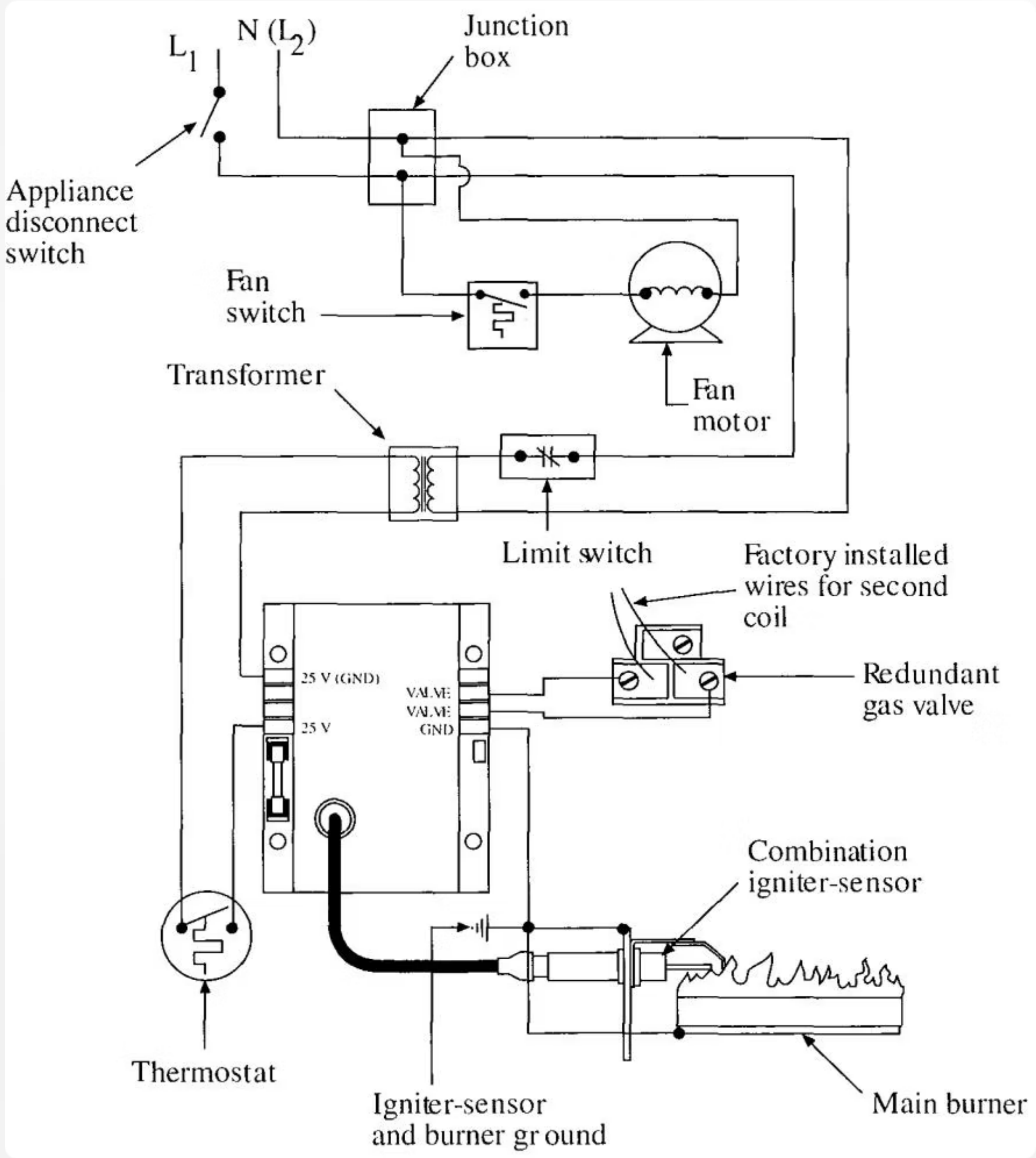
Direct spark ignition does not use a pilot flame but rather directly lights the main burner with a spark.

Valve Configuration

The control module does not have the terminals for pilot valves.

If a redundant type gas valve is used, both coils are wired in parallel and are energized together.





Direct Spark Ignition Terminals

Input Power

Terminals for connecting power to the control module

Main Gas Valve

Terminals for controlling the main gas valve

Ground

Terminals for proper grounding of the system

Igniter-Sensor

Terminals for the combination igniter-sensor

Direct Spark Ignition Operation

Call for Heat

Thermostat contacts close to complete the control circuit

Flame Monitoring

Flame sensor proves flame, igniter de-energizes, and sensor monitors flame during operation

Safe Start Check

Flame sensor performs check; if false signal exists, igniter is not energized

Ignition

Igniter energizes and main gas valve opens to light main flame

Direct Spark Ignition Flame Failure Response

Flame Failure Detection

Flame sensor detects loss of flame

Reignition Attempt

Control module re-energizes the igniter

Safety Lockout

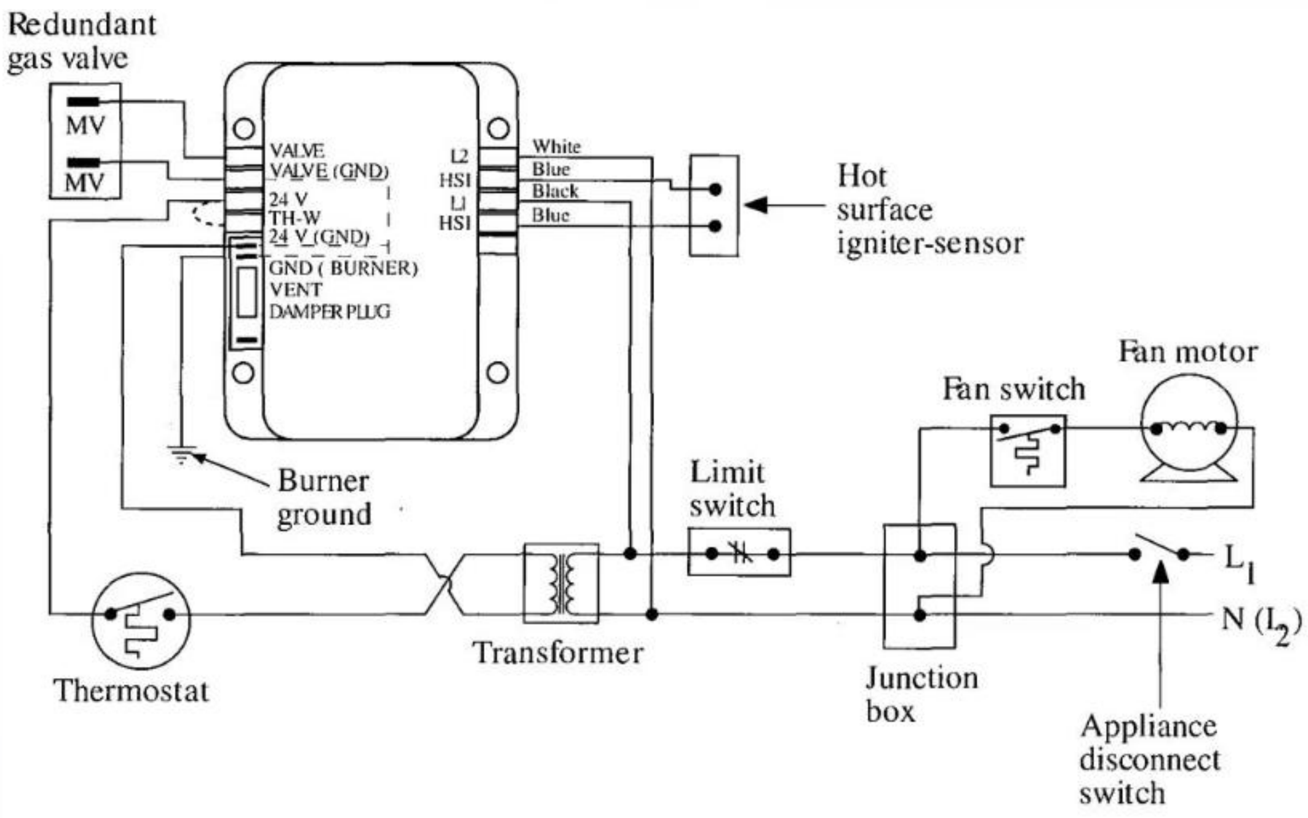
Goes into lockout if unable to relight within trial for ignition period

Hot Surface Ignition Control Module

Operating Principle

Hot surface ignition systems operate the same as direct spark ignition, except that a hot surface lights the main burner.

The hot surface igniter requires line voltage to heat the surface hot enough to ignite gas on contact.

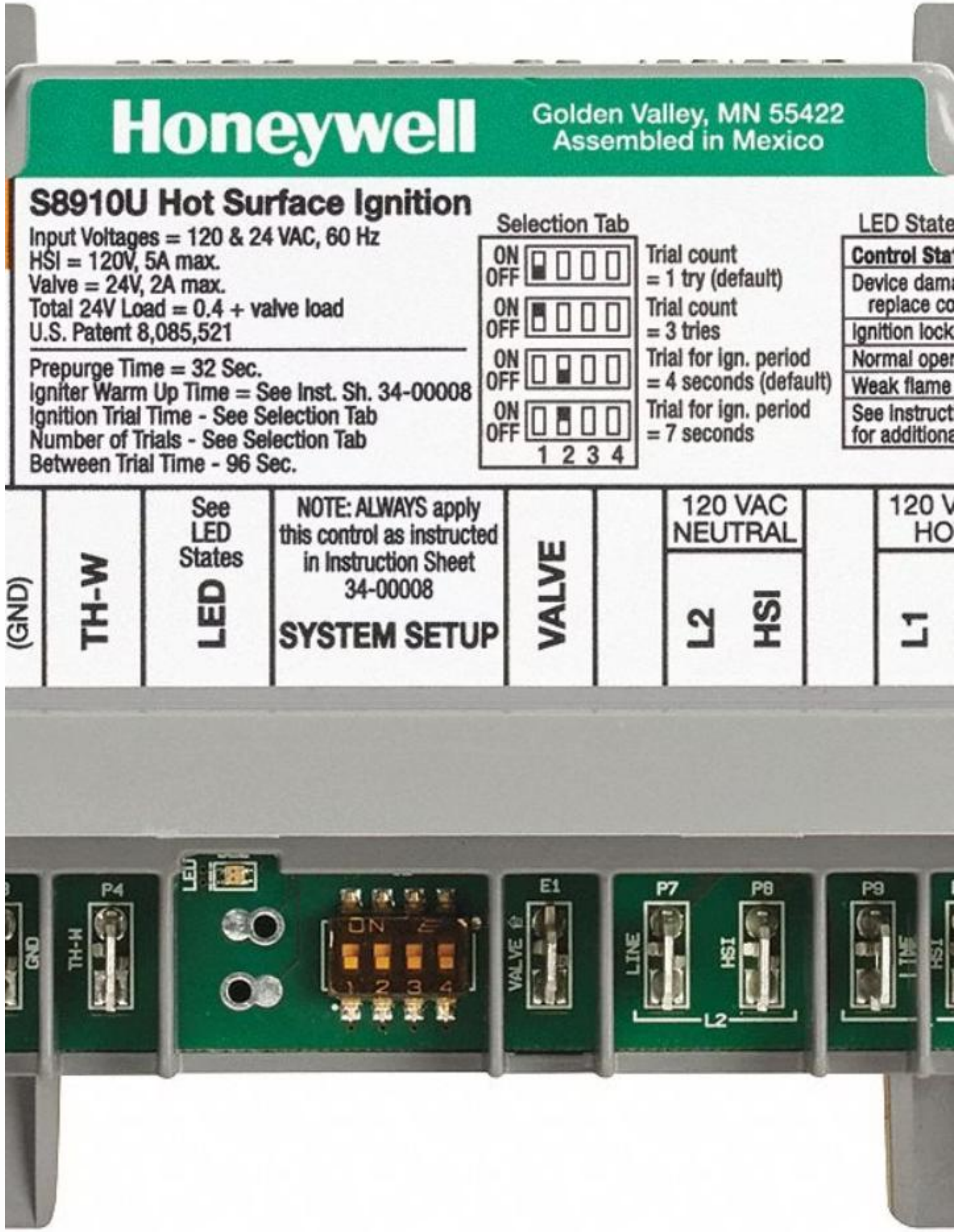


Hot surface ignition with combination igniter-sensor

Hot Surface Ignition Terminals

Terminal	Labelled as
Line voltage input terminals	L1 and L2
Terminals to the hot surface igniter	HSI

The terminals of a hot surface ignition are the same as direct spark ignition, except for the terminals to the hot surface igniter.



Hot Surface Ignition Sequence Operation

Control Circuit Completion

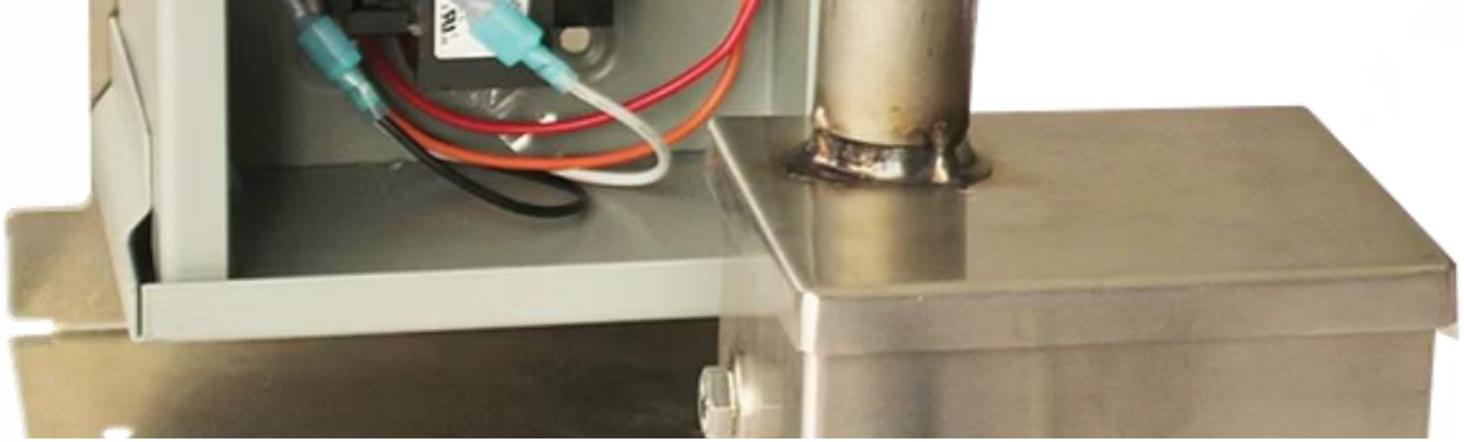
On a call for heat, the thermostat contacts close to complete the control circuit. The control circuit energizes the control module through the terminals labelled "24V."

Safe Start and Warm-up

Energizes the flame sensor and performs a safe start check; if a false flame signal exists, it does not energize the igniter. Warms up the hot surface igniter for approximately 30 seconds through terminals "HSI".

Main Burner Ignition

Energizes the main gas valve through terminals marked "valve". Lights the main flame. De-energizes the igniter. Proves the main flame through the flame sensor.



Hot Surface Ignition Flame Failure Response

Flame Failure Detection

If flame failure occurs, the control module responds immediately

Valve Shutdown

De-energizes the gas valve(s)

3

Reignition Attempt

Re-energizes the ignition cycle

Safety Lockout

Goes into lockout if unable to relight within trial for ignition period

Some modules are designed to cycle the ignition sequence three times before lockout.

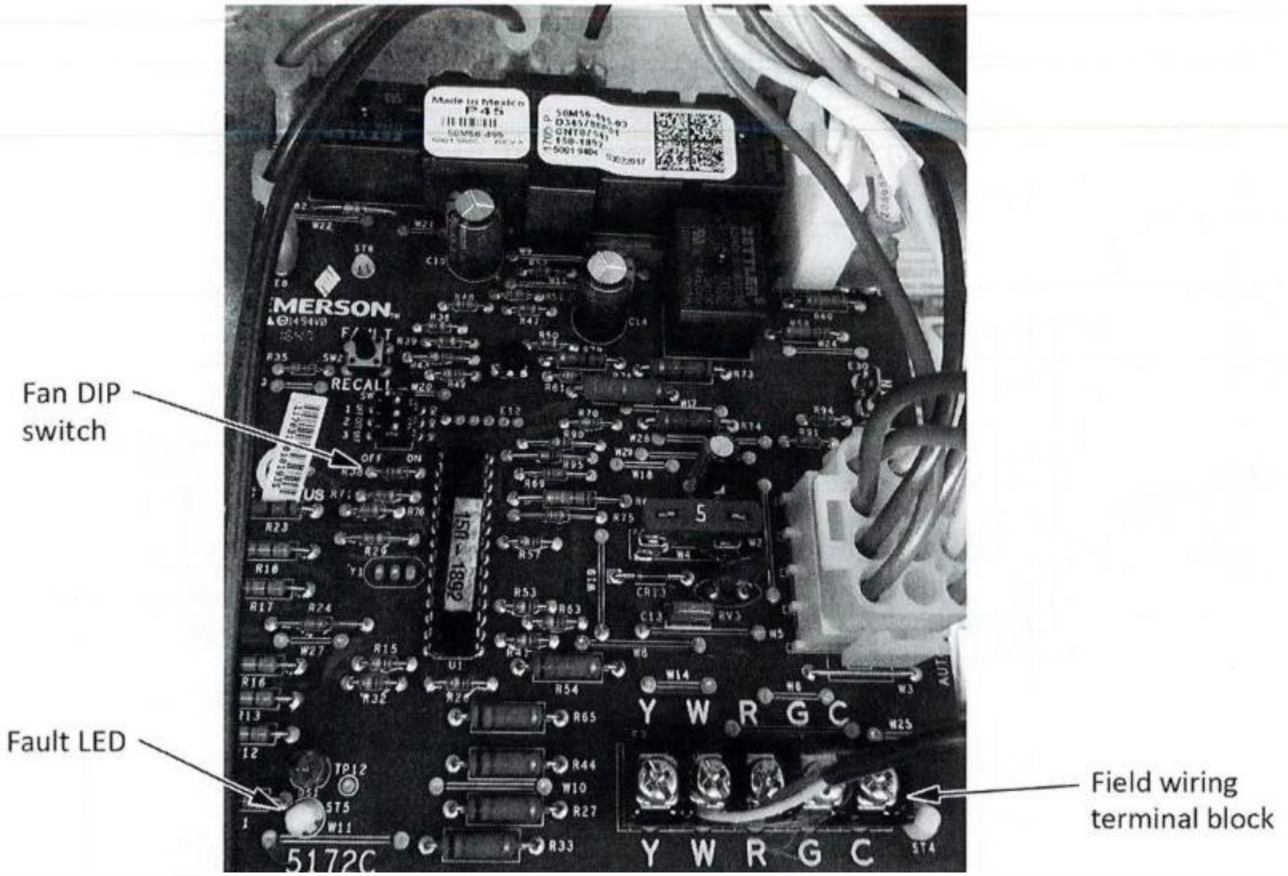
Integrated Furnace Control (IFC)

Function

An integrated furnace control (IFC) manages the entire operation of a furnace.

Options besides ignition control can include two-stage burner operation, variable fan speed, electronic air cleaner, and humidifier, depending on the furnace model.

Figure 1-63
Emerson Electric IFC



The image shows a basic integrated furnace control board with various connection terminals.

IFC Wiring

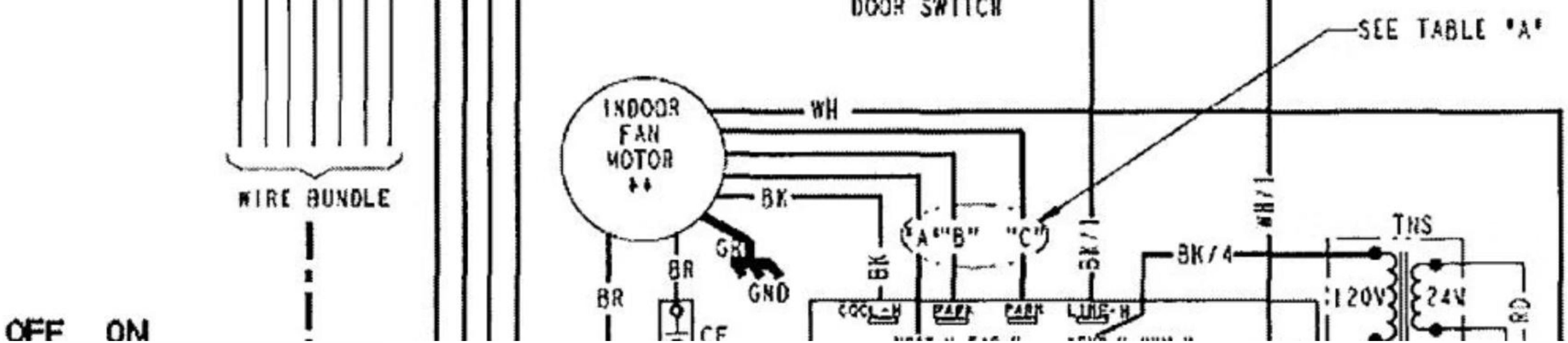
Field Wiring

Although there are a lot of wires connected to an IFC, the only field wiring that needs to be installed is the thermostat wiring, which is connected to the dedicated terminal block.

The field wiring is always identified on wiring schematics with dotted lines.

Figure 1-64
Trane American Standard AUX060 Furnace Wiring Diagram

Wiring diagram showing field connections to the IFC.



Unit Wiring Diagram

Factory Wiring

The unit wiring diagram shows all factory-installed connections between components.

Field Connections

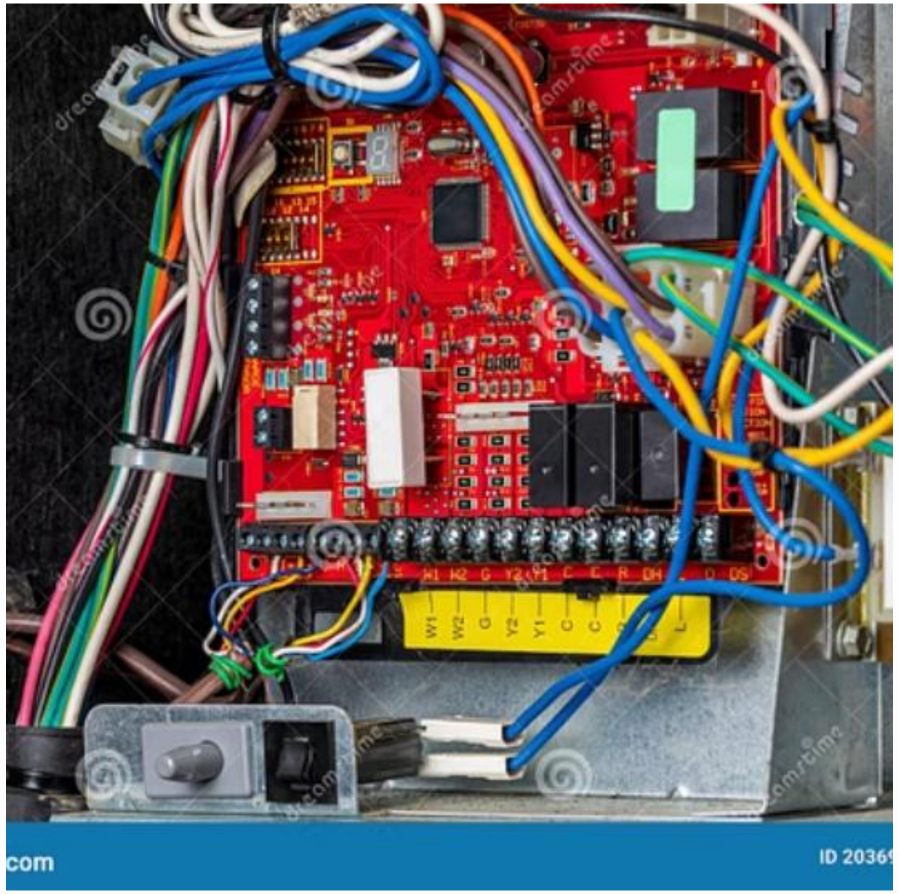
Field connections are typically shown with dotted lines to distinguish them from factory wiring.

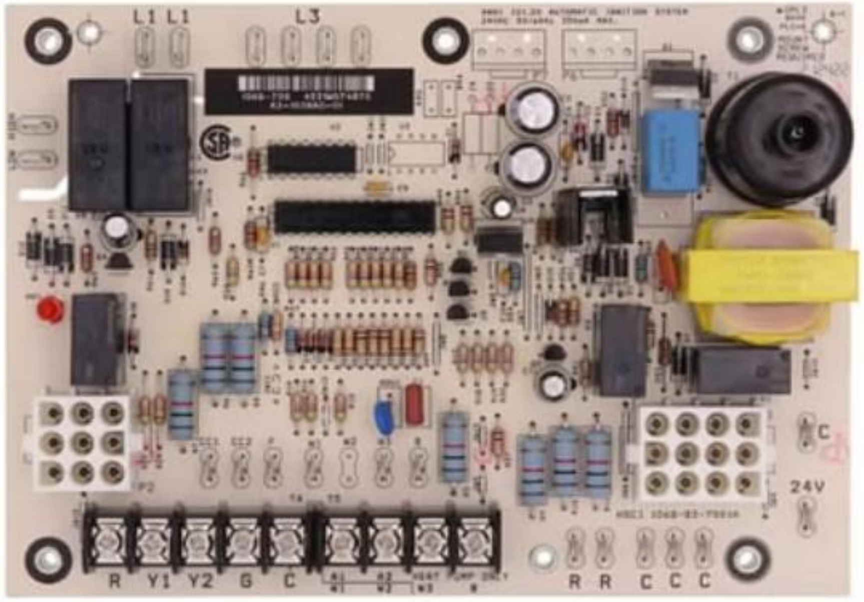
Troubleshooting Aid

The wiring diagram serves as an essential reference for technicians when diagnosing system issues.

IFC Fault Analysis

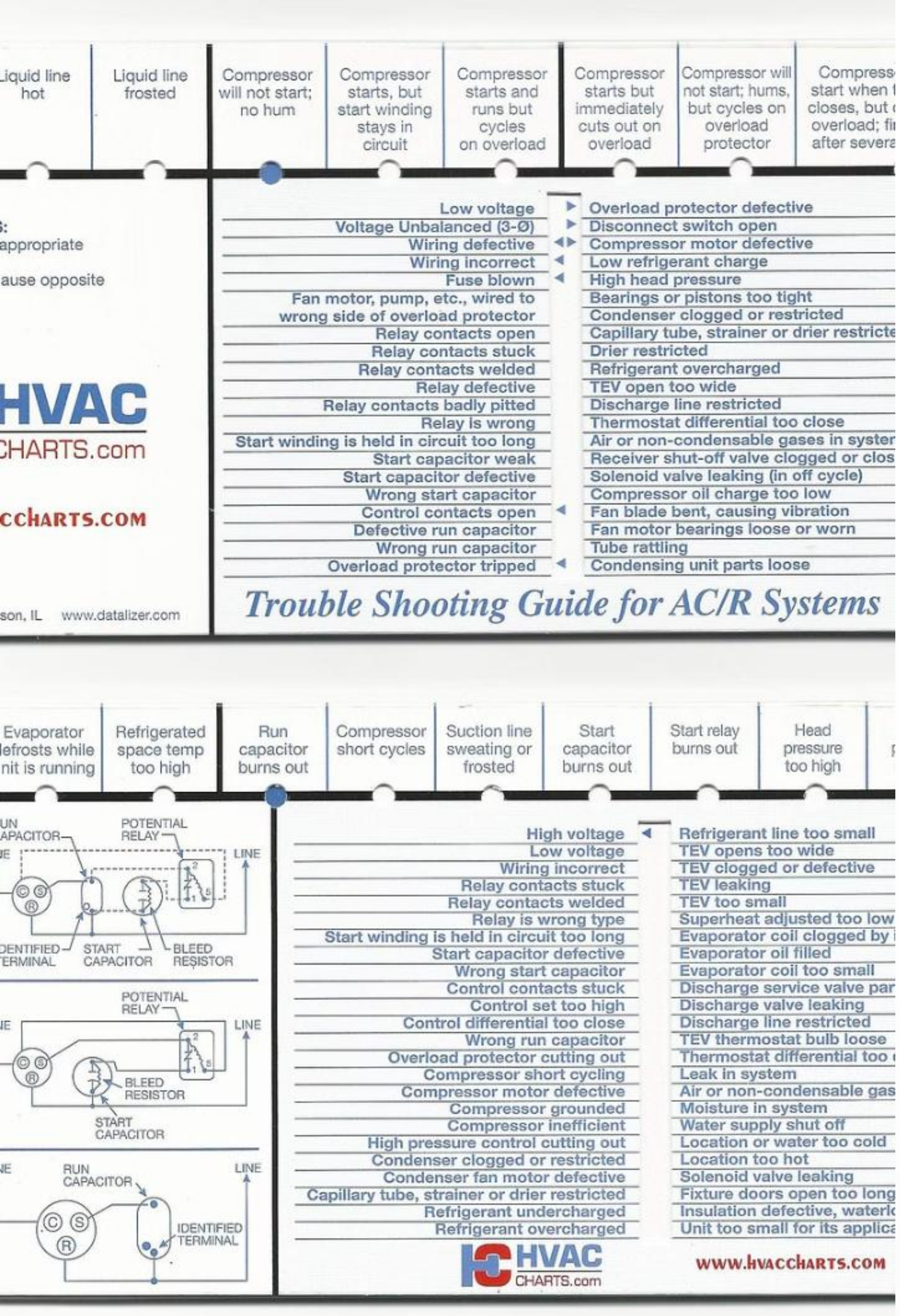
IFCs include fault analysis LEDs to help in troubleshooting. If a fault is detected, the control immediately goes into fault mode and flashes the LED at a different rate depending on which fault is detected.





IFC Error Flash Codes

Flashing slow	Normal - no call for heat
Flashing fast	Normal - call for heat
Continuous ON	Replace IFC
Continuous OFF	Check power
2 flashes	System lockout (retries or recycles exceeded)
3 flashes	Draft pressure error - possible problems



Additional IFC Error Flash Codes

4 flashes	Open temperature limit circuit
5 flashes	Flame sensed when no flame should be present
6 flashes	115 Volt AC power reversed, poor grounding, or system voltage too low
7 flashes	Gas valve circuit error
8 flashes	Low flame sense signal

Flame Safeguard Controls (FSG)

Definition

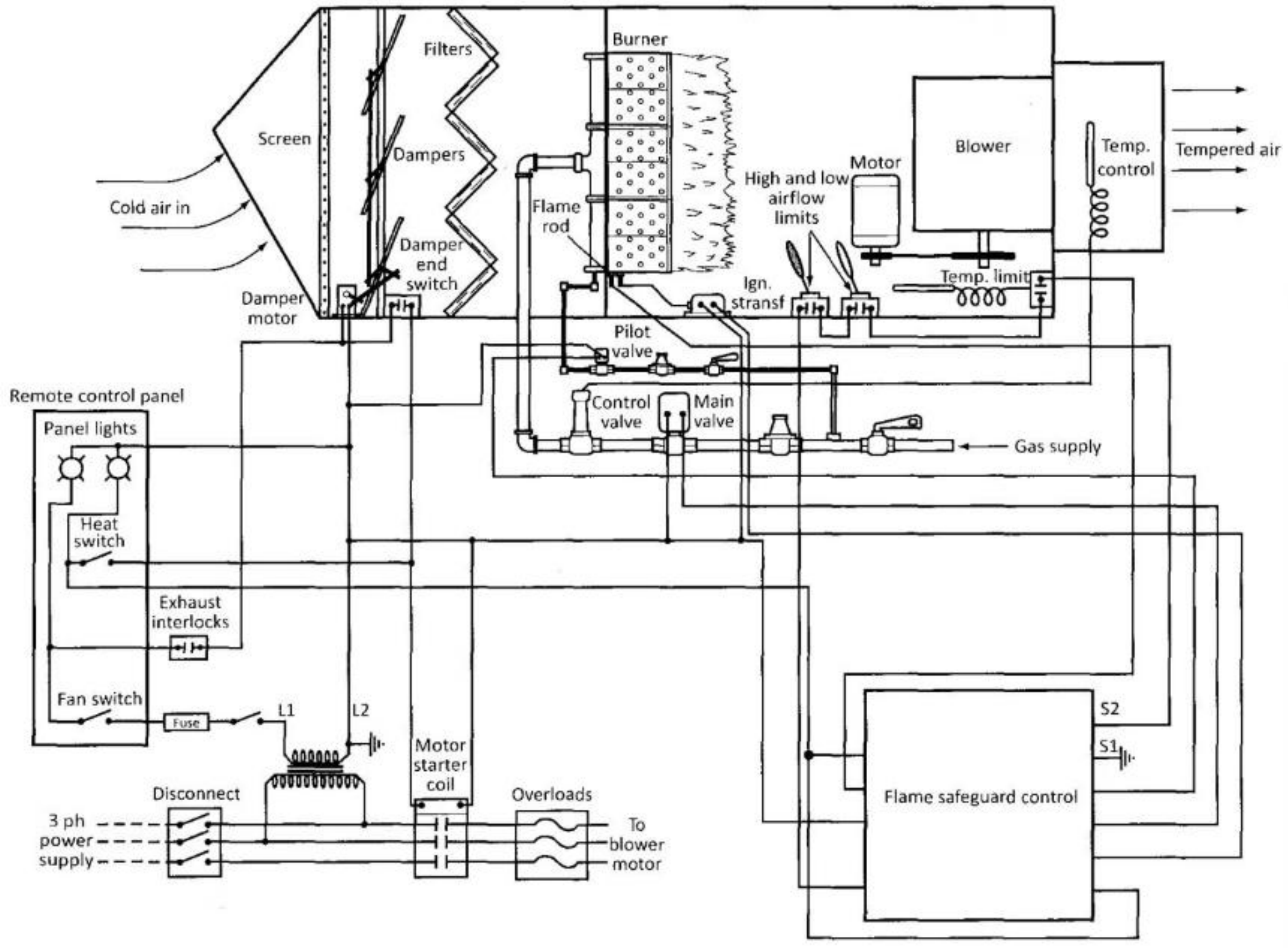
A flame safeguard control (FSG) is the central controller over the safe supply of gas and air to the burner(s).

It processes inputs from the operating control, limits, interlocks, and flame detector into outputs that sequence the burner motor, gas and air input valves, venter motor/damper, ignition system, pilot valve(s), and main fuel valve(s).

Function

The FSG monitors and controls only the safe operation of the appliance and leaves the functional operation to the main operating control.

Safe and functional operations are interconnected for proper system performance.



Primary Functions of Flame Safeguard Controls

Safe Start Check

Prevents burner start-up if flame simulation condition exists

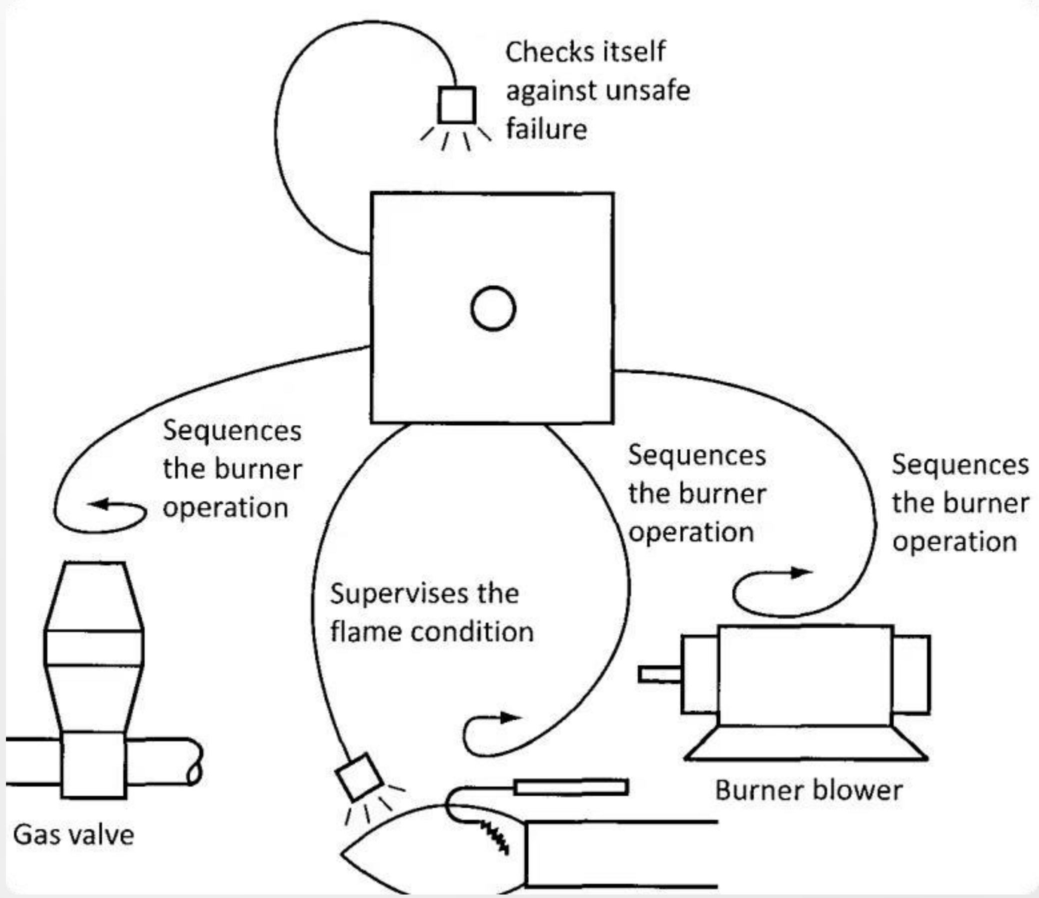
Sequence Control

Manages start-up, running, and shutdown cycles

Flame Supervision

Monitors flame and cuts fuel if flame is not present

Figure 1-67
Three functions of a flame safeguard control



Flame Safeguard Control System Components

Controller

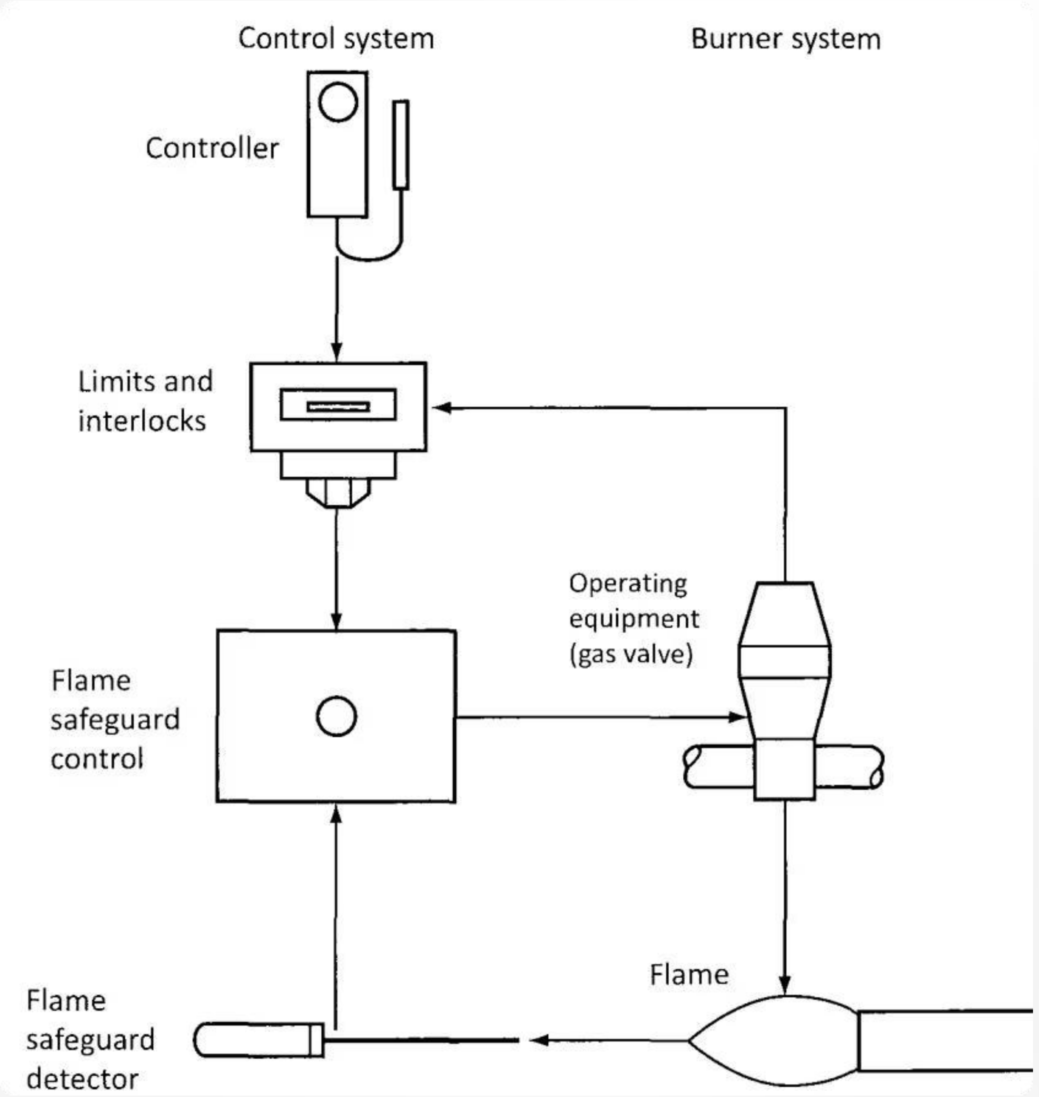
The main operating control that cycles the appliance (thermostat, pressuretrol, aquastat)

Limit Controls

Ensure safe operating limits are maintained (temperature/pressure limits, low water cut-off)

Interlocks

Ensure proper control sequencing (low fire start switch, proof of closure switch, air switch)



Interconnected Components of FSG System

Input Signals

The flame safeguard control receives inputs from the operating control, limits, and flame detector.

Output Control

These signals are transferred into outputs that sequence the burner motor, ignition system, pilot valve(s), and main fuel valve(s).

Safety Integration

The system ensures all components work together to maintain safe operation under all conditions.

Types of Flame Safeguard Controls

Programming Controls

More complex control sequencing for safe light off

Include additional safety features beyond basic functions

Primary Controls

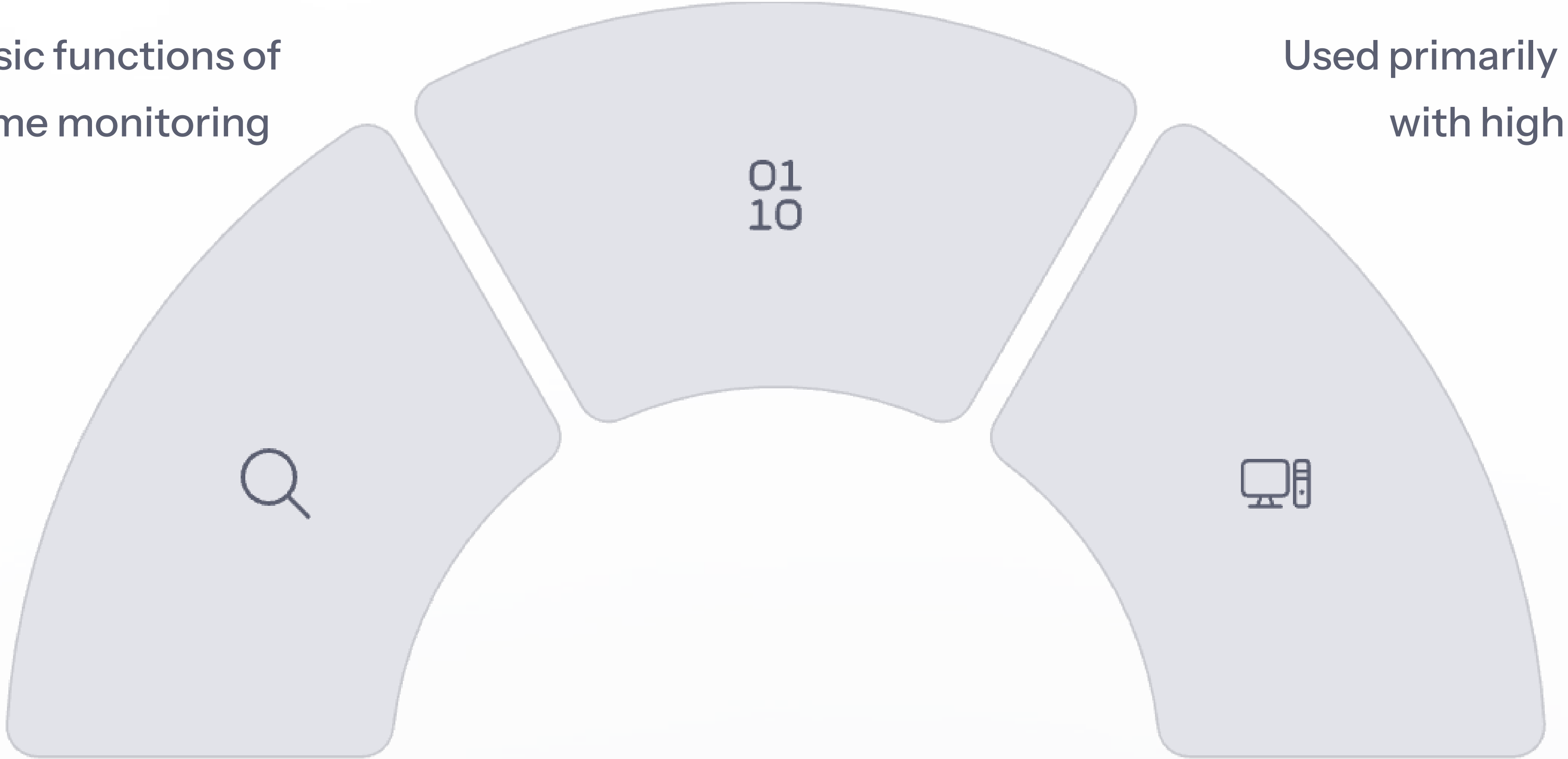
Also known as non-programming controls

Provide only the three basic functions of burner operation and flame monitoring

Programmable Logic Controls (PLCs)

Full function computers that must be programmed during initial activation

Used primarily in manufacturing plants with high input applications

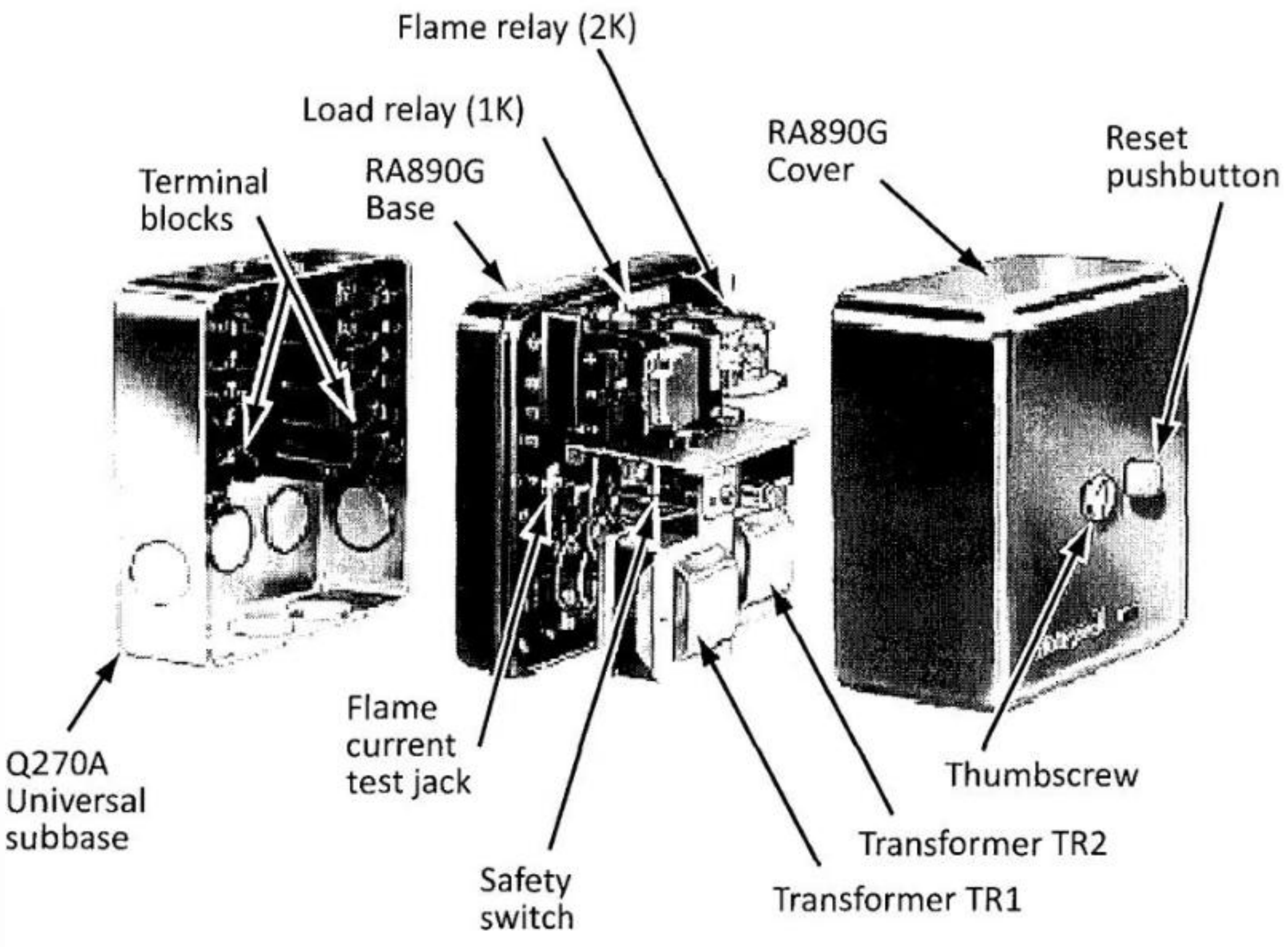


Primary Controls

Definition

A primary or non-programming type of flame safeguard control provides only the three basic functions of burner operation and flame monitoring.

To be classified as a primary control, the device must perform the three basic functions: safe start check, sequence operation, and flame supervision.



Primary controls: Honeywell RA 890

Figure 1-70
Inputs and outputs for a non-programming flame safeguard control

Primary Control Operation

Input Signals

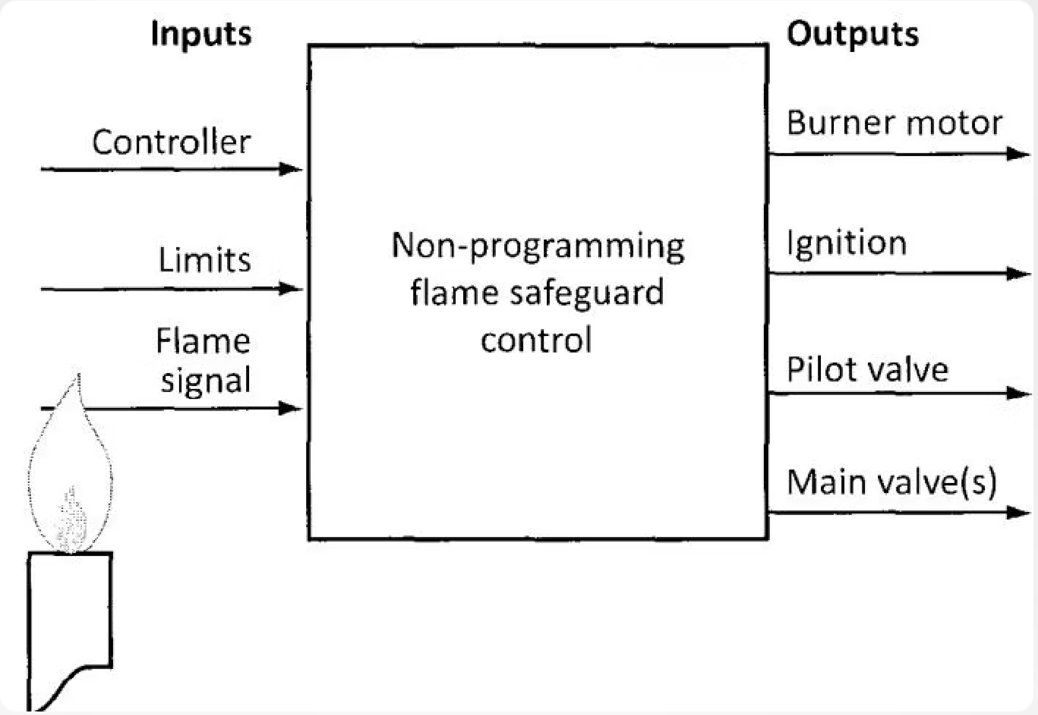
From controller, limits, and flame detector

Processing

Control translates inputs into sequenced outputs

Output Control

Controls burner motor, ignition, pilot, and main fuel valve(s)



Primary Control System Diagram

System Integration

The diagram shows how the primary control integrates with other system components.

Signal Flow

Input signals from various sensors and controls are processed to produce appropriate output actions.

Safety Chain

The system includes multiple safety devices that must all be satisfied for operation to continue.

Programming Controls

Complex Sequencing

Newer residential appliances and larger burner systems usually require more complex control sequencing to ensure safe light off and control of other safety functions.

Added Features

Pre-purge with proven air flow, low fire start positioning, timed pilot trial for ignition, monitoring of interlocks, and more.

Sequencing Methods

Unlike primary controls with fixed relays, programming controls use electromechanical timing devices, plug-in relays, solid-state circuitry, or microprocessor-based circuits.

Fireye M-Series Programming Control

Mixed Technology

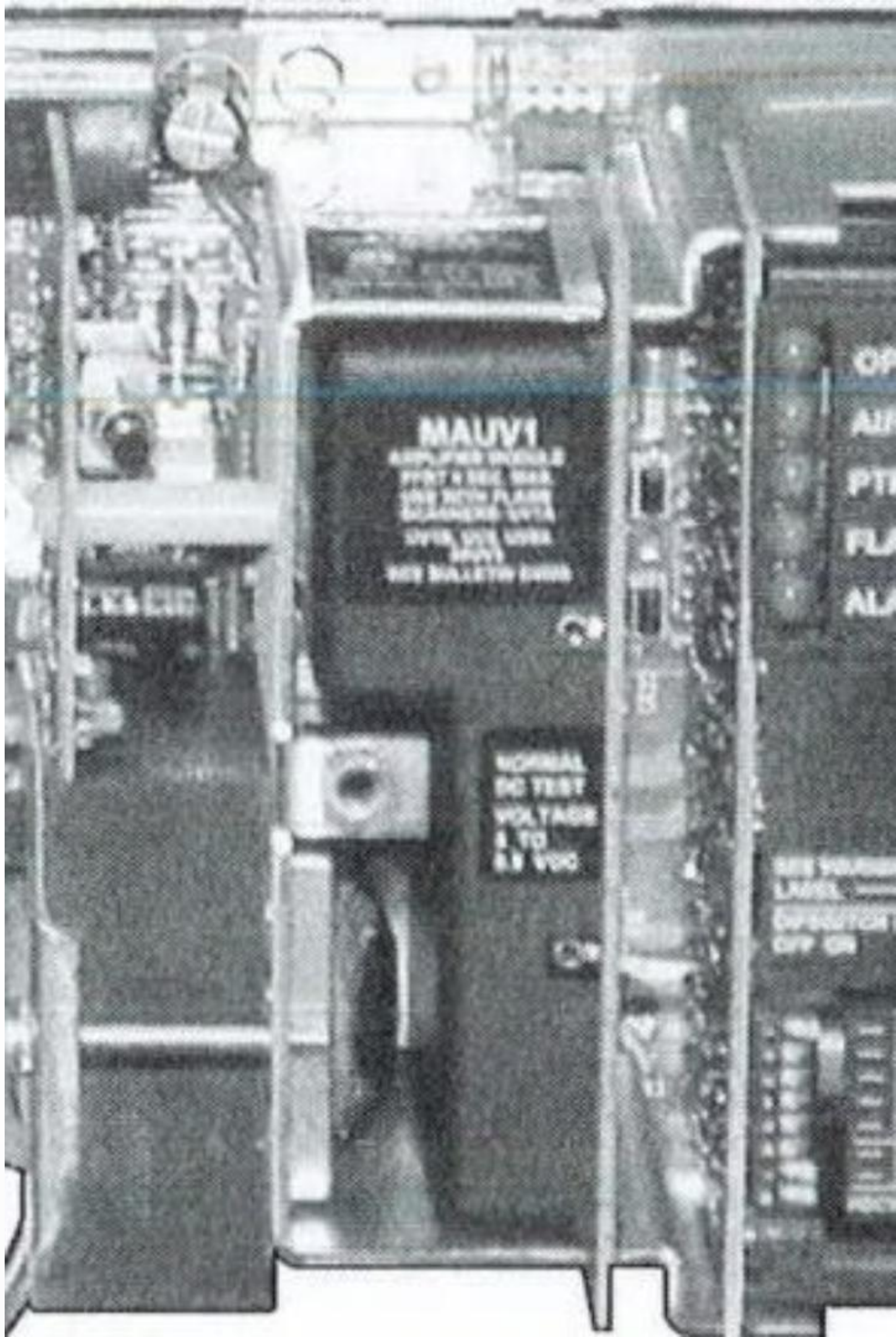
The Fireye M-Series II is an example of a control that uses a mixture of methods, with electromagnetic relays working with solid-state circuitry and microprocessor circuit boards.

Advanced Features

Provides enhanced safety features and more precise control over the combustion process.

Modular Design

Components can be replaced individually for easier maintenance and upgrades.



Microprocessor-based Programming Controls

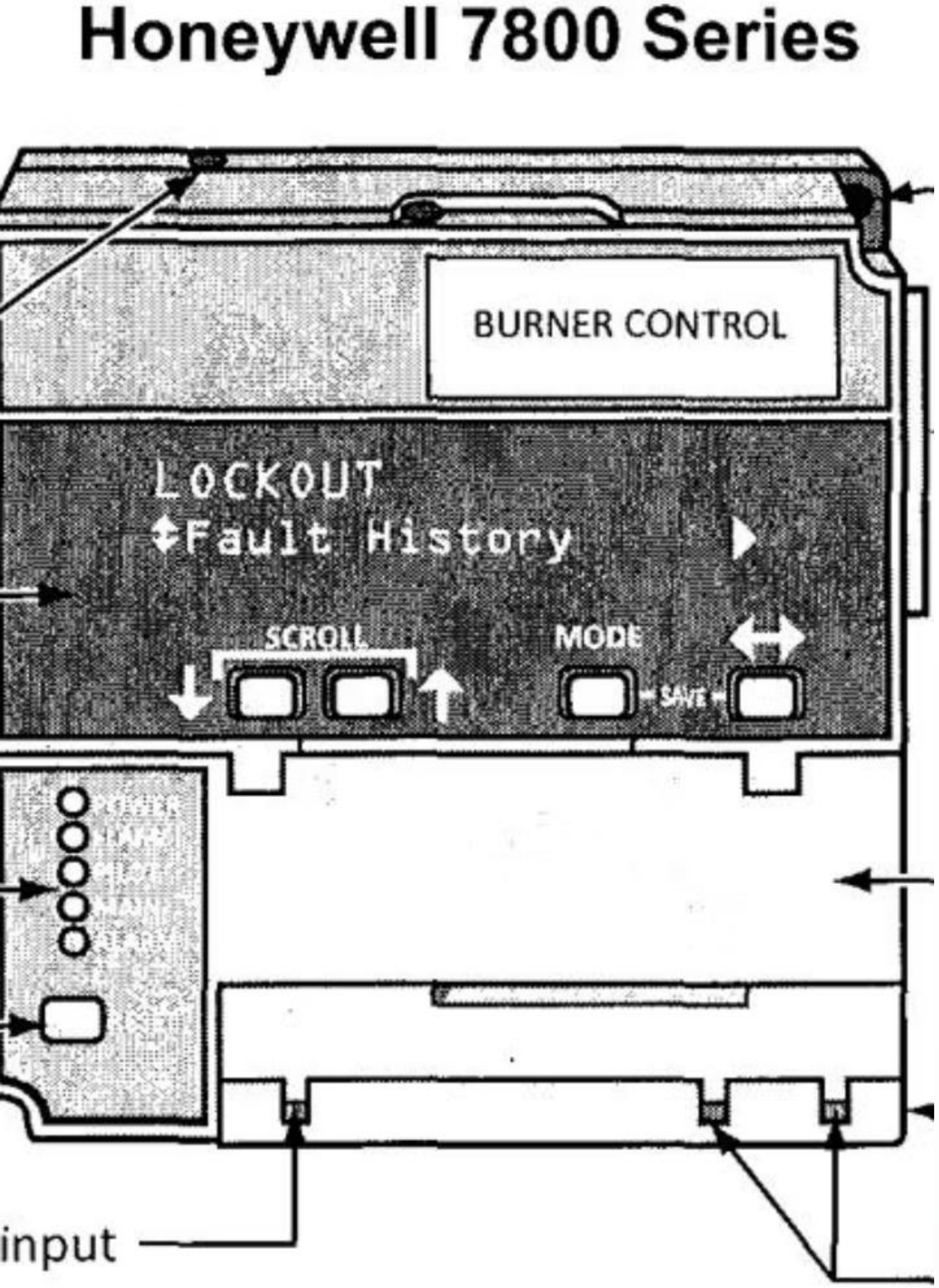
Enhanced Capabilities

Microprocessor-based programming controls extend the sequencing, monitoring, and data collection/transfer options offered by solid-state controls.

They offer plug-in options for flame amplifier and purge cards and often offer field selectable programming options such as recycling or non-recycling.

Design Variations

The main sequencing features may be fixed in the chassis, as is the case in Honeywell and Eclipse units, or fixed in a removable card, as is the case for Fireye units.



Honeywell 7800 Series Programming Control

Microcomputer-based

A popular microcomputer-based FSG is the Honeywell 7800 series programming control.

Data Storage

Like other microcomputer-based FSGs, they store and process an operating and fault history.

Display Options

History can be displayed on an optional plug-in display module or transmitted to a remote computer.

Programmable Logic Controls (PLCs)

Applications

PLCs are often employed for process functions at manufacturing plants in high input applications, but the flame safeguard functions are usually performed by programming controls.

Capabilities

PLCs are basically full function computers that must be programmed during initial activation of the appliance. Normally, only Gas Technician 1 classification would be exposed to these control systems.

Flexibility

Programming options are almost unlimited and can be changed without a change of hardware. These units can monitor more inputs and control more aspects of the appliance operation than any other FSG.

PLC Programming Considerations

Safety First

Extreme care must be taken when programming PLCs to ensure that the functions entered into the computer match the requirements of the particular appliance.

Manufacturer Guidance

Since system applications for PLCs are usually manufacturer-based, always consult the specific manufacturer for operating information.

Qualified Personnel

Programming should only be performed by properly trained and certified technicians.

Valves and Regulators

Function

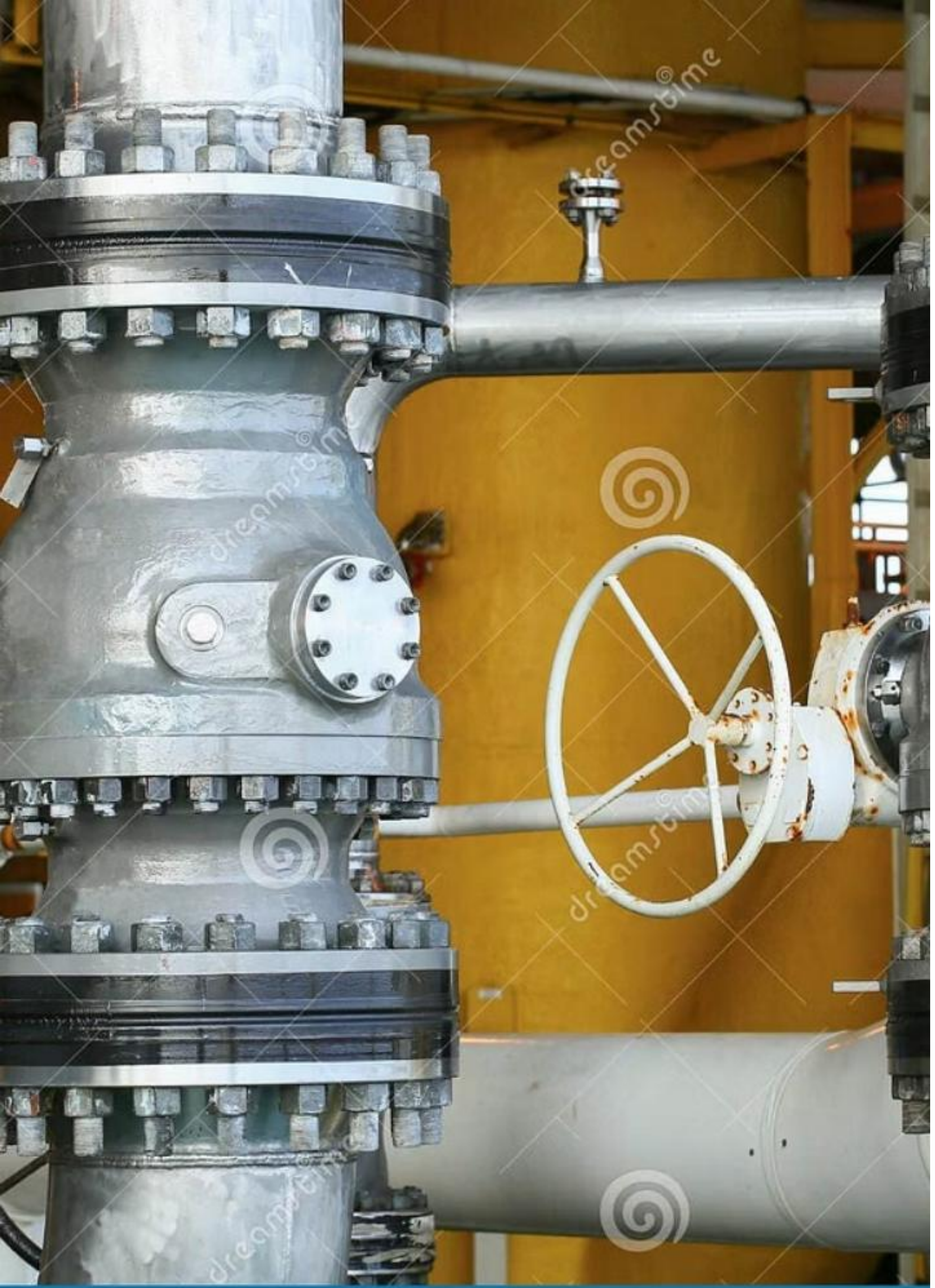
Valves and regulators open or close in varying amounts to control the flow of gas, water, or steam.

There are many different types of valves: some are operated manually, others automatically.

Categories

The presentation will cover:

- Non-electric process valves
- Water shut-off valves
- Relief valves
- Gas valves
- Regulators



Non-electric Process Valves

Process Fluid Control

These are common valves used to control the process fluid, such as the hot water produced by the gas appliance or the cold water supplied to the gas appliance.

Manual Valves

A manual valve is one where a gas technician/fitter must manually open or close the valve. These valves can be installed to control water and are used to isolate parts of the system.

Automatic Non-electric Valves

Automatic non-electric valves typically operate on temperature and pressure changes.

Water Shut-off Valves

Function

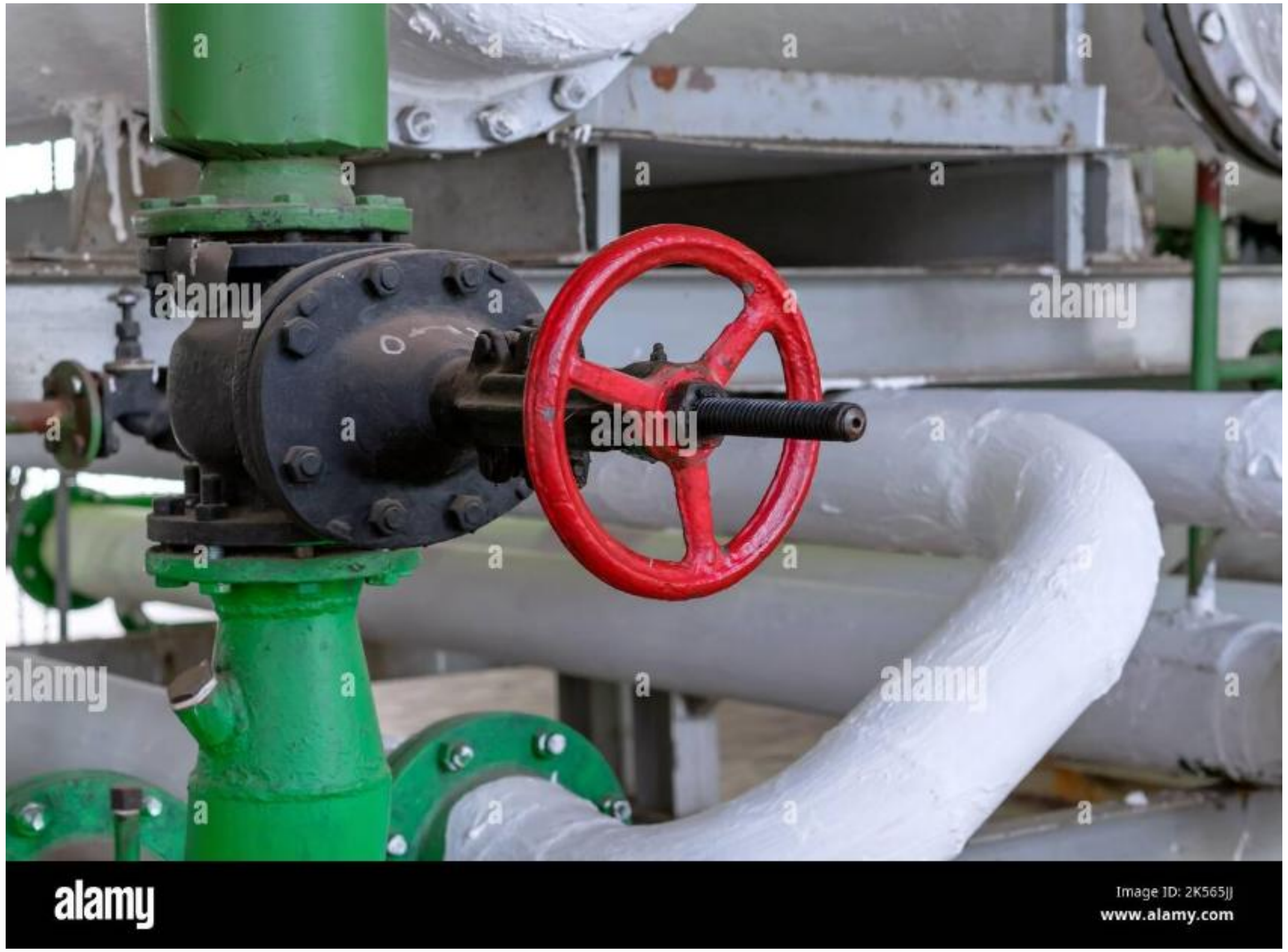
Water shut-off valves control the flow of water to hot water heaters, hot water boilers, and steam boilers.

They are normally open valves that can be shut off to isolate an appliance for repair or servicing.

Types

Two typical types of water shut-off valves are:

- Gate valve
- Globe valve



Gate Valve

Design

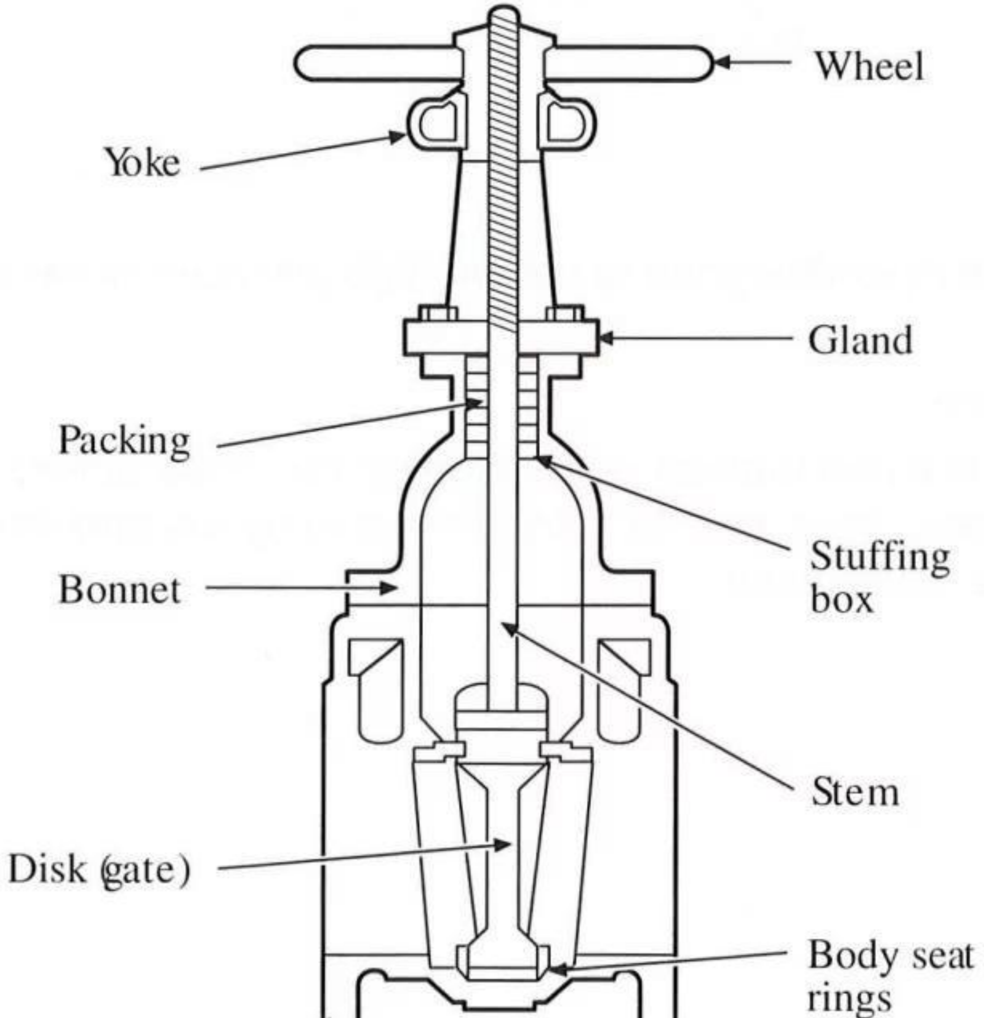
The gate valve has a gate that moves up or down to open or close the valve.

Because of excessive vibration and wear caused by partially opened gates, these valves are not intended for throttling or regulating flow.

Application

They are designed to operate fully open or fully closed and are typically used on water and steam installations.

Figure 1-73
Gate valve
Courtesy of Toyo Valve Co., Ltd.



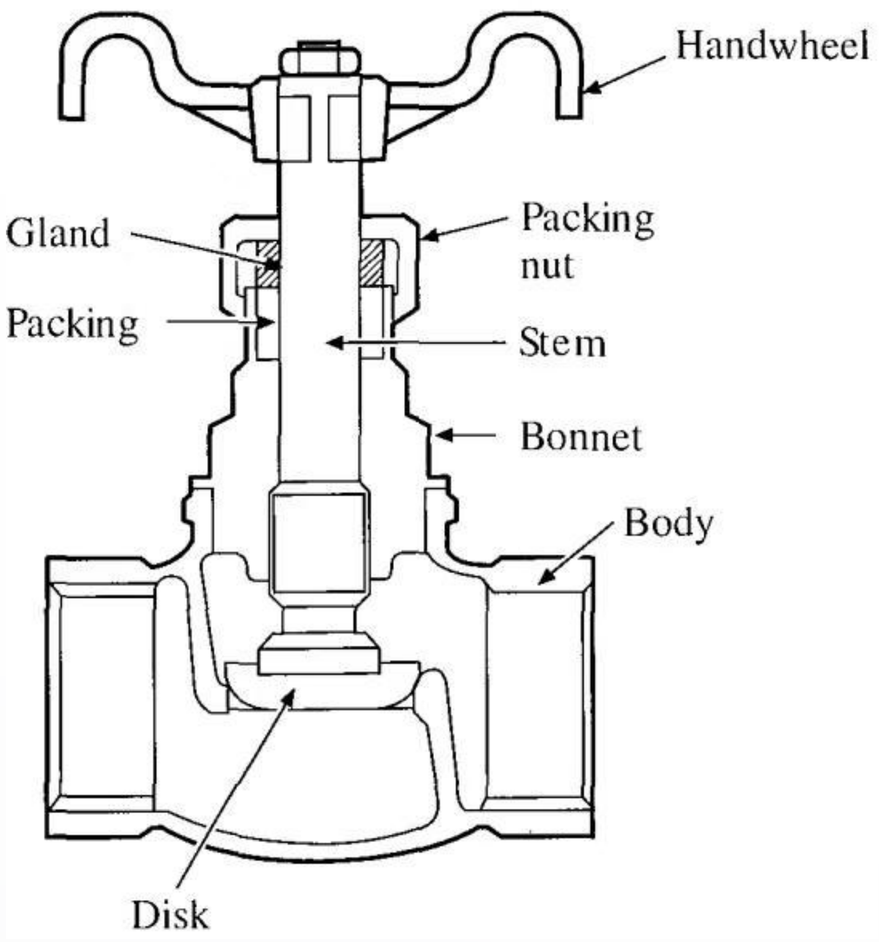
Globe Valve

Design

Globe valves, unlike gate valves, are designed for steady use in applications with frequent throttling or flow regulation.

The design of the globe valve keeps the seat erosion to a minimum.

Figure 1-74
Globe valve
Courtesy of Toyo Valve Co., Ltd.



The globe valve's design allows for precise flow control with minimal wear.

Relief Valves

Purpose

Relief valves are safety devices designed to relieve high pressure or temperature conditions.

They are critical safety components that prevent dangerous pressure buildup in systems.

Types

Common types include:

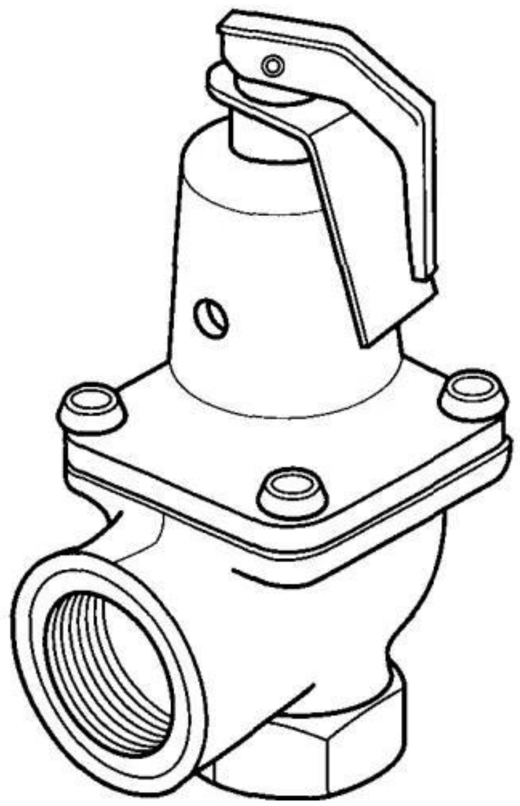
- Pressure relief valve
- Combination pressure-temperature relief valve

Pressure Relief Valve

Function

The pressure relief valve is a mechanical valve used on hot water boilers.

If pressure in the system rises above the set point, the valve opens and dumps water until the pressure drops to an acceptable level.



Pressure relief valve

Combination Pressure-Temperature Relief Valve

Requirements

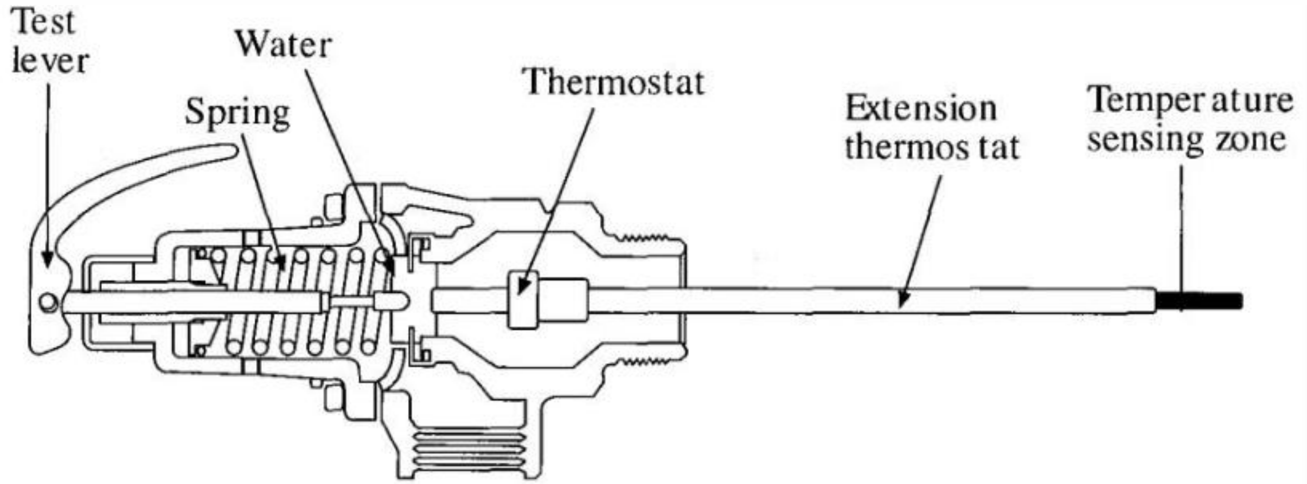
Local and national codes require the installation of storage water heaters with a combination pressure-temperature relief valve.

The sensing stem of this valve extends into the water within the top six inches of the tank. It will open to dump water if the tank pressure or water temperature is excessively high.

Replacement

Whenever a water heater is replaced, a new valve should be installed and the old valve discarded.

Some less-sophisticated relief devices use a fusible plug as the sensing device. Once the plug has melted, it continues to dump water until the water supply is manually turned off.



Water Pressure-Reducing Valve

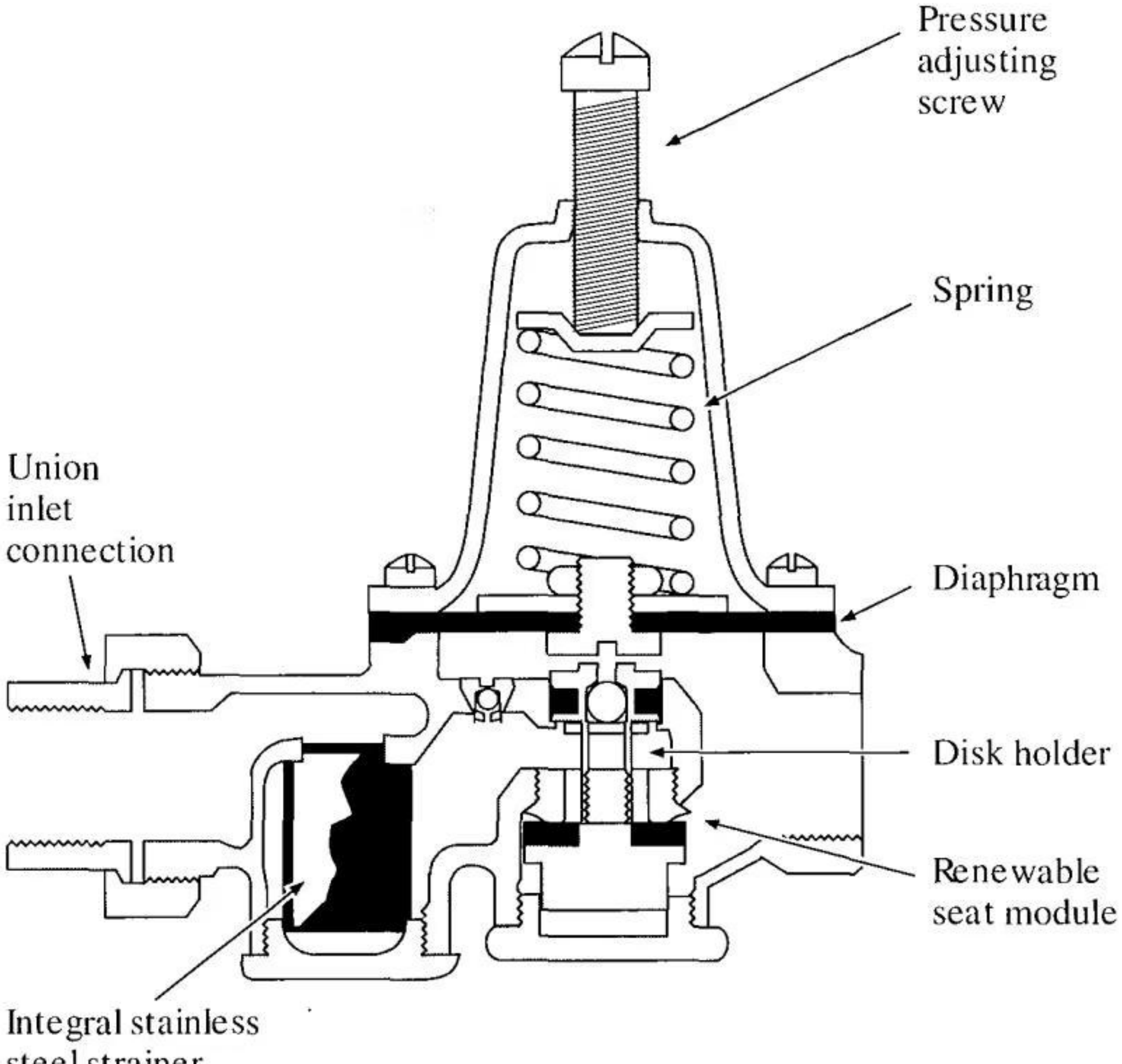
Function

The water pressure-reducing valve reduces the high pressure (e.g., house line pressure of 40 psig) to a lower operating pressure (e.g., 15 psig for a low pressure hot water heating systems).

The valve actuates in response to a pressure drop in the low-pressure side.

Common Name

This valve is commonly called a water makeup valve.



Feedwater Valve

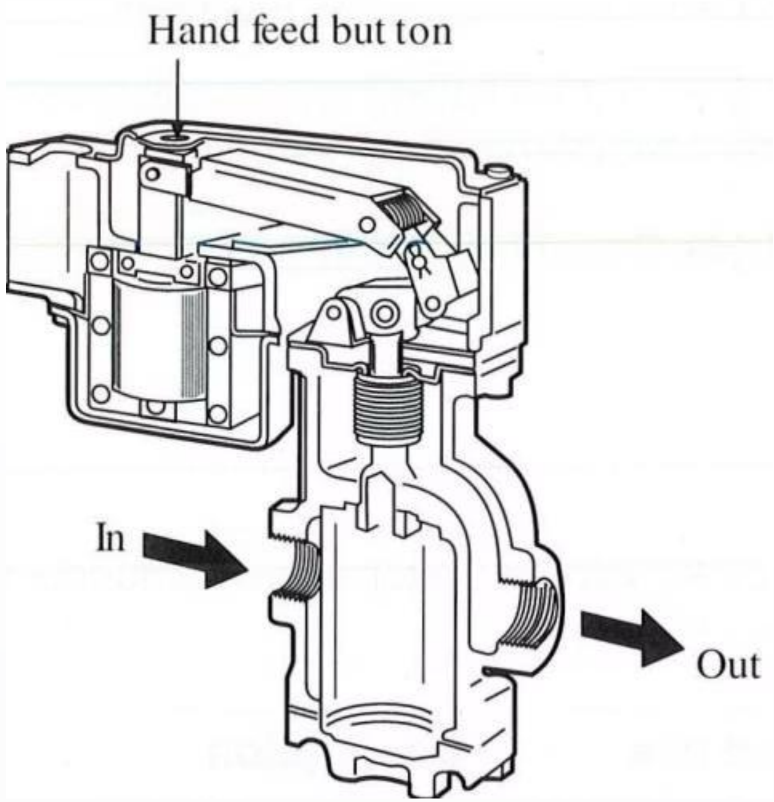
Application

As a gas technician/fitter, you may encounter an automatic electric valve that controls water, such as the feedwater valve, which controls makeup water to a boiler.

Operation

This valve is mounted directly into the feedwater line of a boiler and operates in conjunction with low-water cut-off limit controls to maintain the boiler water level above the safe minimum level.

Upon sensing a low water condition, the boiler low-water cut-off shuts down the burner and powers the feedwater control that lets in makeup water.



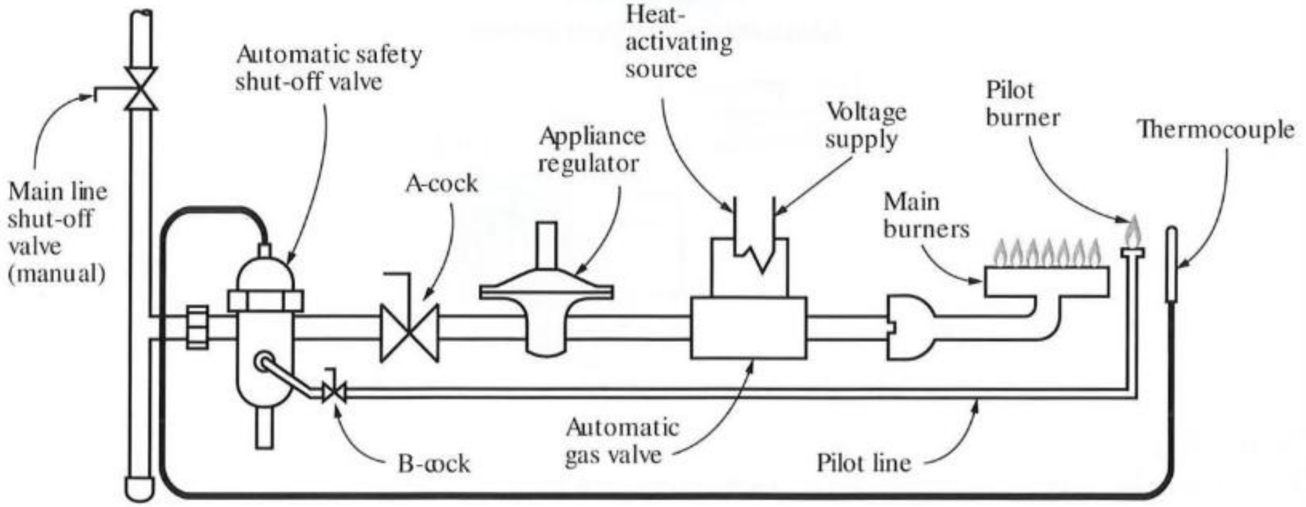
Gas Valves

Valve Train

The series of controls and components from the appliance main shut-off valve to the appliance burner is called the valve-train or manifold assembly.

Although valve-trains vary in how they are assembled, they all have these components in one form or another.

Figure 1-79
Gas valve train



This diagram shows the components of the valve train used to manually and automatically start, stop, and regulate the gas flow to the appliance.

Gas Shut-off Valves

Purpose

A manual gas shut-off valve provides a method of ensuring that the gas has been positively turned off to any area of the piping system or to a particular appliance.

Code Requirements

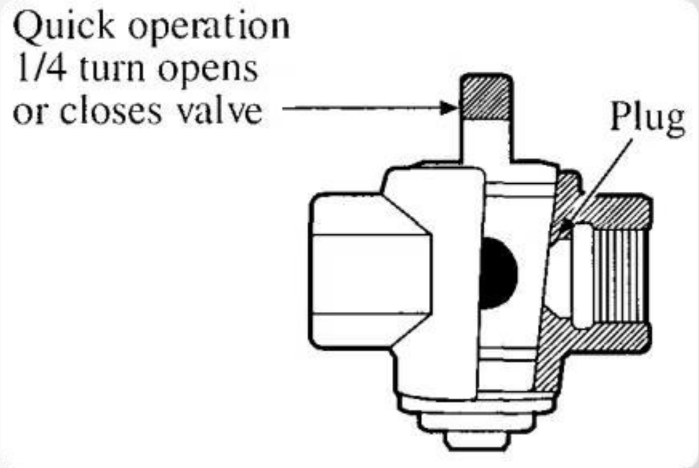
The Code clearly requires that a readily accessible gas shut-off valve for each appliance be installed upstream and external to the valve train assembly.

Types

The two main types of manual gas shut-off valves include: Plug-type and Ball type.

Plug-Type Valves

Type	Approved use	Description
Spring loaded valve	Only for indoor use	Made of brass. This kind of valve is no longer installed.
Lubricated plug valve	For indoor or outdoor use	Made of malleable iron. The common name for this valve is Lube seal. It is designed to be lubricated and maintained with the valve in place and with no interruption of service.



Ball Type Valves

Operation

Ball valves also open and close with a quarter-turn of a handle.

They are approved for both indoor and outdoor use.

Construction

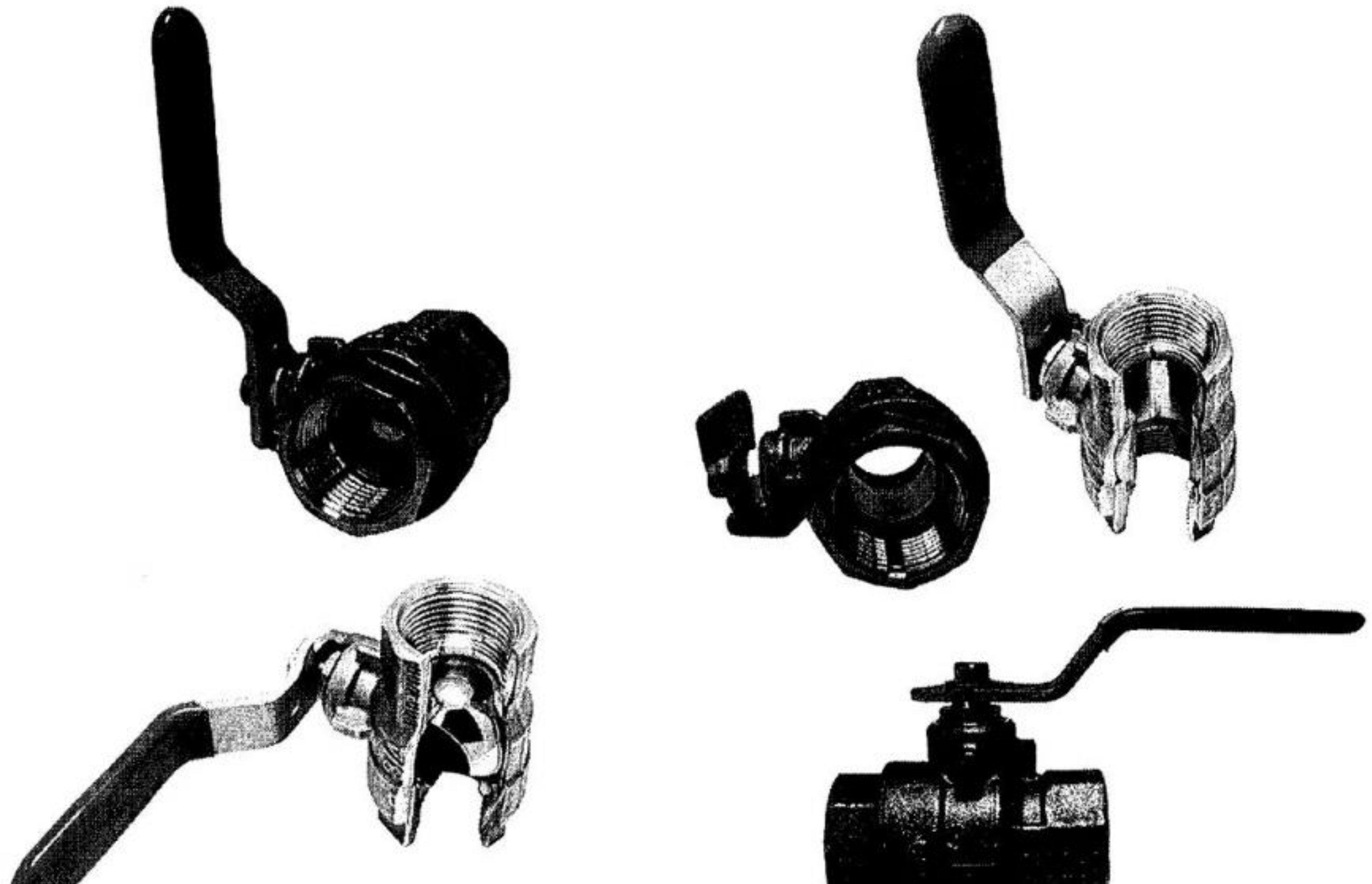
They are constructed with a Teflon seat and a stainless-steel sealing ball.

To control the flow, the ball has a hole drilled through its centre and fits tightly against the Teflon seat in the closed position.

Lubrication is not a concern with this type of valve.

These valves can be used for water, oil, and gas (W.O.G) applications.

Figure 1-81
Cross-section of manual ball-type valve
Image courtesy of Terry Bell



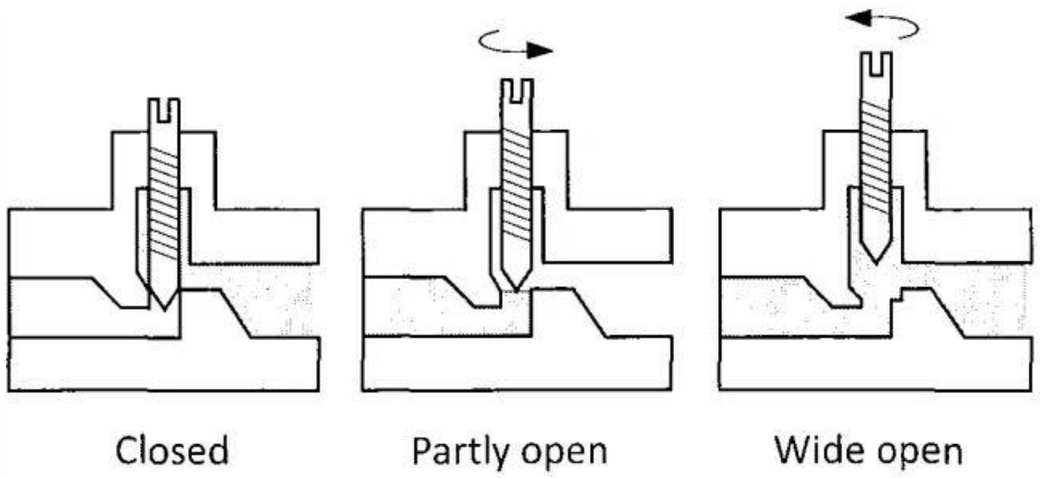
Needle-Type Valves

Applications

Needle valves are used for smaller application and internal control.

When being used as the pilot b-cock, they can be used to open, close, or throttle the flow with the use of a small screwdriver.

Figure 1-82
Manual needle valve



Needle valves provide precise control for small gas flows.

Automatic Safety Shut-off Valves

Function

The automatic safety shut-off valve is one of the most important valves in the valve train, and it may be an individual component of part of a combination gas control.

Purpose

Its function is to provide gas shutdown if a dangerous situation could result from the buildup of gas with no controlled ignition source.

Operation

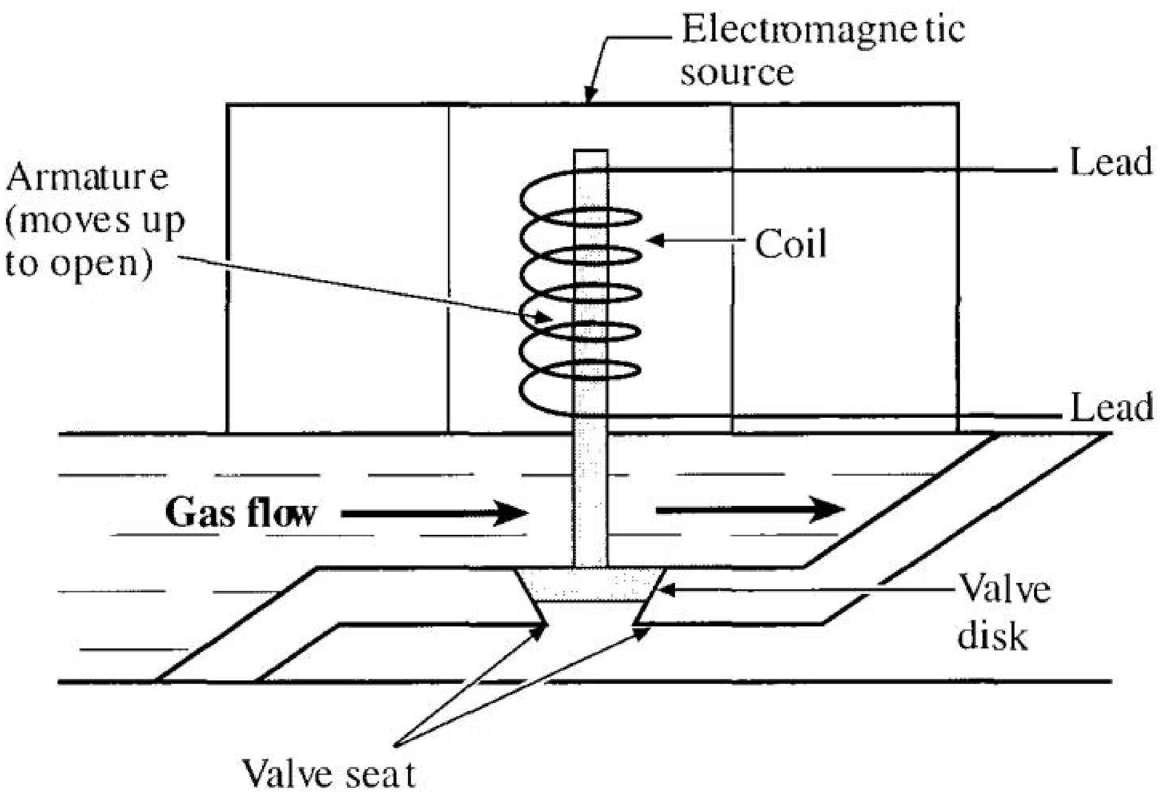
The gas safety shut-off valve shuts off the gas supply when de-energized by a combustion safety control, safety limit control, or loss of actuating medium.

Solenoid Valve

Application

Solenoid valves are commonly used as safety shut-off valves on pilot lines of large input appliances.

When the solenoid's electromagnet coil is energized, a metal plunger is drawn up into the coil's centre. By coupling the plunger to the valve seat, the rising action of the plunger is used to lift the seat off the valve port, opening the valve.



Solenoid valve in closed position

Types of Solenoid Valves

Lever-Actuated

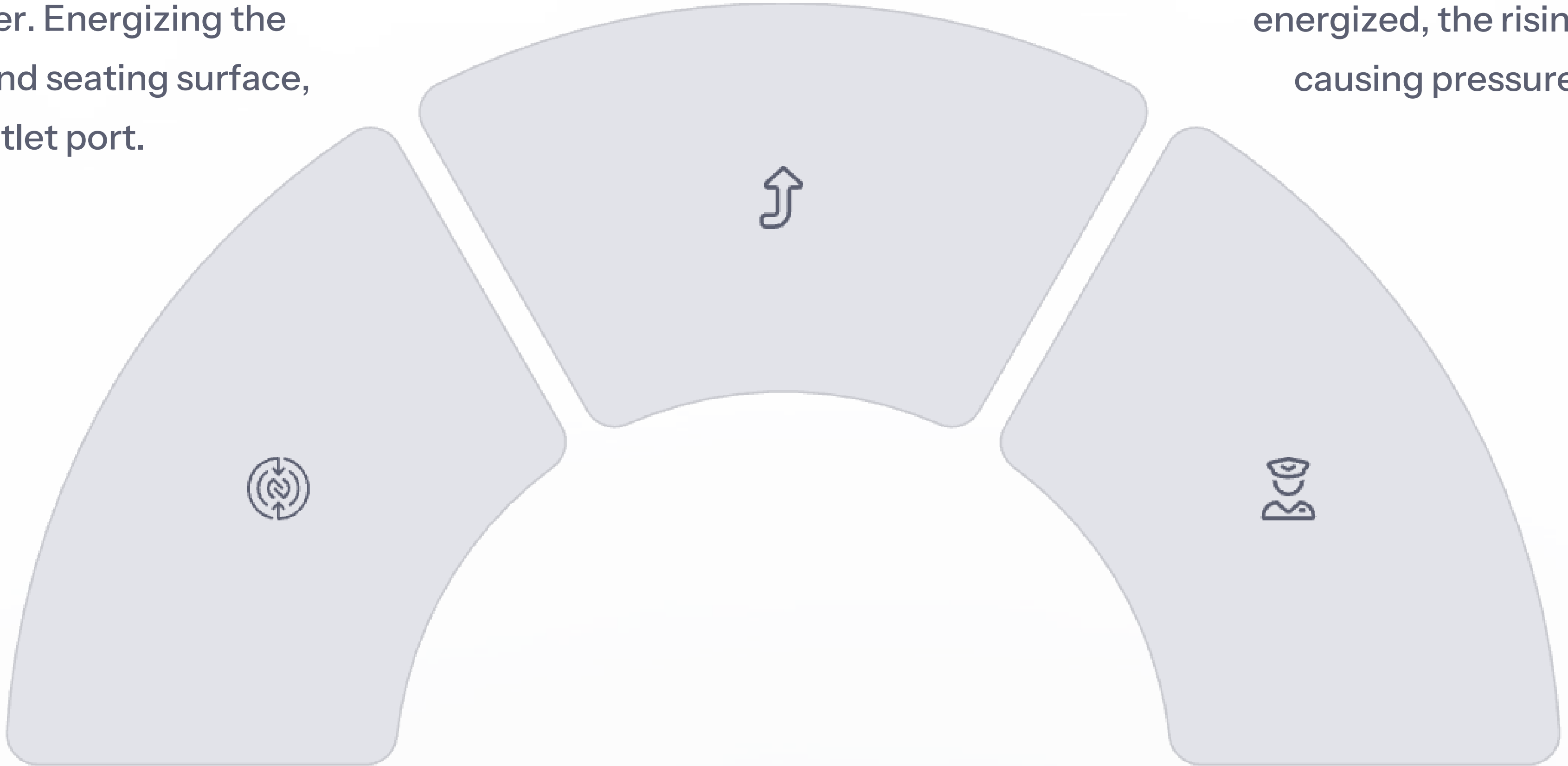
In the lever-actuated valve, the seating surface is connected to the plunger through a lever arm. When the solenoid is energized, the plunger lifts the level arm arrangement, opening or closing the valve with a greater force.

Pilot-Operated

The pilot-operated valve uses pressure differential to assist the plunger in opening and closing the main valve. When the solenoid is energized, the rising plunger opens the pilot valve causing pressure changes that help open the main valve.

Direct Acting

A direct acting solenoid valve has the seat directly coupled to the plunger. Energizing the solenoid coil lifts the plunger and seating surface, opening the valve outlet port.

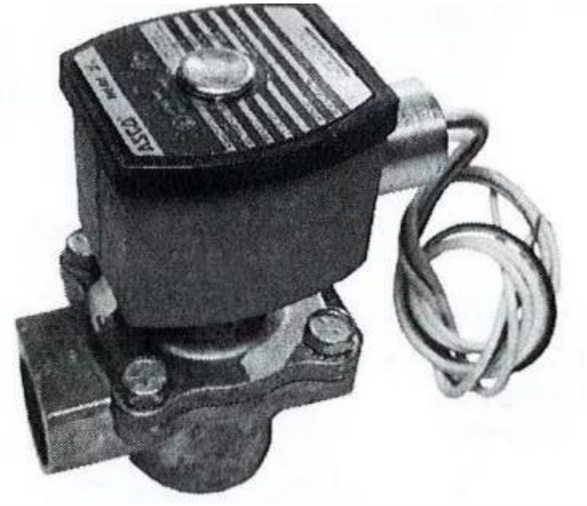


Direct Acting Solenoid Valve

Operation

The solenoid type of safety shut-off valves typically operates on 120 V AC.

Many solenoid valves rely on the weight of the disc and stem to assist the spring in seating them, so they must be installed in an upright position.



120 V AC Direct acting solenoid valve

Thermoelectric Valve

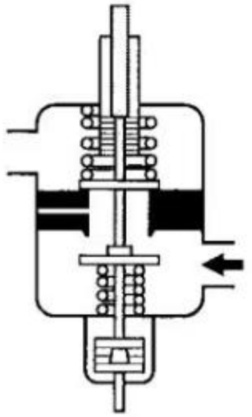
Power Source

An internal electromagnet (solenoid) powered by a thermocouple that produces pilot flame heat-generated DC millivolts controls the thermoelectric safety shut-off valve.

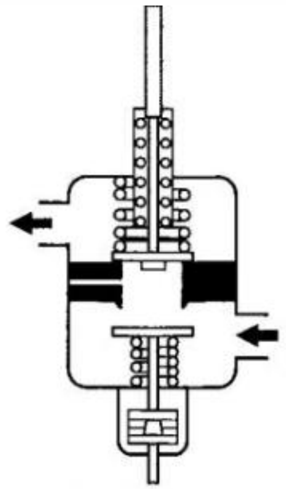
Functions

Note that the pilot flame's main function is to ignite the main burner when called upon and the thermocouple's function is to prove the existence of the pilot flame.

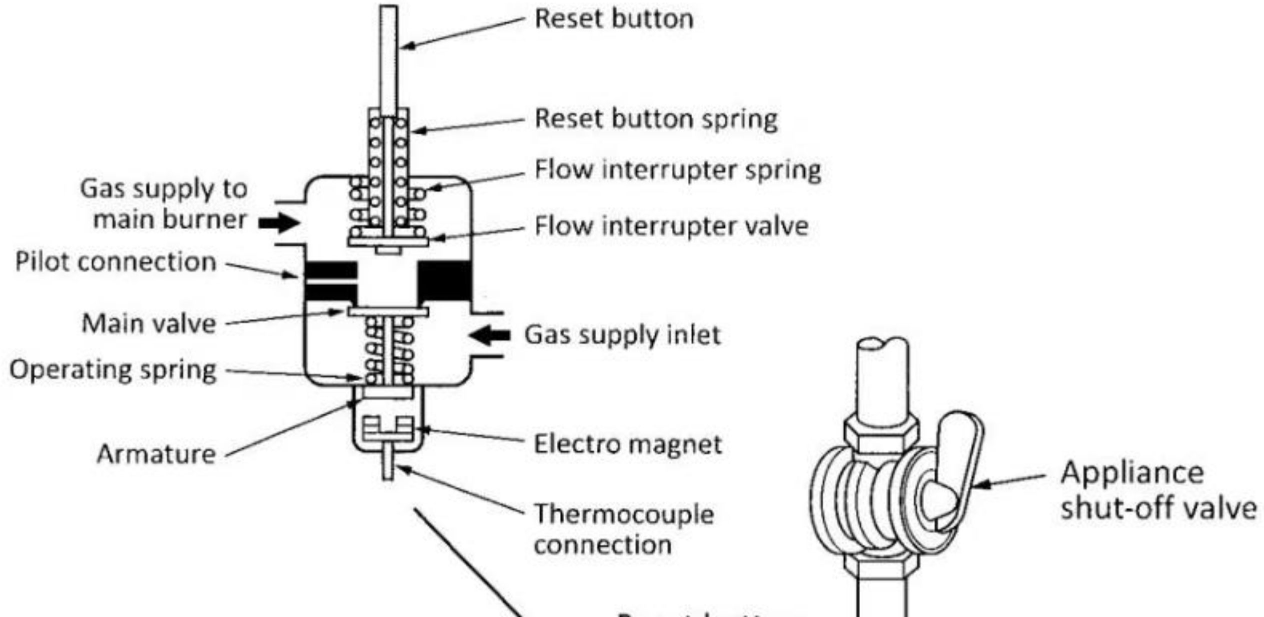
Thermoelectric safety shut-off valves are often referred to as pilotstats as they thermally monitor the pilot flame.



When the reset button is pressed, gas will only flow to the pilot burner. Then the pilot burner must be manually lit.



Once the pilot is lit and the thermocouple is heated, it will produce enough electricity to energize the electro magnet and hold the main valve open. Gas can now flow to both the pilot and the main burner.

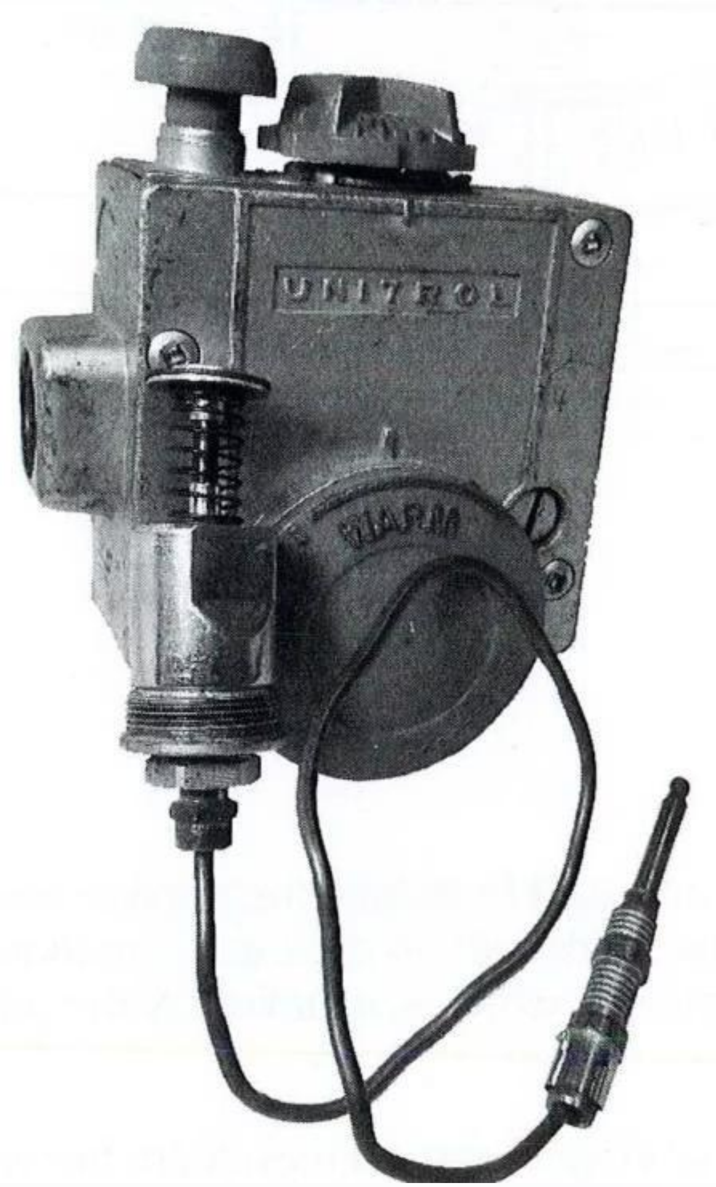


Pilotstat Module

Integration

Safety shut-off valves may be one part of a combination gas valve.

In the image, you can see that the pilotstat module has been removed from the body of a combination gas valve. It has been placed in front aligned with its appropriate internal location.



Pilot stat and thermocouple removed from gas valve

Gas Pressure Regulators

Purpose

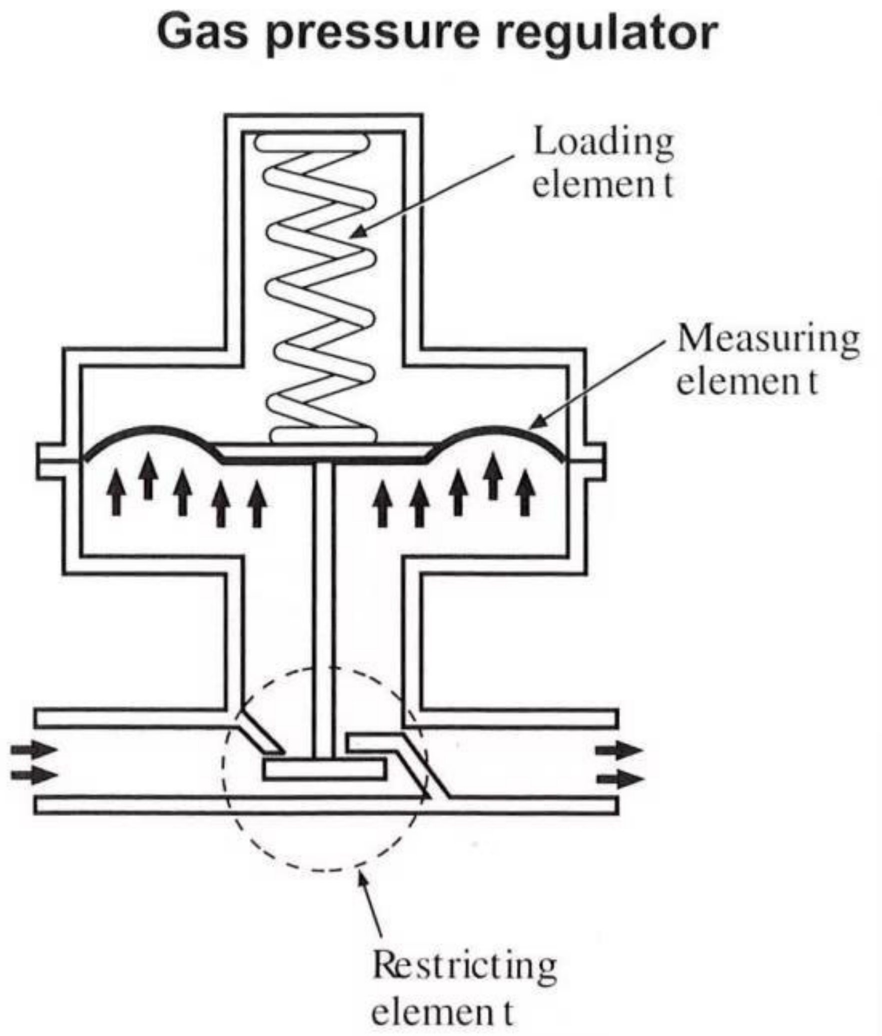
Gas pressures in service piping are often much higher than the pressures acceptable for appliances and equipment.

Gas pressure regulators, when properly selected and installed, help maintain constant downstream gas pressure over a wide range of upstream gas pressure variations.

Categories

There are essentially three categories of gas pressure regulators:

- Service
- System (line pressure)
- Appliance



Service and Line Pressure Regulators

Service Regulators

For natural gas, service regulators are used to reduce the service-line pressure to house-line pressure at the gas meter set in order to deliver an allowable pressure to the building.

For propane, the gas technician/fitter installs service regulators between the storage container and the building.

Line Pressure Regulators

In some cases, a system of appliances and/or equipment in a building requires a different gas pressure from the building-line pressure delivered by the service regulator.

The use of a line pressure regulator is generally for reducing the building-line pressure accordingly. For example, a 2-psig service needs to be reduced to a maximum of 0.5 psig as that is the maximum inlet pressure to most appliance regulators.

Appliance Regulators

Function

Appliance regulators are necessary to reduce the building-line pressure to that required for the proper performance of the appliances (e.g., approximately 3 inches w.c. for natural gas and 11 inch w.c. for propane gas).

Valve Train Component

The appliance regulator is one of the components referred to in the valve train components diagram (this one is shown connected to the A-cock).

The main purpose of the appliance regulator is to maintain a relatively constant gas pressure.

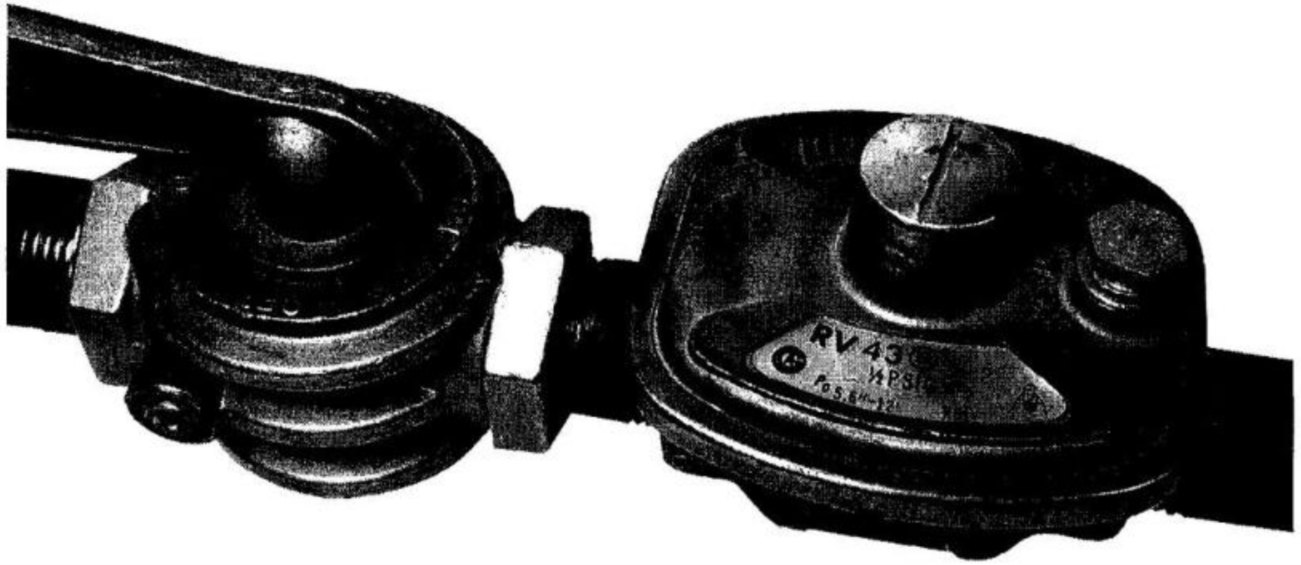
Gas Valves and Controls

This presentation explores the various types of gas valves and control systems used in heating appliances. We'll examine how these critical components regulate gas flow, ensure safe operation, and provide precise temperature control in residential and commercial applications.

Appliance Regulators

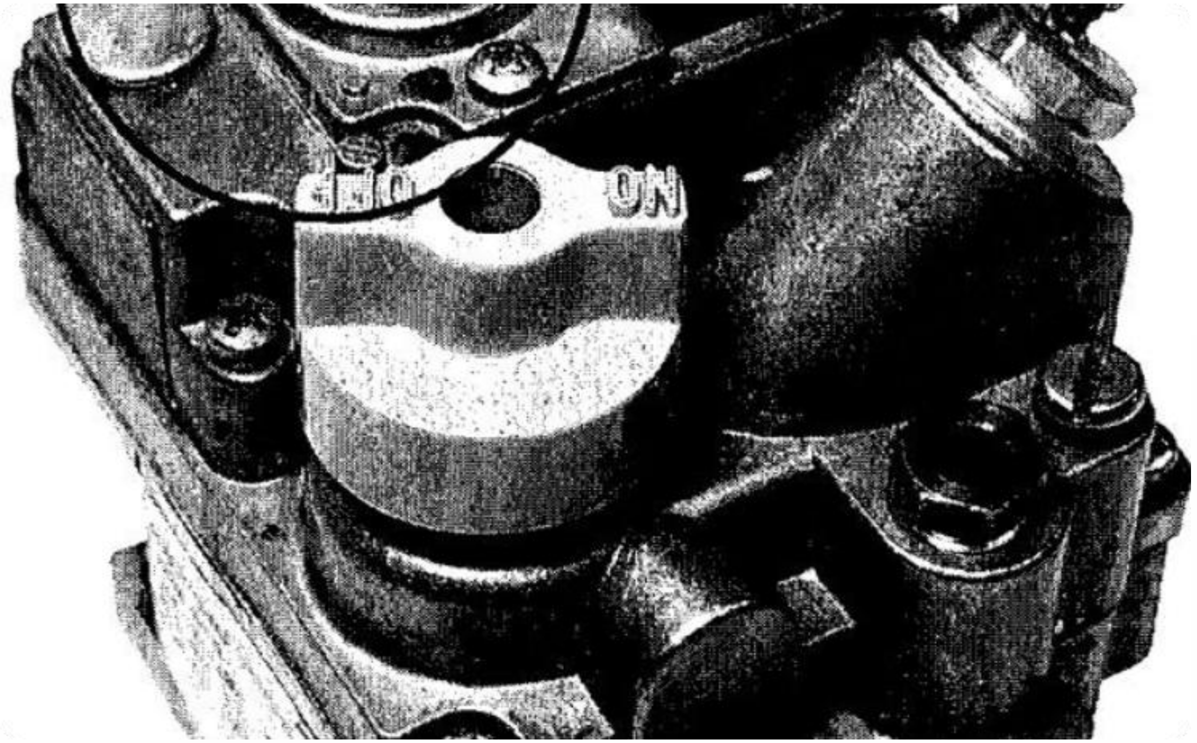
Function

Appliance regulators maintain constant outlet pressure to the burner(s) over a sometimes-fluctuating gas inlet pressure. This assures a constant, even flame at the main burners.



A-cock and appliance regulator shown above provides consistent gas flow regardless of inlet pressure fluctuations.

Combination Control Valves



Integrated Design

Often, the appliance regulator is built into a combination control valve as is the case in the gas valve shown here. The appliance regulator portion of the valve can be identified by the familiar shape of the spring housing and adjustment screw cover.

Automatic Gas Valves

Purpose

The automatic gas valve starts and stops the flow of gas to the appliance main burners. A sensing device activates the automatic gas valve, allowing the gas to flow to the burners where ignition will take place.

Variety

There are many types of automatic gas valves with various sensing devices and activation methods.

Methods of Operation

Mechanical Operation

Non-electric operation by a mechanical sensing device such as a capillary or rod and tube acting directly as the valve operator

Electromagnetic Operation

Solenoid-operated where the control circuit is energized or de-energized to activate the valve

Activation Methods

Electromechanical switches containing sensing devices or electronic control modules monitoring sensing devices

Non-Electric Automatic Gas Valves

Definition

Non-electric gas control valves rely upon a thermo-mechanical sensing element to act directly upon them.

Common Types

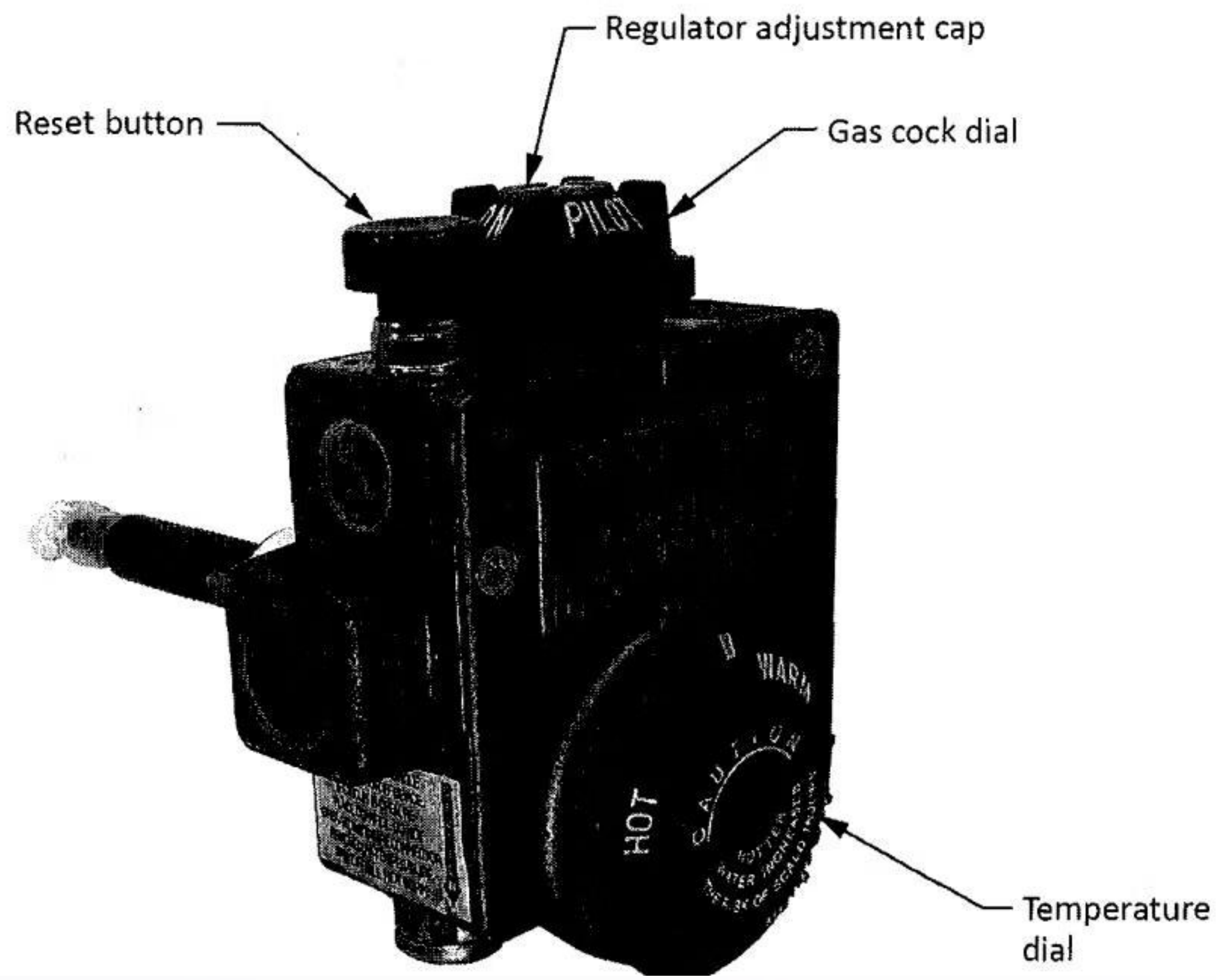
- Rod and tube water heater gas valves
- Hydraulically operated gas valves

Rod and Tube Combination Gas Valve

Applications

The rod and tube combination gas valve is a multi-purpose valve typically installed in storage type water heaters. They are sometimes referred to as a Unitrol as this was one of the first most popular models used.

Figure 1-90
Unitrol multi-purpose valve
Image courtesy of Terry Bell



Components of Rod and Tube Valve

Safety Components

An automatic safety shut-off valve and an over temperature energy cut-off (eco) device

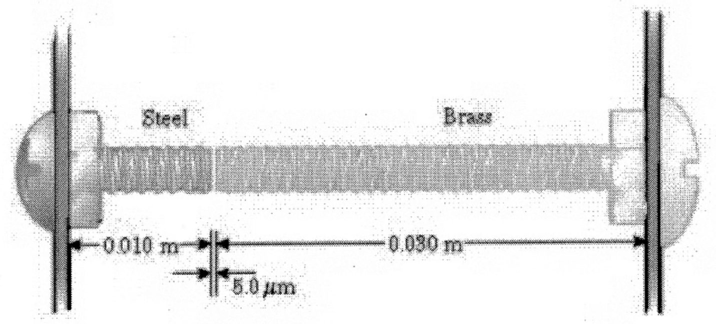
Control Components

A main and standby gas cock, a thermostat, and an automatic main gas valve

Regulation

A main pressure regulator

Consider a steel bolt and a brass bolt secured to two immovable plates, as shown in Figure Q3(c) below. The bolts almost touch each other when the temperature of the system is 27 °C. At this temperature the length of the steel bolt is 1 cm and the length of the brass bolt is 3 cm. As the temperature increases the ends of the bolts move toward each other. Coefficients of linear expansion for steel and brass are $\alpha_{st} = 11 \times 10^{-6}$ °C^{-1} and $\alpha_{br} = 19 \times 10^{-6}$ °C, respectively. If the initial gap between the ends of the bolts is 5 μm at 27 °C, at what temperature will the bolts touch? [6 marks]



Rod and Tube Operation

Temperature Sensing

The Unitrol actuates in response to changes in water temperature. Its sensing device works on the rod and tube principle.

Thermal Expansion

The copper tube expands or contracts based on the temperature of the water it is immersed in.

Mechanical Action

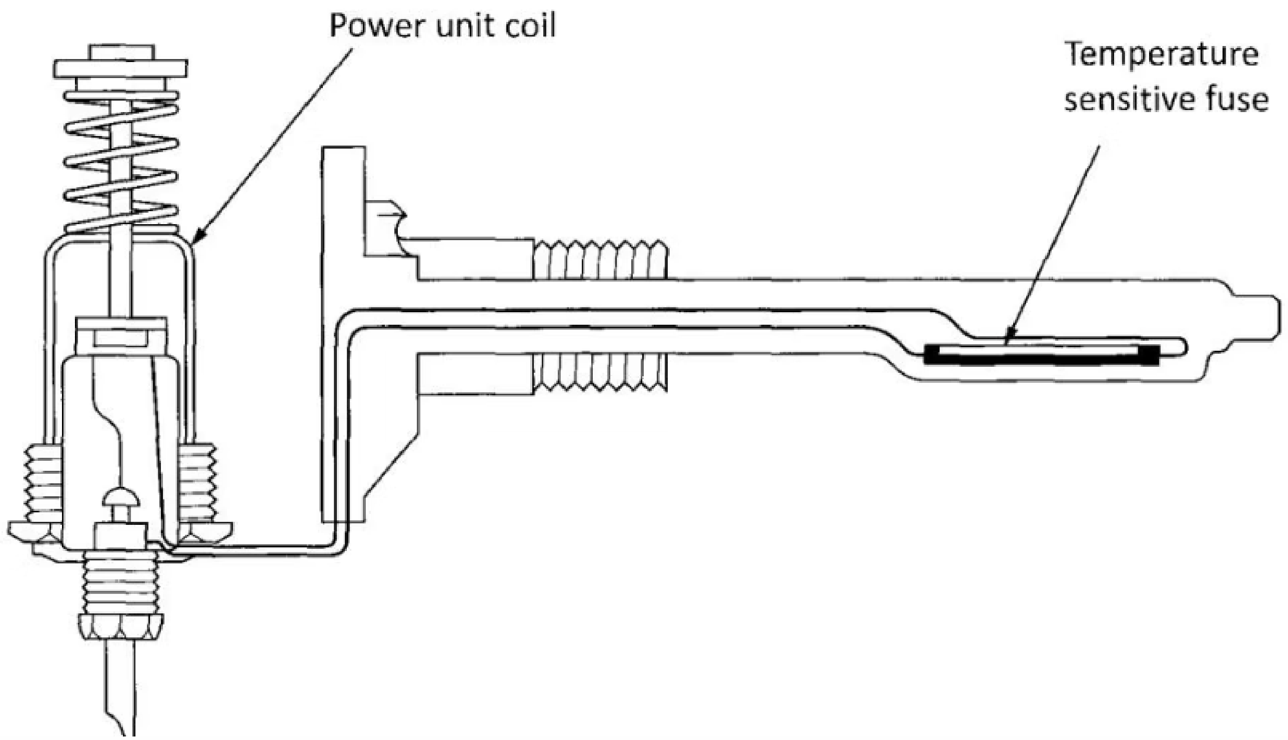
The invar rod moves in and out of the valve body as the copper tube changes length, controlling gas flow.

Energy Cut-Off (ECO) Device

Safety Feature

The ECO is a fusible link wired in series with the safety valve solenoid. If the temperature-sensitive fuse exceeds 200°F, the fuse will melt, and the electrical current to the safety valve power unit coil will be interrupted, shutting all of the gas off.

Most ECOs are one-shot controls; if the ECO has tripped, the valve will have to be replaced.



The cutaway on the left has extra wires within the copper tube. This is a built-in safety device called an Energy Cut-Off (ECO).

Modern Hot Water Gas Valves

Power Requirements

More recent hot water gas valves for higher efficiency type water heaters with ventor motors require 120 V power

Ignition Type

These valves use direct-ignition systems

Efficiency

Designed for higher efficiency water heaters

Modulating Valve

Definition

A modulating valve is a combination of two valves in a single unit designed to give precision temperature control with minimum cycling and maximum operating efficiency.

Modulating valves are also used for oven controls and liquid temperature controls.

Modulating Valve Operation Sequence

Initial Heat Call

A snap-acting valve opens at the initial call for heat to provide the minimum rate of gas flow

Temperature Assessment

If this gas flow is sufficient to bring the room up to the set temperature, the snap-acting valve closes

Additional Heat

If more heat is required, a modulating valve adjusts the gas flow rate between the fixed minimum and full burner capacity

Minimum Rate

The valve is provided with a minimum rate that is intended to match the minimum gas flow requirement of the burner that it serves

Temperature Sensing Mechanism

Components

The temperature-sensing bulb, capillary tubing, and bellows are filled with a temperature-sensitive liquid.

Temperature Response

Changes in temperature at the bulb contract the liquid on temperature fall and expand it on temperature rise, causing the bellows to shorten and lengthen respectively.

Mechanical Action

This movement is transmitted to the valve assembly by a horizontal pivot arm.

Electric Automatic Gas Valves

Prevalence

Most automatic gas valves are electrically actuated and are primarily found on the gas valve train to control gas flow to the burner.

Advantages

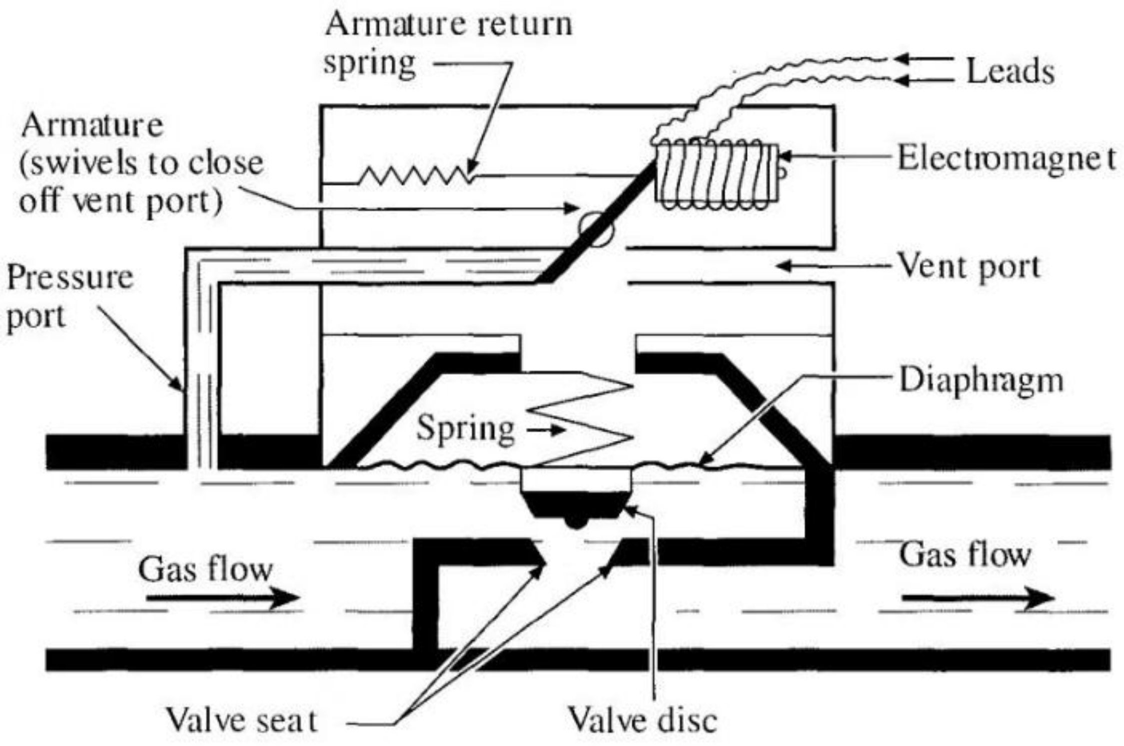
- Precise control
- Remote operation
- Integration with electronic control systems
- Safety features

Diaphragm Valve

Description

The diaphragm gas valve is a pilot operated solenoid valve in that it uses available gas pressure as the primary force to open or close the valve. They are simply an on/off automatic valve and do not regulate or modulate the flow.

Although this style of diaphragm valve is rare today, it serves well as an introduction to an important concept used on most advanced valves.



Cutaway view of a diaphragm gas valve

Diaphragm Valve Operation

Heat Call

On a call for heat, the electromagnet is energized

Armature Movement

The electromagnet pulls the armature to block the pressure port, allowing gas pressure above the diaphragm to bleed off through the vent port

Pressure Differential

The gas pressure below the diaphragm lifts the diaphragm and valve disc from the valve seat, allowing gas to flow

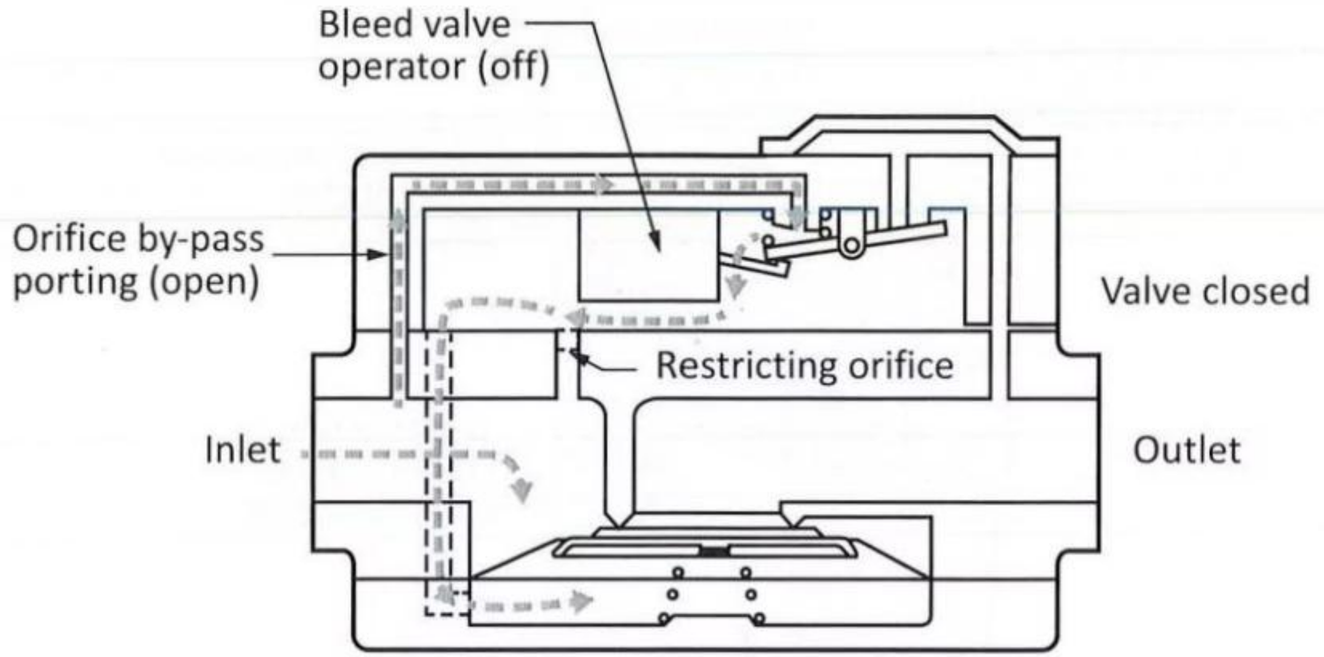
Valve Closing

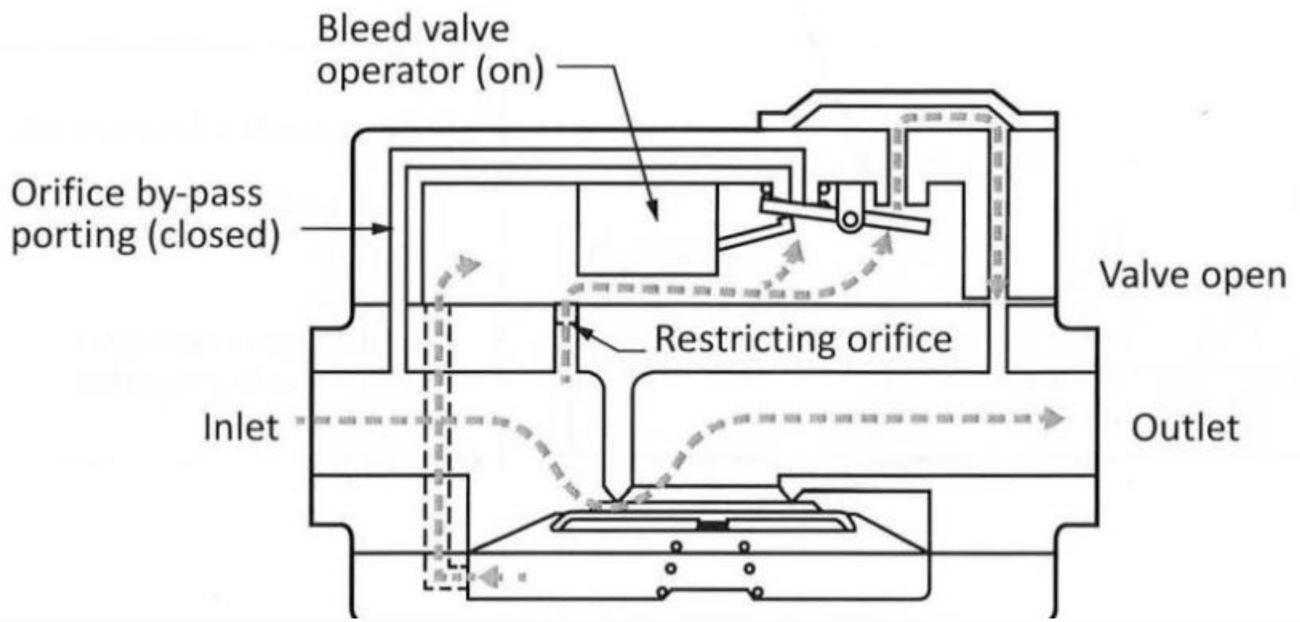
When heat call ends, the electromagnet de-energizes, the armature blocks the vent port, pressure equalizes, and the spring closes the valve

Alternative Diaphragm Valve Design

Key Differences

- An internal bleed line vents the gas back into the outlet chamber
- The valve disc is inverted, and working gas pressure is diverted to the underside of the diaphragm
- The armature return spring is compressed when the operator is energized

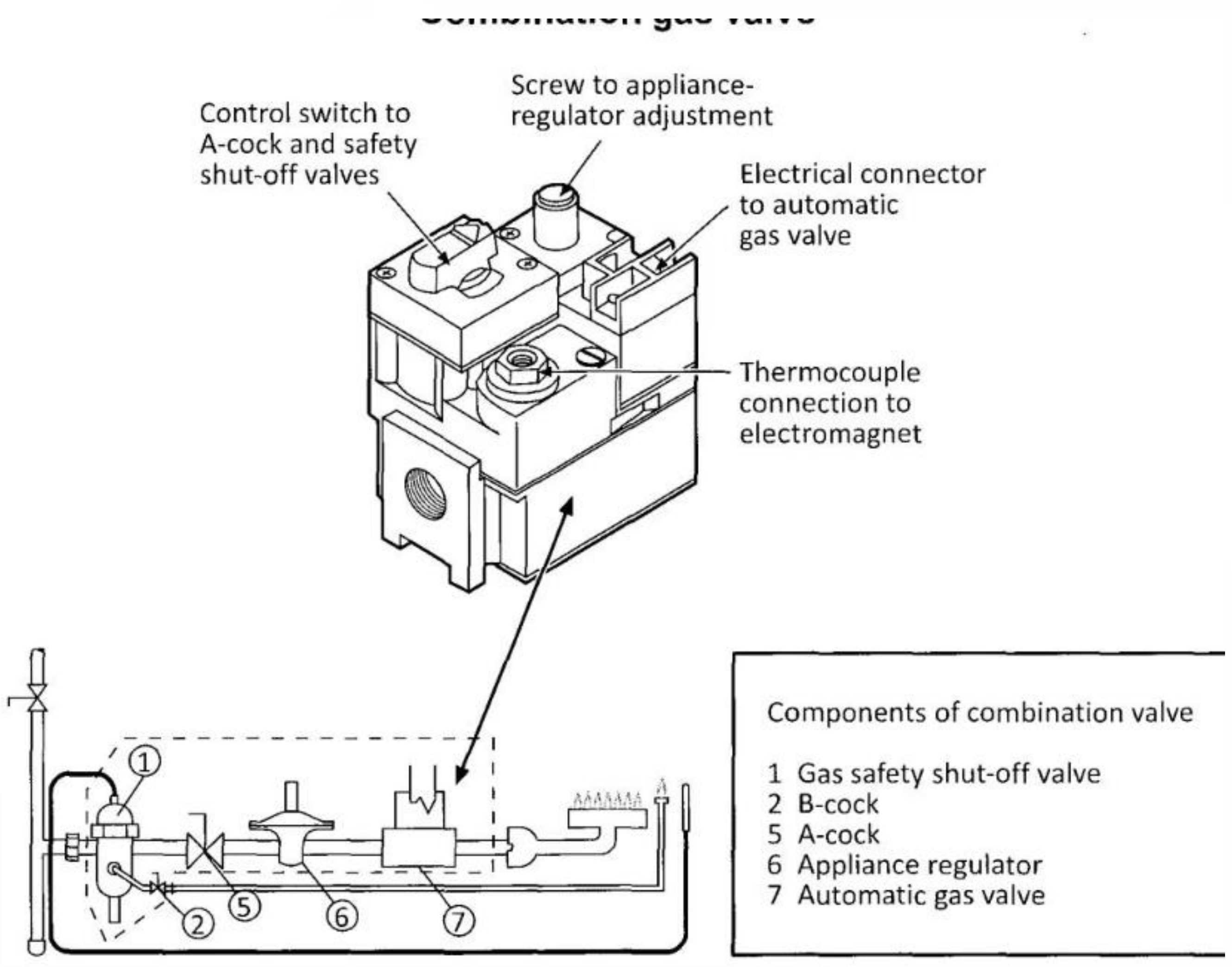




Combination Gas Valves

Purpose

Combination gas valves were designed to combine several controls into one unit in order to save on space. These valves are generally found in appliances with inputs 400,000 Btu/h or less.



A typical combination gas valve integrating multiple functions

Combination Valve Components

Standard Components

The compact body of a combination gas valve includes a manual shut-off valve, an automatic gas valve, and a pressure regulator.

Additional Controls

Some combination valves also include 100% safety shut-off, pilot gas adjustment, and control module.

System Integration

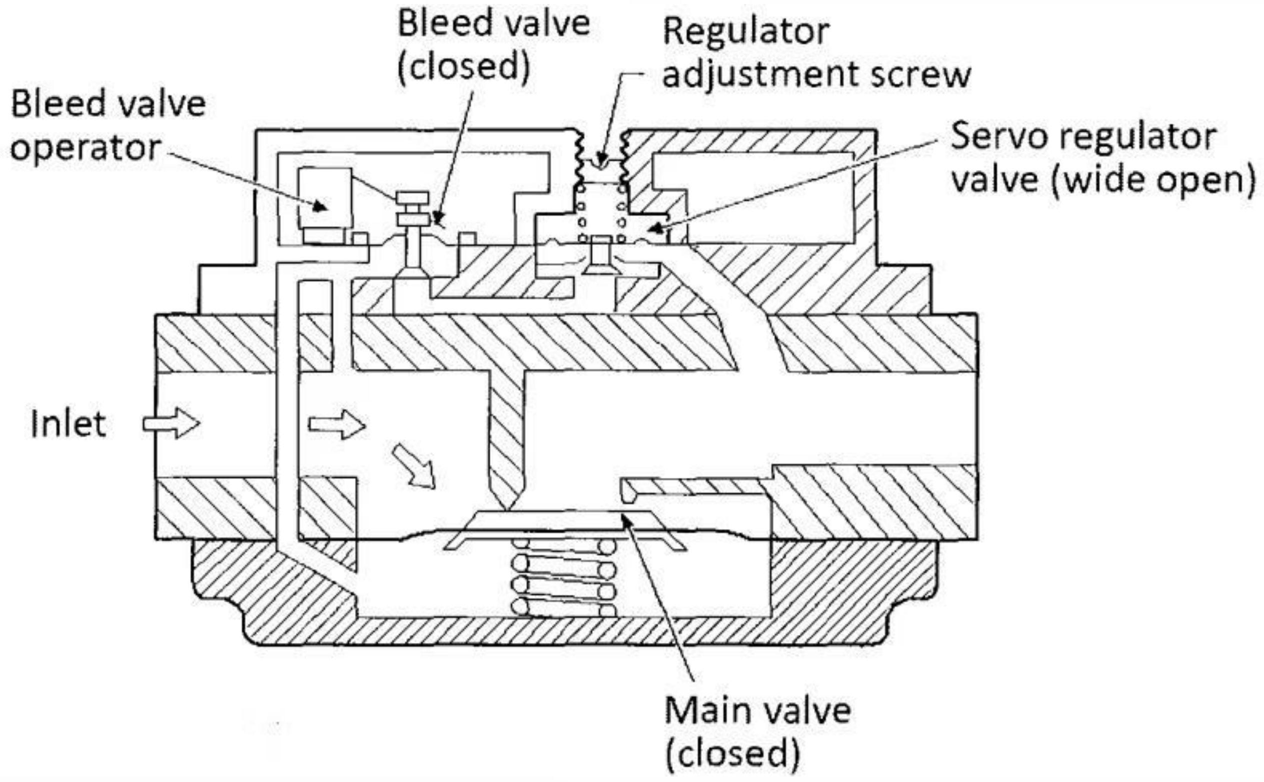
The system's ignition and the control system determine what additional controls are included in the combination valve.

Servo Gas Valve

Design Principle

The servo regulated combination gas valve is essentially a diaphragm gas valve with the addition of a servo regulator. The servo gas valve uses the same principle as the diaphragm gas valve in that it manipulates a small amount of upstream gas flow onto the working chamber of a diaphragm.

Whereas the diaphragm valve has strictly open or closed valve, the servo gas valve can act as a pressure regulator by partially opening or closing the valve seat.



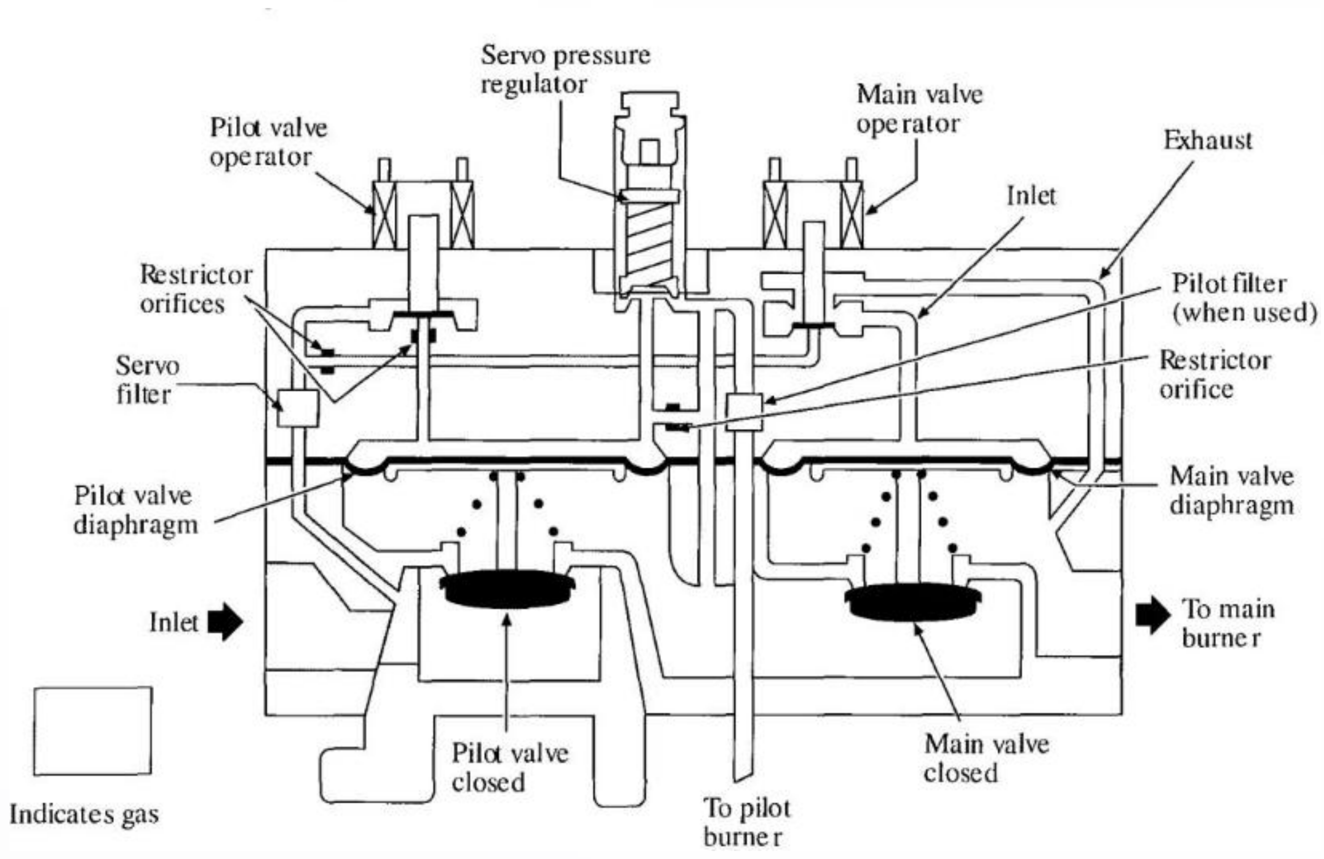
Combination gas valve with servo operated regulator

Redundant Gas Valve

Safety Features

The redundant (in excess) gas valve is one of the most popular gas safety controls used in the field today. It is of the 100% safety shut-off type with, as extra protection, a second shut-off valve incorporated in the valve body.

This second (redundant) valve eliminates the possibility of an operational failure, allowing gas to enter the combustion chamber while a proper ignition source is absent.



Redundant gas valve with both valves closed before operating cycle

Redundant Valve Pressure Regulation

Servo Regulator Function

The servo pressure regulator is regulating the downstream pressure with the first (pilot) valve.

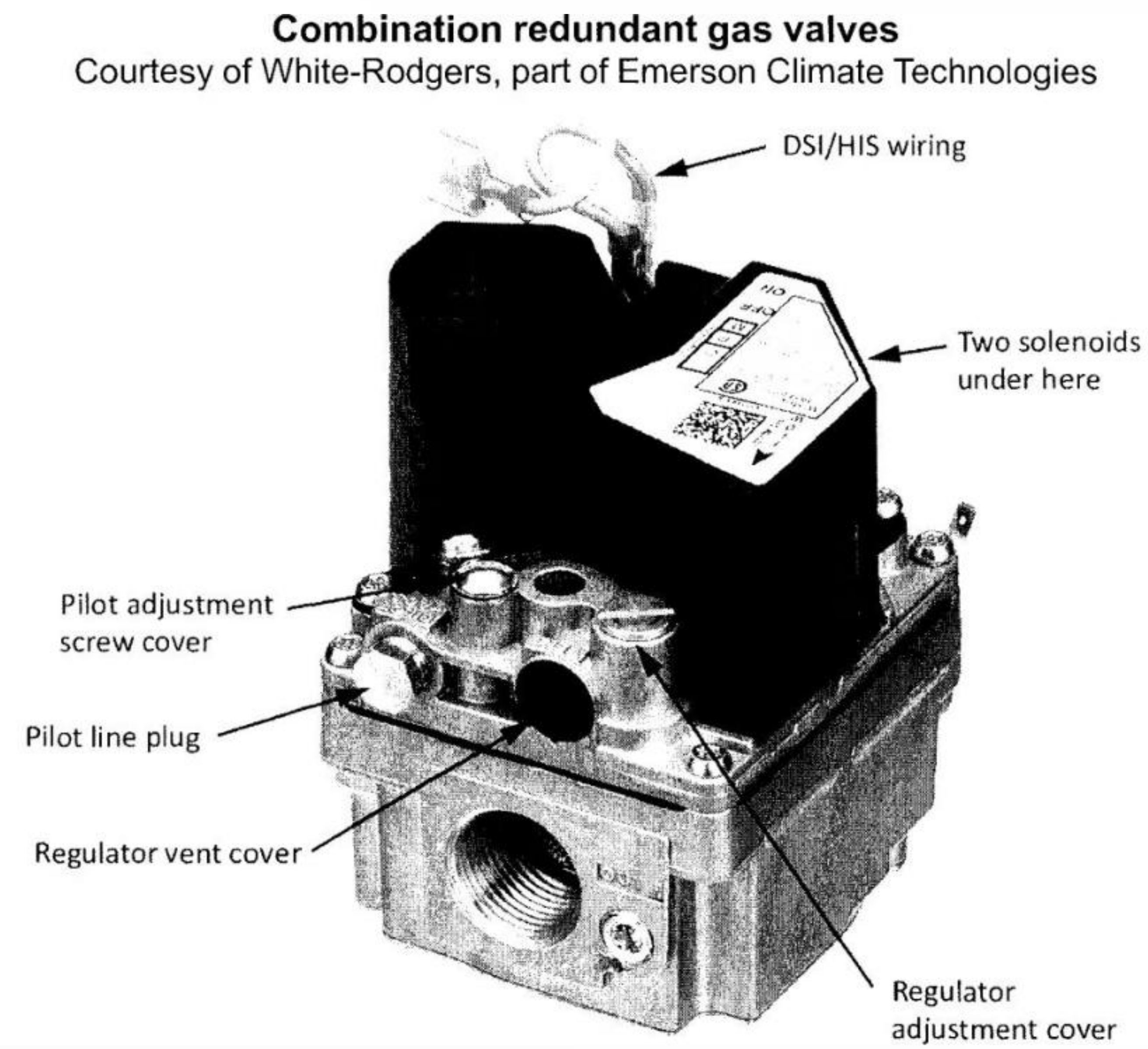
Manufacturer Variations

For many manufacturers of redundant gas valves, the servo regulator will use the second valve, and the pilot line pressure will be throttled with an internal needle valve, rather than regulated.

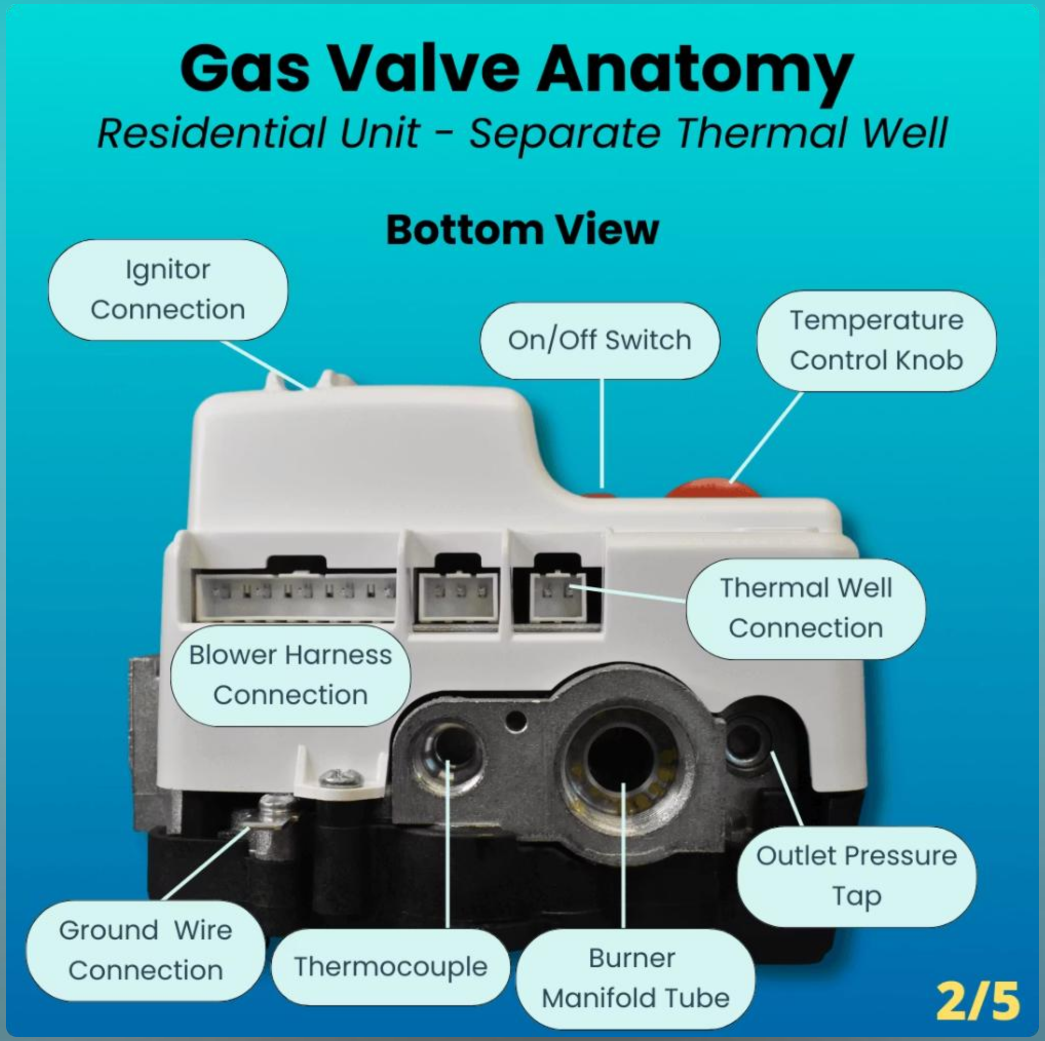
Configurable Redundant Valves

Versatile Design

Gas valve manufacturers often design their redundant gas valves with the ability to configure for intermittent pilot or for hot surface ignition (HSI) and direct spark ignition (DSI) setups.



Configurable redundant gas valve



Configuration Methods

HSI/DSI Configuration

When used on HSI or DSI systems, a wiring harness is used to energize both the pilot and main valve operators simultaneously.

Pilot Line Blocking

A threaded plug is installed in the pilot line connection for HSI/DSI applications.

Intermittent Pilot Setup

For intermittent pilot applications, these components are removed so the pilot tubing can be connected, and the solenoid operators can signal independently from the control module for separately sequenced operation.

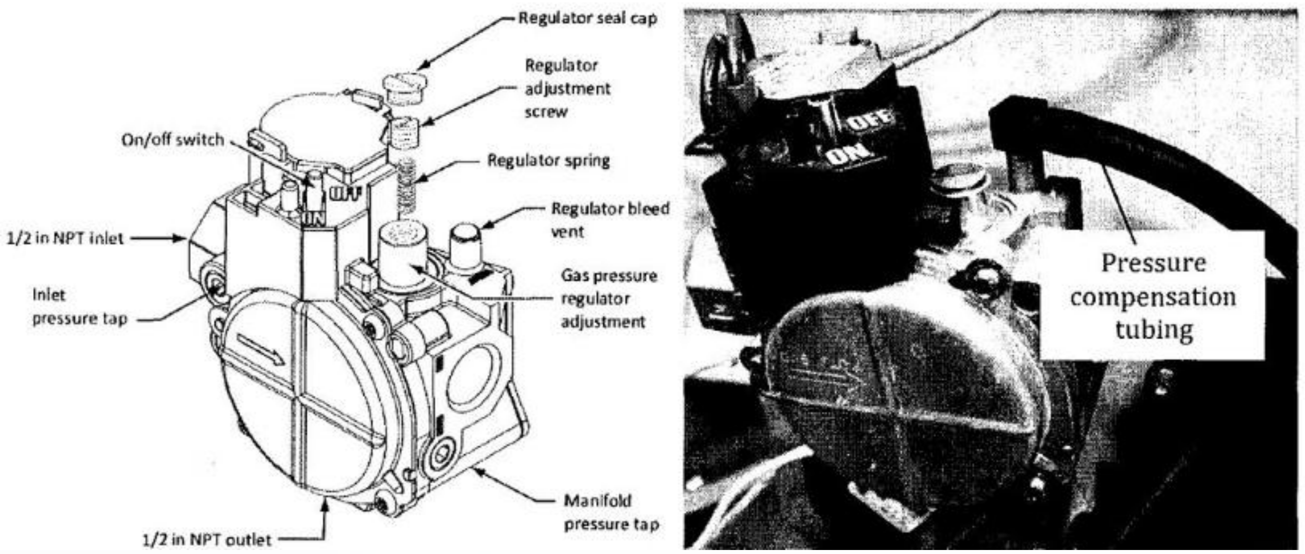
Specialized Redundant Valves

Purpose-Built Designs

Other styles are designed specifically to be used for DSI or HSI application, with the two operators internally wired together without pilot tapping.

The servo system regulates a third main valve and large diagrams of which chamber is visible on the side of this valve.

Figure 1-99
Redundant gas valve
Courtesy of Camosun College, Rodney Lidstone, licenced under CC BY



Specialized redundant valve for direct ignition applications

Gas Conversion and Pressure Compensation

Gas Conversion

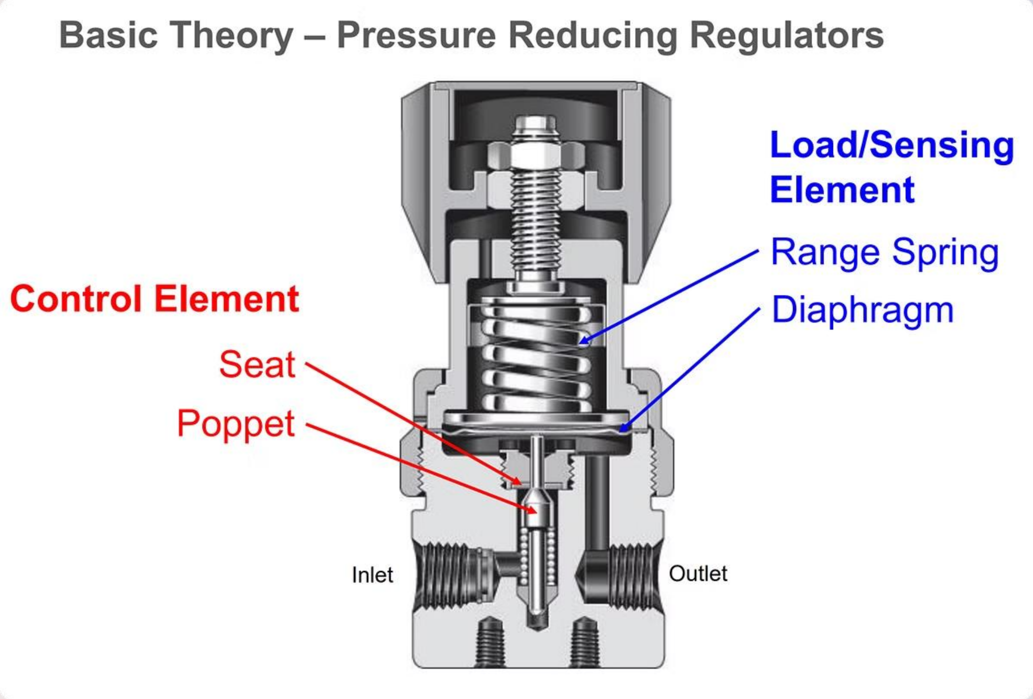
Certified gas conversion kits may require the replacement of the regulator spring to change the manifolds pressure.

Regulator Vent

Regulator vent cover serves as a dust cover only as air must be able to move freely in and out of the upper chamber of the servo regulator diaphragm.

Pressure Compensation

By connecting a combustion chamber pressure compensation tube to the regulator vent opening, the gas valve can automatically change the manifold pressure to maintain a constant pressure differential across the orifice.

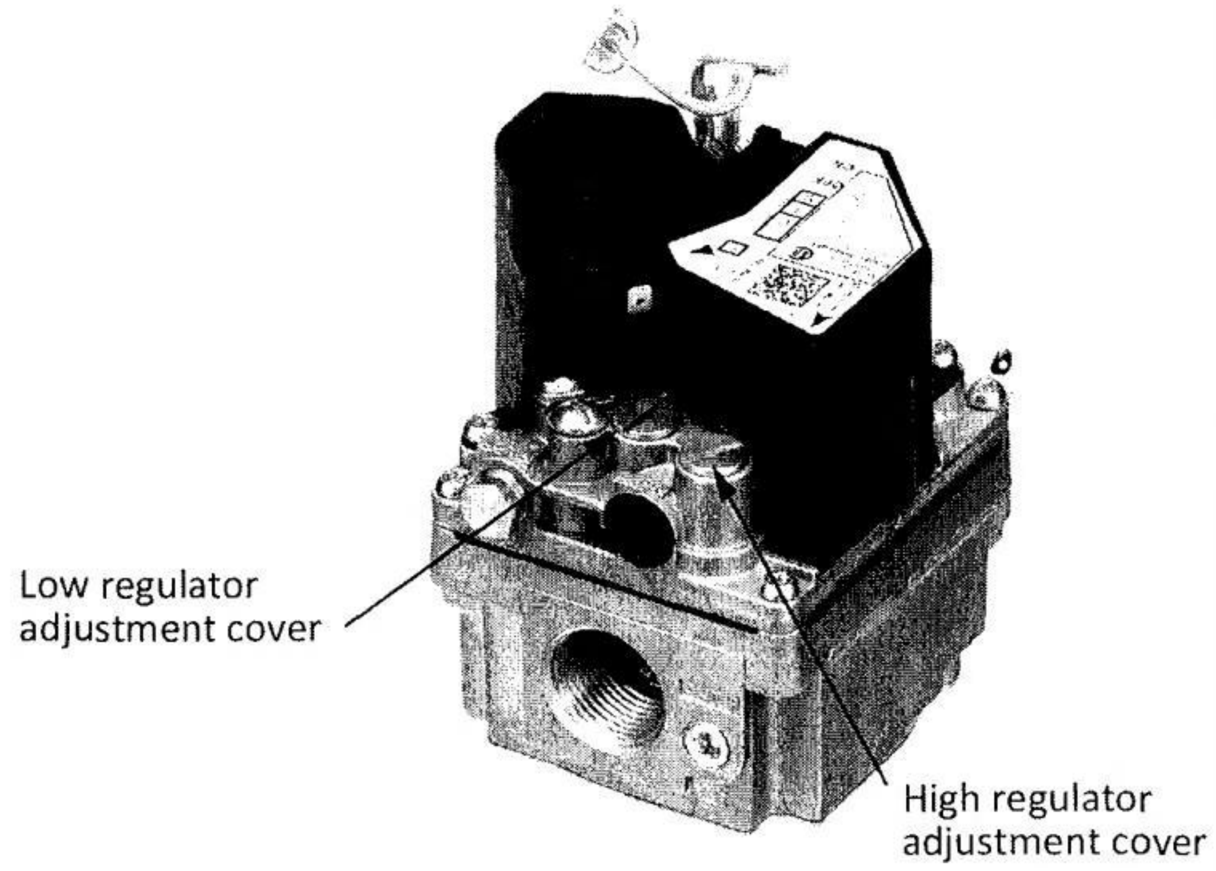


Two-Stage Redundant Gas Valves

Function

A two-stage gas valve is used with a two-stage thermostat to supply fuel in quantities necessary to meet staged demand.

The valve is built with two servo regulators, enabling it to supply lower manifold pressure and less fuel on a first-stage heating call. When the second stage is energized, 100% fuel flow is sent to the burner.



Two-stage combination redundant gas valve

Two-Stage Valve Design

Structural Similarities

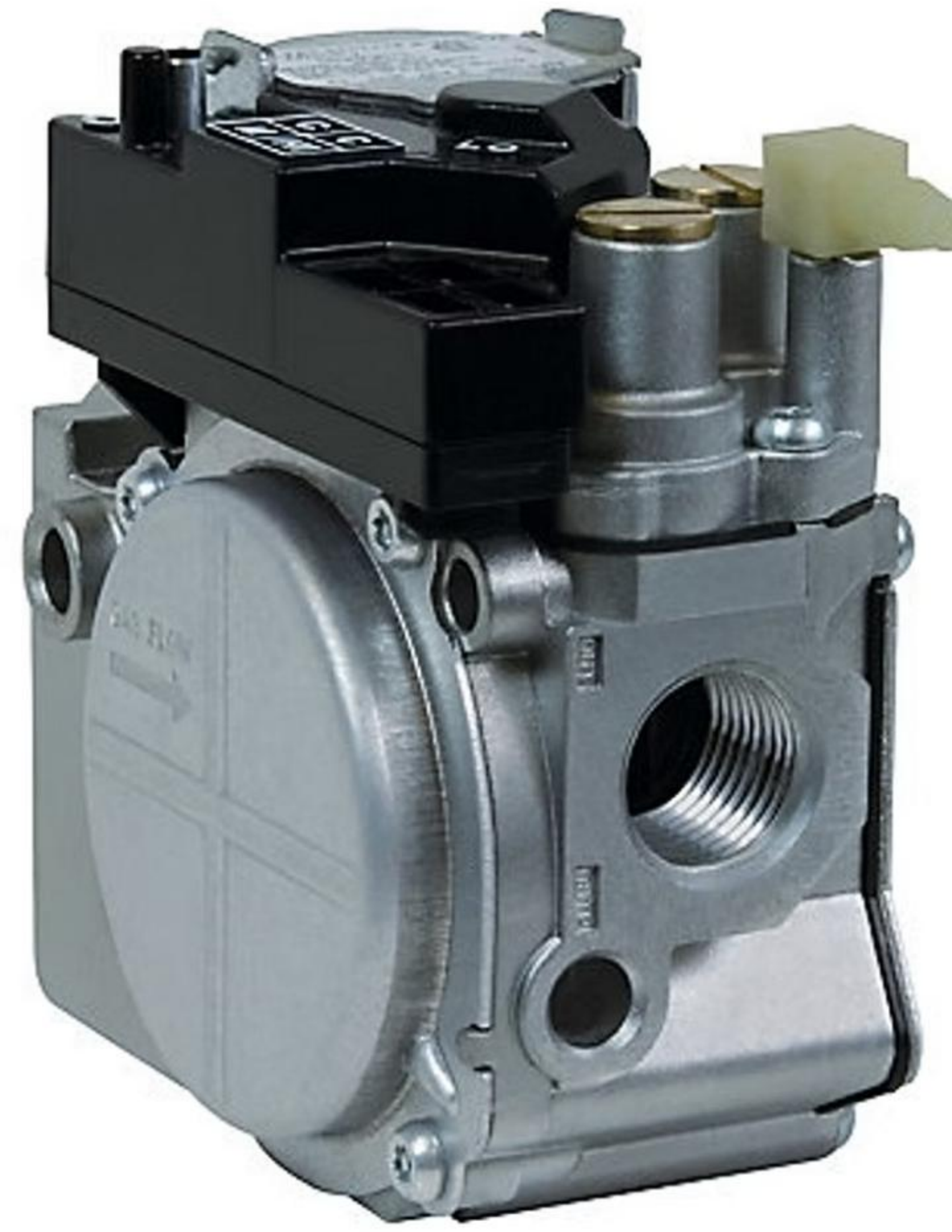
The valve body is very similar to standard redundant valves with key additions.

Additional Components

- Extra servo regulator adjustment cover
- Additional wiring connection to activate servo switching solenoid valve

Efficiency Benefits

Two-stage operation allows for more efficient heating by matching fuel supply to actual demand.

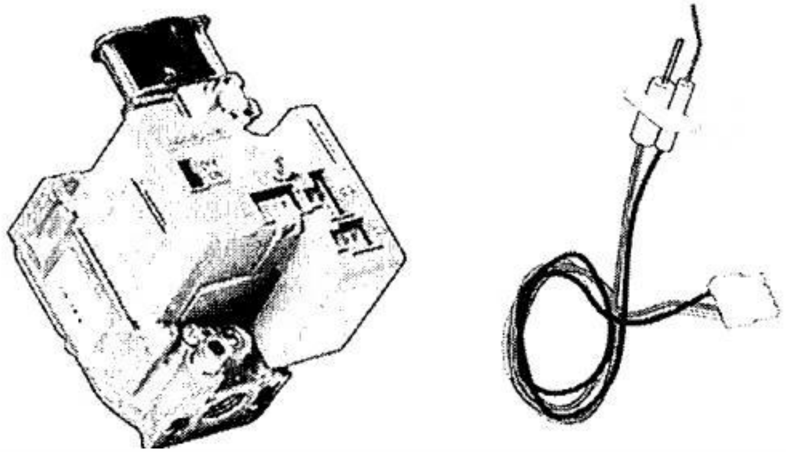


Smart Valve Systems

Integrated Functions

Smart valve system controls combine gas flow control and electronic intermittent pilot sequencing functions into a single valve body and control system.

Figure 1-101
Smart valve

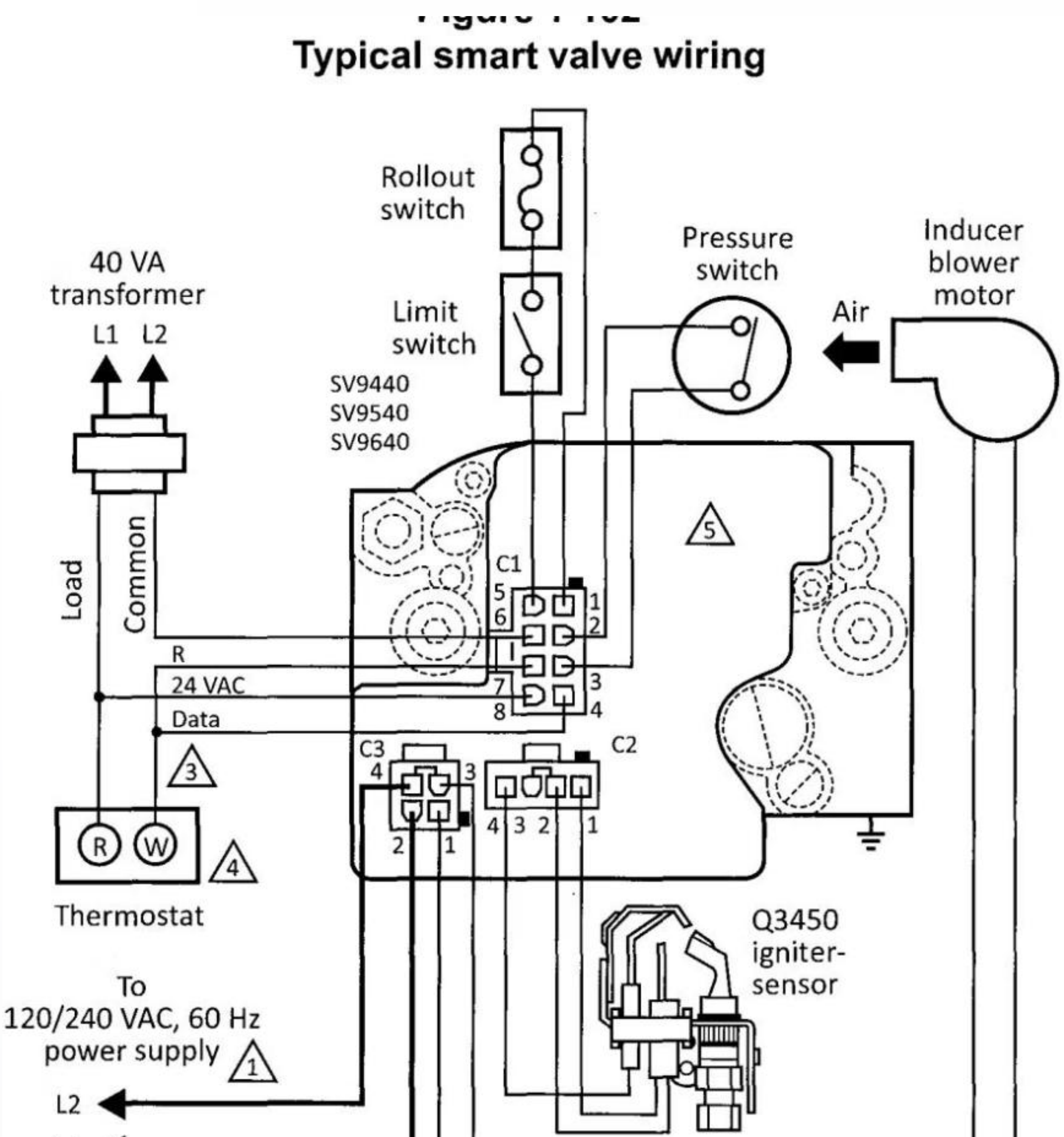


Smart valve system with integrated controls

Smart Valve Ignition System

Specialized Igniter

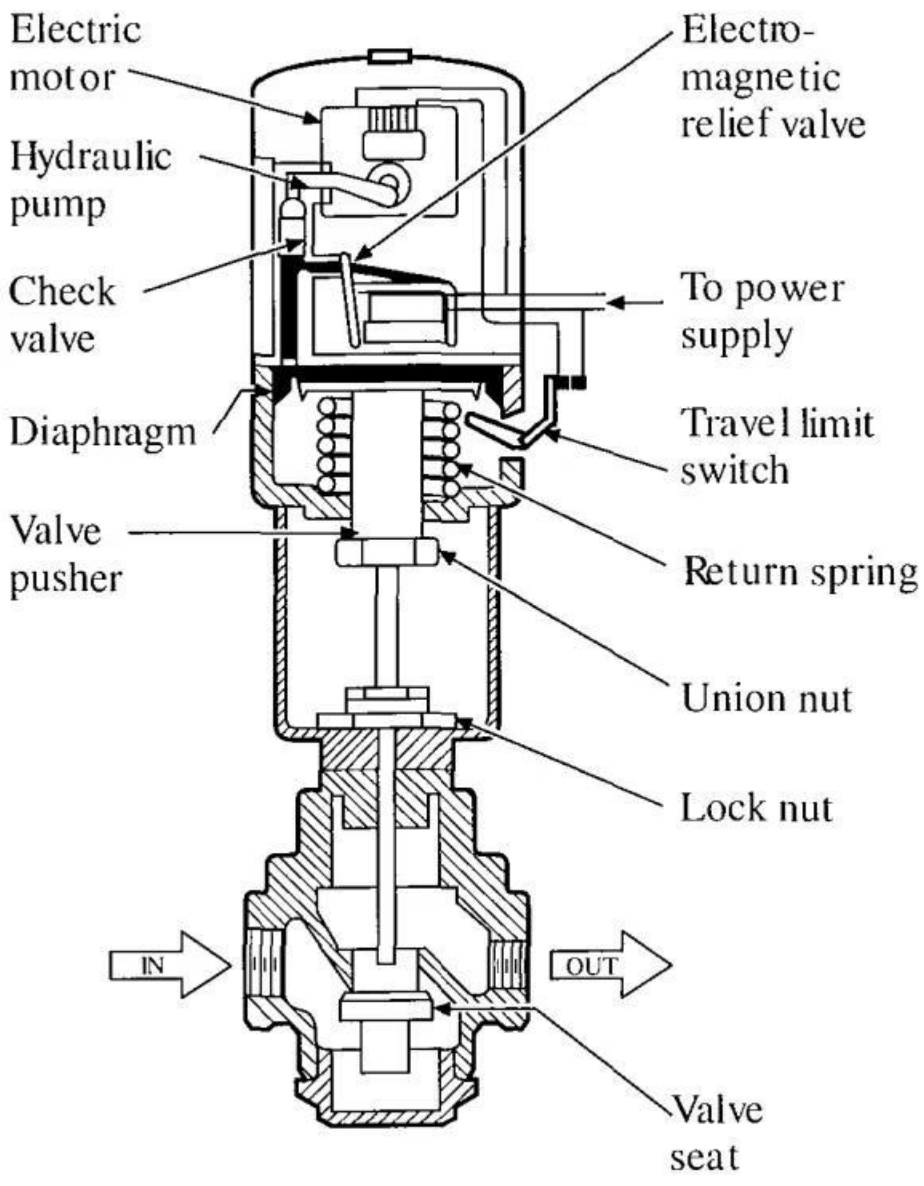
The igniter flame rod assembly for the smart valve contains a special 24 V HSI (Hot Surface Igniter).



Motorized Valve

Operation Principle

The motorized valve is completely opened by the operation of an electric motor and is generally automatically closed by a spring or other mechanical means when the electrical circuit is broken.



Motorized hydraulic gas valve

Hydraulic Actuated Valve

Motor Operation

The electric motor runs an oil pump

Hydraulic Action

Oil fills the chamber and pushes down on a piston or diaphragm

Valve Closing

To close, the relief valve is released, bleeding the cylinder as the return spring closes the valve

Full Open Position

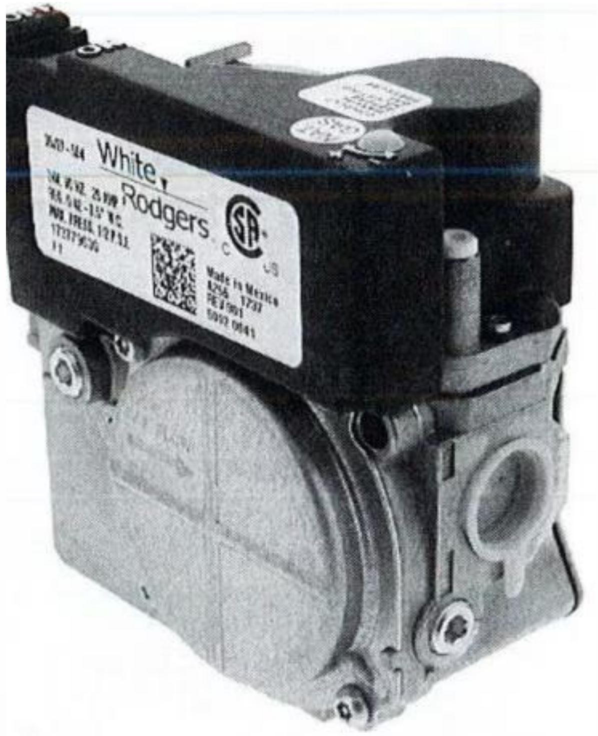
When fully open, a switch turns off the motor, and the oil remains captured in the cylinder

Modulating Operation with Stepper Motor

Advanced Control

With the use of a stepper motor, diaphragm gas valves can be used to modulate the firing rate. The valve has the same body and internals as redundant gas valves previously introduced with the addition of the DC motor operator.

This motor operator receives a signal from the controller and adjusts the setting of the servo regulator to the required manifold pressure. These valves can achieve a full range of modulation from 35-100% with 1% increments.



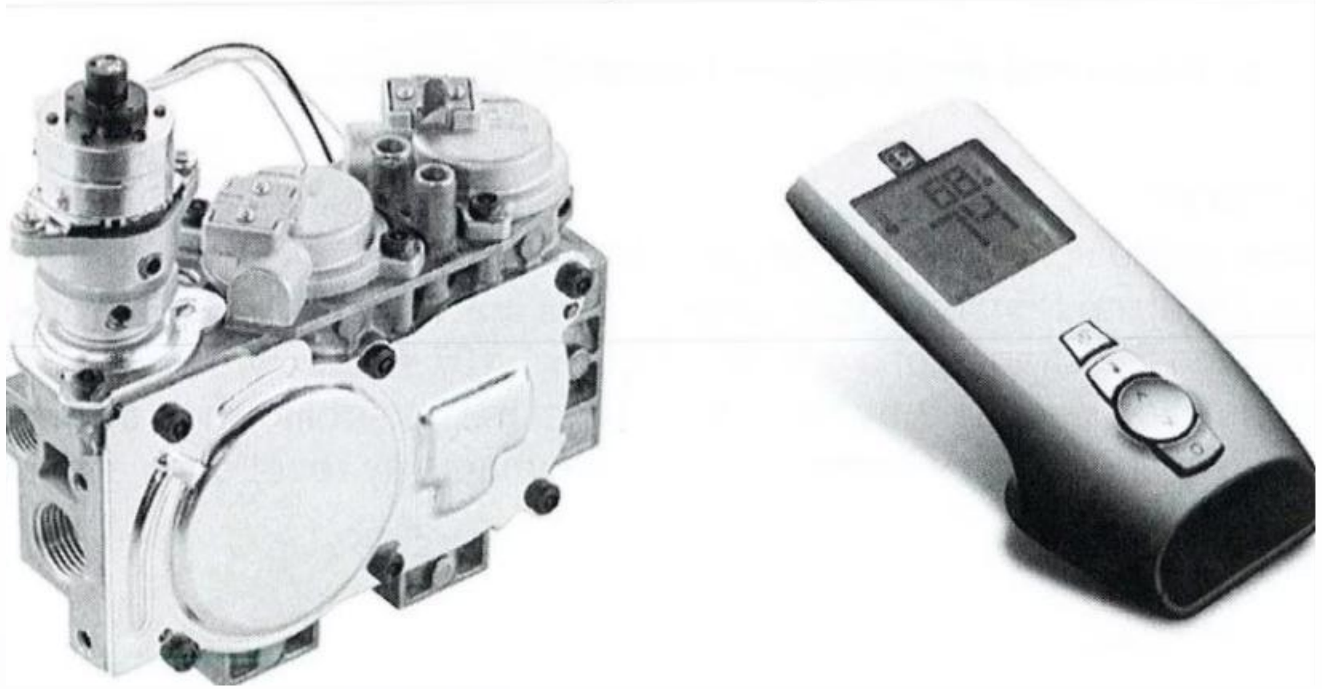
DSI and HSI modulating combination gas valve

SIT Valves

Company Background

SIT is an Italian company originally focused on millivolt gas controls. Its name became synonymous with gas valves used on fireplaces so much that some gas fitters often use "SIT valves" to refer to all slender millivolt gas valves used on fireplaces.

Courtesy of SIT S.p.A



SIT valve with remote control

SIT Valve Features

Redundant Design

There are millivolt redundant gas valves, many of which have an adjustable servo regulator to change the flame size.

Adjustment Methods

The adjustable servo can be manual dial, or electric motor connected.

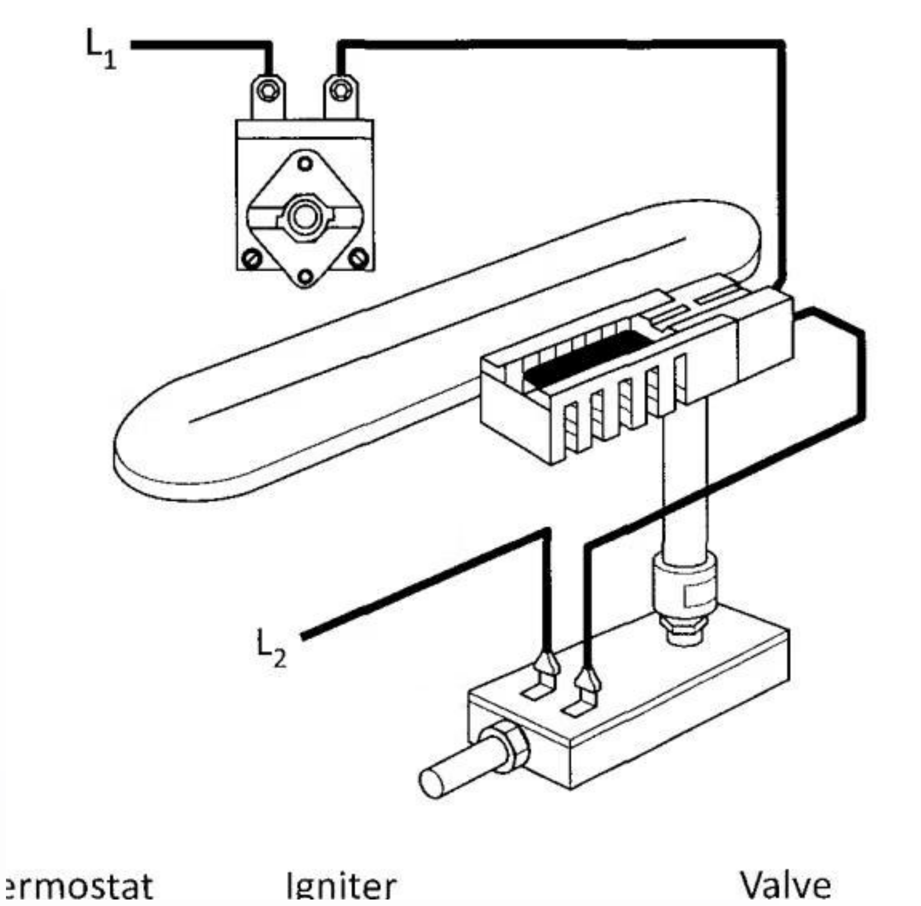
Remote Control

Many models feature battery-powered burner control with remote operation capabilities.

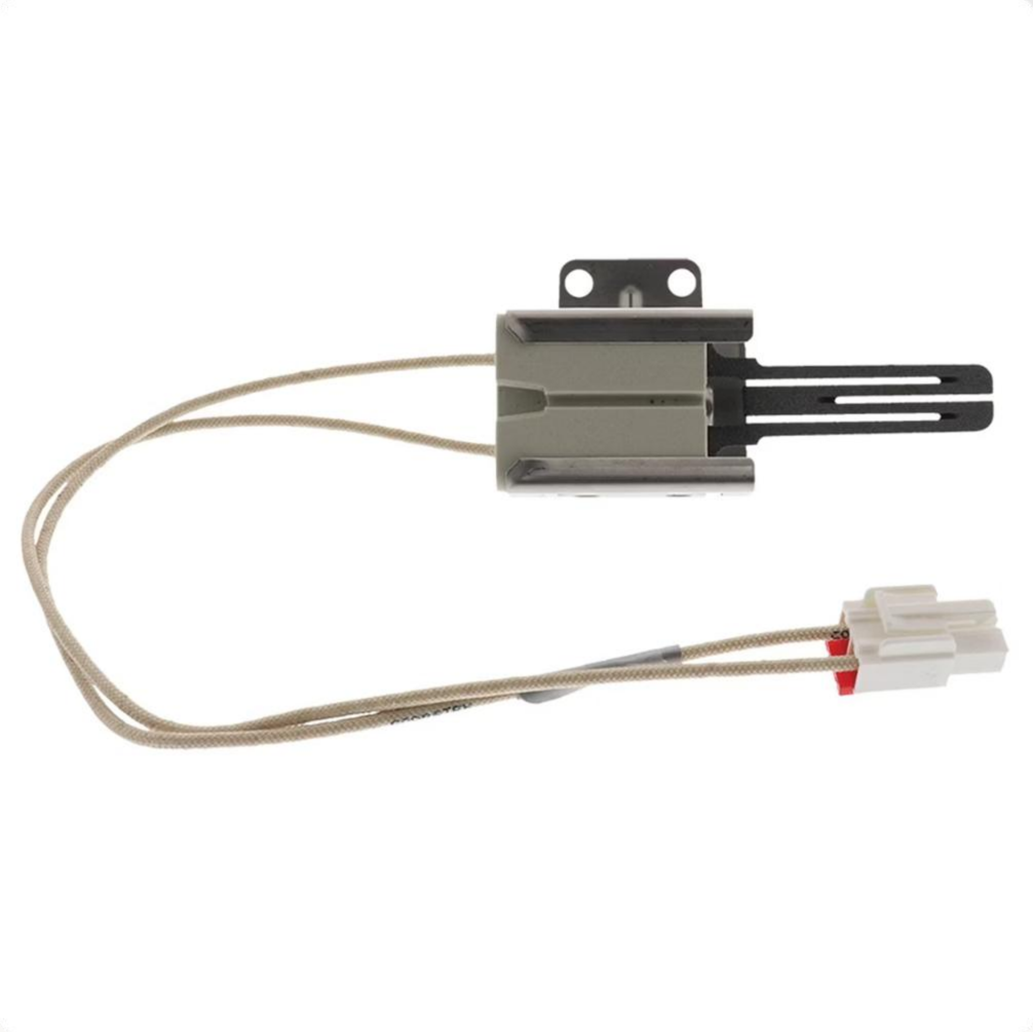
Oven Safety Valve

Safety Function

Electric oven gas valves are also safety devices that only allow gas to flow to the bake or broil burners if the HSI (glow bar) circuit is energized and creating adequate current.



Oven safety valve wiring diagram



Oven Safety Valve Operation

Series Circuit

The thermostat, glow bar igniter, and gas safety valve are wired in series, meaning electricity must pass through the glow bar and then to the safety valve.

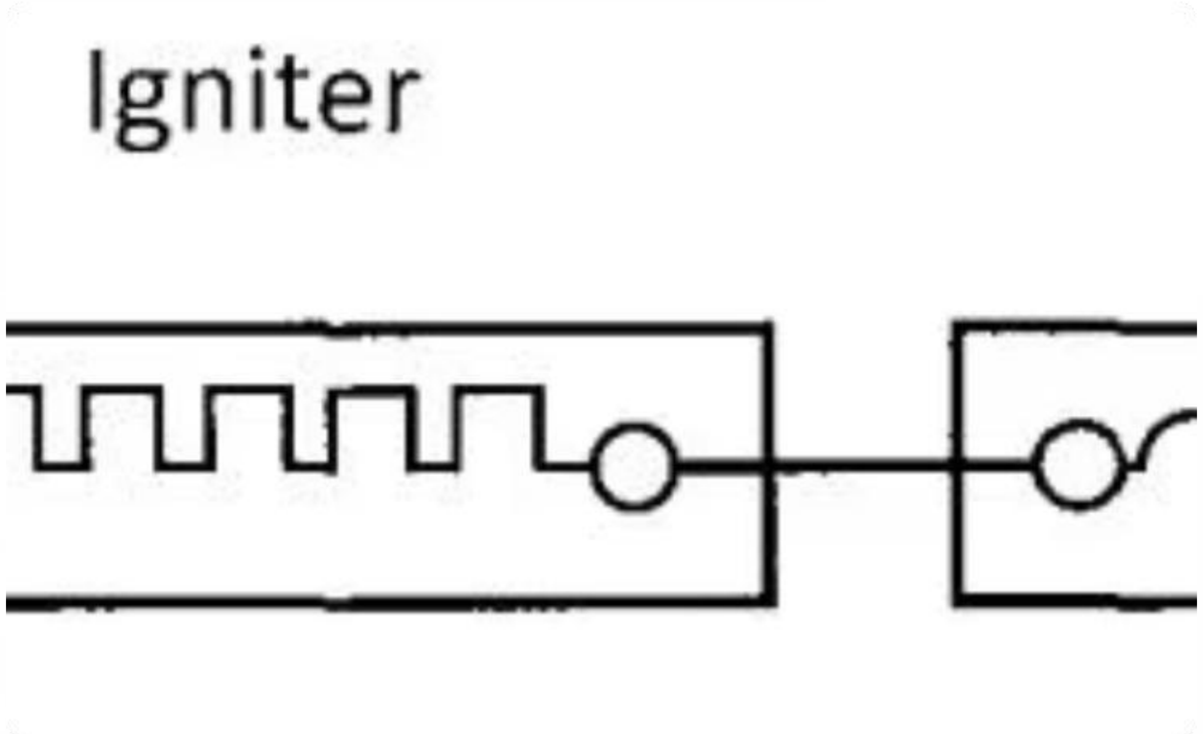
Resistance Principle

The glow bar blocks current to the gas valve through electrical resistance, which declines as the bar's temperature rises.

Ignition Threshold

When the bar reaches yellow heat, sufficient to ignite the gas, it allows passage of enough electricity to open the gas valve.

Oven Safety Valve Wiring



Wiring Diagram

The wiring diagram shows the electrical connections between the thermostat, glow bar igniter, and gas safety valve in a typical oven installation.

Specialized Gas Valves

Purpose-Specific Designs

There are some gas valves that are designed for specific purposes beyond standard heating applications.

Safety Applications

- Seismic gas valves
- Fire suppression gas valves

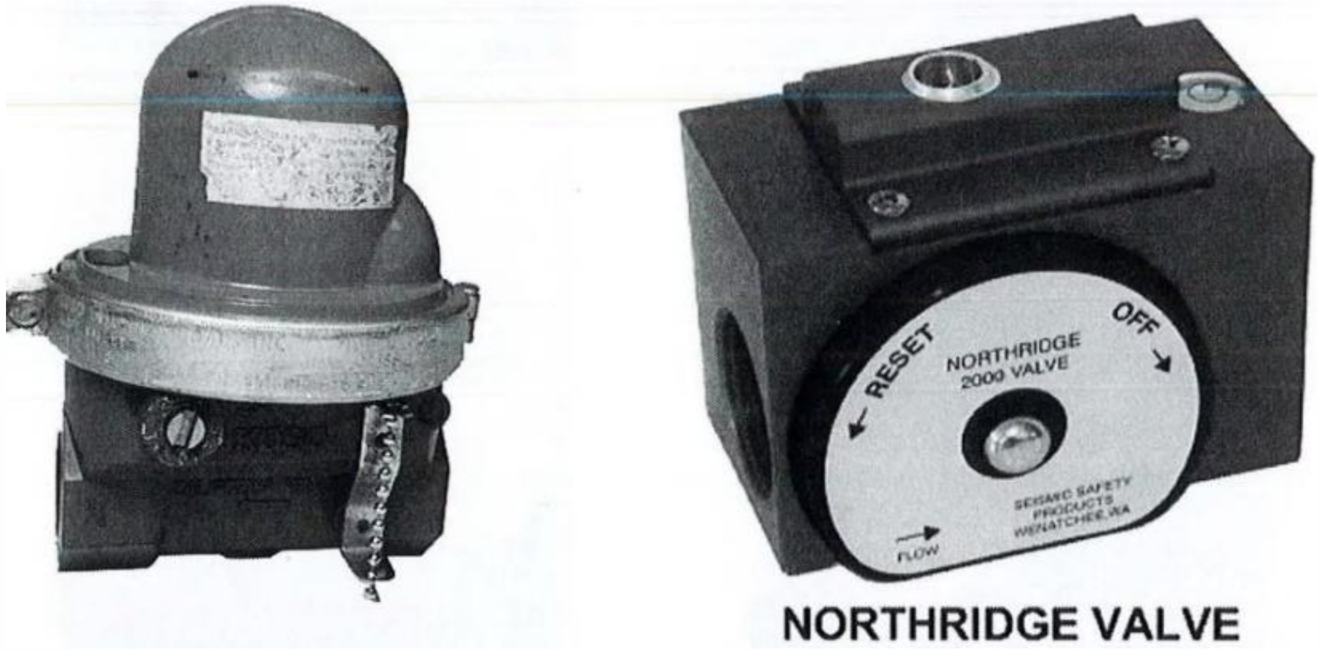
Specialized Functions

These valves provide critical safety functions in emergency situations.

Seismic Gas Valves

Purpose

Seismic gas valves are designed to shut off gas supply to a building during an earthquake. This prevents gas from escaping from any downstream lines that may have been ruptured during the quake, thus minimizing the chance of a gas fire.



Two models of seismic gas valves

Seismic Valve Operation

Installation Requirements

Both popular models need to be installed level as they have an internal ball that rolls when subject to horizontal vibration.

Status Indication

They have an indicating window to show valve status.

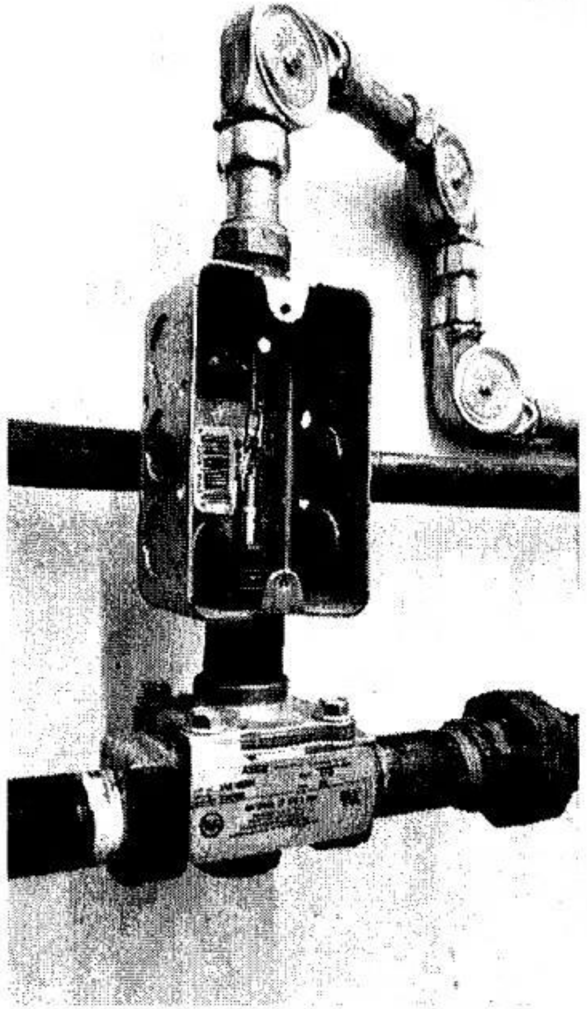
Manual Reset

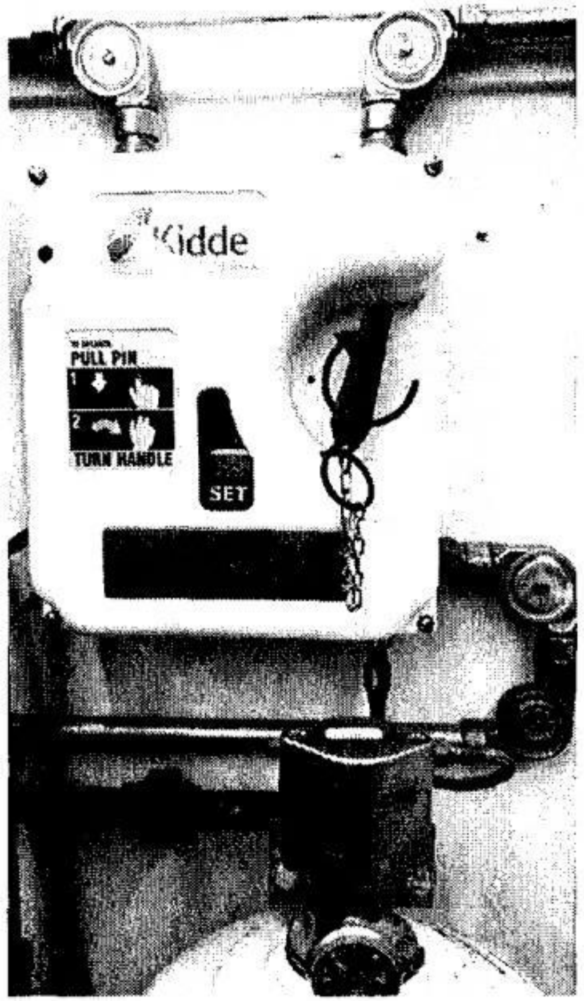
Must be manually reset once activated by seismic activity.

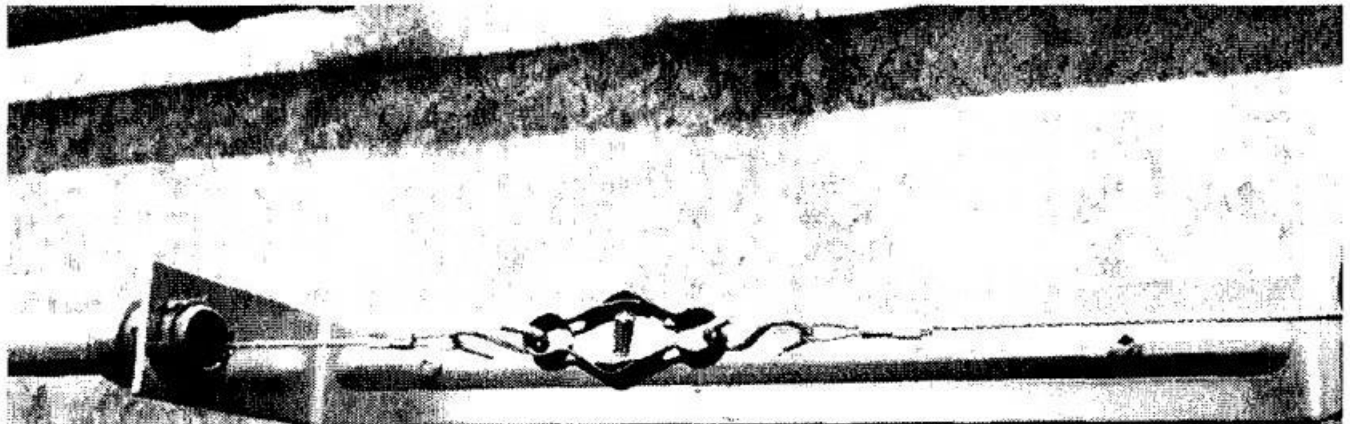
Fire Suppression Gas Valve

Application

The fire suppression gas valve is designed to shut off the gas supply to commercial cooking equipment if there is a fire. They are activated by a cable connected to the fire suppression system and must be manually reset.







Fire Suppression System Components

Release-to-Close Valve

The system has a release-to-close valve which is being held open by a cable.

Manual Pull Station

The cable can be released by a manual pull station for emergency shutdown.

Fusible Link

A temperature activated fusible link located above the cooking equipment can automatically trigger the system.

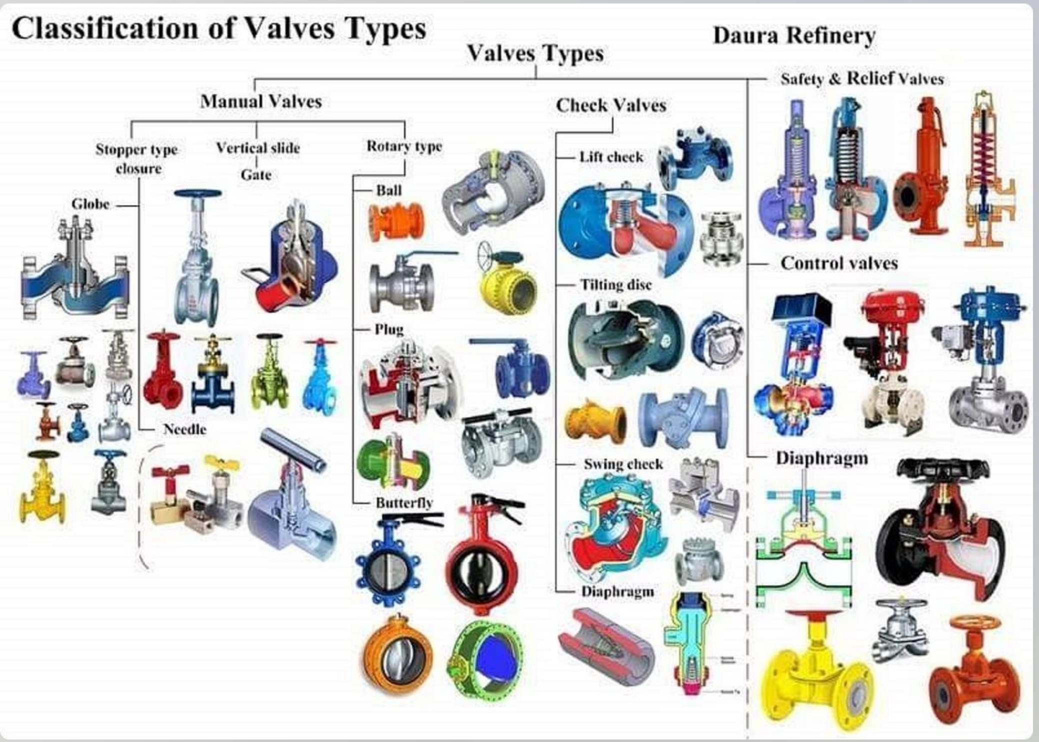
Extinguishing Agent

When activated, the system releases extinguishing agent onto the cooking area.

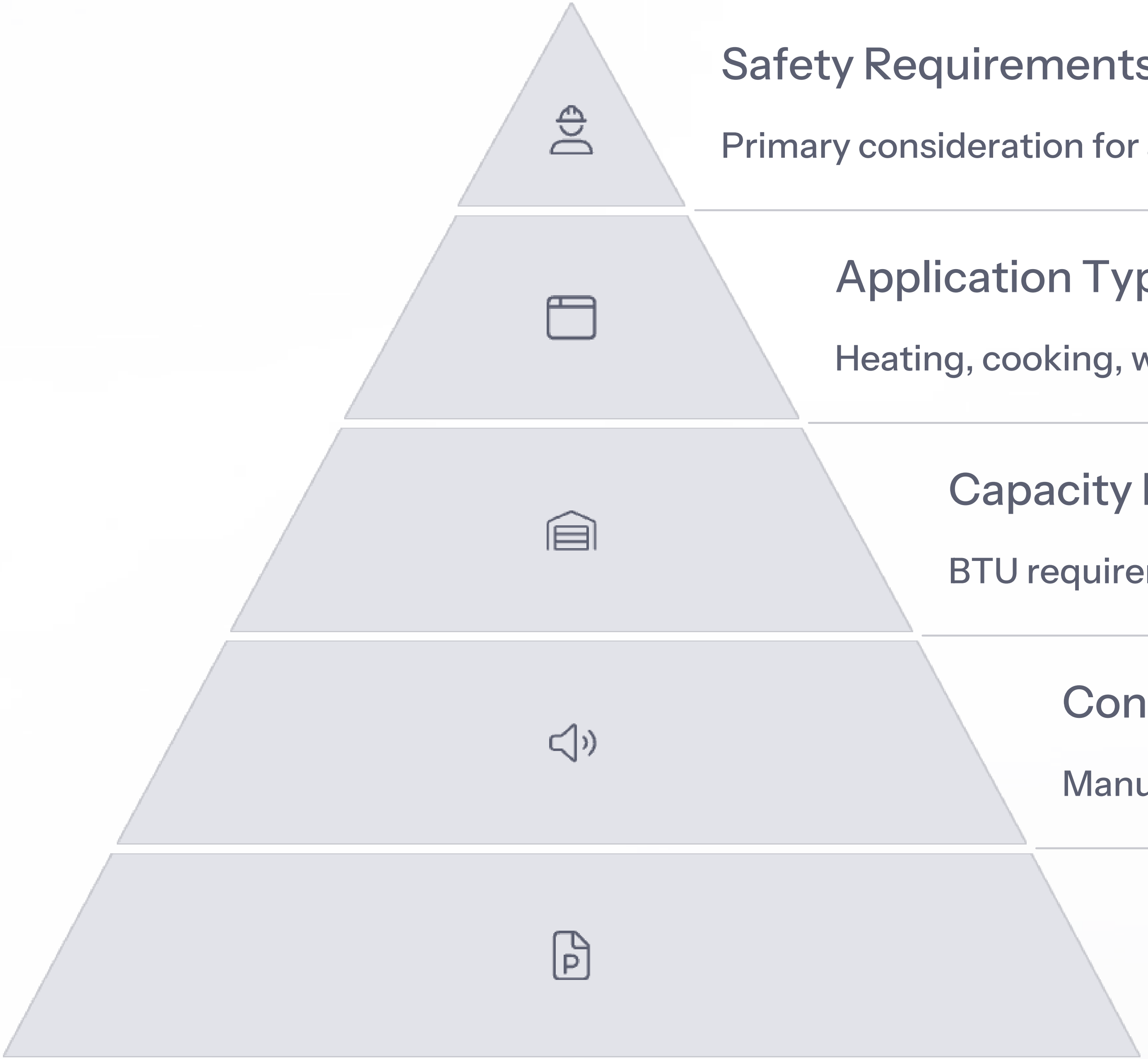
Thermal Expansion Principle

Comparing Gas Valve Types

Valve Type	Power Source	Applications	Features
Rod and Tube	Non-electric	Water heaters	Simple, reliable
Diaphragm	Electric	Furnaces, boilers	On/off control
Redundant	Electric	Furnaces, boilers	Dual safety valves
Modulating	Electric	Precision heating	Variable flow



Gas Valve Selection Criteria



Safety Requirements

Primary consideration for all installations

Application Type

Heating, cooking, water heating, etc.

Capacity Needs

BTU requirements and flow rates

Control Method

Manual, automatic, or modulating

Power Source

Electric, non-electric, or millivolt

Gas Valve Troubleshooting

Visual Inspection

Check for physical damage or loose connections

Verify Power

Confirm proper voltage to valve

Pressure Testing

Measure inlet and outlet gas pressure

Component Replacement

Replace faulty valves or components

Gas Valve Maintenance

Regular Inspection

Visually inspect valves for signs of wear, damage, or corrosion.

Operational Testing

Verify proper operation through cycling and response testing.

Cleaning

Remove dust and debris from external components.

Documentation

Maintain records of all maintenance and testing performed.

Gas Valve Safety Considerations

Proper Installation

Gas valves must be installed according to manufacturer specifications and local codes.

Ventilation

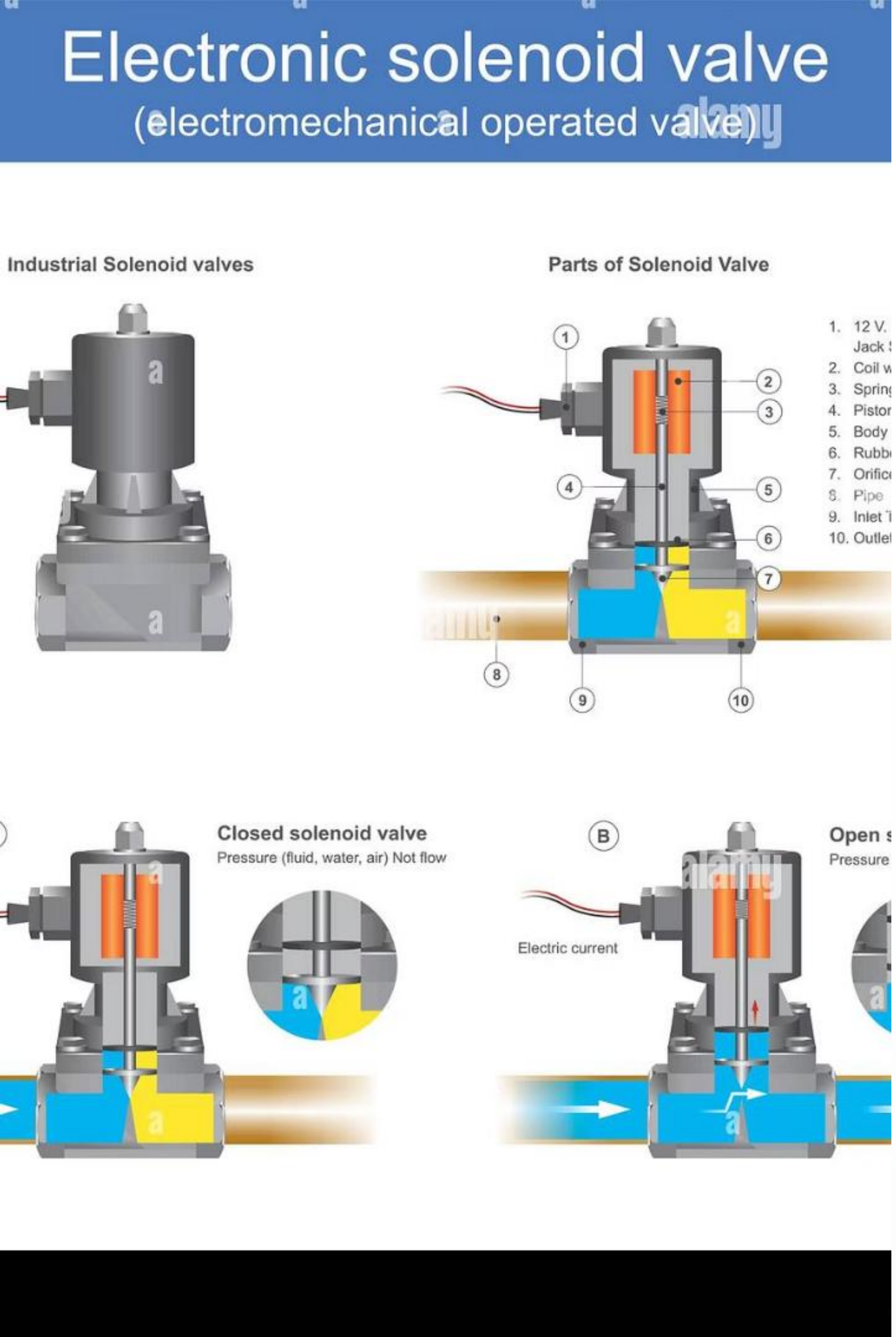
Ensure adequate ventilation for regulator vents and pressure relief devices.

Certification

Only use valves certified for the specific gas type and application.

Professional Service

Gas valve service should only be performed by qualified technicians.



Gas Valve Evolution

1. **Early Mechanical Valves**

   Simple mechanical designs with limited safety features

2. **Electromechanical Valves**

   Introduction of solenoid operation and basic safety controls

3. **Combination Valves**

   Integration of multiple functions into single compact units

4. **Smart Valves**

   Modern microprocessor-controlled systems with advanced diagnostics

Gas Valve Applications

Residential Heating

Furnaces, boilers, water heaters, fireplaces

Commercial

Rooftop units, makeup air systems, commercial cooking

Industrial

Process heating, large boilers, manufacturing

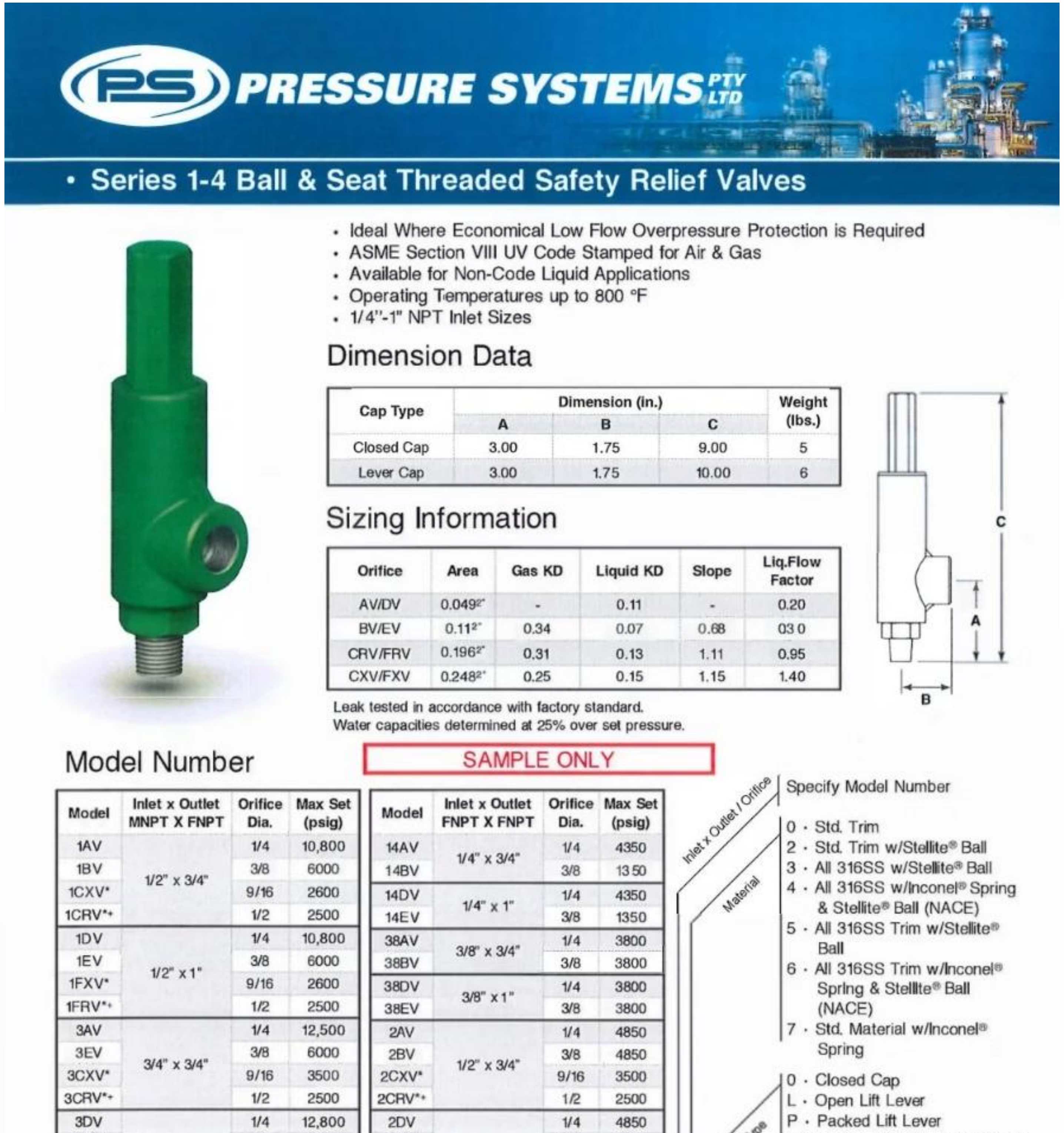
Cooking

Ranges, ovens, commercial kitchens

Gas Valve Sizing Considerations

Critical Factors

- BTU/h capacity requirements
- Gas type (natural gas or propane)
- Inlet pressure available
- Required outlet pressure
- Pressure drop across the valve
- Maximum and minimum flow rates



PRESSURE SYSTEMS PTY LTD

• Series 1-4 Ball & Seat Threaded Safety Relief Valves

- Ideal Where Economical Low Flow Overpressure Protection is Required
- ASME Section VIII UV Code Stamped for Air & Gas
- Available for Non-Code Liquid Applications
- Operating Temperatures up to 800 °F
- 1/4"-1" NPT Inlet Sizes

Dimension Data

Cap Type	Dimension (in.) A	B	C	Weight (lbs.)
Closed Cap	3.00	1.75	9.00	5
Lever Cap	3.00	1.75	10.00	6

Sizing Information

Orifice	Area	Gas KD	Liquid KD	Slope	Liq.Flow Factor
AV/DV	0.049^{2}"	-	0.11	-	0.20
BV/EV	0.112^{2}"	0.34	0.07	0.68	03 0
CRV/FRV	0.196^{2}"	0.31	0.13	1.11	0.95
CXV/FXV	0.248^{2}"	0.25	0.15	1.15	1.40

Leak tested in accordance with factory standard.
Water capacities determined at 25% over set pressure.

C
A
B

Model Number

SAMPLE ONLY

Model	Inlet x Outlet MNPT X FNPT	Orifice Dia.	Max Set (psig)
1AV	1/2" x 3/4"	1/4	10,800
1BV		3/8	6000
1CXV*		9/16	2600
1CRV*+		1/2	2500
1DV	1/2" x 1"	1/4	10,800
1EV		3/8	6000
1FXV*		9/16	2600
1FRV*+		1/2	2500
3AV	3/4" x 3/4"	1/4	12,500
3EV		3/8	6000
3CXV*		9/16	3500
3CRV*+		1/2	2500
3DV		1/4	12,800

Model	Inlet x Outlet FNPT X FNPT	Orifice Dia.	Max Set (psig)
14AV	1/4" x 3/4"	1/4	4350
14BV		3/8	13 50
14DV	1/4" x 1"	1/4	4350
14EV		3/8	1350
38AV	3/8" x 3/4"	1/4	3800
38BV		3/8	3800
38DV	3/8" x 1"	1/4	3800
38EV		3/8	3800
2AV	1/2" x 3/4"	1/4	4850
2BV		3/8	4850
2CXV*		9/16	3500
2CRV*+		1/2	2500
2DV		1/4	4850

Inlet x Outlet / Orifice

Material

Specify Model Number

0 · Std. Trim
2 · Std. Trim w/Stellite® Ball
3 · All 316SS w/Stellite® Ball
4 · All 316SS w/Inconel® Spring & Stellite® Ball (NACE)
5 · All 316SS Trim w/Stellite® Ball
6 · All 316SS Trim w/Inconel® Spring & Stellite® Ball (NACE)
7 · Std. Material w/Inconel® Spring

0 · Closed Cap
L · Open Lift Lever
P · Packed Lift Lever

Gas Valve Certification and Standards

Certification Bodies

Gas valves must be certified by recognized agencies such as CSA, UL, or AGA.

Industry Standards

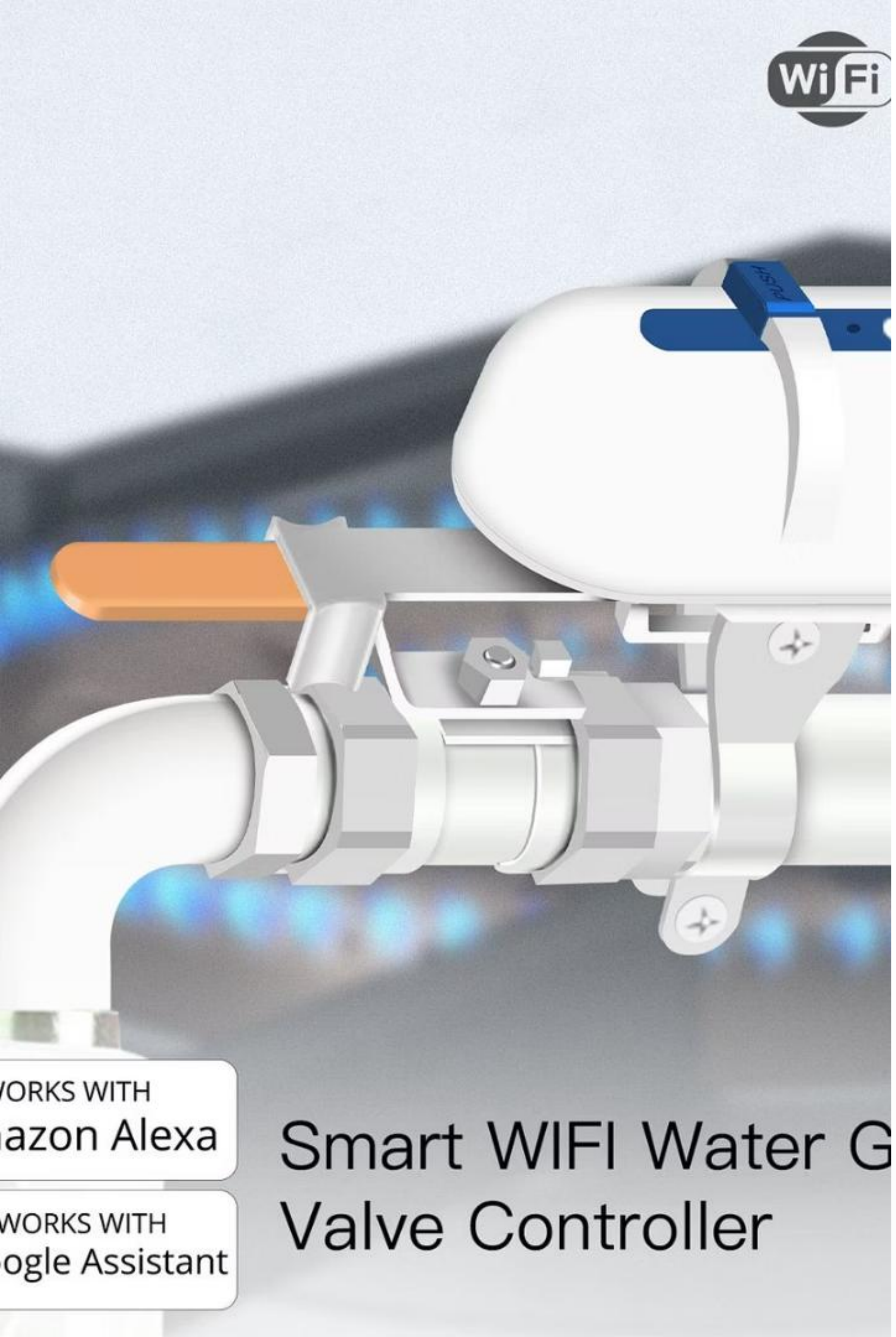
Valves must meet ANSI Z21 series standards for gas appliance components.

Code Compliance

Installation must comply with local and national fuel gas codes.

Testing Requirements

Valves undergo rigorous testing for safety, durability, and performance.



Future Trends in Gas Valve Technology

Smart Integration

Integration with home automation and building management systems

2

Enhanced Efficiency

More precise modulation for improved energy efficiency

Advanced Diagnostics

Self-diagnostic capabilities and predictive maintenance

Remote Monitoring

Cloud-connected valves with remote monitoring and control

Gas Valve Installation Best Practices

Proper Orientation

Install valves in the correct orientation as specified by the manufacturer, particularly for valves with gravity-dependent components.

Adequate Support

Ensure valves are properly supported and not stressed by connected piping.

Electrical Connections

Make secure electrical connections with proper wire gauge and protection.

Leak Testing

Thoroughly test all connections for leaks using approved methods.

Common Gas Valve Issues

Electrical Problems

Faulty wiring, incorrect voltage, or failed solenoids

Pressure Issues

Incorrect inlet pressure or regulator failure

Mechanical Wear

Worn diaphragms, springs, or valve seats

Contamination

Dirt or debris affecting internal components

Gas Valve Testing Equipment

Manometers

Used to measure gas pressure at inlet and outlet of valves to verify proper operation and regulation.

Multimeters

Essential for checking electrical connections, resistance, and voltage to solenoids and operators.

Leak Detectors

Specialized electronic detectors or soap solutions to identify gas leaks at connections.

Gas Valve Replacement Considerations

Exact Replacement

Always use the manufacturer's recommended replacement valve or an approved equivalent.

Conversion Kits

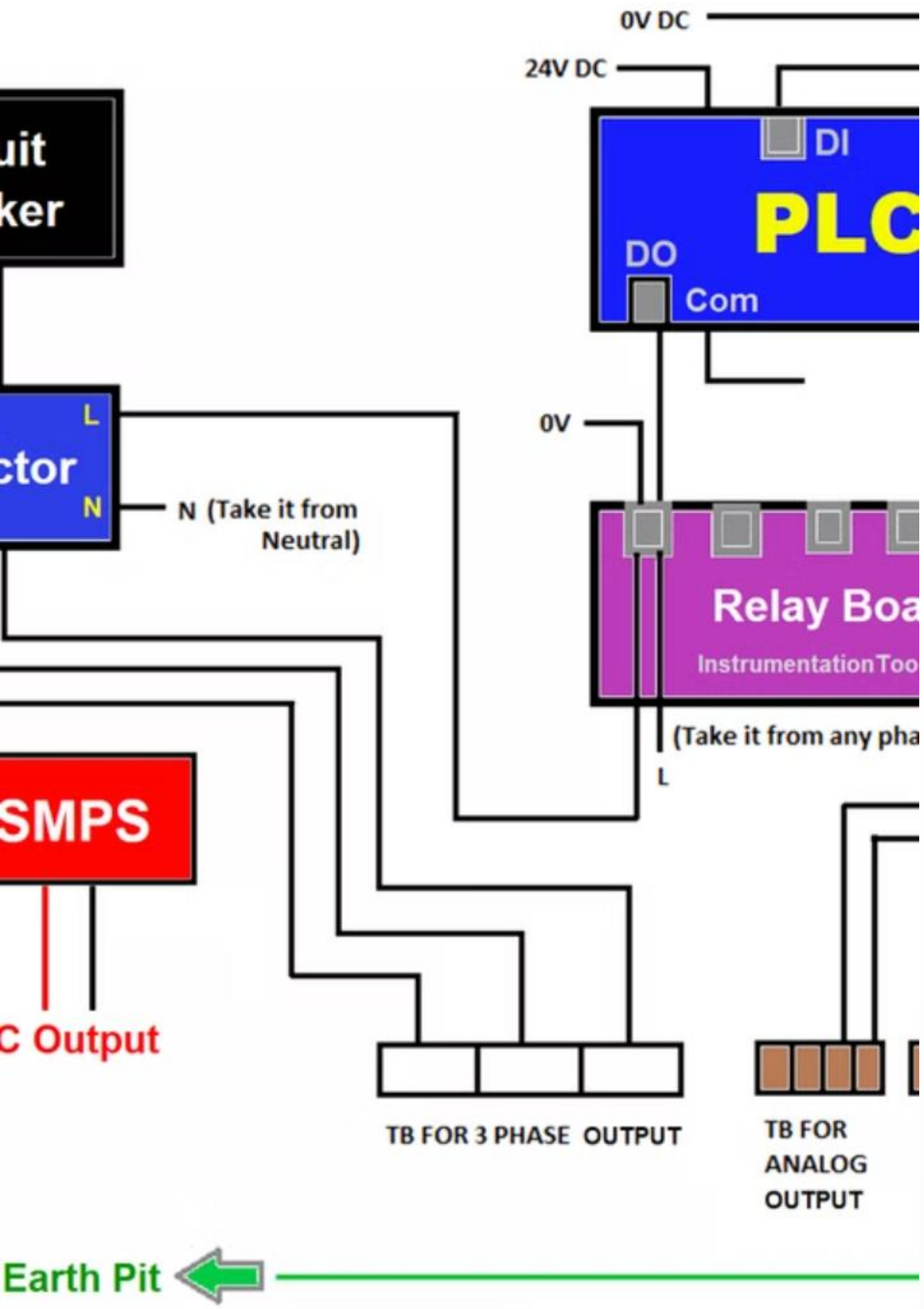
When changing gas types, use certified conversion kits that include the proper regulator spring.

System Compatibility

Ensure the replacement valve is compatible with the existing control system and ignition method.

Documentation

Maintain records of the replacement including model numbers, settings, and test results.



CSA Unit 13

Chapter 2 Understanding Electrical Control Systems

This presentation explores the fundamentals of electrical control systems, including terminology, diagrams, symbols, and auxiliary devices. We'll examine how to read and interpret wiring and schematic diagrams, understand electrical symbols, and follow the sequence of operations in control circuits.

Key Terminology

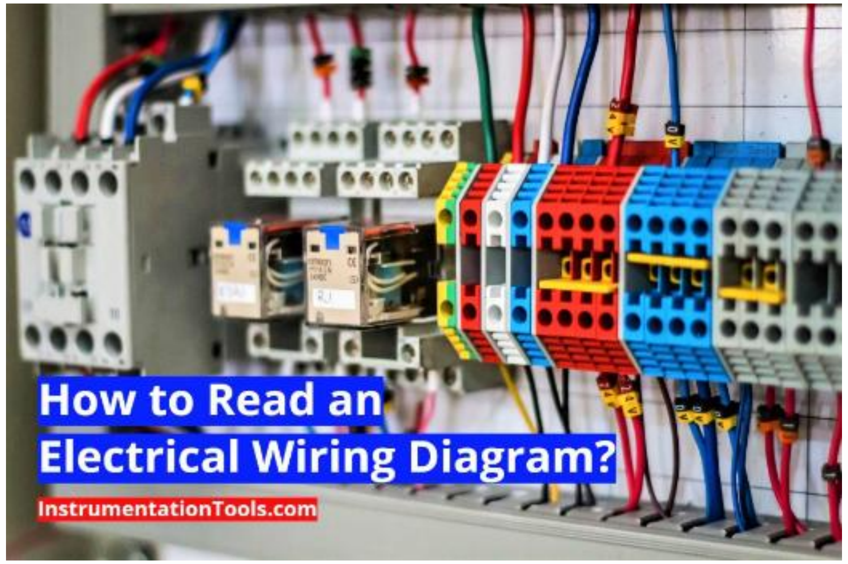
Control Circuit Diagrams

Purpose of Diagrams

The control system's schematic and wiring diagrams are the basis for determining the specific sequence of operation as well as for identifying the electrical connections between safety controls.

Availability

These diagrams are available in Unit 12 Basic electricity for gas-fired equipment.



Control circuit diagrams provide essential information for understanding how electrical systems function and how components are connected. They serve as the foundation for troubleshooting and maintaining electrical systems in gas-fired equipment.

Wiring Diagrams

Maps of electrical circuits

Very useful for initially wiring a circuit and for troubleshooting

Show exact connections

They show exactly how and where the wires are connected between devices

Component locations

They show, as clearly as possible, the actual location of all the components of a circuit

Standard symbols

The components are usually shown as standard electrical symbols

Wiring diagrams are essential tools for electricians and technicians working with electrical systems. They provide a visual representation of how components are physically connected in a circuit.

Wiring Diagram Example

Horizontal and Vertical Wires

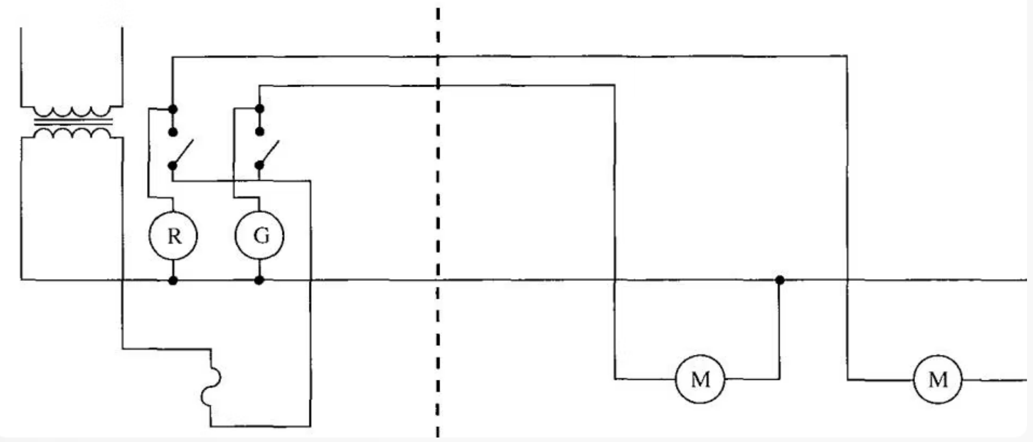
To make the wiring diagram clearer and easier to follow, all wires are run either horizontally or vertically.

Wire Connections

When the wires cross, a dot means that the two wires are connected. If a dot is not shown, the wires cross each other but do not connect electrically.

This wiring diagram shows the starting and stopping of two motors complete with running light indication. The layout is designed to be as clear as possible, making it easier to trace connections when troubleshooting.

Figure 2-1
Wiring diagram



Schematic Diagrams

Definition

The basic means of communicating the language of control is through the use of the schematic diagram. This type of diagram consists of a series of symbols interconnected by line to indicate the flow of current through the various devices.

What They Show

- The power source
- How current flows through the various parts of the circuit such as contacts, coils, and overloads

The schematic diagram is intended to show the circuitry that is necessary for the basic operation of the system. It gives no indication of the physical relationship between the components.

Also Known As

This schematic is also called a ladder diagram.

Ladder Diagram Structure

Left-hand side

Represents the incoming voltage

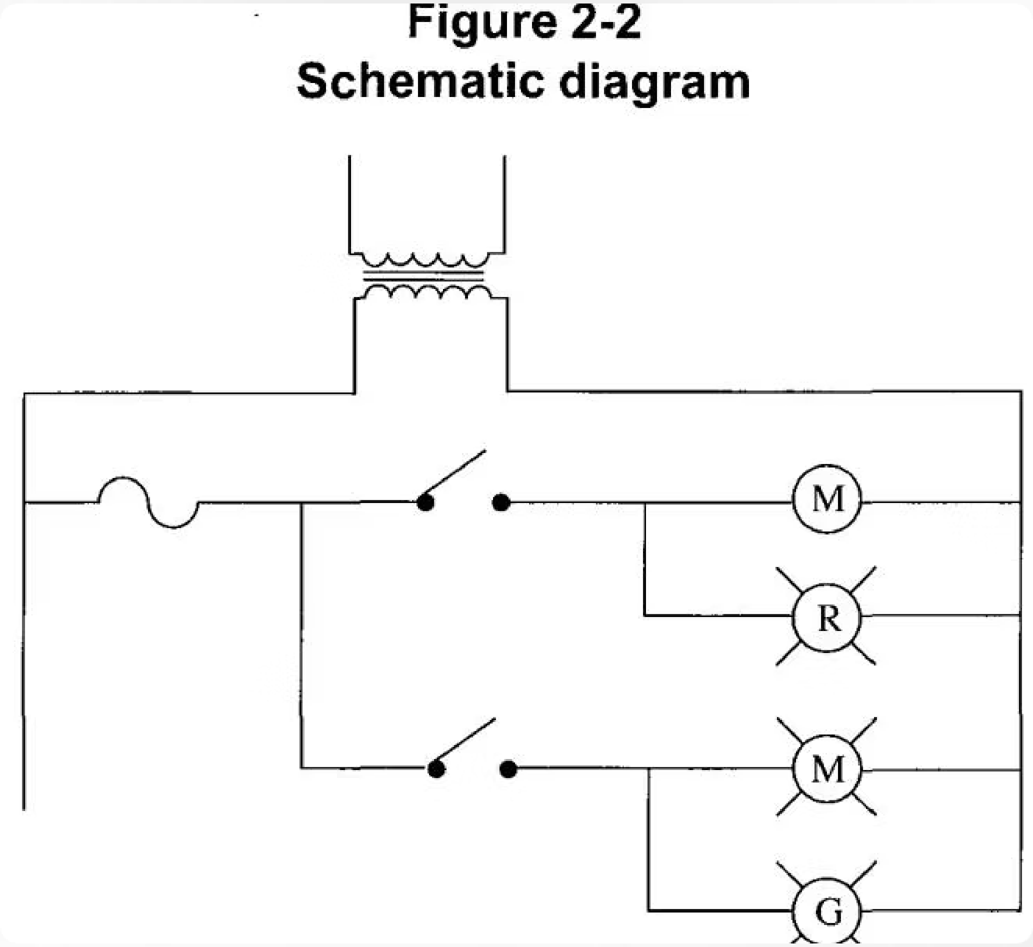
Middle section

Wires and devices connecting the two sides form the "rungs" of the ladder

Right-hand side

Represents the outgoing current; each parallel load will have a separate connection/rung

From the schematic, you can clearly see how the circuit works electrically and can use it to trace the electrical sequence of operation. The ladder structure makes it easier to follow the flow of current through the circuit.



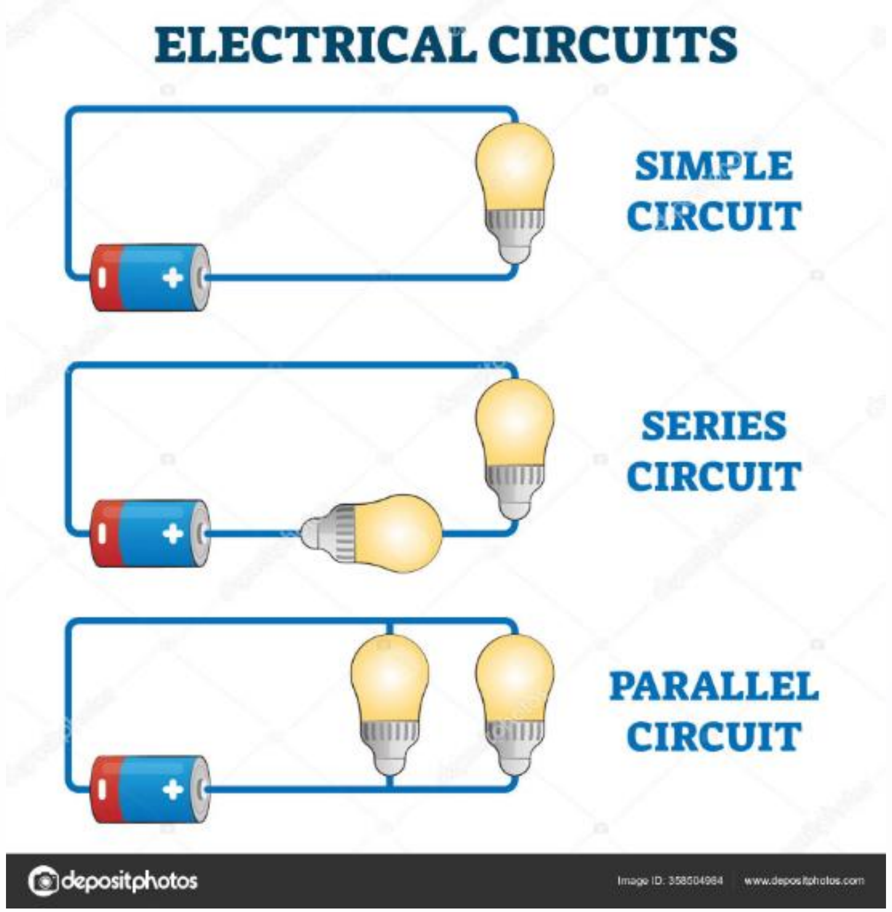
Schematic Diagram Example

This figure shows the same circuit as the previous wiring diagram, except it is drawn as a schematic. As you can see, it is much easier to follow the flow of current in this format. The schematic representation clearly shows the electrical relationships between components, making it simpler to understand how the circuit functions.

Series and Parallel Circuits

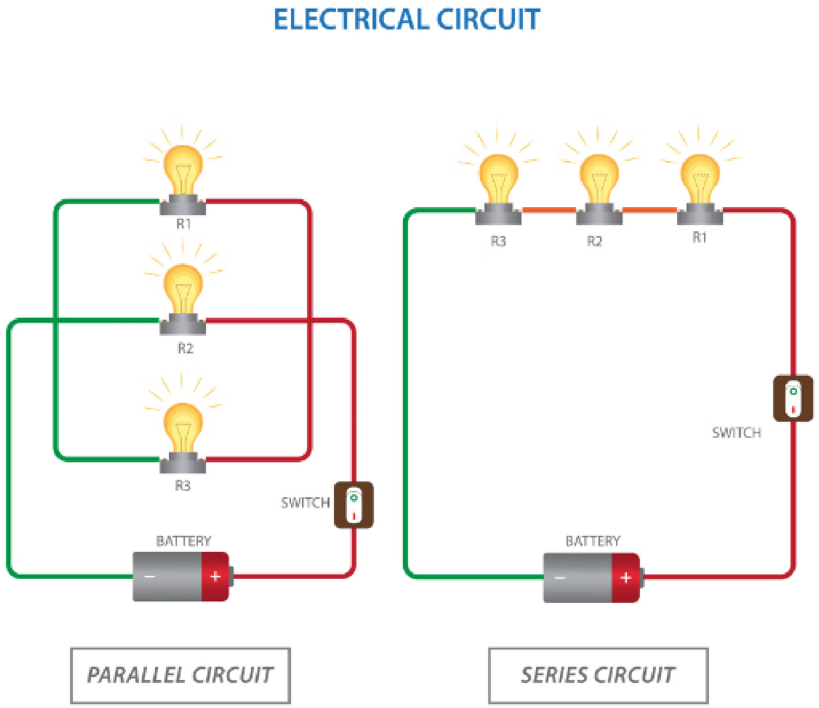
Series Circuits

The components are connected in such a way that the electric current must pass through each one in sequence.



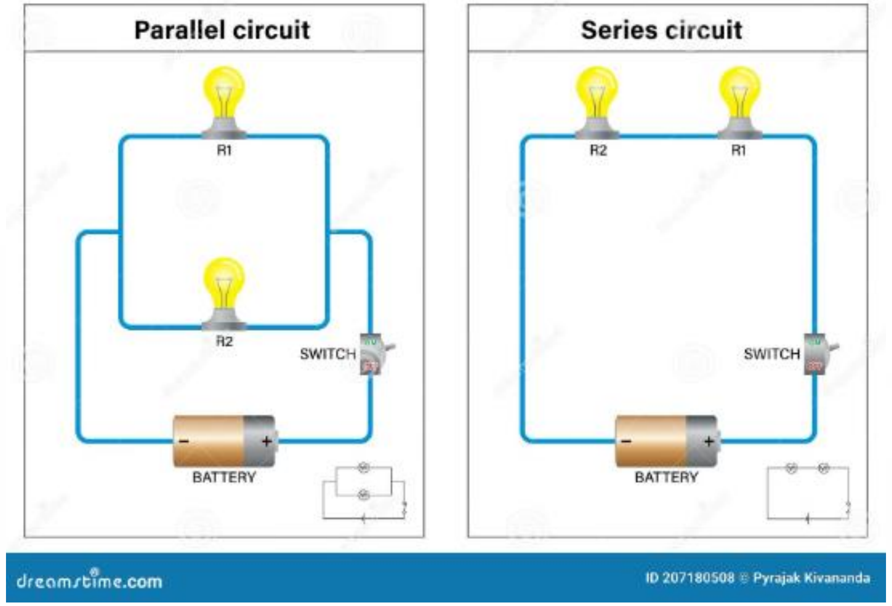
Parallel Circuits

More than one path is available for current flow.



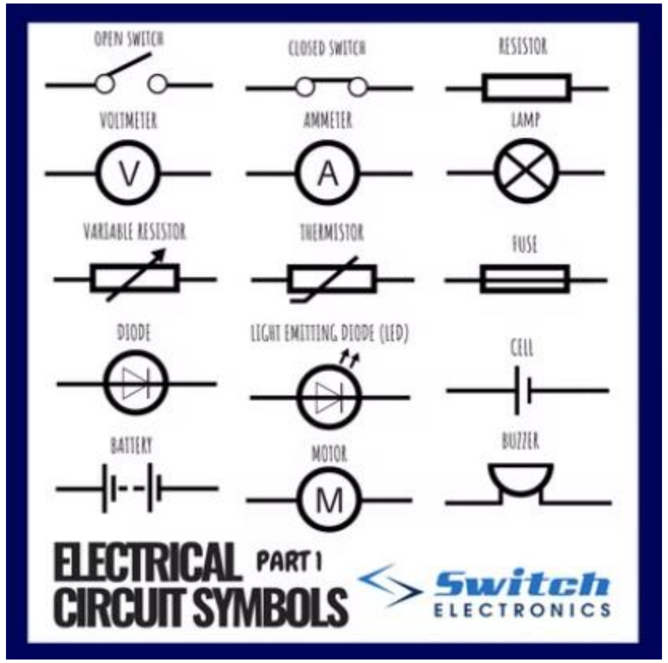
Series/Parallel Circuits

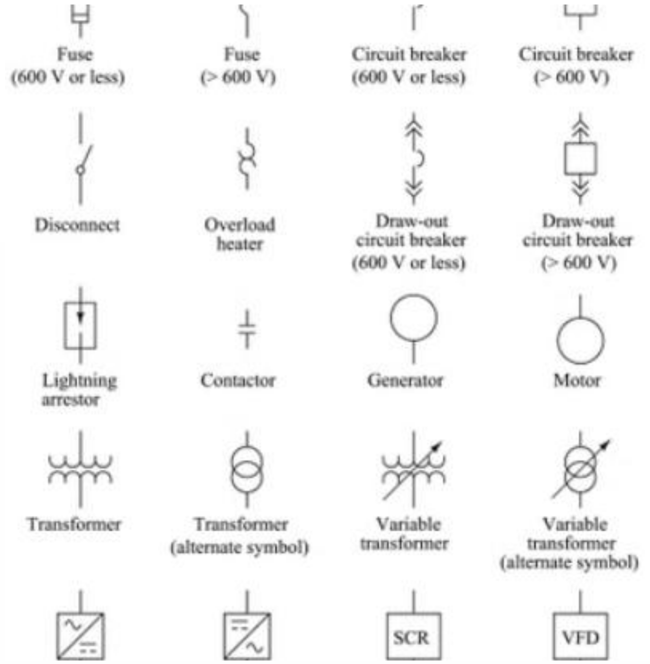
A complete electrical circuit may have some parts wired in series and others wired in parallel.

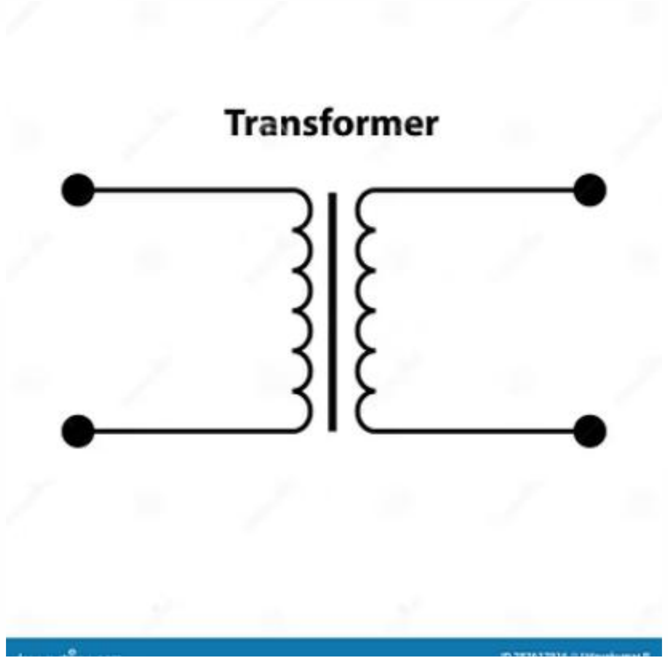


Circuits often include more than one device or component. The several devices may be arranged in their circuits in any one of many ways, but any arrangement can be classified by type of circuits

Electrical Symbols



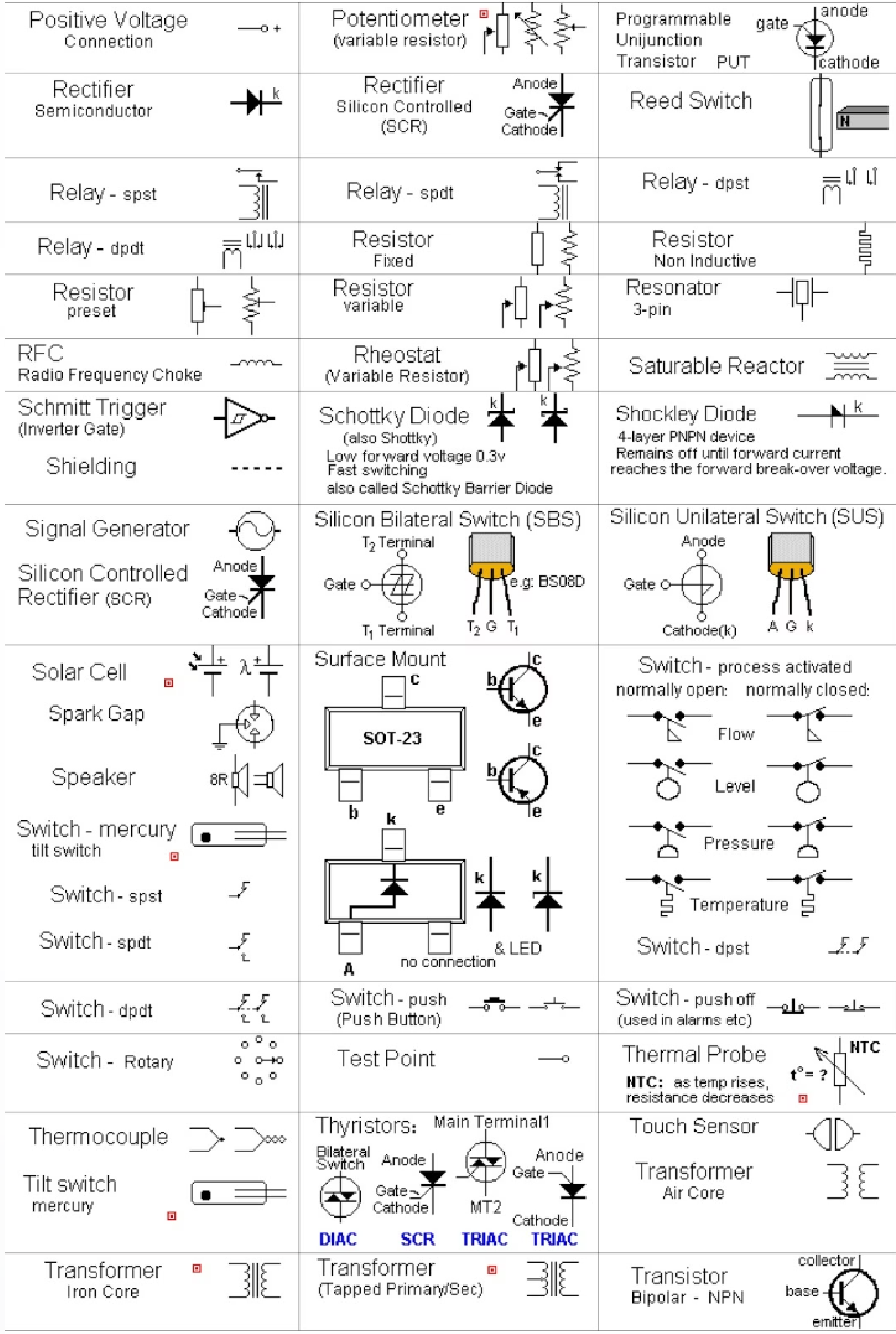


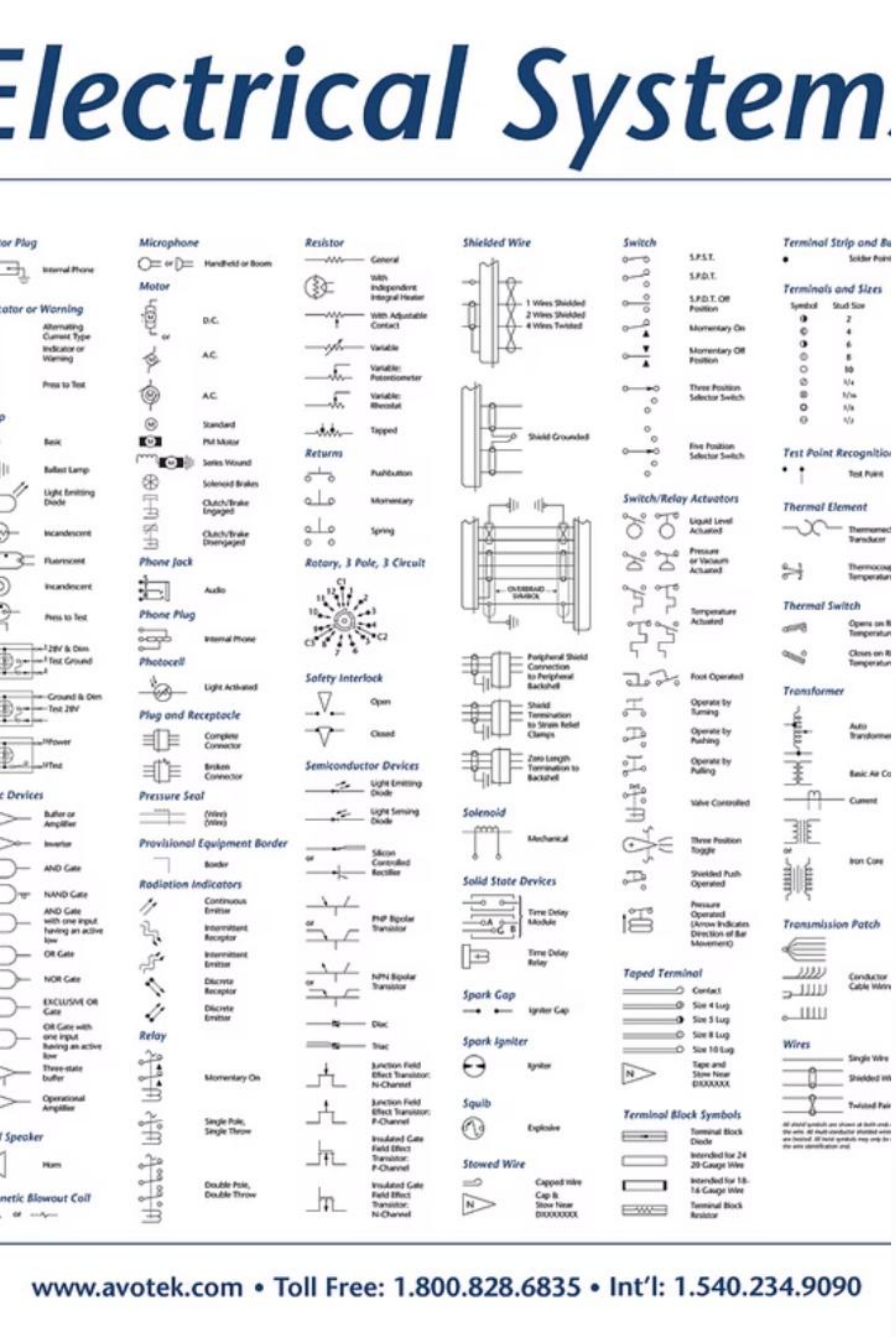


Wiring and schematic diagrams use symbols instead of pictures to represent the switches and loads of a circuit. These are the international symbols for the most commonly used electrical devices in the gas industry. Understanding these symbols is essential for reading and interpreting electrical diagrams.

Common Electrical Symbols

Component	Schematic symbol
Disconnect switch	I I(I(r--
Circuit breaker	11)1 i i i
Limit switch (Normally Open)	~
Limit switch (Normally Closed)	o<:Jo
Temperature actuated switch	~
Pressure and Vacuum switch	°1°

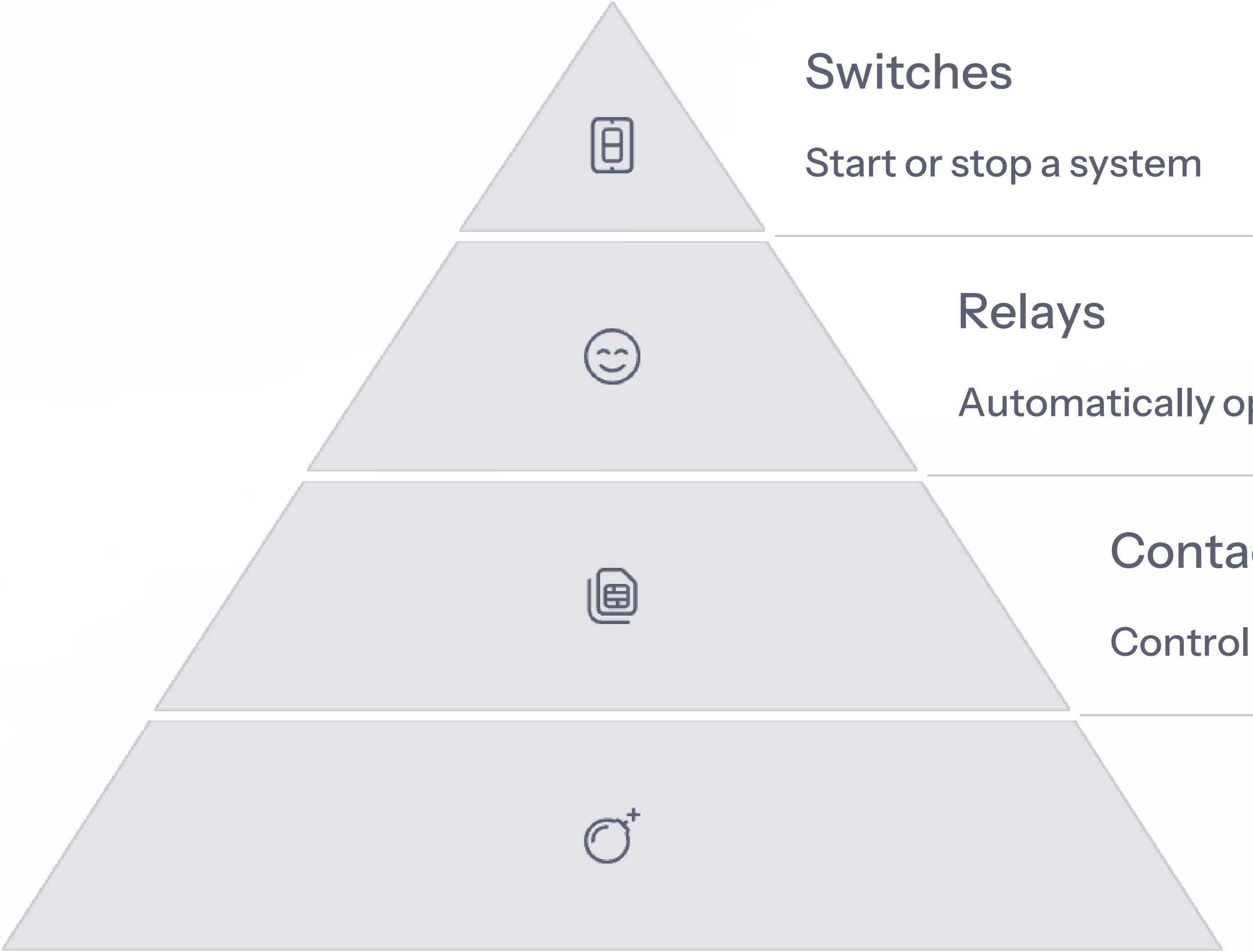




More Electrical Symbols

Component	Schematic symbol
Flow Switch (air, water, etc.)	°1:
Liquid Level switch	6
Fuses	~
Power or Control Contacts	0 ~
Instant opening	J_ T
Iron core transformers	~ (YYYI
Ground	J_

Auxiliary Devices in Control Systems



Switches

Start or stop a system

Relays

Automatically operated switches

Contactors

Control large amounts of current

Protective Devices

Protect against overcurrent

In order for the loads to operate, auxiliary devices must be incorporated into the control system. These devices work together to ensure the safe and efficient operation of electrical systems.

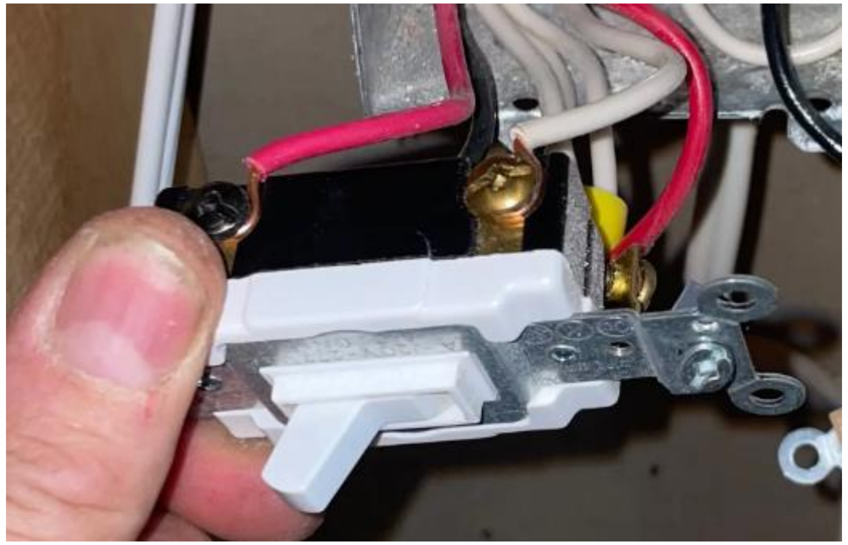
Switches in Control Systems

Purpose

Switches are the most common auxiliary device found in control systems; they are used to start or stop a system.

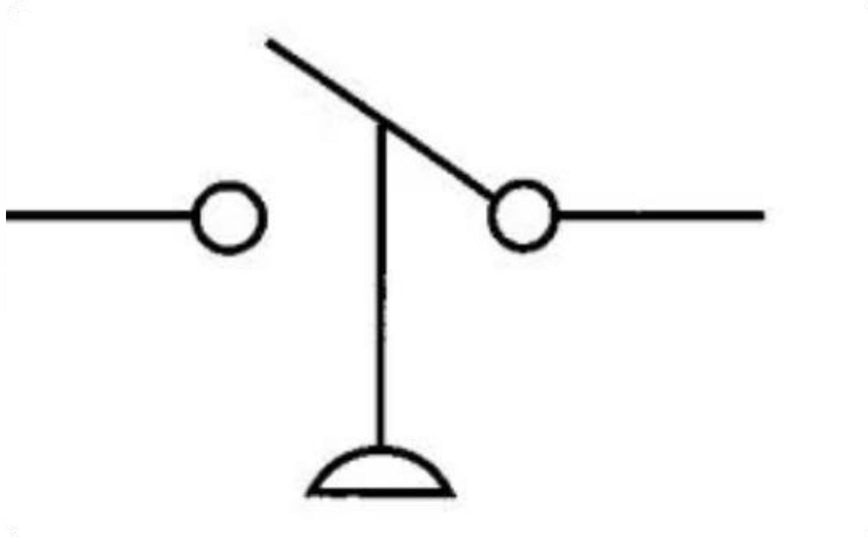
Representation

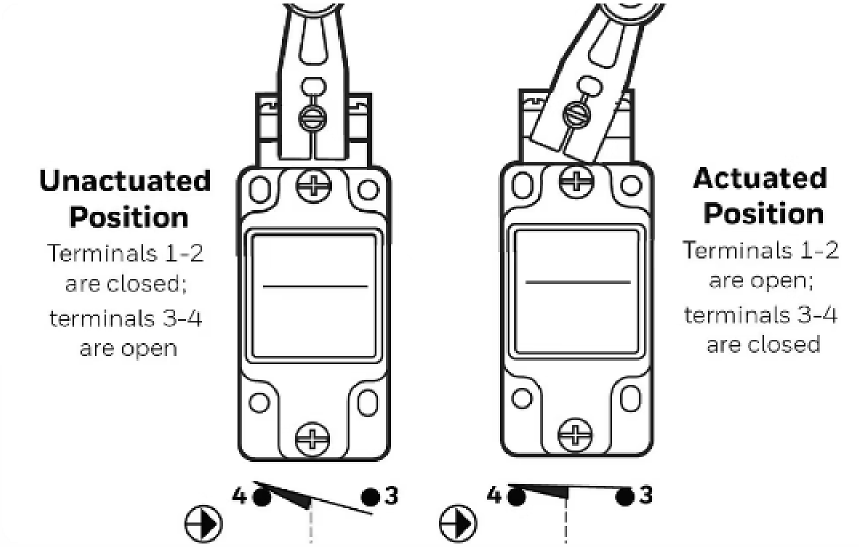
All switch symbols in a wiring diagram are shown in the "resting" position. Resting means that the medium (heat, pressure, etc.) has not caused the switch to change positions.



Switches are fundamental components in electrical control systems, allowing for the control of current flow through circuits. Understanding how switches are represented in diagrams is essential for interpreting electrical schematics.

Normally Open (NO) Switches





Normally Open Position

Switches are normally open (NO) when the resting position of the switch is open. Typically, actuating switches are in the NO position.

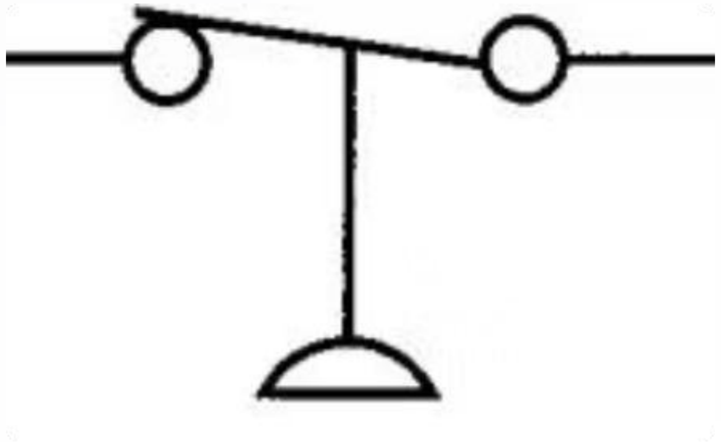
Switch Position Above the Line

If the NO switch symbol is shown above the line, the switch will close on a decrease in the activating medium (heat, pressure, etc.).

Switch Position Below the Line

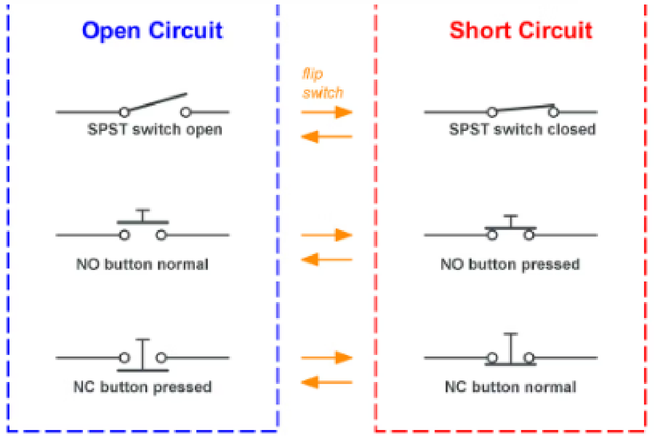
If the NO switch symbol is shown below the line, the switch will close on an increase in the activating medium.

Normally Closed (NC) Switches



Normally Closed Position

Switches are designated normally closed (NC) when the resting position of the switch is closed. Typically, limit switches are in the NC position.



Switch Operation

NC switches remain closed until activated by their control medium, at which point they open the circuit.

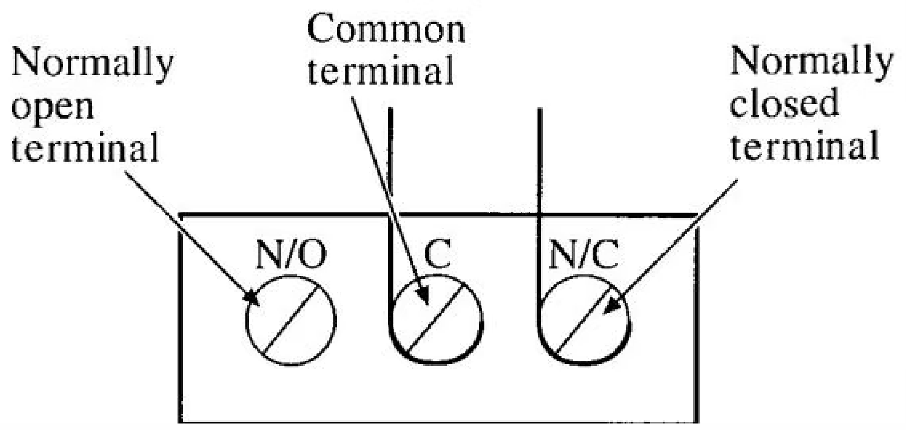
Common Applications

NC switches are often used in safety circuits where the circuit must be broken if a problem occurs.

Multiple Terminal Switches

SPDT Switches

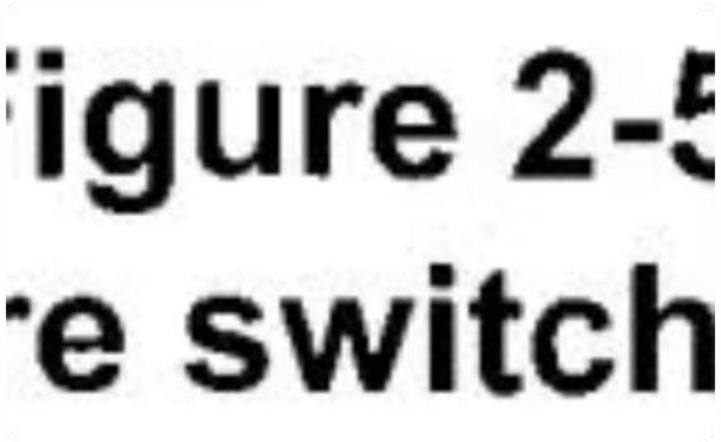
Switches that are SPDT (Single Pole, Double Throw) can be wired either as NO or NC, depending on the application. These switches have three terminals, but only two are typically used.



For example, if wired in NO position, the wire will be connected to the NO terminal and the common terminal. Likewise, if wired in the NC position, the wire will be connected to the NC terminal and the common terminal.

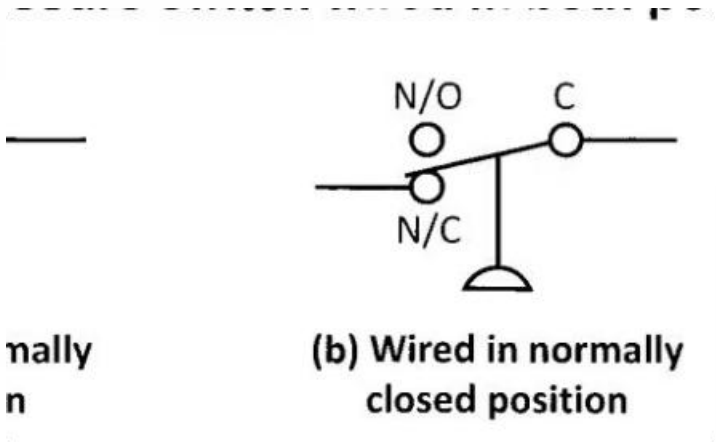
Figure 2-5
Schematic of air pressure switch wired in both positions

SPDT Switch Wiring Examples



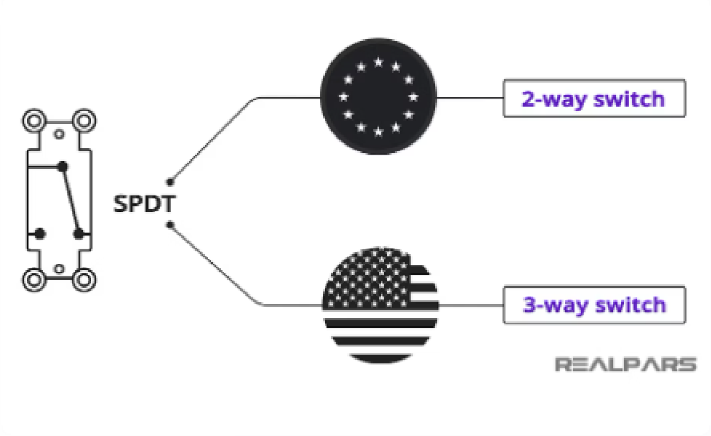
NO Wiring Configuration

When wired as normally open, the circuit connects the common terminal to the NO terminal.



NC Wiring Configuration

When wired as normally closed, the circuit connects the common terminal to the NC terminal.



Versatile Applications

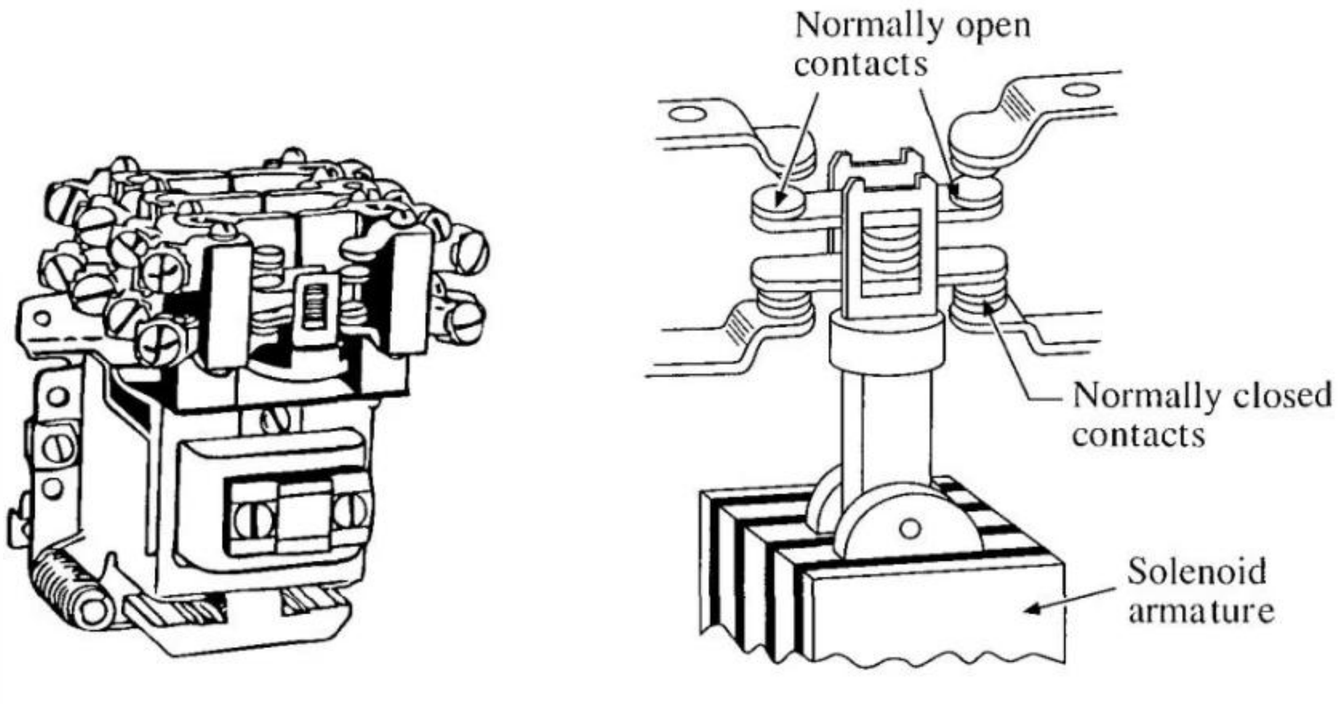
The flexibility of SPDT switches makes them useful in a variety of control applications where different circuit behaviors are needed.

Relays in Control Systems

Definition

In a broad sense, a relay is an automatically operated switch. A switch could be operated by compressed air, in which case it is a pneumatic relay. For electric control systems, the relay can be operated by an electromagnet or solenoid.

Figure 2-6
Solenoid relay

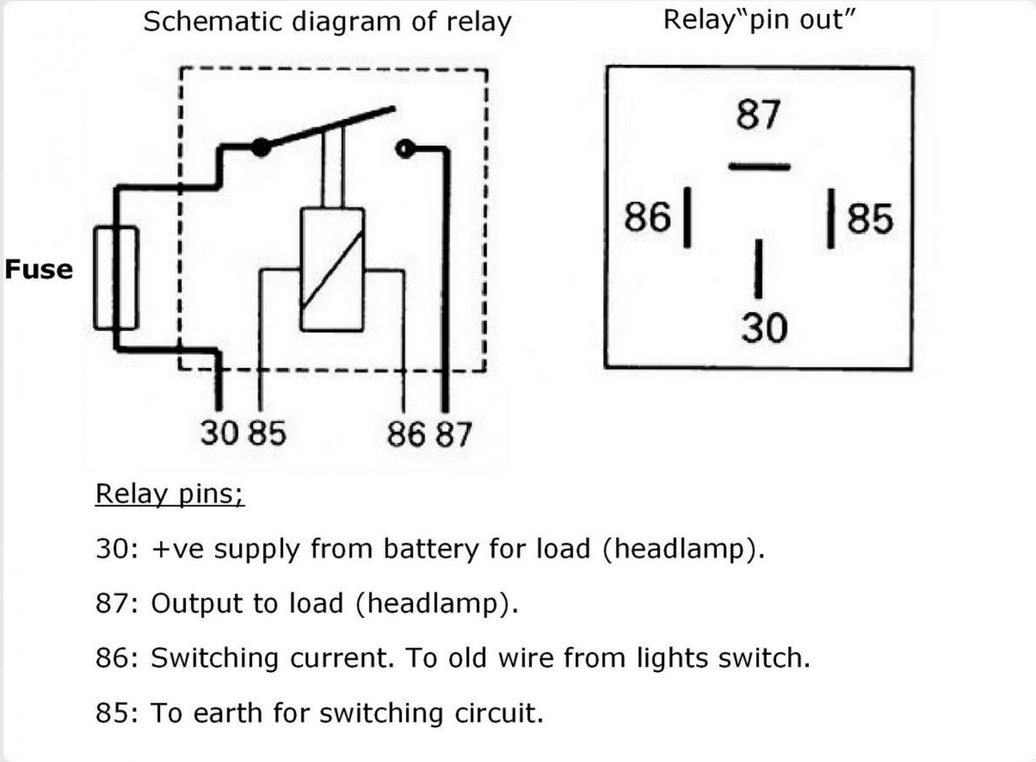


(a) Relay (b) Detail of the contacts

In a solenoid relay, the electrical contacts open and/or close when the contact relay's coil is energized or de-energized in response to a change in the conditions of the electrical circuit.

The operations of the contacts affect the operation of other devices in the same circuit or in other circuits. Relays allow a low-power control circuit to switch a relatively high current on or off in another circuit.

Relay Voltage Considerations



Low Voltage Control

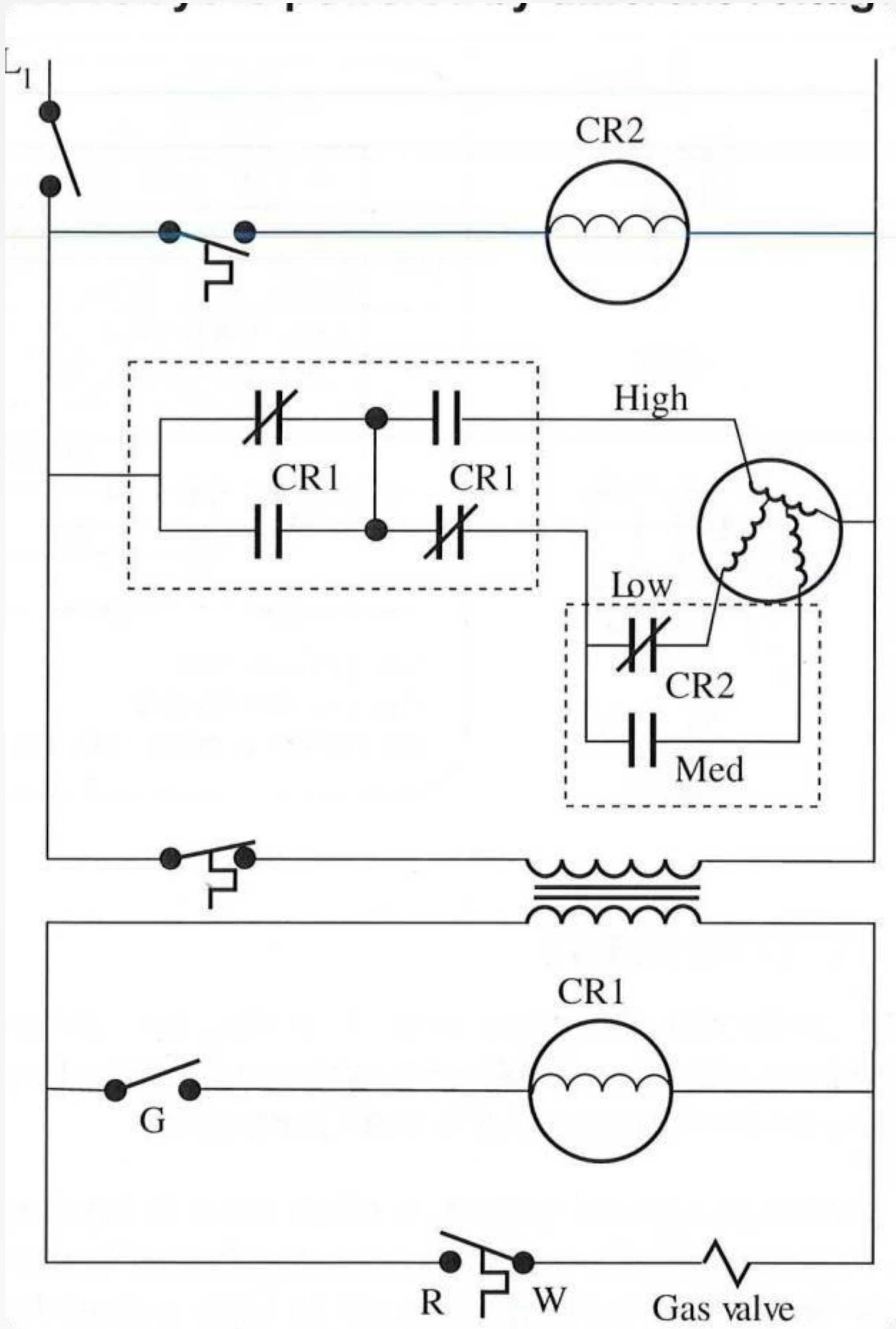
It is quite common for relays to be powered by 24 V, but they close a 120 V circuit. This way, the control circuit can operate on safer lower voltage wiring.

Voltage Availability

Relays are available in many coil voltages to suit the particular application. It is, therefore, important to check the relay coil for proper voltage.

Voltage Verification

Always verify that the relay coil voltage matches the control circuit voltage to ensure proper operation.



Relay Circuit Example

1. ## CR1 Relay

One coil (CR1) is located on a 24 V circuit while its contacts are located in a line (120) voltage circuit, thus the low voltage coil controls the higher voltage contact.

2. ## CR2 Relay

CR2's coil and contact are both in line voltage circuits.

3. ## Voltage Separation

This arrangement allows for safer control of high-voltage circuits using low-voltage control signals.

This example illustrates how relays can be used to interface between different voltage levels in a control system, providing both safety and functionality.

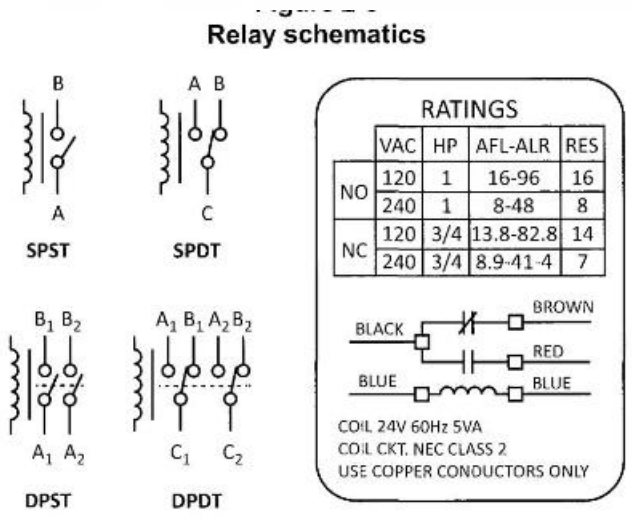
Relay Identification and Ratings

Identification

The switch portion of the relay is identified the same way as a manual switch by the number of poles and throws with an additional solenoid symbol. The relay terminals would be labelled to match the schematic stamped onto the exterior of the relay.

Contact Ratings

The rating for the switch contacts are shown depending on the voltage they are switching. These represent the maximum voltage/current that the switch can repeatedly connect and interrupt without overheating or arcing.



For example, the NO contacts when connected to a 120 V AC circuit are rated for: 1 horsepower (HP), 16 Amps full load (AFL), 96 Amps lock rotor (ALR), and 16 Ohms (0) contact resistance (RES). The solenoid coil rating is also shown as 24 V, 60 Hz 5 VA.

Time-Delay Relays (Timers)

Purpose

There are many reasons for controlling the operation of heating and air conditioning equipment according to predetermined time intervals.

Terminology

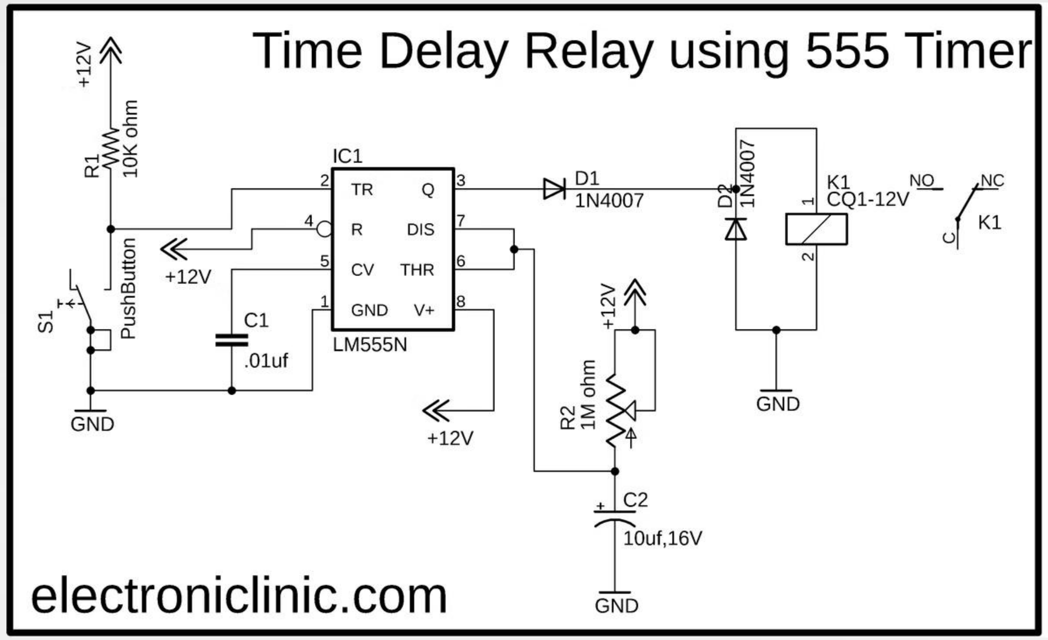
Timing relays may be called by terms such as time-delay relays, timers, and sequencers, according to their purposes.

Application Example

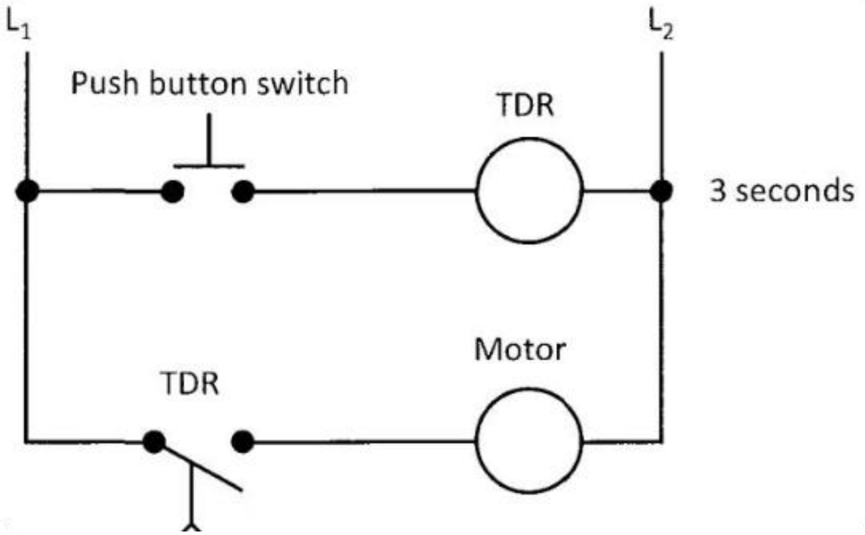
Sequenced control of several motors is often used in heating and air conditioning systems to prevent simultaneous starting and excessive current draw.

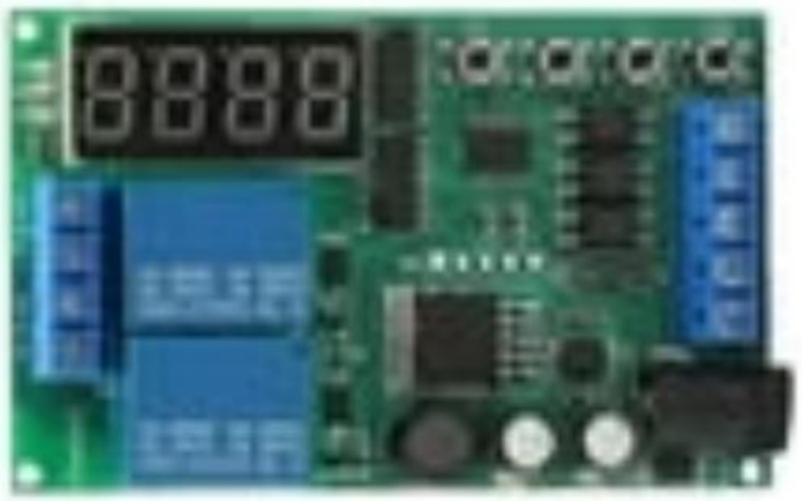
Diagram Notation

Time delay relays are commonly denoted in ladder diagrams by "TD", "TDR", or "TR" designations near the coil symbol and arrows on the contact symbols.



Time-Delay Relay Diagrams





Time-Delay Relay Symbol

This diagram shows how time-delay relays are represented in schematic diagrams, with special notation to indicate the timing function.

Time-Delay Contact Symbol

The contacts associated with time-delay relays have special symbols to indicate their delayed operation.

Modern Implementation

Most of the new equipment manufactured today have integrated control boards that include all the time-delay functions needed to operate the equipment.

Building Automation for Equipment Coordination

Equipment Coordination Need

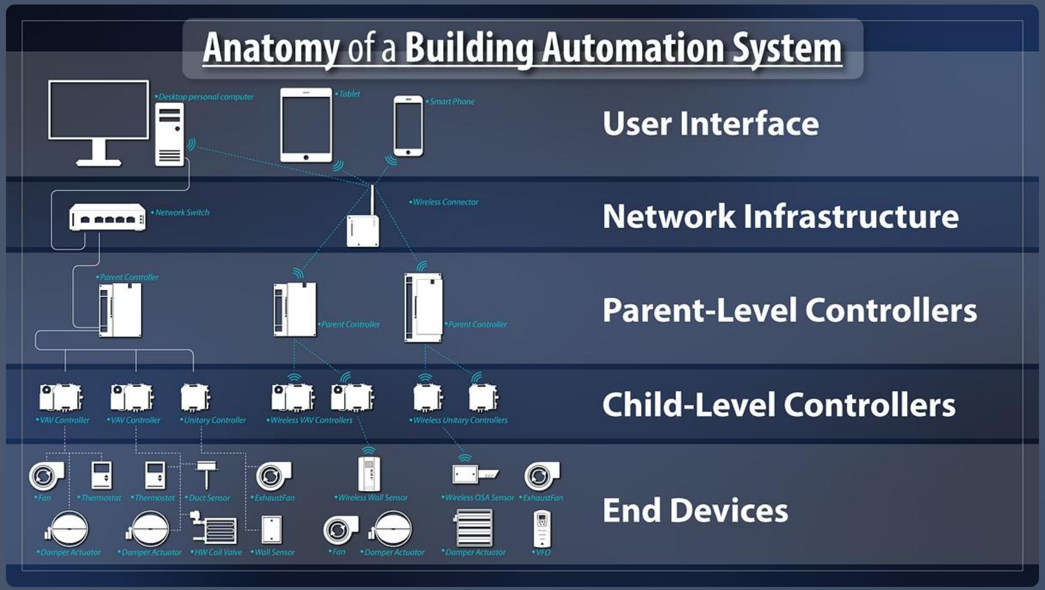
When it is necessary to coordinate multiple equipment starting and stopping, a building automation strategy is implemented.

Centralized Control

Building automation systems provide centralized control of HVAC, lighting, and other systems in a building.

Sequencing Benefits

Proper sequencing through automation reduces peak electrical demand, extends equipment life, and improves overall system efficiency.

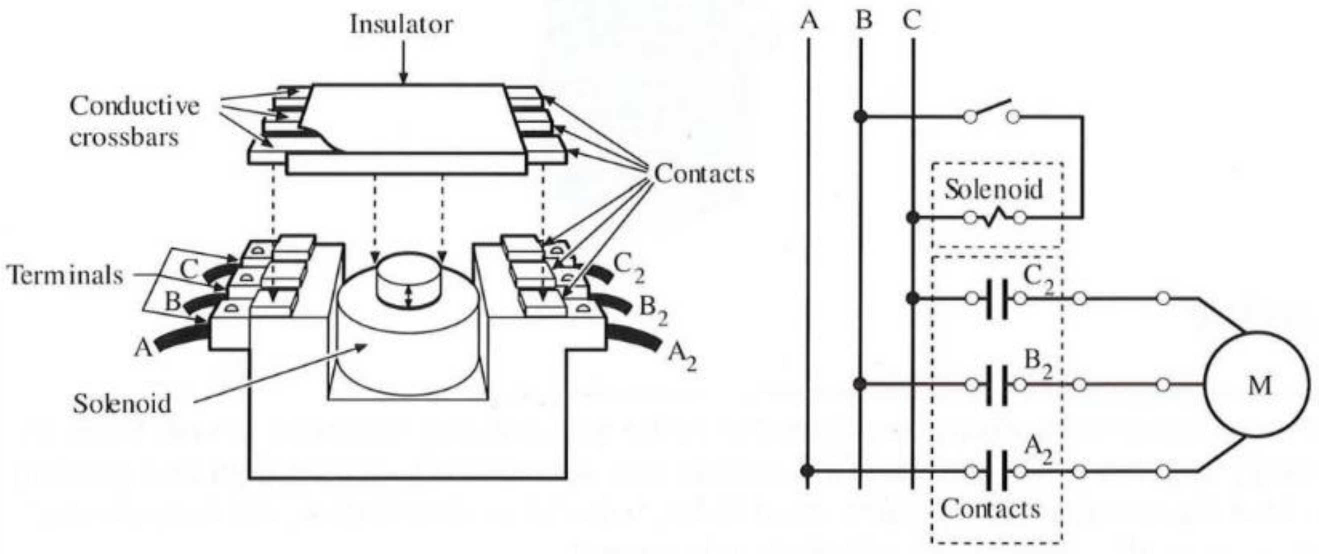


Contactors

Definition

Heavy duty contactors are solenoid/armature operators for switching heavy-duty electrical contacts. They are used to control the large amounts of current and high voltages required by industrial equipment.

Heavy duty contactor



This figure shows a contactor that might be used to turn on a three-phase motor on a larger boiler. Note that the insulators that hold the conductive crossbars are attached to the T-bar armature that closes several sets of contacts at once.

The wiring diagram shows the switch in the 110 V solenoid circuit that simultaneously activates the 240 V three-phase lines to the motor. (Overload protectors that are normally located in the motor are not shown in the wiring diagram.)

Protective Devices

Purpose

Protection of the control circuit against overcurrent protects wiring, electrical devices, and loads from short circuit and overcurrent

Fuses

Circuit-protection devices connected in series with a load

Circuit Breakers

Protect electrical conductors and equipment from overload and overcurrent

Reference

Unit 12 Basic electricity for gas-fired equipment covers the operation of these protectors in detail

Fuses

Function

Fuses are circuit-protection devices. They are connected in series with a load. In the event of excessive current flow, the fuse melts. This opens the circuit and protects the load device and its supply conductors from overheating.

Construction

The fuse element is usually made of an alloy such as silver-tin. This alloy combines the high conductivity of silver with the low melting point of tin.

Rating

A fuse is rated according to the value of current that may continually flow through it without causing the fuse-element to overheat and melt.

Time Characteristic

Fuses have an inverse time characteristic, which means that the greater the value of a fault current, the faster the fuse breaks the circuit.

Circuit Breakers

Function

Circuit breakers, like fuses, protect electrical conductors and equipment from the effects of overload and overcurrent.

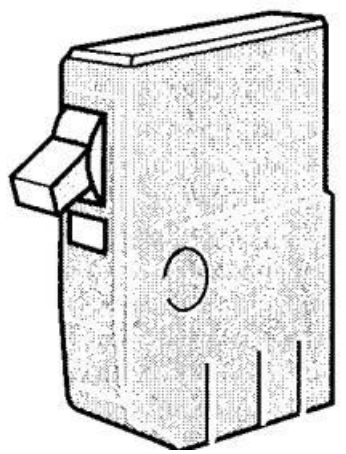
Applications

The type of circuit breaker shown is used in low-voltage distribution systems under 750 V. It is often used to protect lighting and motor circuits.

Advantage

When a circuit breaker trips to open a circuit, it can be reset by hand without replacing any parts.

Circuit breaker



Polarity and Phasing

Importance

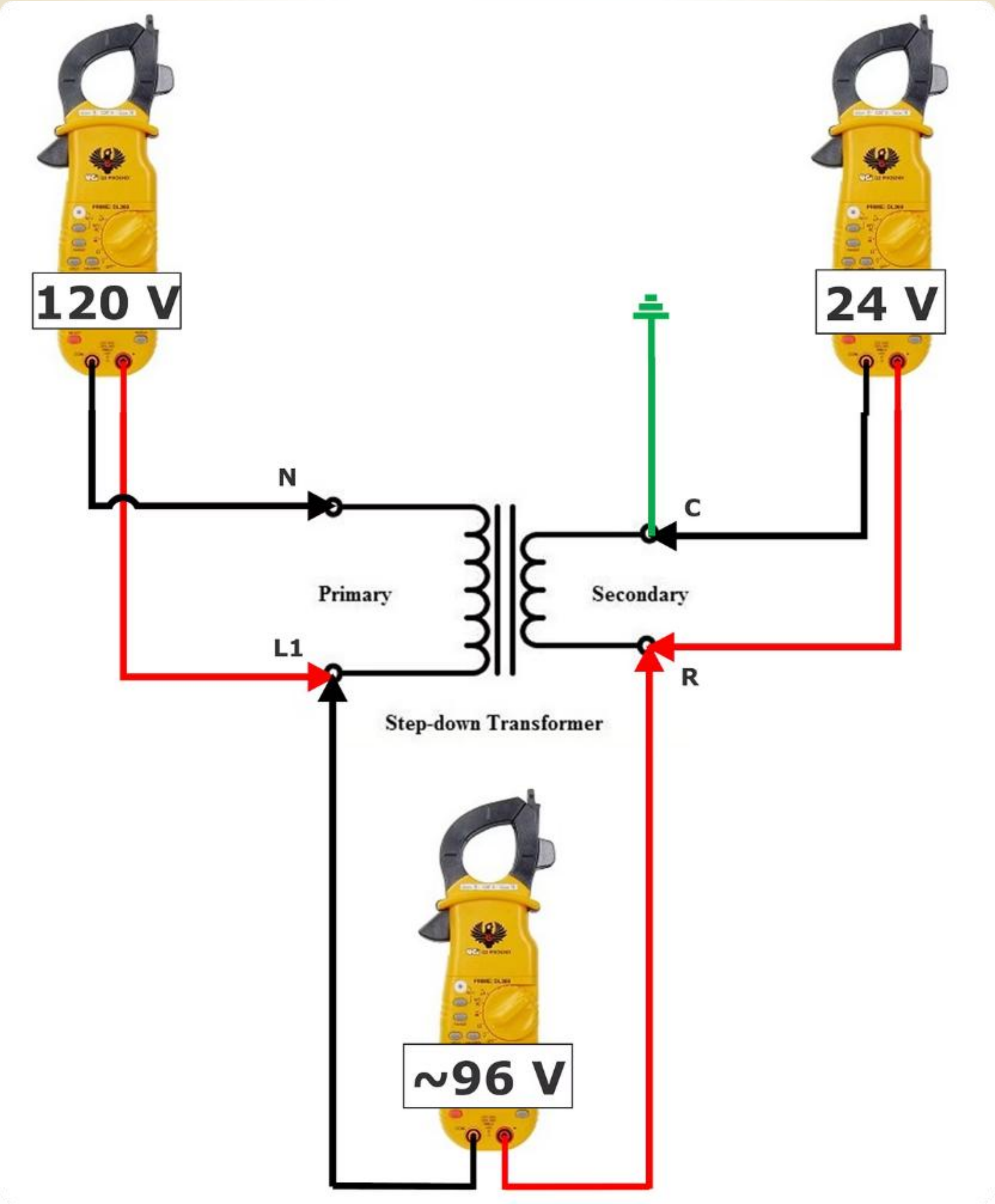
As more and more electronics are introduced to the gas industry, two factors have become increasingly important during normal installation and service calls: polarization and phasing.

Electronic Boards

Some of the electronics boards being used today, with flame rectification, will not function properly - or at all - unless the polarization is correct.

Transformer Phasing

Phasing of primary to secondary voltage on transformers: some electronic boards also require phasing of step-down transformers.



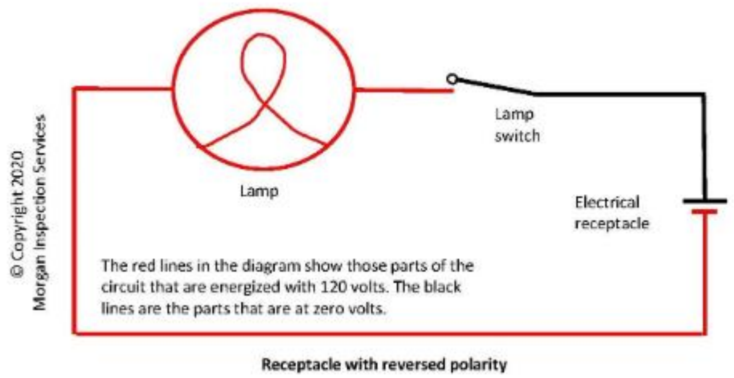
Understanding Polarity

DC Circuits

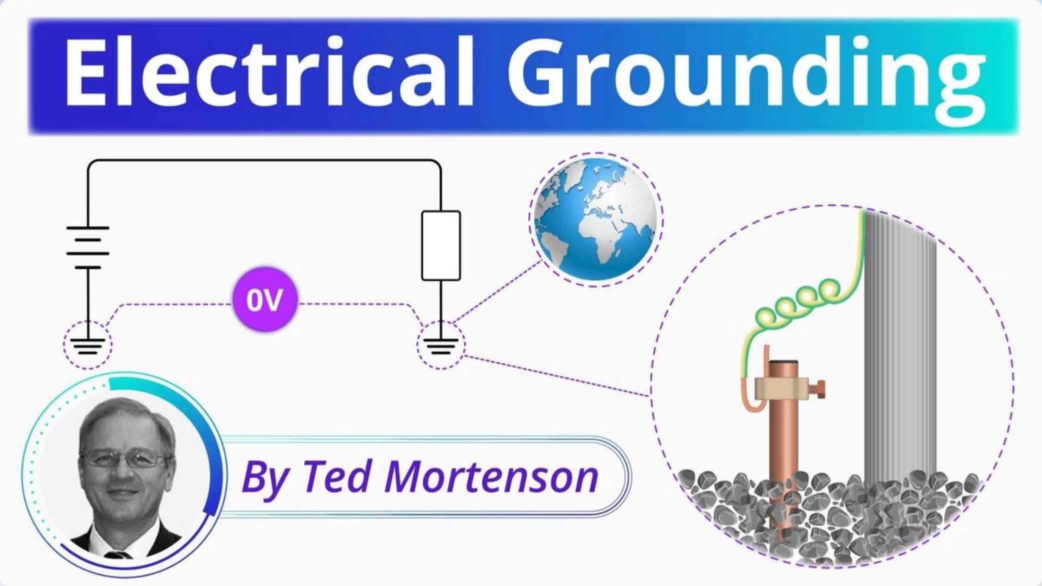
In a DC circuit, polarity refers to the direction of current flow.

AC Circuits

In an AC circuit, polarity refers to the differentiation between hot, neutral, and ground.



Wire	Description
Hot wire	Any non-grounded conductor that carries current
Neutral wire	Carries current when the circuit is closed
Ground wire	Is connected to ground and only carries current when there is a short to ground in the circuit



Ground Wire Function

Safety Purpose

The ground wire provides a path of least resistance for fault current

Resistance Comparison

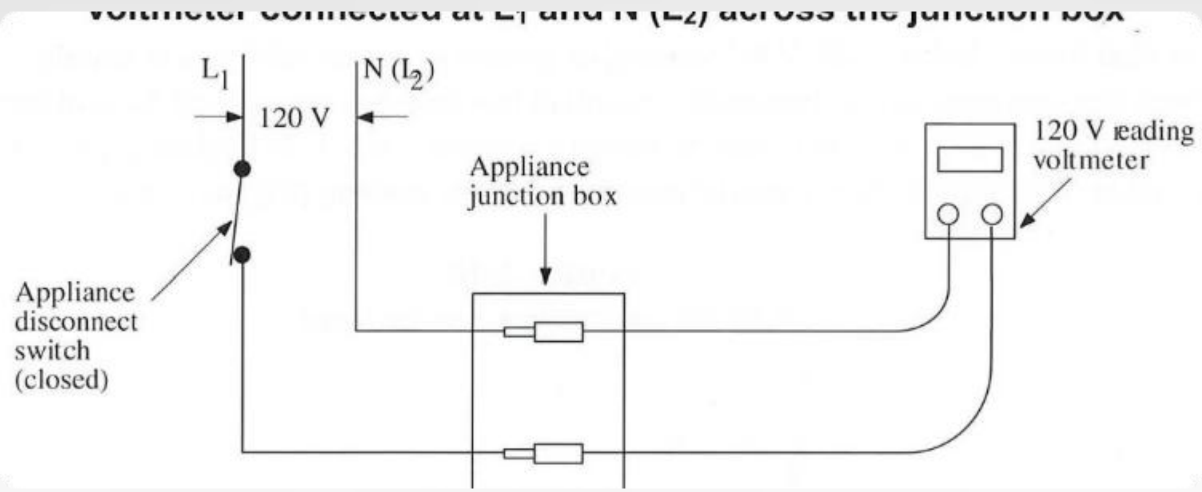
The electrical resistance of the grounding wire is less than the electrical resistance of a human body

Current Path

Electricity travels through the wire to ground rather than through a person

Protection

This prevents electrical shock hazards when equipment develops a fault



Determining Polarity - Step 1

Set Meter Range

Set the meter to a voltage range higher than that of the branch circuit.

Connect Voltmeter

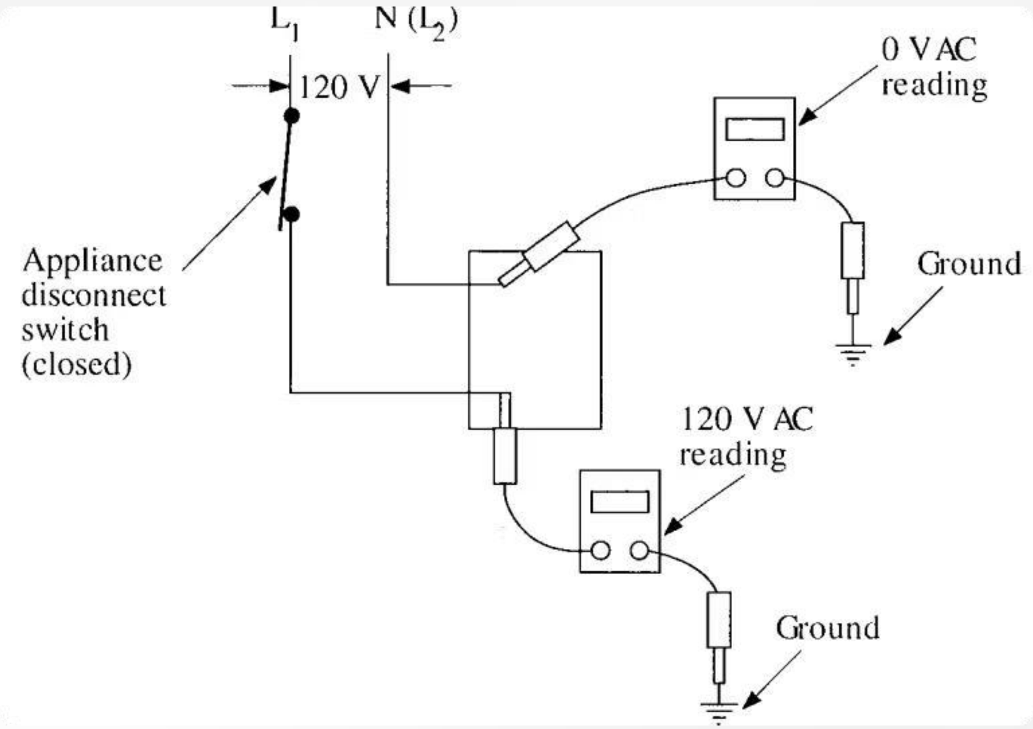
Connect the voltmeter across L1 and N (L2) at the junction box, as shown in the figure.

Check Voltage Potential

Determine if there is a voltage potential between them.

This is the first step in determining the polarity of branch circuit leads - which is hot and which is neutral.

Determining Polarity - Step 2



Connect to Ground

If there is a voltage potential, connect the meter from each wire to ground, as shown in the figure.

Identify Hot Wire

Determine which is hot (120 V AC reading) and which is neutral (0 V AC reading).

Wire Designation

On 120 V circuits, L1 is used to designate the hot lead and N or L2 the neutral.

The lead which shows a 120 V AC reading to ground is the hot wire and is usually black.

Determining Polarity - Step 3

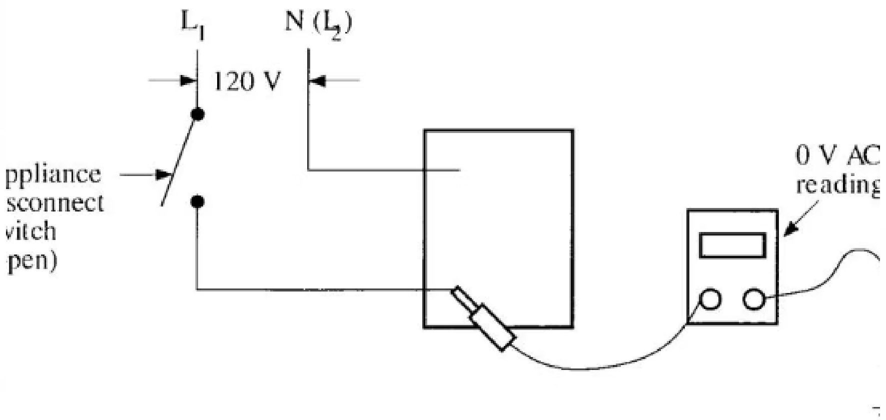
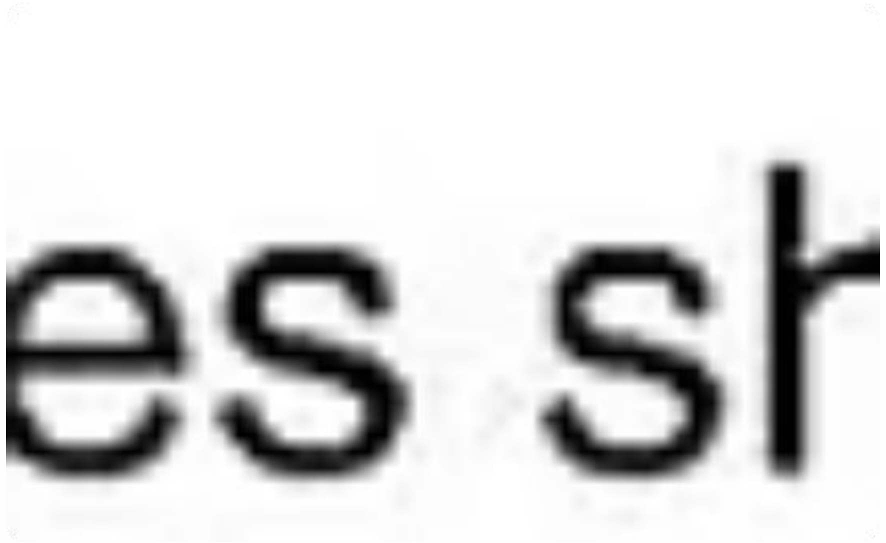


Figure 2-14
Checking hot lead to ground



Disconnect Switch Test

Check the operation of the disconnect switch to ensure it will turn off the power on the hot lead.

Verification

After you have disconnected it (turned it to the off position), you must check the hot lead to ground.

Expected Reading

There should now be a 0 V AC reading, confirming the disconnect switch is functioning properly.

Understanding Phasing

Definition

Matching the polarity of the primary and secondary sides of a transformer, phasing, becomes important only when the secondary side of the step-down transformer must be grounded.

Application

For example, you must ensure proper grounding and phasing when the transformer is connected to certain types of control modules that use a flame sensor circuit operating with flame rectification.

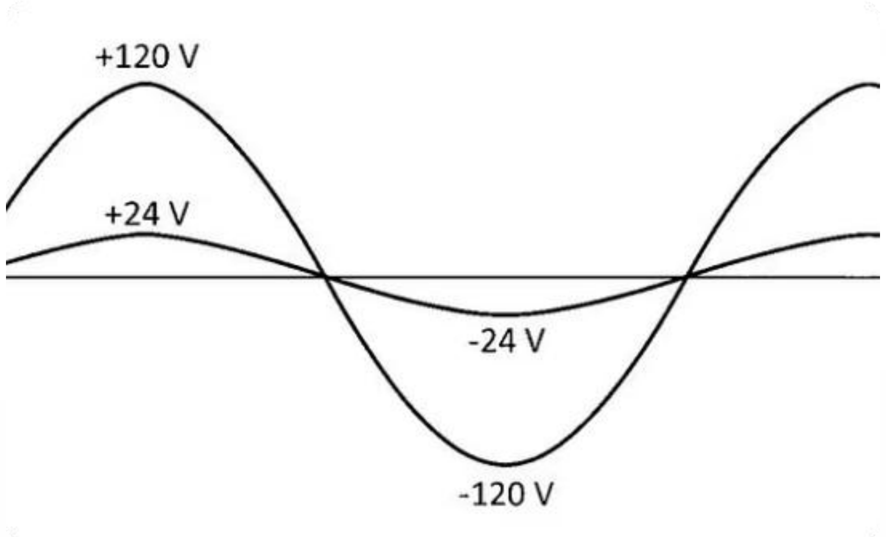
Examples

Some intermittent pilot, direct spark, and hot surface ignition modules have one of the transformer terminals grounded.

In-Phase Transformer

Sine Wave Representation

A sine wave will indicate the polarity of the current flow at any specific time.



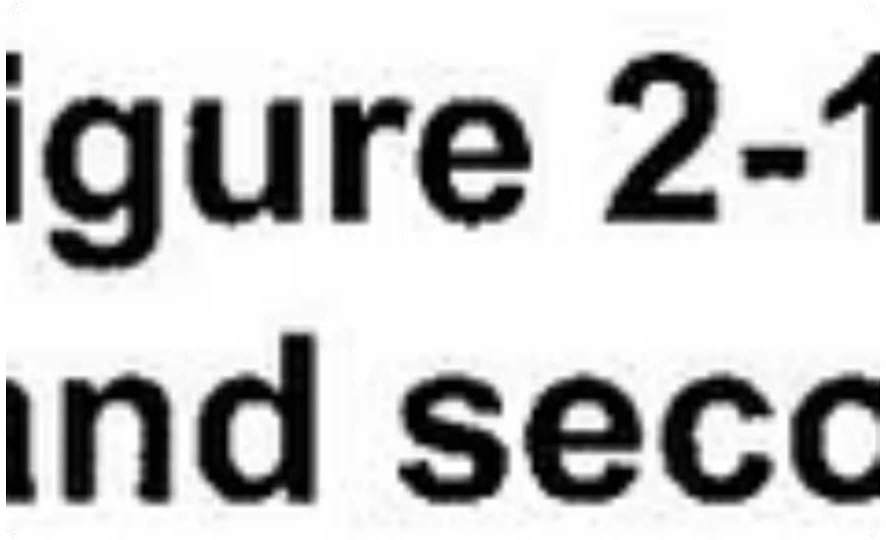
In-Phase Condition

If the secondary side of the transformer is in phase with the primary, its sine wave will appear as the small sine wave which is 24 V positive at the top and 24 V negative at the bottom.

Voltage Difference

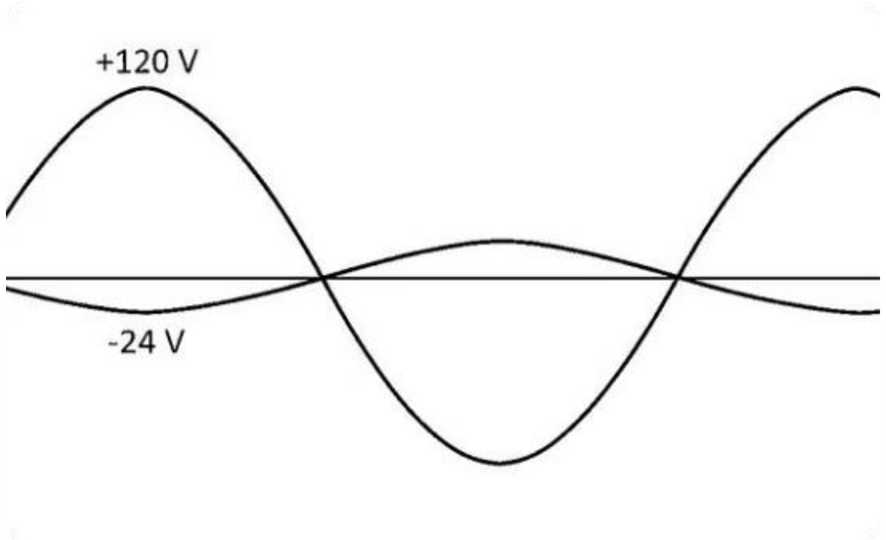
If in phase, the difference between the primary and secondary voltage is 96 V (120V - 24V).

Out-of-Phase Transformer



Sine Wave Representation

Where the primary and secondary are not in phase, the sine wave will appear as shown.

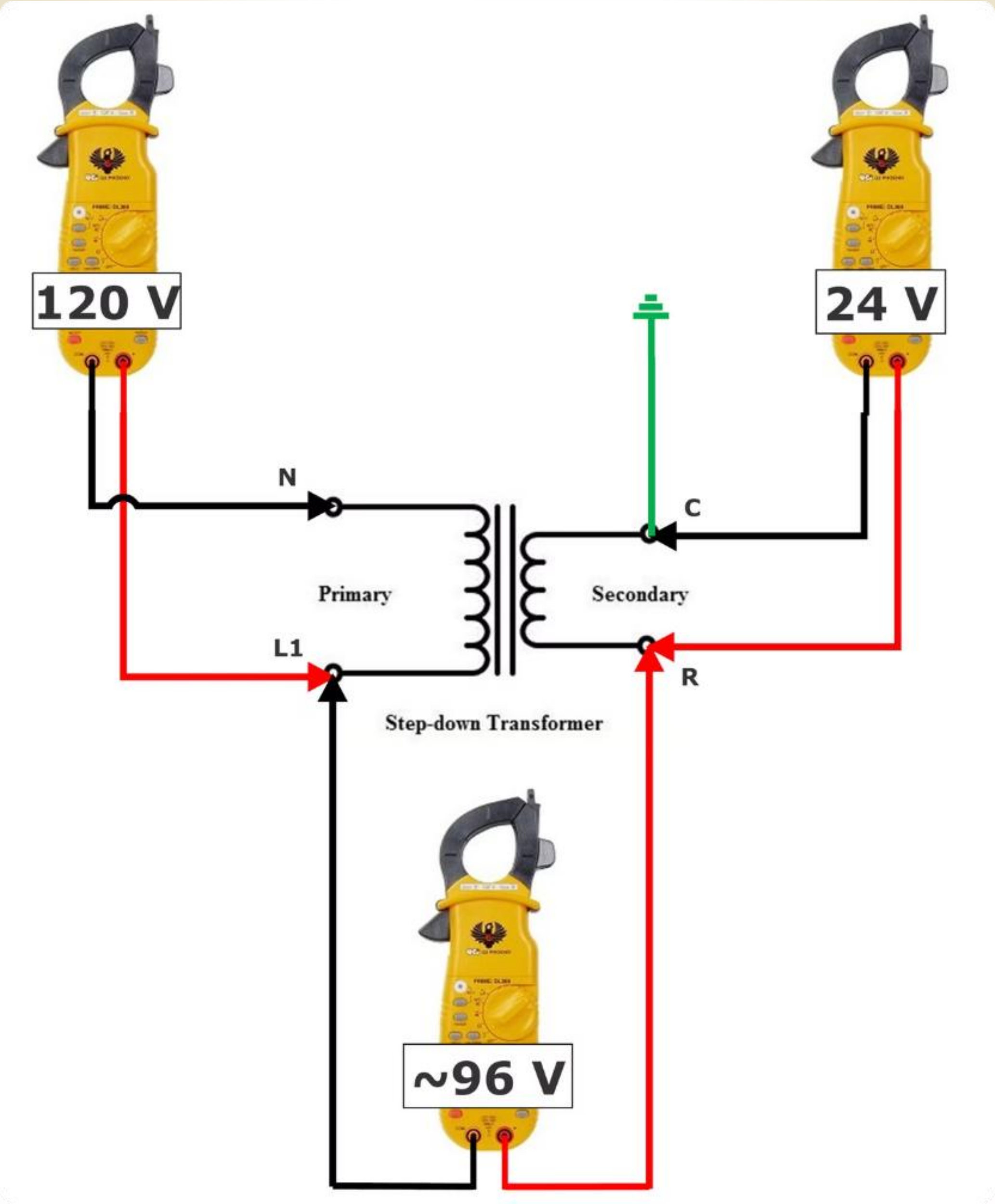


Out-of-Phase Condition

When out of phase, the secondary voltage is inverted relative to the primary.

Voltage Difference

The difference in the potential between the primary and secondary is now 144 V (120V + 24V).



Checking Transformer Phasing - Step 1

Identify Hot Lead

Check which lead in the junction box is hot (L1) and connect it to the black lead of the transformer.

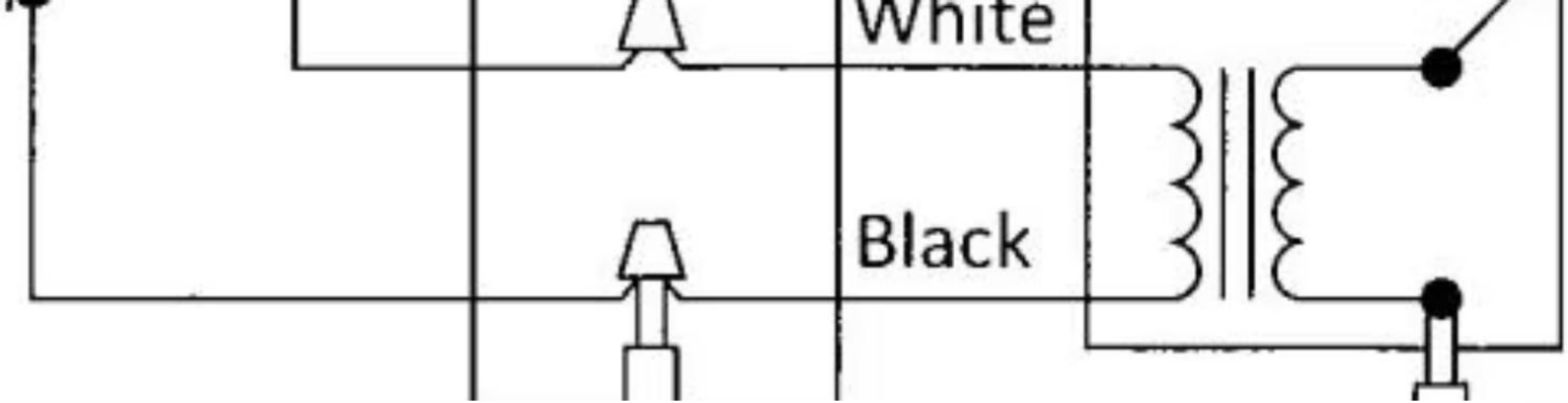
Connect Neutral

Connect the neutral lead (L2) in the junction box to the white lead of the transformer.

Ground Secondary

Connect one side of the transformer secondary to ground.

You need a voltmeter to check the phasing of a transformer. This procedure helps ensure proper operation of electronic control modules.



Checking Transformer Phasing - Step 2

Measure Voltage

Check the voltage between the hot and the ungrounded side of the secondary.

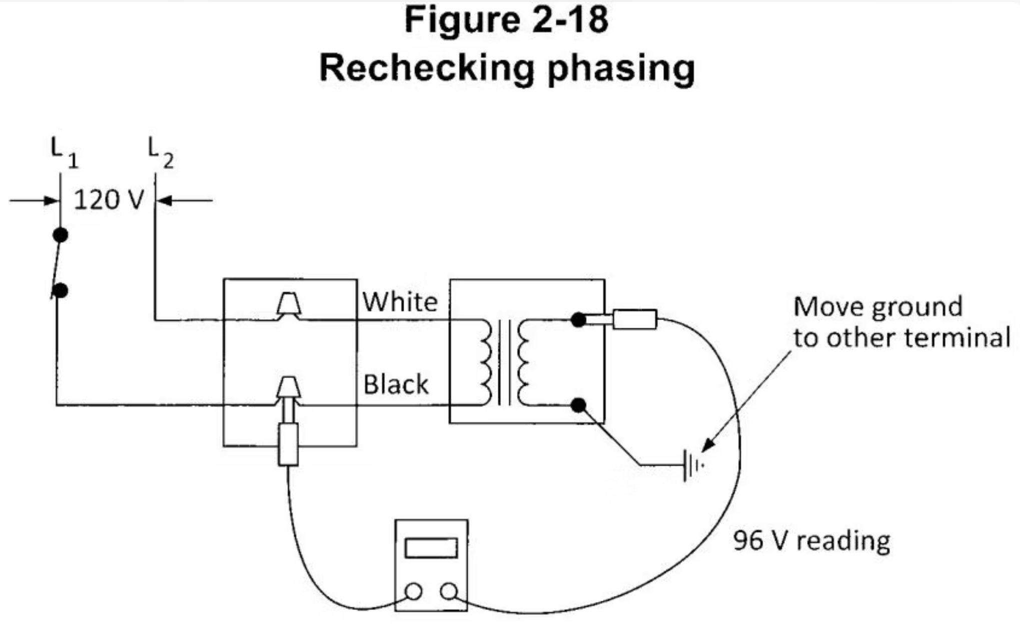
In-Phase Reading

If the primary and secondary are in phase, the reading should be 96 V.

Out-of-Phase Reading

If the reading is 144 V, the primary and secondary are not in phase.

This step confirms whether the transformer is properly phased for the application.



Checking Transformer Phasing - Step 3

Adjust If Out of Phase

If the reading is 144 V, move the ground to the other terminal of the secondary.

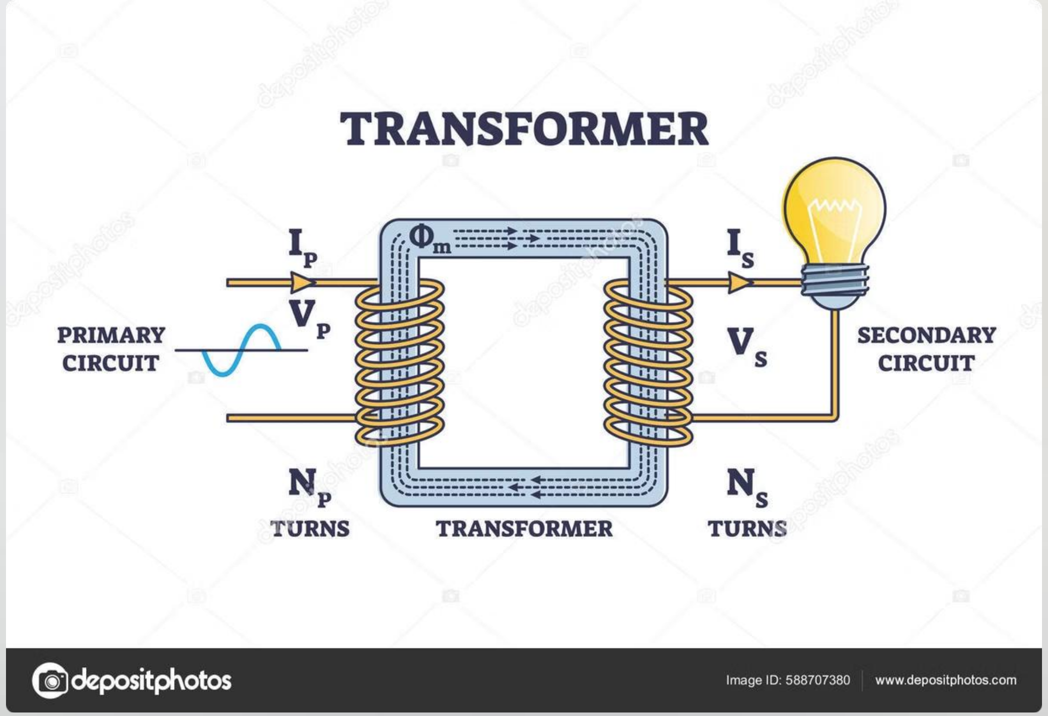
Recheck Voltage

Now the reading between L1 and the ungrounded side of the secondary will read 96 V.

Identify Hot Terminal

You have now identified the proper secondary side terminal to use as Hot (R).

Once the primary and secondary sides of the transformer are placed in phase, the hot (R) and grounded (C) side of the secondary can be connected to the appropriate terminals on the control module.



Labeled Transformer Terminals

Terminal Labeling

Some transformers have the secondary terminals labelled C for common, which would be grounded when connected, and R for hot.

Testing Procedure

When checking this type of transformer, you would test between L1 and R. If you find it out of phase (144 VAC), then you should switch the leads on the primary (120 VAC) connections to the transformer.

Result

This will place the secondary labels in phase.

Electrical Sequence of Operation

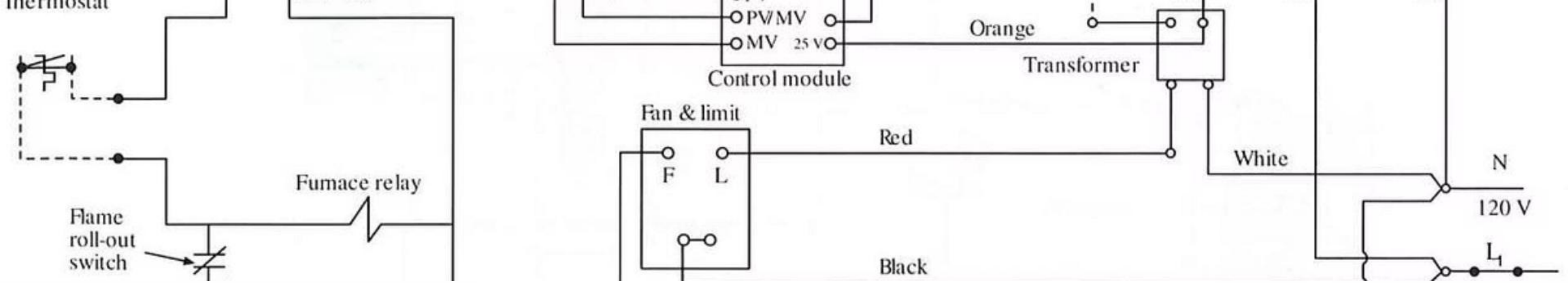
Importance

As a gas technician/fitter, you must be able to determine the operating sequence of gas appliances based on the electrical circuitry provided by the manufacturer.

Skill Requirement

Since there are many variations on the type of control systems installed, you will need a solid grounding in reading wiring and schematic diagrams so that you can easily trace the electrical circuitry of any system.

Understanding the electrical sequence of operation is crucial for proper installation, troubleshooting, and maintenance of gas appliances.



Electrical Sequencing Example

Diagram Components

The circuit for a simple residential warm-air furnace is shown in the figure and will be used to explain how to read an electrical sequence of operation.

Wiring Diagram

The wiring diagram on the right shows the electrical connections between the switches and loads.

Schematic Diagram

The schematic diagram (ladder diagram) on the left is laid out in order to follow the electrical sequence of operation.

Complexity Note

Control systems for large input appliances will have a more complex sequence with more interlocks, safeties, etc.

Switches and Loads Placement

Standard Placement

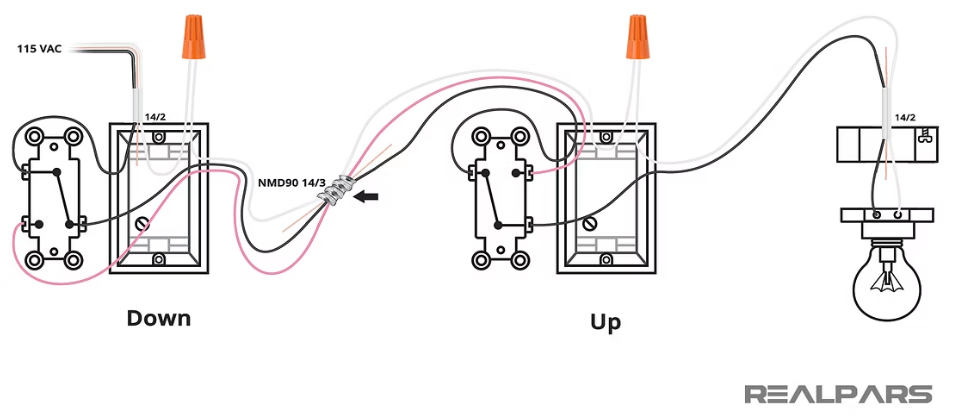
Switches connected to loads are normally located on the hot line - never in the neutral line.

Exceptions

Occasionally manufacturers will wire in a switch or load in the neutral line, in which case they provide a wiring diagram showing this arrangement.

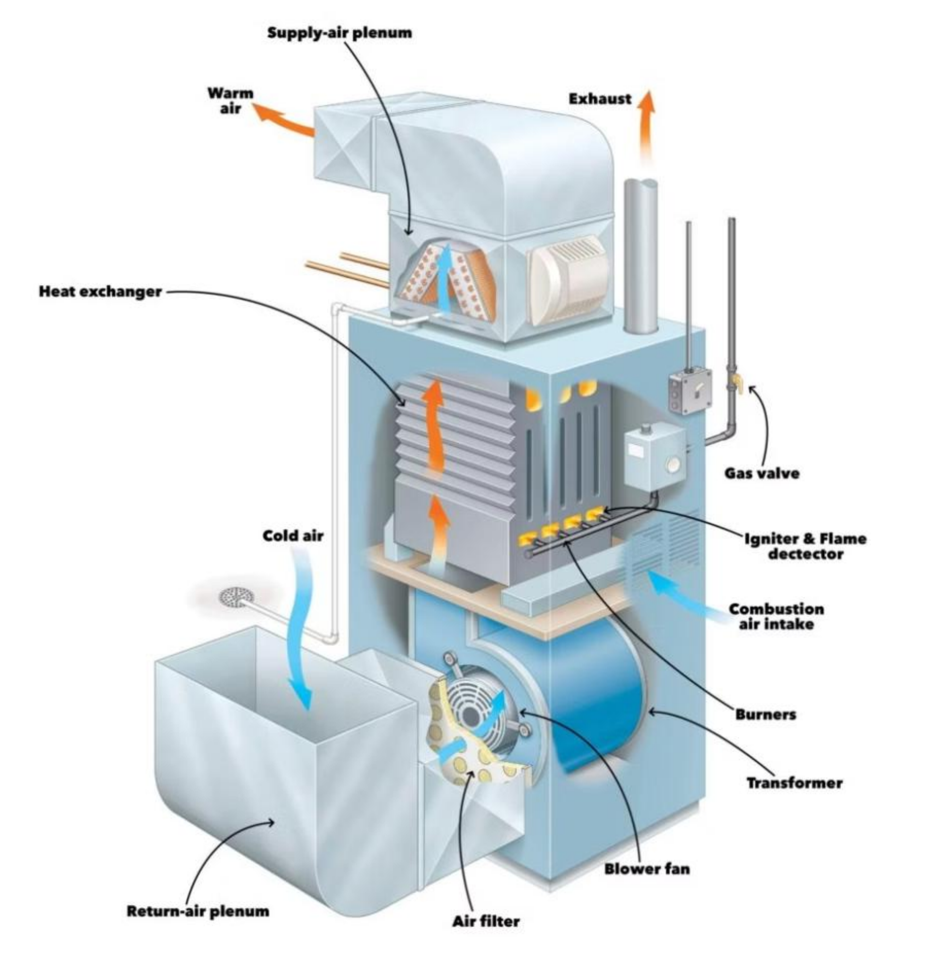
Safety Consideration

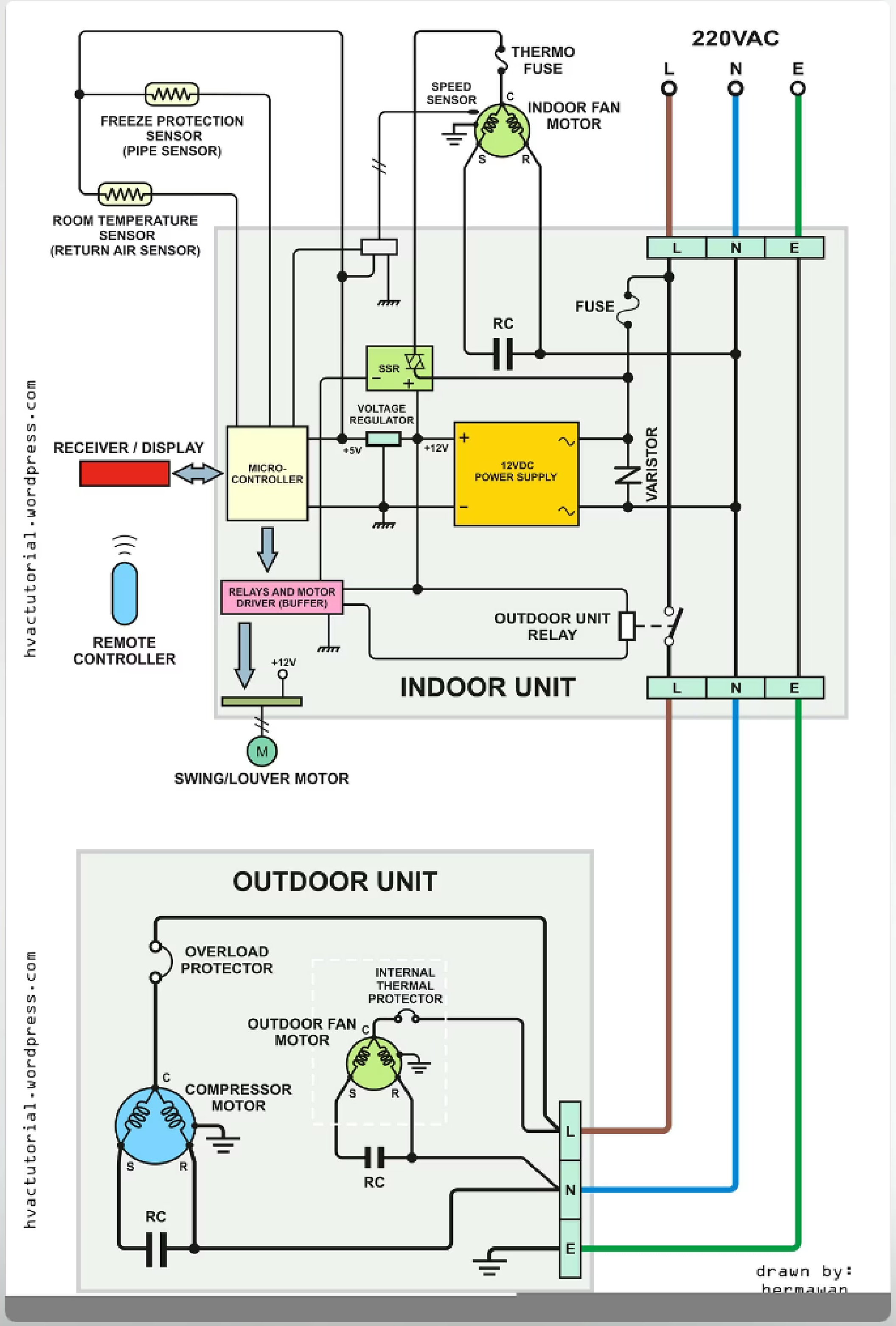
Placing switches on the hot line ensures that the circuit is fully de-energized when the switch is open, enhancing safety.



Furnace Circuit Components - Line Voltage

Circuit and power	Switches	Loads
Line voltage - 120 V	Appliance disconnect (NC) - not shown	
Fan circuits - 120 V	Door switch (NC)	Induced blower motor (120 V)
	Furnace relay contacts (NO)	Circulating air blower motor (120 V)
	Combination fan (NO) and limit control (NC) switch	





Furnace Circuit Components - Control Voltage

Circuit and power	Switches	Loads
Transformer circuit - 120/24 V	Limit switch (NC)	Transformer 120/24 V
Control circuit - 24 V	Thermostat (NO)	Furnace relay solenoid
	Flame rollout switch (NC)	Control module - Igniter sensor
	Vent safety switch (NC)	- Pilot valve
	Air proving switch (NO)	- Redundant gas valve

Control Module Function

Dual Role

The electronic control module will have transistors, diodes and a flame sensing transformer inside of it so it will act as both a load and a switching device.

Internal Circuitry

The internal circuitry of control modules differs with each model and type. The control module sequence as indicated represents a typical example.

Manufacturer Information

Module sequencing information would need to come from the module manufacturer, as it cannot be determined from a wiring diagram alone.

Furnace Operation Sequence - Part 1

Power to Transformer

With the door switch and the limit switch in the closed position, the 120/24 V transformer is powered

Thermostat Call

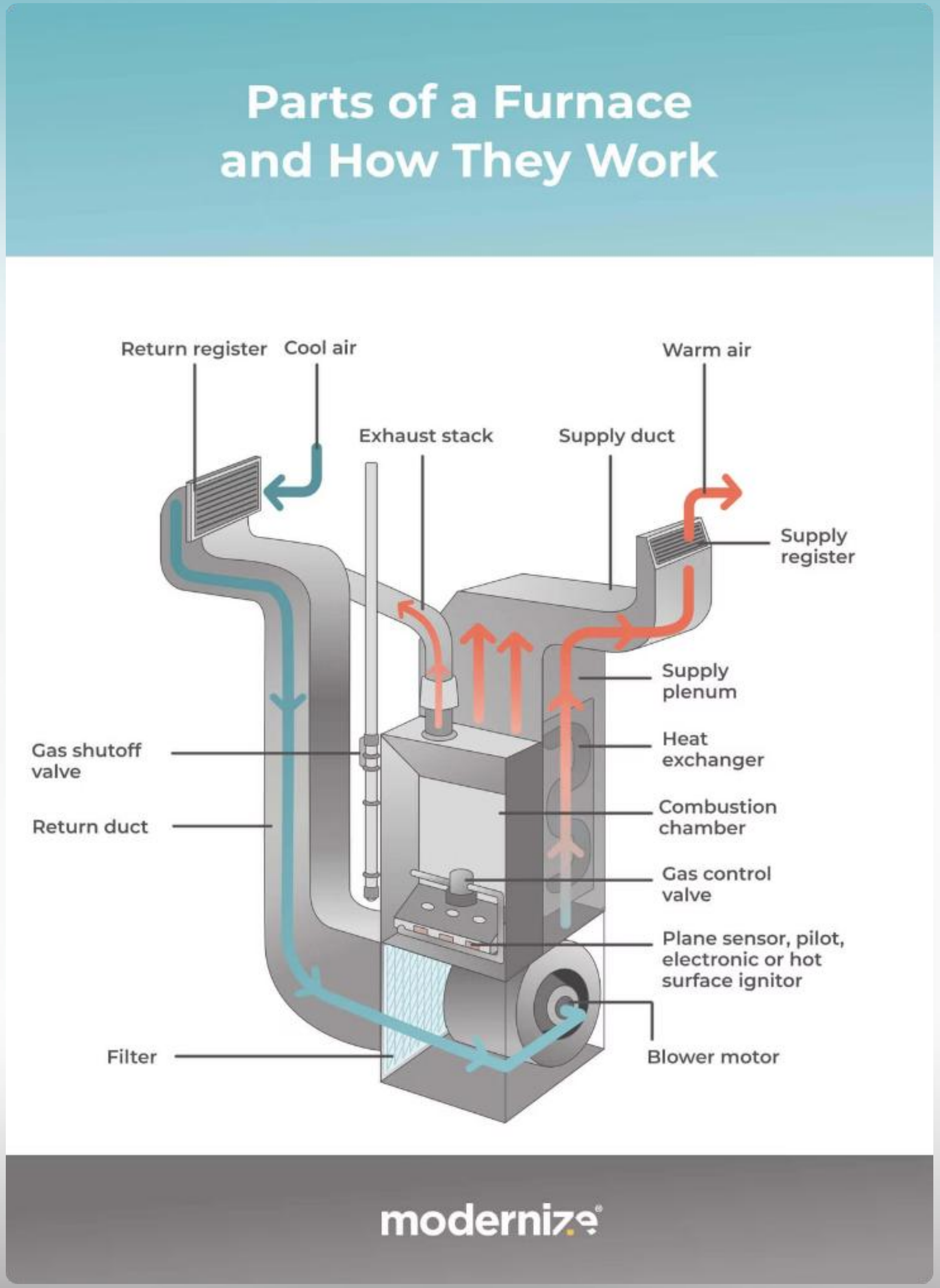
Thermostat calls for heat and the thermostat switch closes

Relay Activation

This powers the furnace relay coil, which in turn closes the furnace relay contacts

Induced Blower

These contacts then power the induced blower motor



Furnace Operation Sequence - Part 2

Air Proving

The running of the induced blower will cause the air proving switch to close

Control Module Power

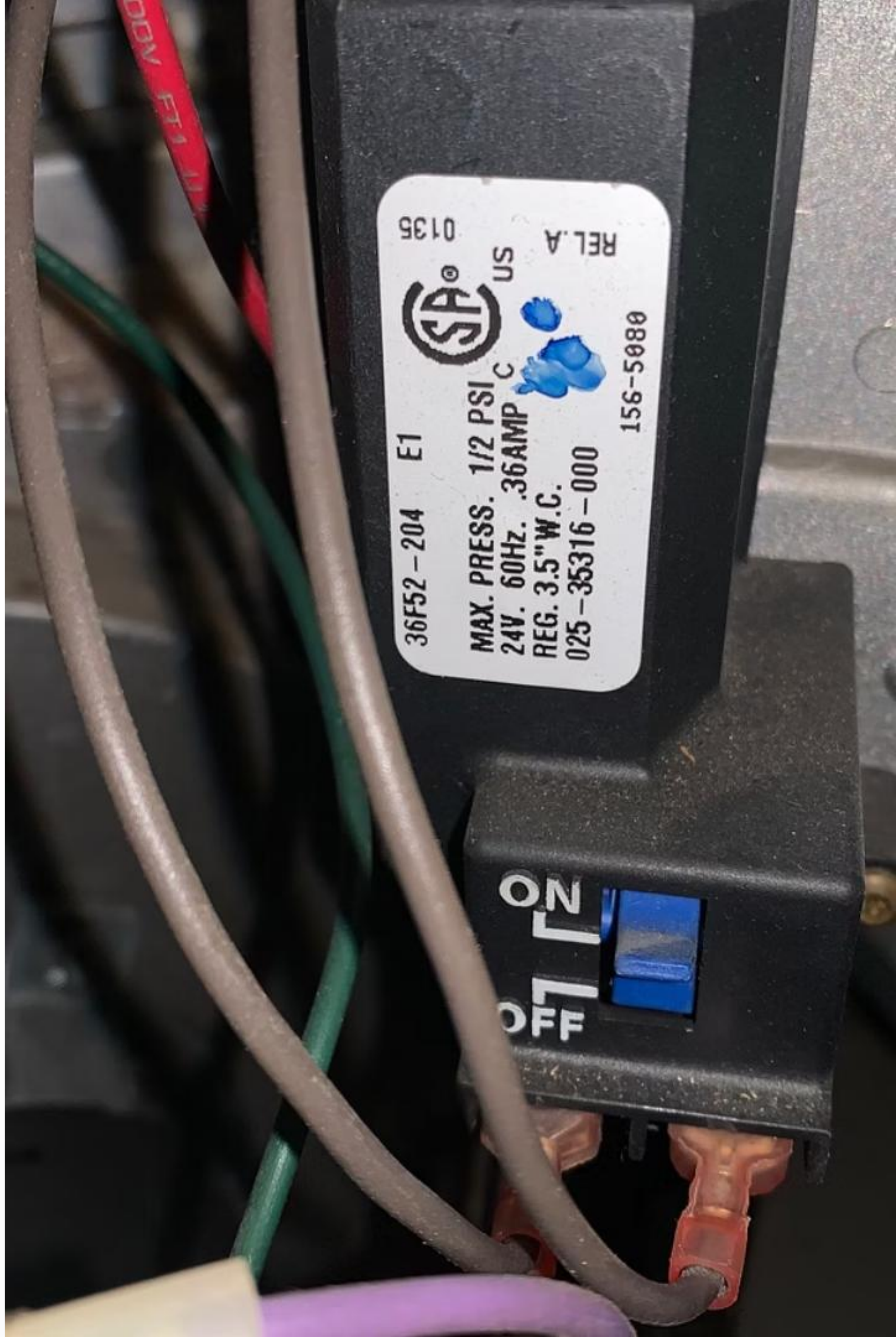
This powers the control module as the flame rollout switch and vent switch are normally closed

Safe Start Check

The control module performs safe start check to confirm there is not already an existing flame

Ignition Sequence

If safe start is indicated, the igniter and pilot valve are powered simultaneously



Furnace Operation Sequence - Part 3

Flame Proving

The pilot is proven through the flame sensor

Main Valve

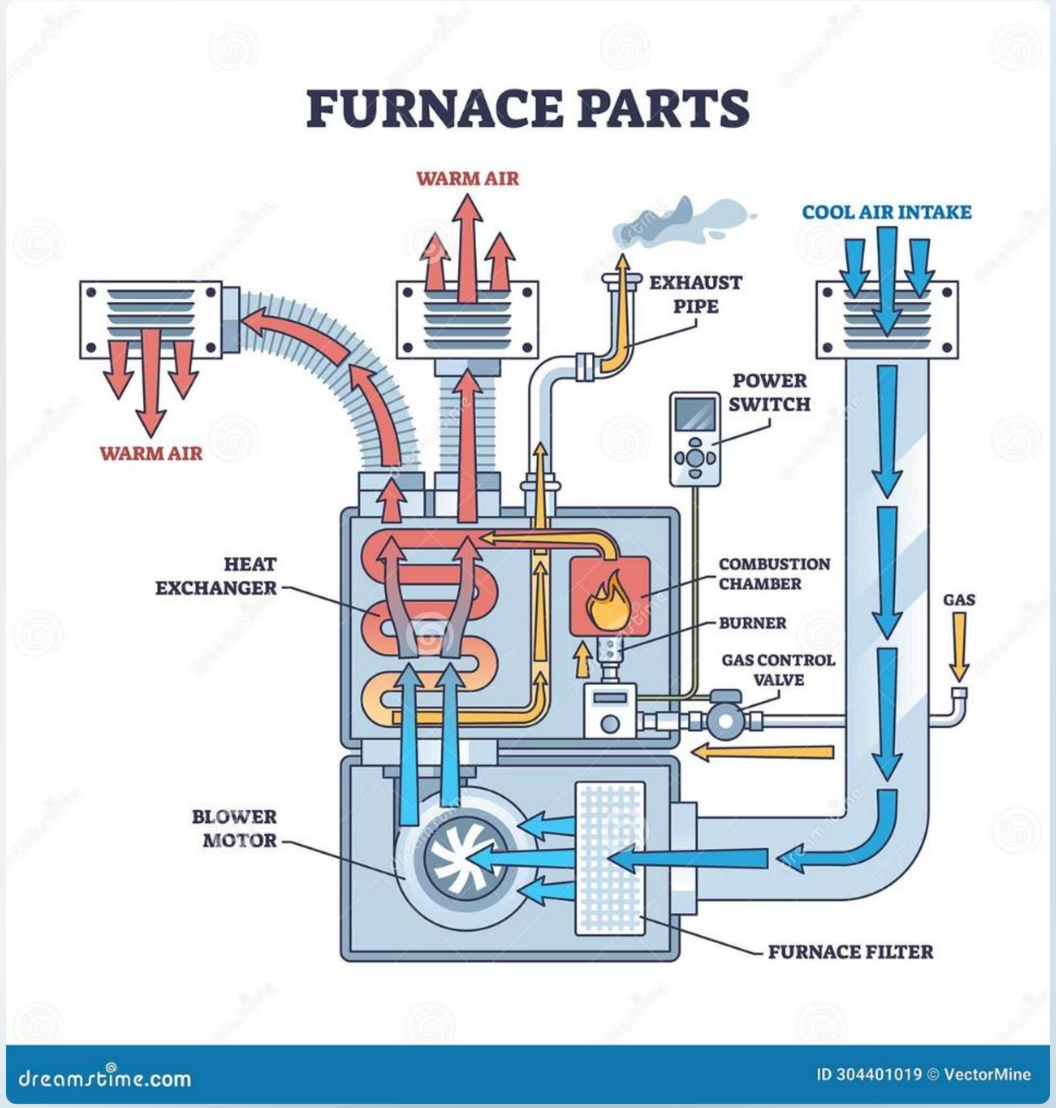
If the pilot is proven, the main valve is powered, and the igniter is de-energized

Main Burner

At this point, the main burner is firing

Circulating Fan

As the temperature rises to the fan control setpoint, the fan control switch will close, energizing the circulating blower motor



Furnace Operation Sequence - Part 4

Continued Operation

The burner will continue to fire until the thermostat is satisfied.

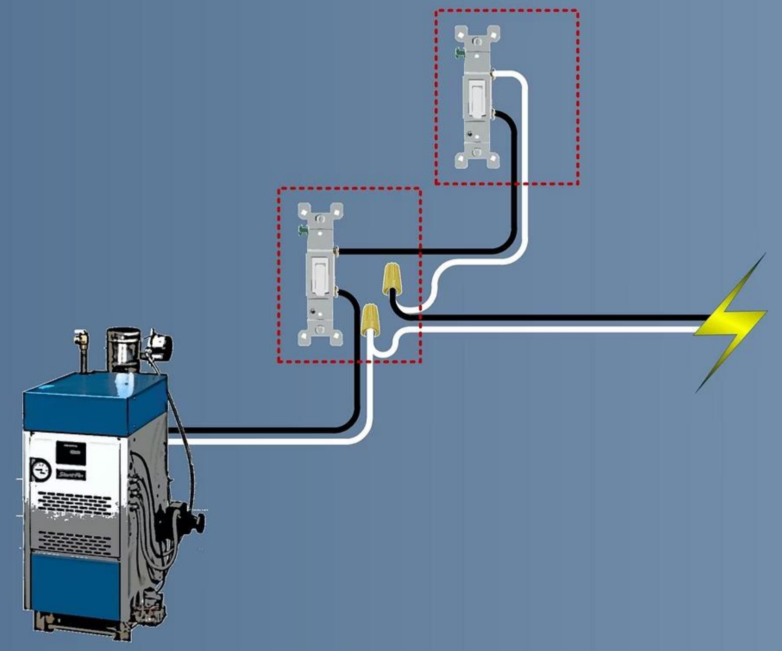
Blower Operation

The circulating blower motor will continue to operate after the thermostat opens until the temperature drops below the fan control switch setpoint differential.

System Shutdown

Once the temperature drops below the fan control setpoint, the system enters standby mode until the next call for heat.

Note: The appliance disconnect is not shown in the diagram but would be used to completely remove power from the system when needed.



Integrated Furnace Control (IFC)

Definition

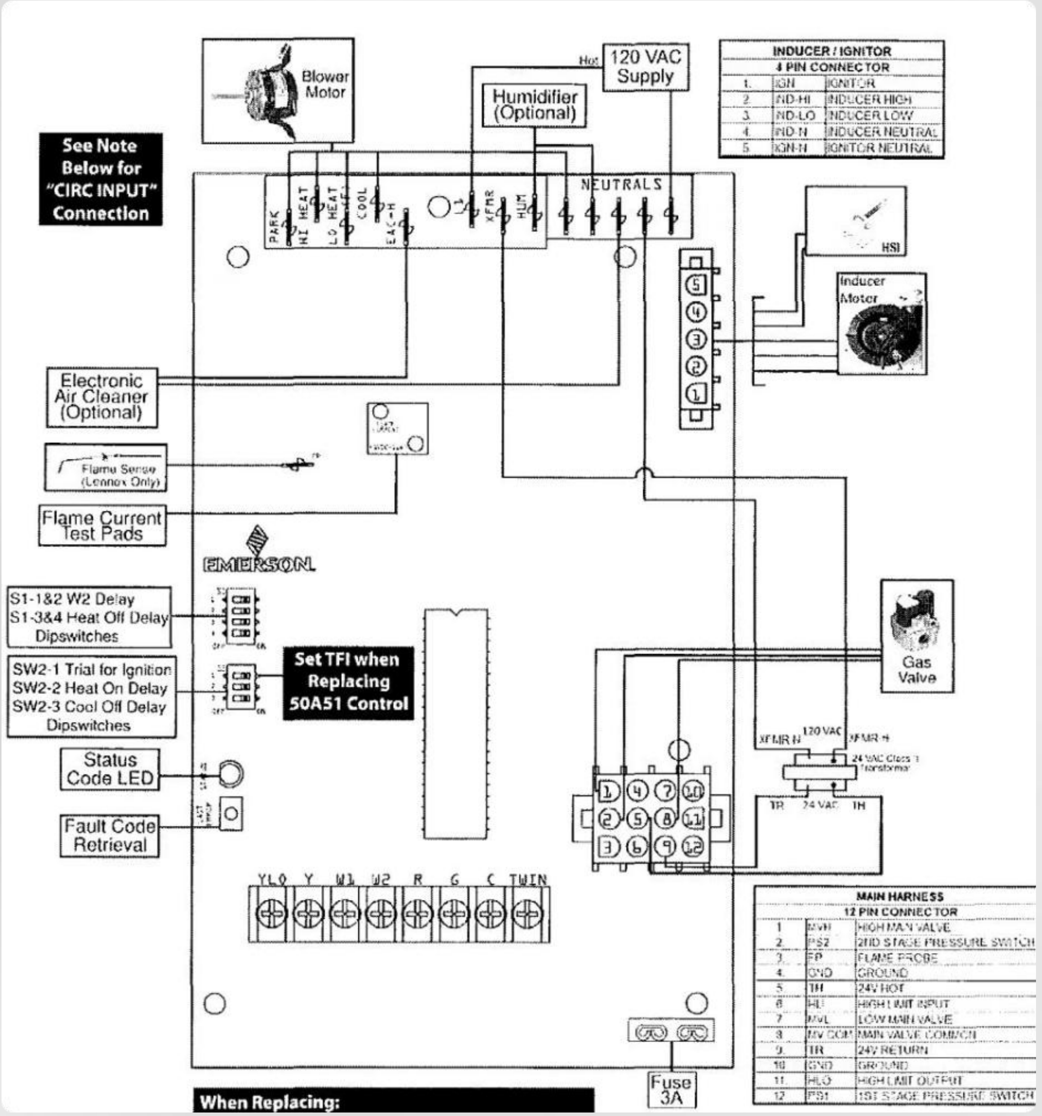
An integrated furnace control (IFC) manages the entire operation of a furnace, besides the ignition control, this can include two-stage burner operation, variable fan speed, electronic air cleaner, and humidifier depending on the furnace model.

Sequence Determination

Just as you could not determine the sequence of events for the ignition control module from the previous wiring diagram, you now cannot determine the sequence for any load shown connected to the IFC.

Figure 2-20
Wiring diagram for White-Rodgers 21M51U-843 Universal IFC
Courtesy of White-Rodgers, part of Emerson Climate Technologies

The sequence of operation needs to be determined from the operating instructions provided by the manufacturer.



IFC Wiring Diagram

Complex Integration

The wiring diagram shows how the IFC connects to various components of the furnace system.

Multiple Functions

The IFC controls not just basic heating functions but also advanced features like variable speed fans and accessory components.

Manufacturer Documentation

Due to the complexity of the IFC, detailed operation sequences must be obtained from manufacturer documentation.

Modern furnace control systems integrate multiple functions into a single control board, simplifying wiring but requiring more detailed documentation for service and troubleshooting.

Courtesy of White-Rodgers, part of Emerson Climate Technologies

Sequence of Operation Graph

Graphical Representation

Some manufacturers will include a graphical table to explain the sequence.

Layout

The stages are shown across the top row, and the various loads and switches that change are listed on the left column.

Status Indication

The lines coming out horizontally from each component will move vertically to indicate a change in their status at the appropriate stage.

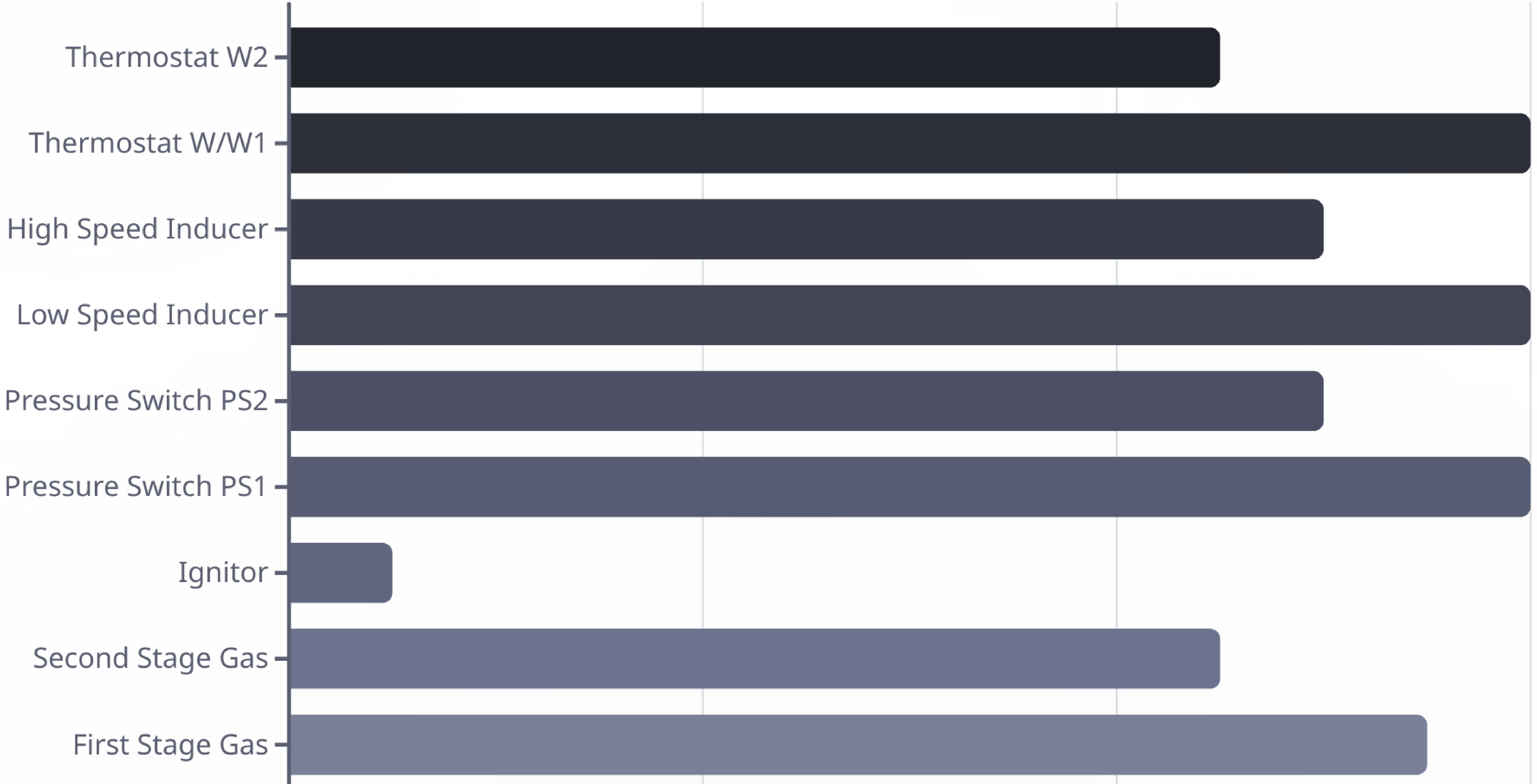
Two-Stage Operation

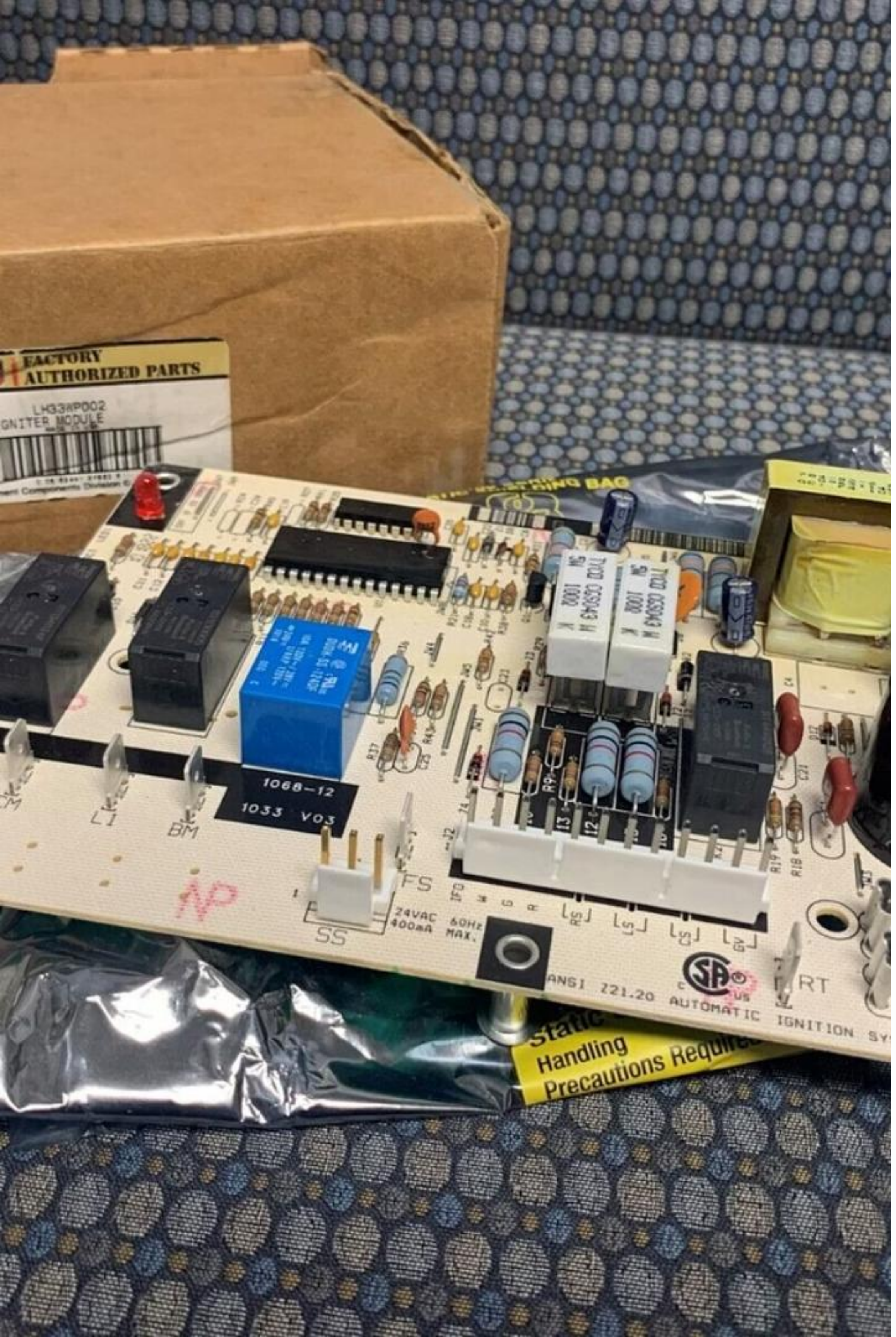
This sequence graph represents a two-stage furnace; components such as the gas valve, inducer, and blower will have extra upward movement associated with their lines representing an increase for the second stage of heat.

Heat Mode Sequence Details

1. **Standby**
   System is idle, waiting for call for heat
2. **Call for Heat**
   Thermostat initiates heating cycle
3. **Self-Check**
   System performs internal diagnostics
4. **Pre-Purge**
   Inducer runs to clear combustion chamber (15s)
5. **Ignition Warm-Up**
   Ignitor heats up (17s)
6. **Ignition Activation**
   Gas valve opens, flame established (3s)
7. **Heat ON Delay**
   Delay before blower starts (30/45s)
8. **Heating**
   System runs until thermostat is satisfied
9. **Post-Purge**
   Clears remaining combustion gases
10. **Blower Off Delay**
   Blower continues to run (90-180s)

IFC Component Status During Operation





LED Status Indicators

Amber LED - 1 flash

Indicates normal operation during call for heat, self-check, pre-purge, and ignition warm-up

Amber LED - 2 flashes

Indicates ignition activation period

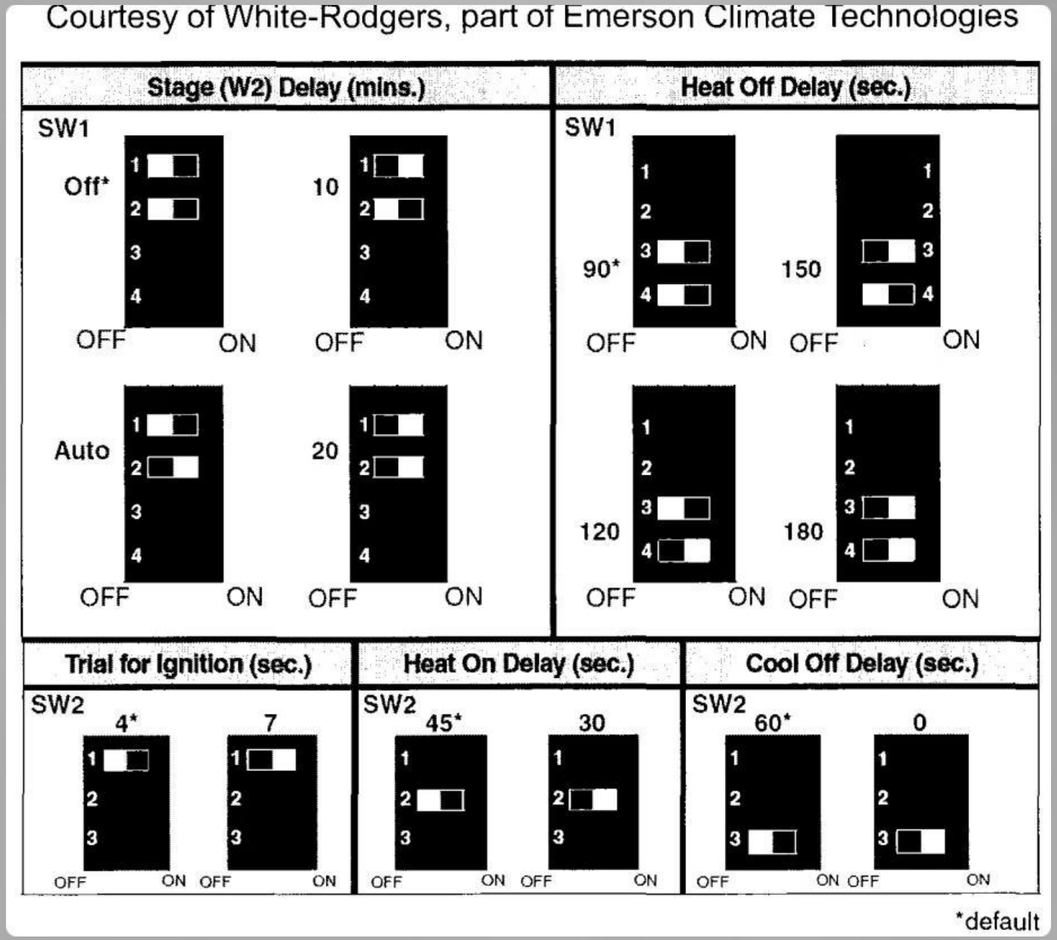
Green LED - 1 flash

Indicates normal heating operation

Red LED (not shown)

Would indicate fault conditions, with number of flashes corresponding to specific error codes

LED indicators on the IFC provide valuable diagnostic information about the current operating state of the furnace and can help identify problems when they occur.



IFC DIP Switch Configuration

Adjustable Parameters

The IFC is manufactured to be used by different furnace models and makes; therefore; they require adjustable timing options to maximize usability.

DIP Switch Functions

The IFC will have DIP switches that can be used to change some of the operating parameters such as heat off delay, trail for ignition, heat on delay, stage delay (for single-stage thermostat), and cool of delay.

Replacement Caution

If you replace an IFC, make sure to match the DIP switch configuration to the original IFC and/or manufacturer's specifications.

Summary of Electrical Control Systems

Diagrams

Wiring and schematic diagrams are essential tools for understanding electrical control systems

Symbols

Standardized electrical symbols allow for clear communication of circuit components

Auxiliary Devices

Switches, relays, contactors, and protective devices work together in control systems

Sequence of Operation

Understanding the electrical sequence is vital for installation, troubleshooting, and maintenance

Polarity & Phasing

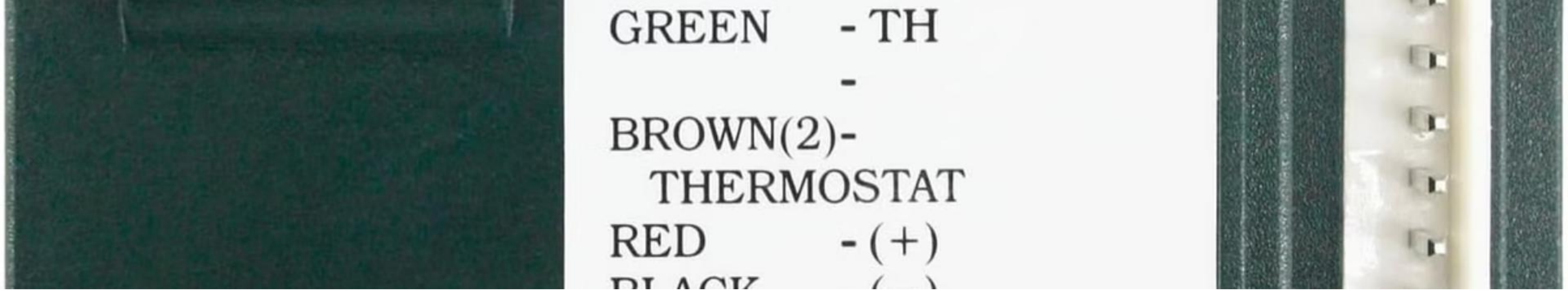
Proper polarity and transformer phasing are critical for modern electronic control boards

CSA Unit 13

Chapter 3 Servicing and Troubleshooting Circuits and Components

A gas technician's/fitter's regular duties include servicing and maintaining gas equipment. Isolating problem areas, replacing components, and troubleshooting control problems are learned skills that come with experience. An understanding of servicing and troubleshooting procedures is essential in building these skills.

Testing circuits may require working with live voltage. Remember to use extreme caution when doing any live testing. CSA Z462 provides the minimum requirements that should be followed. Only proceed with live testing if you are trained, authorized by your employer, and are using all recommended personal protective equipment.



Control Modules and Manufacturer Approval

Variety of Control Modules

There are many different types of control modules in use and available from a wide variety of manufacturers.

Manufacturer Approval

Some control modules are specifically approved for use with the appliance and are not interchangeable with other makes and models of control modules, including ones advertised as universal control modules.

Technician Responsibility

Gas technicians/fitters must ensure that the correct device is installed as approved by the manufacturer of the appliance.

Learning Objectives

Describe the servicing of controls and components

Understanding how to properly maintain and service various gas equipment controls and components.

Describe troubleshooting procedures of control systems

Learning systematic approaches to identify and resolve issues in gas control systems.

Describe the testing and troubleshooting of ignition control modules

Understanding specific procedures for testing and resolving issues with various ignition systems.

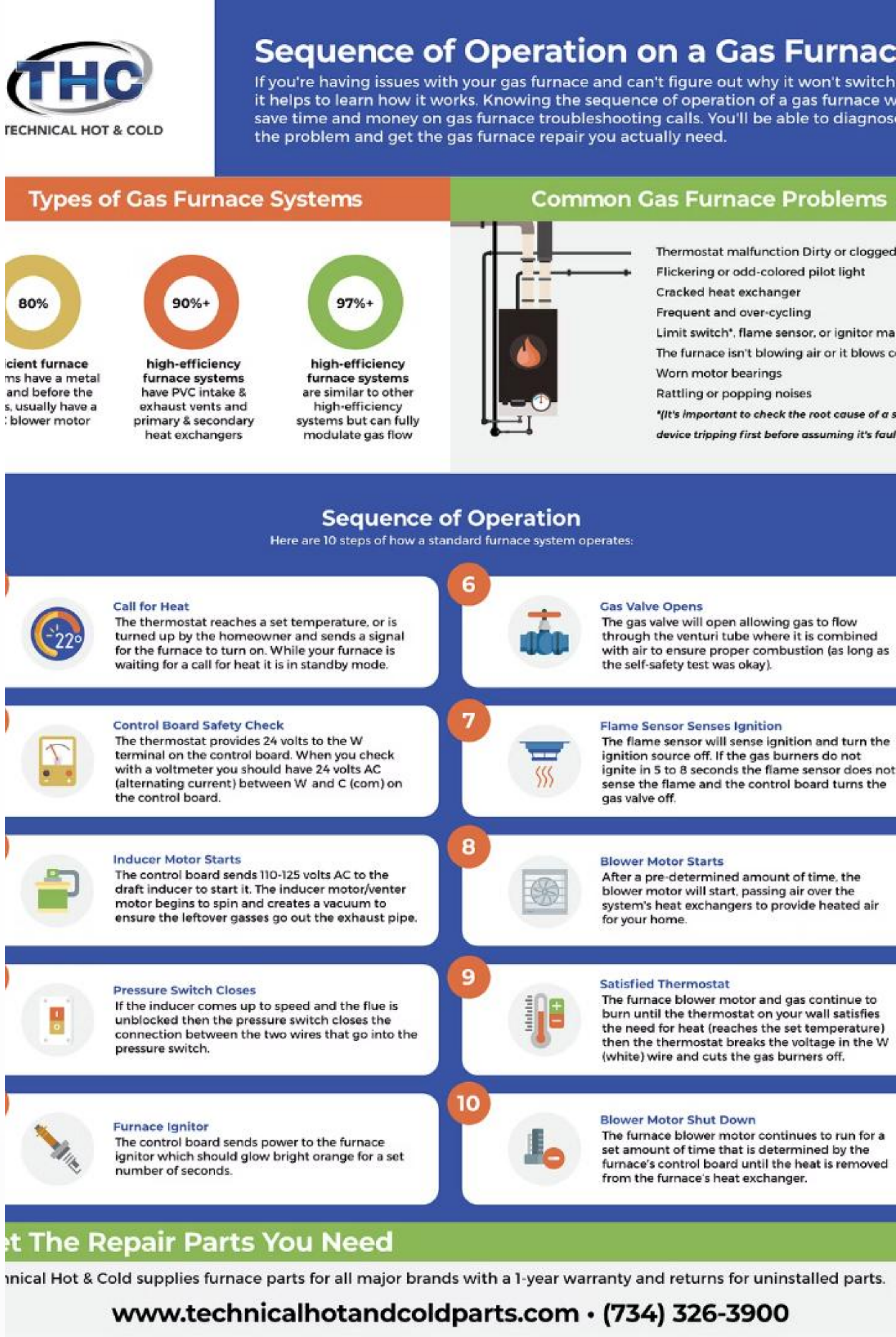
Describe the recalibration and the replacing of components

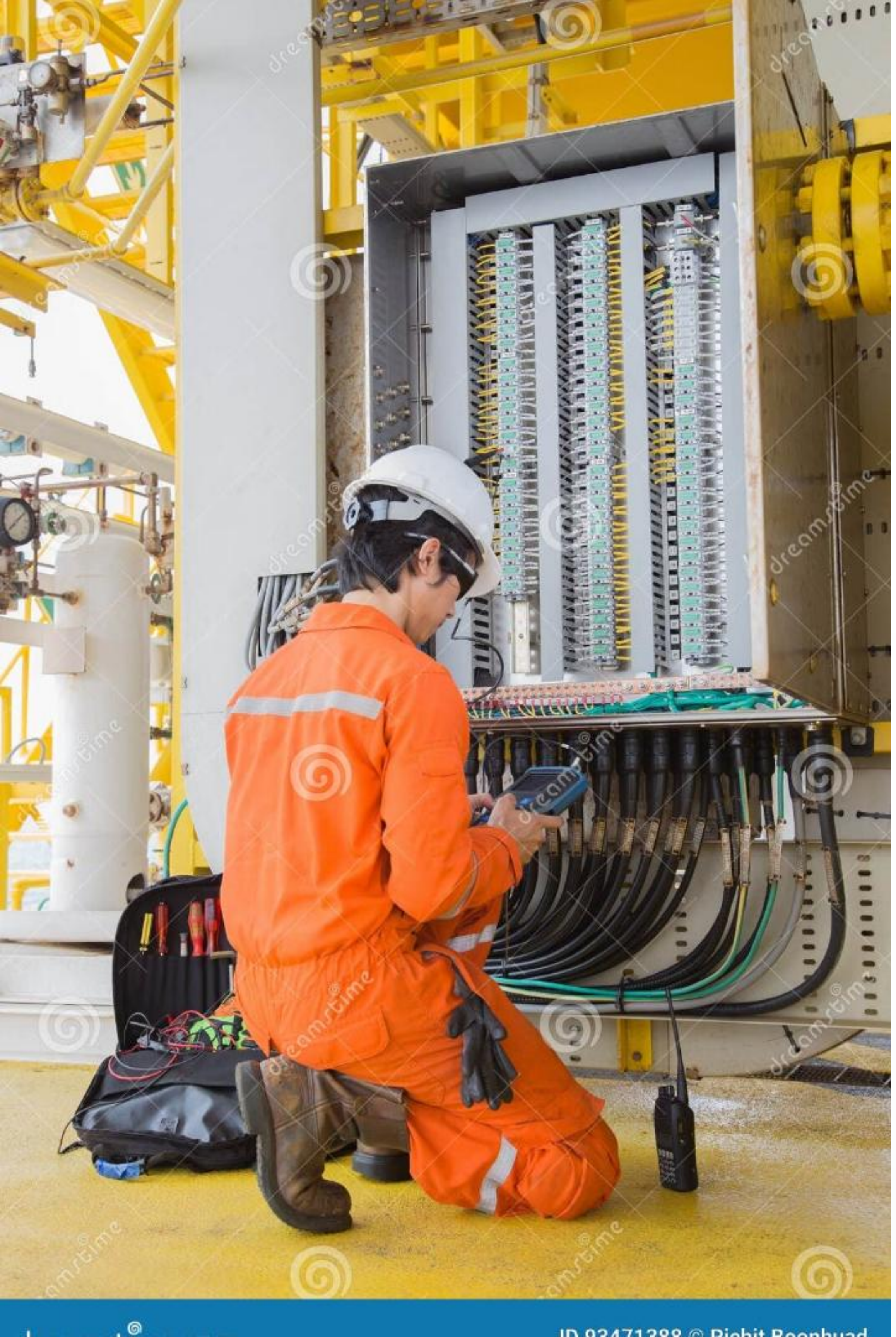
Learning when and how to properly recalibrate or replace gas system components.

Key Terminology

Term	Abbreviation (Symbol)	Definition
Sequence of operation (in manufacturer's manual)		Flow chart to understand the overall operation of the appliance from top to bottom and assist in troubleshooting

Understanding the terminology used in gas equipment servicing is essential for proper diagnosis and repair. The sequence of operation is particularly important as it provides a roadmap for how the system should function.





Servicing Controls and Components: Initial Checks

Clean Electrical Contacts

Use a clean, sturdy paper that is non-oily. Electrical contacts may be corroded, resulting in failure to close a circuit properly.

Clean Primary Air Vents

Primary air openings may be blocked by lint or other material, affecting combustion quality.

Replace Dirty Furnace Filters

Dirty furnace filters may cause the furnace to cycle on the limit control, giving the appearance of a short-cycling thermostat.

In the field of equipment servicing, many appliance malfunctions are due to dirt and debris accumulated from lack of maintenance. On service calls, before adjusting, repairing, or replacing components, complete these initial checks.

Servicing Controls and Components: Additional Checks

Clean Pilot System

Blow out or replace the pilot orifice. Failure of an ignition system may be due to a dirty or partially blocked orifice.

Clean Burner Orifices

Use a toothpick, **never** a piece of wire. Low heat input may be due to a dirty or partially blocked orifice.

Clean Valve Components

Clean the seat or pivot point in the valve. Dirt on the seat or pivot point in the valve may cause a valve to remain partially open.

Proper cleaning of components is essential before determining if replacement is necessary. Many issues can be resolved through thorough cleaning of key components.

Servicing Controls and Components: Final Adjustments

1. ## Readjust to Nameplate

To adjust the appliance input rate: Change the manifold pressure, adjust the gas regulator, or put in new orifice spuds if greater change is required.

2. ## Flush Water Heaters/Boilers

Remove sediment from the tank bottom to improve efficiency and prevent premature failure.

3. ## Verify Vent Operation

Make sure vents are clear and working properly to ensure safe operation and proper combustion.

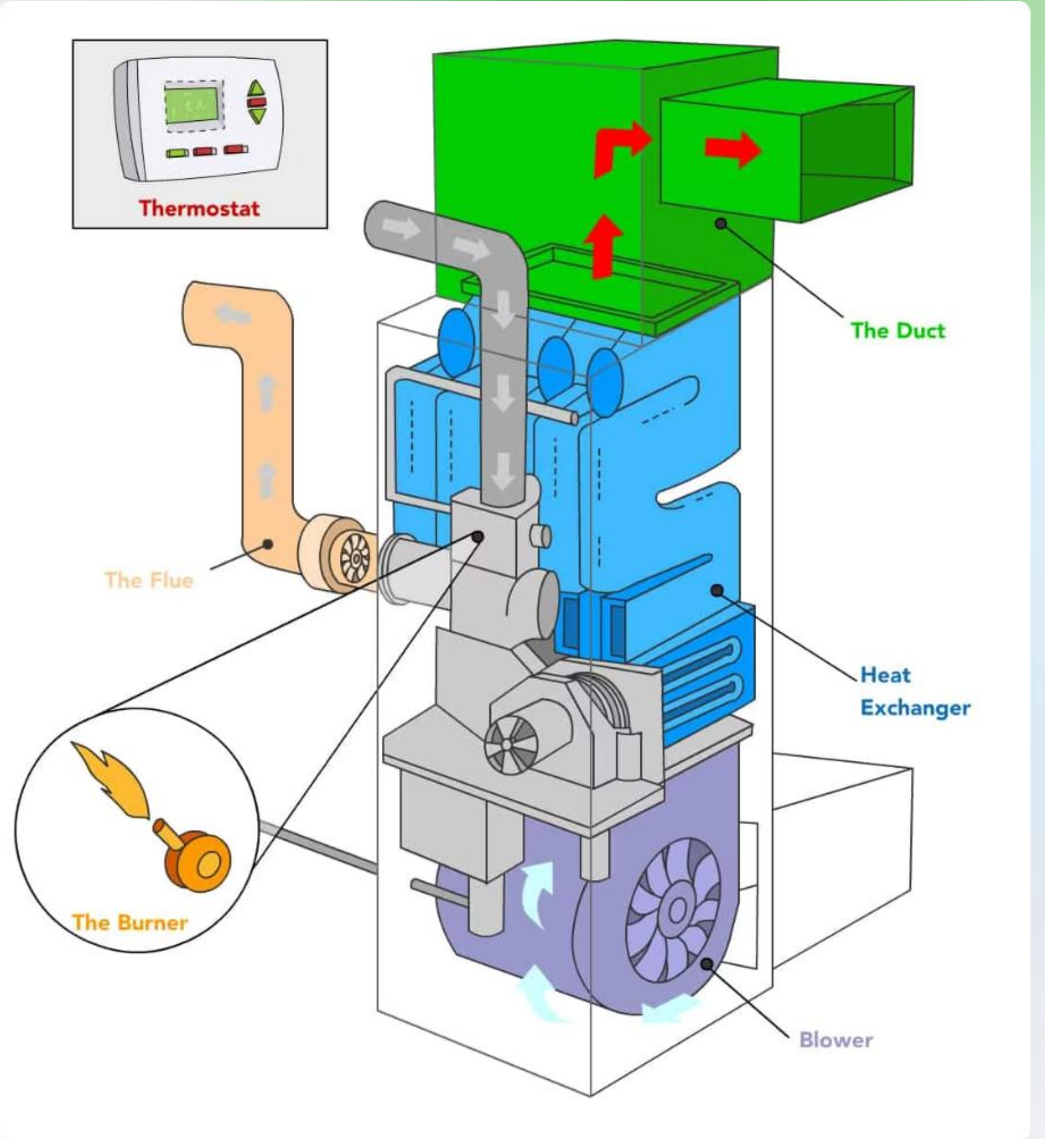
After cleaning components, these final adjustments and checks ensure the appliance operates at peak efficiency and safety.

Understanding the Sequence of Operation

A visual representation of the sequence of operation is presented in manufacturer's manuals. This flow chart can help gas technicians/fitters understand the overall operation of the appliance from top to bottom and assist in troubleshooting.

The sequence of operation shows the logical progression of how an appliance functions, from initial call for heat through ignition, operation, and shutdown. Understanding this sequence is crucial for effective troubleshooting.

When a system fails to operate properly, comparing its actual behavior against the expected sequence helps identify exactly where in the process the failure occurs.



Troubleshooting Control System Problems: Tools

Electrical Meters

For measuring voltage, current, and resistance in circuits

Manometers

For measuring gas pressure in the system

Thermometers

For measuring temperatures at various points

Flue Gas Analyzers

For testing combustion efficiency and safety

Troubleshooting control systems requires special tools and instruments. The proper use of these tools and instruments is directly related to proper diagnosis; in addition, it minimizes the time necessary for repair or replacement.

Troubleshooting Procedure: Step 1 - Know the System

Study Technical Manuals

In other words, "Do your homework." Study the manufacturer's technical manuals. Know how the system works.

Review Service Bulletins

Keep up with the latest service bulletins. Read them and then file them in a handy place. The problem on your appliance may be addressed in one month's bulletin, giving the cause and remedy.

Understand System Operation

Having a thorough understanding of how the system should operate is essential for identifying when something isn't working correctly.

The first step in any troubleshooting procedure is to thoroughly understand the system you're working with. This knowledge forms the foundation for all subsequent troubleshooting steps.

Troubleshooting Procedure: Step 2 - Ask Questions

When does the shutdown occur?

Timing of failures can provide important clues about the cause.

During what part of the cycle?

Identifying which part of the operation sequence is failing.

How long after the start-up?

Duration before failure can indicate different types of problems.

Does a shutdown occur after every start?

Consistency of the issue helps determine if it's intermittent or constant.

How is the light-off?

The quality of ignition can reveal issues with the ignition system.

Usually, the information available on arrival at the installation consists of a simple statement such as "The burner shuts down." Start by asking all the questions possible of anyone who might have some knowledge of what happened.

Troubleshooting Procedure: Step 3 - Evaluate Information

Consult Manuals

Use the supplied manufacturer's manuals for reference

Review Charts

Check service suggestions and troubleshooting charts

Form Hypothesis

Develop initial ideas about possible causes

Apply Experience

Draw on personal experience with similar issues

Use the supplied manufacturer's manuals, charts, service suggestions, together with your personal experience, to evaluate any information you have concerning the problem. The conclusions drawn at this stage only provide an idea of where to look for the exact solution to the problem.

Modern Appliances with Integrated Controls

Operational Parameters

On modern appliances that use integrated controls, problems can be either operational parameters or faults. Operational parameters will be discussed in more detail within the study units related to each specific type of gas appliance as there are many options depending on application.

Fault Indicators

Faults are typically shown by way of an LED status light on the control panel or a touch screen user interface. Units with integrated controls typically can retrieve previous fault codes.

Be aware that some appliances recover and display the latest fault codes on power up. Be prepared to observe the codes and have the manufacturers' error code chart available for interpretation.

Troubleshooting Procedure: Step 4 - Make a Trial Run

Observe the Sequence

Was each step of the start-up according to the design sequence?

Note Deviations

Did any deviations occur from the expected operation?

Verify Shutdown Issues

Did the shutdown occur exactly as described by the customer?

Document Observations

Make notes of any new information discovered during the trial run.

Cycle the burner system and observe its operation carefully. This hands-on observation often reveals issues that weren't apparent from the initial description.

Troubleshooting Procedure: Steps 5-7

Step 5: Re-evaluate

The re-evaluation of available facts can often be made during the trial run. Look over your list of possible causes and decide which are most likely and which are easiest to verify.

Remember that in some instances, more than one factor may be contributing to the problem and must be considered in the solution.

Step 6: Test Your Conclusions

After determining the apparent cause(s) of appliance problem, perform a second test run to see if the evaluation is correct.

If you haven't found the answer, make a new evaluation that includes any new information that has been obtained during the second test run.

Step 7: Correct the Condition(s)

At this stage, you would be confident in adjusting or replacing the faulty part(s).

Note that not all parts can be adjusted in the field - check with the manufacturer's manual.

Do a final run through to check that the problem has been solved.

Typical Electrical Checks and Readings

Performing a thorough electrical check on the system allows you to pinpoint whether the fault is electrical or mechanical. Mechanical failures include bent, damaged, or seized components such as shafts, rods, and operators.

The following procedures show how to conduct common electrical tests in order to isolate a problem. Note that this circuitry is only one of many you will encounter. On modern equipment, all of the logic and sequencing circuitry is within electronic modules.

For the purpose of understanding the operation and sequencing of components, it is best to first study the troubleshooting of older control schemes as all of the logic can be seen within the actual wiring.

Safety Warning for Live Testing

Never Work on Live Circuits Without Authorization

Never work on live circuits unless you are authorized and supervised!

Use Proper PPE

Before proceeding with any live testing of electrical, ask yourself if you have all the personal protective equipment required to keep you safe.

Follow Safety Standards

CSA Z462 provides the minimum requirements that should be followed for electrical safety in the workplace.

Problem 1: No 120V Power Supply

Check Source Voltage

Check for source voltage by testing A to B and A to G. It should be 120V.

Verify Switch Position

If the switch is in closed (on) position and there is no voltage reading, check whether the disconnect switch is closed.

Check Circuit Breaker

If disconnect is closed (on), check voltage S to G. If you get a 0 reading, check whether the branch circuit breaker at the main electrical panel has tripped.

Replace Switch If Needed

If you obtain a 120V reading and switch contacts have failed to close, replace the switch.

Problem 2: Fan Motor Fails to Run

Check Source Voltage

Check for source voltage in the junction box. Place a voltmeter across A to B to see if 120V are present.

Check Fan Switch

If you obtain a 120V reading in the junction box, check the voltage across fan switch C-D. If the main burner is operating and the heat exchanger is above the fan-on set point, the fan switch should be closed (on) and the voltmeter should read 0V.

Replace Switch If Needed

If the fan switch contacts are open and the voltmeter reads 120V, replace the switch.

Check Motor Terminal Voltage

Check the voltage at motor terminal E-G. This should read 120V to indicate there is power to terminal E.

Problem 2: Fan Motor Fails to Run (Continued)

Check E to F Voltage

Check E to F. It will read 120V whether or not the motor windings are good.

Check Motor Windings

To check the condition of the motor windings, disconnect the wiring from E and reset the meter scale to read ohms. Place the meter leads across the motor terminals and watch the meter.

- If the ohms scale moves to infinity, the windings are burnt out
- If the reading is 0Ω, the motor windings have a dead short to ground
- A normal winding would display several ohms of resistance produced by the large amount of wiring in the motor winding

Note: A voltmeter will display the same 120V reading across a properly operating motor winding and one that is burned out.

Problem 3: Transformer Secondary Not Powered

Check Source Voltage

Check for source voltage in the junction box between the wire connections A to B. If no power is available, refer to the troubleshooting procedure in Problem 1.

Check High Limit Switch

If you obtain a 120V reading in the junction box, check the voltage across high limit terminals H-I. A reading of 120V indicates the switch is open. The switch is faulty and should be replaced.

Check Voltage at Terminal L

Check the voltage drop between L-G. This will indicate 120V if power is present at terminal L.

Check Primary Winding

Check J-L. It will read 120V whether or not the transformer coil is in good working order.

Problem 3: Transformer Secondary Not Powered (Continued)

Check Primary Winding Condition

To check the condition of the transformer windings, disconnect the wiring from L and reset the meter scale to read ohms. Place the meter leads across terminals J-L and watch the meter.

- If the ohms scale moves to infinity, the coil winding is broken
- If the reading is 0Ω, the transformer coil has a direct short
- Replace the transformer in either case
- If the coil is all right, several ohms of resistance will register

Check Secondary Winding

Place the meter leads across terminals K-M and watch the meter.

- If the ohms scale moves to infinity, the secondary winding is broken
- If the reading is 0Ω, the transformer coil has a direct short
- If the coil is all right, several ohms of resistance will register

Note: A voltmeter indicates the same reading across normally operating transformer windings regardless of whether or not the windings are good. You must use the ohmmeter to determine the condition of the winding. Double check that the power has been disconnected!

Problem 4: Main Burner Fails to Operate

Check Transformer Secondary Voltage

Check the source voltage at terminals K-M on the secondary side of the transformer. It should show 24V. If no voltage reading is obtained, refer to the troubleshooting procedure in Problem 3.

Check Thermostat

Check the voltage across P-O of the thermostat. On a call for heat, the thermostat contacts are closed, and the meter reading should be 0V.

If the contacts have failed to close or the circuit is open (broken/loose wire, heat anticipator is burnt out), the reading will be 24V. Replace the thermostat.

Check Gas Valve Voltage

If the thermostat is all right, take a voltage reading across terminals N-O of the gas valve. It will read 24V whether or not the valve coil is still in good working order.

Problem 4: Main Burner Fails to Operate (Continued)

Check Gas Valve Coil

To check the condition of the valve coil, disconnect the wiring from N, and reset the meter scale to read ohms. Place the meter leads across terminals N-O and watch the meter.

Interpret Readings

- If the ohms scale moves to infinity, the coil is burnt out
- If the reading is 0Ω, the coil has a direct short
- If the coil is all right, several ohms of resistance will register

Take Action

Replace the gas valve if the coil is burnt out or has a direct short.

Testing Intermittent Pilot Ignition Control Modules

The following testing and troubleshooting procedures provide a general method for testing intermittent pilot systems. For the purpose of this explanation, the Honeywell S86 control module will be used.

Although the procedure for testing control modules follows a similar sequence as outlined below, use the instructions and guides specific to the make and model of the control module you are testing and troubleshooting.

Preliminary Checks

Initial inspection of power, gas supply, and wiring

System Troubleshooting

Observing system response and identifying issues

Component Checks

Testing specific components to isolate problems

Preliminary Checks for Intermittent Pilot Systems

1. **Check Power Supply**

   Check the disconnect switch and fuse to the S86 control system.

2. **Verify Gas Supply**

   Check that the manual shut-off valve in the gas line to the appliance is open.

3. **Inspect Wiring**

   Ensure all wiring connections are clean and tight.

4. **Check Lockout Status**

   Check that the module is not in safety lockout. If it is in lockout, follow the procedure described for resetting the system after lockout.

System Troubleshooting for Intermittent Pilot Systems

Start the System

Start the system by setting the temperature controller above room temperature.

Observe Response

Observe the system response carefully during startup and operation.

Identify Malfunction

Establish the type of system malfunction or deviation from normal operation by using manufacturer's sequence of operation or troubleshooting charts.

Continue Checking

Continue checking until a solution, or how to make the repair, is fully clear to you.

Component Checks for S86 Control Module

Reset System After Lockout

Procedure to reset the module before further operation or checkout

Check Spark Ignition Circuit

Testing the high voltage spark generation circuit

Check Spark Igniter

Inspecting the physical condition and positioning of the igniter

Check Grounding

Verifying proper electrical grounding of components

Check Flame Sensor Circuit

Testing the flame detection capability

Resetting System After Lockout

S86 Control Module Lockout

If a system with an S86 C, D, G, or H control module goes into safety lockout (other S86 modules do not offer this feature), reset the module before attempting further operation or checkout. The system will remain in safety lockout until it is reset.

Reset Procedure

1. Shut off the system by adjusting the thermostat below room temperature or adjusting the controller to Off or disconnecting electrical power.
2. Wait at least one minute, then turn the system on.

Checking Spark Ignition Circuit

The electronic module and step-up transformer in the S86 provide spark ignition at 15,000V (open circuit). You can check this circuit at the S86 module as follows:

Prevent Gas Flow

Turn off the manual gas valve to prevent the flow of gas.

Isolate Circuit

Disconnect the ignition cable at the S86 stud terminal to isolate the circuit from the pilot burner/igniter-sensor.

Prepare Test Jumper

Prepare a short jumper lead using heavily insulated wire, such as ignition cable.

Caution! Do not touch any bare wires or terminals. This is a very high voltage circuit, and electrical shock can result from improper handling of the cables.

Test Spark Generation

Energize the S86 while touching one end of the jumper firmly to the S86 ground terminal (GND). Do not disconnect the existing ground lead.

Checking Spark Ignition Circuit (Continued)

Create Test Spark

Move the free end slowly toward the stud terminal to establish a spark.

Measure Arc Length

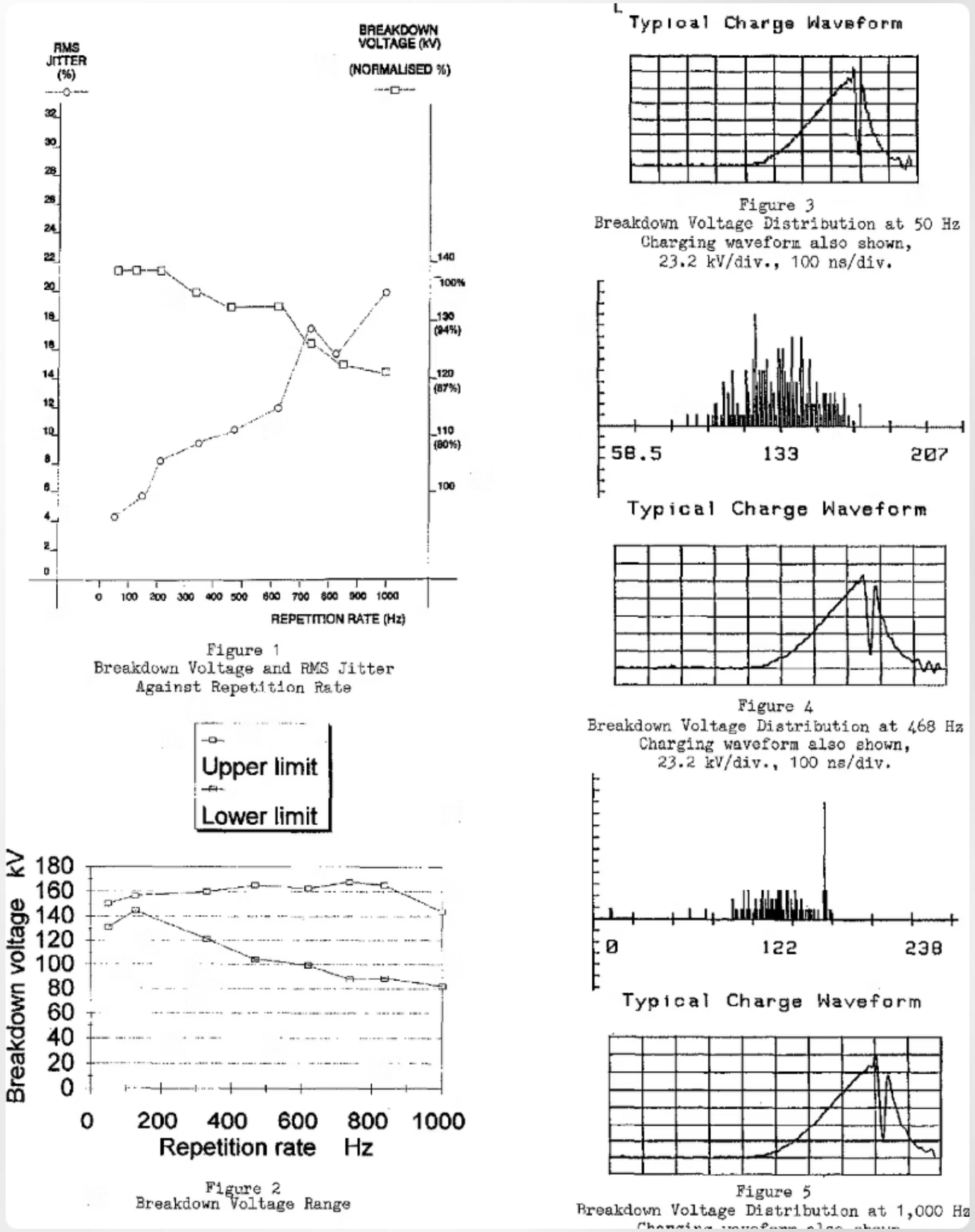
Pull the jumper lead slowly away from the stud. Note the length of the gap at which arcing stops.

Evaluate Results

An arc length of 1/8 inch (3.2 mm) or more indicates satisfactory voltage output.

Take Action

Replace the S86 if no arc can be established or the maximum gap is less than 1/8 inch (3.2 mm) and the fuse and power to the S86 input terminal are all right.



Checking Spark Igniter and Pilot Flame

Check Igniter Spark-Gap

Check the igniter spark-gap to make certain it is correct: 1/8 inch (3.2 mm).

If necessary, use needle-nose pliers and carefully bend the tip of the outer electrode to the correct position.

Check Pilot Flame Adjustment

Check that the pilot flame is properly adjusted to cover 3/8 to 1/2 inch (9.5 to 12.7 mm) of the tip of the igniter sensor.

Proper pilot flame adjustment ensures reliable ignition and flame sensing.

Checking Ignition Cable

1. ### Check Cable Routing

   The ignition cable must not touch metal surfaces or current-carrying wires. Use ceramic standoff insulators, if necessary.

2. ### Verify Cable Length

   Check the length of the ignition cable, which must not exceed 3 ft (0.9 m).

3. ### Inspect Connections

   Check that connections to the igniter and control module stud are clean and tight. (Loose connections may not conduct a flame current even though the ignition spark is satisfactory.)

4. ### Test Continuity

   Check the electrical continuity of the cable.

5. ### Replace If Damaged

   Replace the cable if it is damaged or has deteriorated.

Additional Spark Ignition Circuit Checks

Disconnect Cable at Igniter

If the spark ignition circuitry check was all right, yet no spark or a weak spark occurs, disconnect the ignition cable at the igniter (or igniter-sensor).

Measure Arc from Cable

Measure the arc from the cable end to the igniter stud.

Caution! Do not touch either the exposed end of the jumper or the stud terminal. This is a very high voltage circuit, and electrical shock can result.

Replace Igniter If Needed

If the arc is correct, replace the igniter (or igniter-sensor).

Test with Jumper Wire

If the arc is less than it should be, disconnect the ignition cable and use a jumper wire from the control module stud terminal.

Checking Grounding

A common ground is required for the pilot burner, the igniter-sensor, the GND terminal of the S86, and the main burner. The main burner generally serves as the common ground.

Importance of Good Grounding

If the ground is poor or erratic, safety shutdowns may occur occasionally even though operation is normal at the time of the checkout. Therefore, if nuisance shutdowns have been reported, be sure to check the grounding precautions.

S86 System Control Behavior

Note that if the ground circuit path is incomplete, the S86 C, D, G, and H system control will allow one trial-for-ignition before going into safety lockout.

Ground Connection Quality

Electrical ground connections at the pilot burner, igniter-sensor, and S86 must be clean and tight. If the lead wire is damaged or deteriorated, use only No. 14 or 18-gauge, moisture-resistant, thermoplastic insulated wire with 105°C (221°F) minimum rating for replacement.

Checking Flame Sensor Circuit

The control module provides AC power to the igniter-sensor which the pilot burner flame rectifies to DC. If the flame signal back to the control module is not at least 1.5 microampere (μA) DC, the system will lock out.

Since the output of the flame sensing circuit cannot be checked directly, check the flame sensing circuit indirectly by checking the flame sensing current from the igniter-sensor to the control module as follows:

Connect Meter

Connect a meter (DC microammeter scale) in series with the flame signal ground wire.

Disconnect Ground Wire

Disconnect the ground wire at the control module.

Connect Meter Leads

Connect the red (positive) lead of the meter to the free end of the ground wire. Connect the black (negative) meter lead to the quick-connect ground terminal on the control module.

Read Flame Current

Restart the system and read the meter. The flame sensor current must be at least 1.5 μA, and the reading must be steady.

Testing Direct Spark Ignition Control Modules

The following provides a general method for testing direct spark ignition systems (DSI). For the purpose of this explanation, the Honeywell S87 control module will be used.

Although the procedure for testing control modules follows a similar sequence as outlined below, use the instructions and guides specific to the make and model of the control module you are testing and troubleshooting.

Preliminary Checks

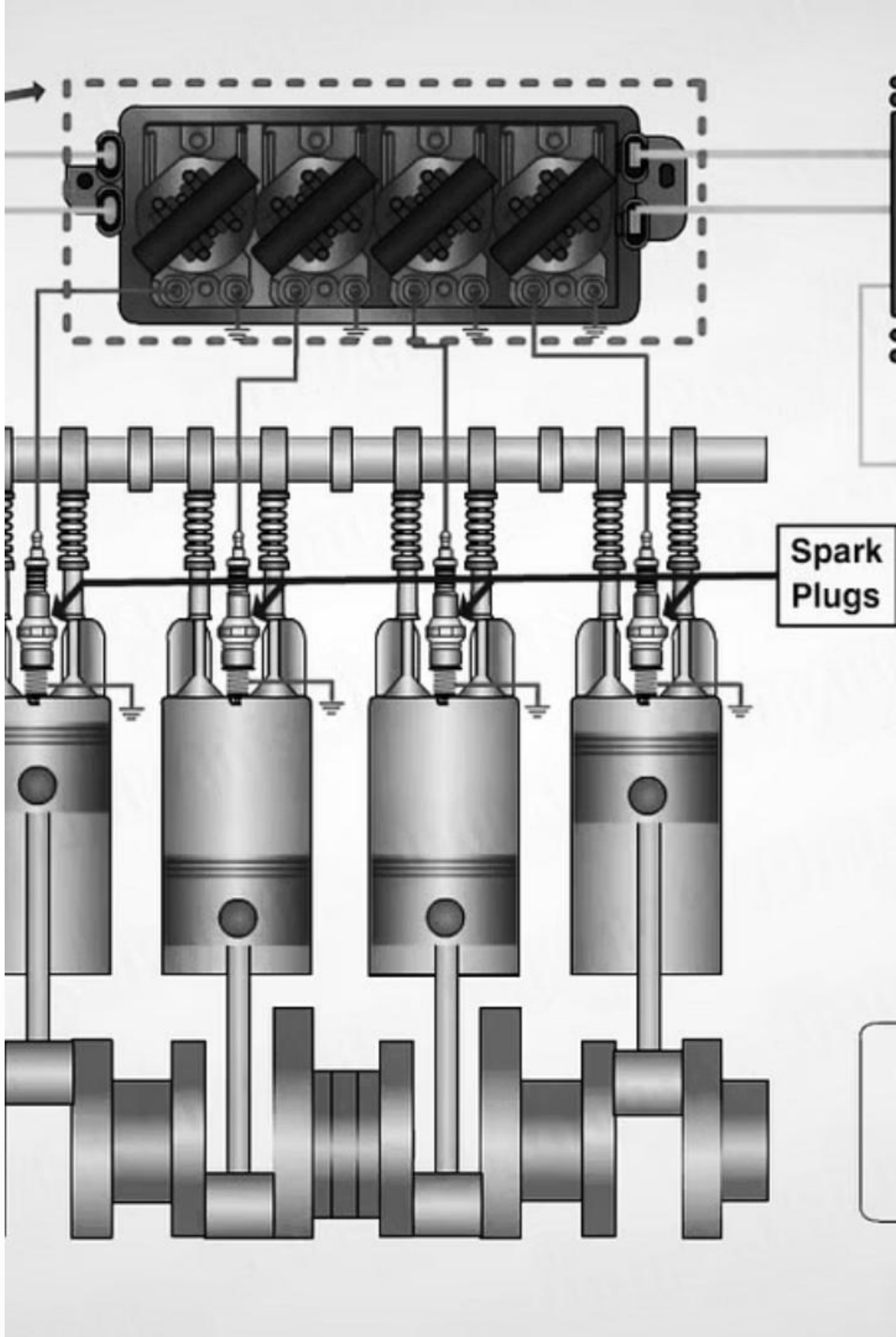
Initial inspection of power, gas supply, and wiring

System Troubleshooting

Observing system response and identifying issues

Component Checks

Testing specific components to isolate problems



Preliminary Checks for Direct Spark Ignition Systems

1. **Check Power**

   Check the power to the appliance and control module.

2. **Check Fuse**

   Check the fuse on the control module and replace if necessary.

3. **Verify Gas Supply**

   Check that the manual shut-off valve in the gas line to the appliance and the automatic gas valve are open.

4. **Inspect Wiring**

   Make sure all wiring connections are clean and tight.

5. **Check Lockout Status**

   Check that the module is not in safety lockout. If it is in lockout, follow the procedure for resetting the system after lockout.

6. **Inspect Ceramic Insulators**

   Check the ceramic insulator on the flame sensor and spark igniter or on the igniter-sensor. A cracked insulator will allow current to leak to ground.

7. **Check Flame Sensor Position**

   Check the flame sensor and its mounting bracket. Correct its position if it is bent out of shape.

System Troubleshooting for Direct Spark Ignition

Start the System

Start the system by setting the temperature controller above room temperature.

Observe Response

Observe the system response during startup and operation.

Identify Malfunction

Establish the type of system malfunction or deviation from normal operation by using the manufacturer's sequence of operation or a troubleshooting table provided by the manufacturer.

Follow Troubleshooting Chart

Follow the questions supplied by the manufacturer's troubleshooting chart.

Continue Checking

Continue checking until a solution, or how to make the repair, is fully clear to you.

Component Checks for S87 Control Module

Reset System After Lockout

Procedure to reset the module before further operation

Check Spark Ignition Circuit

Testing the high voltage spark generation circuit

Check Spark Igniter

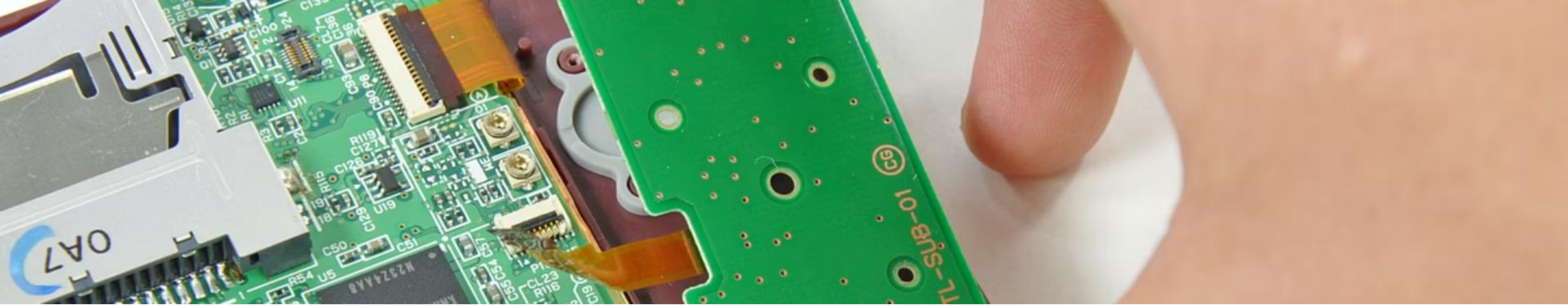
Inspecting the physical condition and positioning of the igniter

Check Grounding

Verifying proper electrical grounding of components

Check Flame Sensor Circuit

Testing the flame detection capability



Resetting S87 System After Lockout

S87 Control Module Lockout

If a system with an S87 control module goes into safety lockout, the module must be reset before attempting further operation or checkout. The system remains in safety lockout until it is reset.

Reset Procedure

1. Shut off the system by adjusting the thermostat below room temperature or adjusting the controller to Off or disconnecting electrical power.
2. Wait at least 30 seconds, then turn the system on.

Checking S87 Spark Ignition Circuit

The electronic module and step-up transformer in the S87 provide spark ignition at 30,000V (open circuit). This circuit can be checked at the S87 module as follows:

Prevent Gas Flow

Turn off the manual gas valve to prevent the flow of gas.

Isolate Circuit

Disconnect the ignition cable at the S87 stud terminal to isolate the circuit from the igniter or igniter/sensor.

Prepare Test Jumper

Prepare a short jumper lead using heavily insulated wire, such as ignition cable.

Test Spark Generation

Energize the S87 while touching one end of the jumper firmly to the GND.

Caution! Do not touch any bare wires or terminals. This is a very high voltage circuit and electrical shock can result.

Checking S87 Spark Ignition Circuit (Continued)

Maintain Ground Connection

Do not disconnect the existing ground lead.

Create Test Spark

Move the free end slowly toward the stud terminal to establish a spark.

Measure Arc Length

Pull the jumper lead slowly away from the stud. Note the length of the gap at which arcing stops.

Evaluate Results

An arc length of 1/8 inch (3.2 mm) or more indicates satisfactory voltage output.

Take Action

Replace the S87 if no arc can be established or the maximum gap is less than 1/8 inch (3.2 mm), and the power to the S87 input terminal was all right.

Checking DSI Spark Igniter

Check Igniter Position

Make sure that the spark igniter is positioned so that the ground electrode portion of the igniter is not blocking the gas flow.

Check Spark Gap

Check the igniter spark-gap to make certain it is correct, 5/32 to 3/16 inch (4-5 mm).

If necessary, use needle nose pliers and carefully bend the tip of the outer electrode to its correct position.

Check Electrode Placement

Immerse only the tips of the electrodes in the burner flame. Spacing between tip assembly and burner head is generally 1/4 to 1/2 inch (6-13 mm).

Check for bent mounting bracket.

Checking DSI Ignition Cable

1. ## Check Cable Routing

The ignition cable must not touch metal surfaces or current-carrying wires. Use ceramic standoff insulators, if necessary.

2. ## Verify Cable Length

Check the length of the ignition cable. It must not exceed 3 ft (0.9 m).

3. ## Inspect Connections

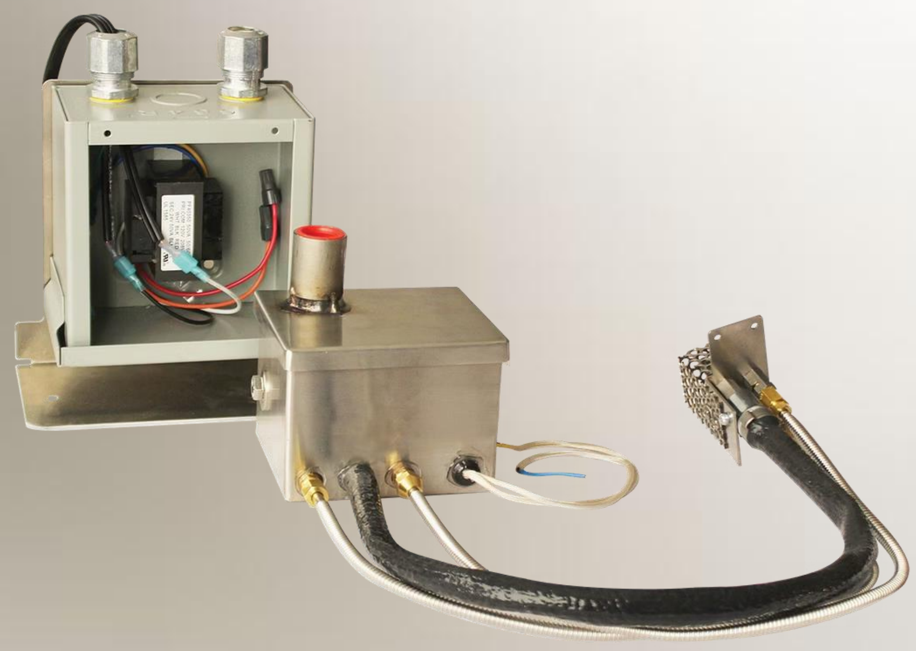
Check that connections to the igniter and control module stud are clean and tight. Loose connections may not conduct a flame current even though the ignition spark is satisfactory.

4. ## Test Continuity

Check the electrical continuity of the cable.

5. ## Replace If Damaged

Replace the cable if it is damaged or deteriorated.



Testing Hot Surface Ignition Control Modules

Hot surface ignition systems are used in a wide variety of central heating equipment and on appliances found in agricultural equipment, industrial heating equipment, and pool heaters. For the purpose of this explanation, the Honeywell S89 and S890 control modules will be used.

Although the procedure for testing control modules follows a similar sequence as outlined below, use the instructions and guides specific to the make and model of the control module you are testing and troubleshooting.

Preliminary Checks

Initial inspection of power, gas supply, and wiring

System Troubleshooting

Observing system response and identifying issues

Component Checks

Testing specific components to isolate problems

Preliminary Checks for Hot Surface Ignition Systems

1. **Check Power Supply**

   Check disconnect switch and fuse to the S89 or S890 control system.

2. **Verify Gas Supply**

   Check that the manual shut-off valve in the gas line to the appliance is open.

3. **Inspect Wiring**

   Ensure all wiring connections are clean and tight.

4. **Check Lockout Status**

   Check that the module is not in safety lockout. If it is in lockout, follow the procedures for resetting the system after lockout.

System Troubleshooting for Hot Surface Ignition

Start the System

Start the system by setting the temperature controller above room temperature.

Observe Response

Observe the system response during startup and operation.

Identify Malfunction

Establish the type of system malfunction or deviation from normal operation by using the manufacturer's sequence of operation or troubleshooting chart.

Continue Checking

Continue checking until a solution, or how to make the repair, is fully clear to you.

Component Checks for S89/S890 Control Modules

Reset System After Lockout

Procedure to reset the module before further operation

Check Ignition System

Testing the hot surface igniter and related components

Check Grounding

Verifying proper electrical grounding of components

Check Flame Sensor

Testing the flame detection capability

Hot Surface Ignition Module Operation Phases

Pre-purge

For the S890 only - clears combustion chamber

Igniter Warm Up

Heating the igniter to ignition temperature

Burner Operation

Normal running with flame supervision

Trial-for-Ignition

Opening gas valve and attempting ignition

The S89 and S890 provide 100% shut-off or safety lockout on ignition failure or on loss of established flame. Modules offer either one or three trials-for-ignition.

Checking Hot Surface Ignition System

Check Ignition Wire

Ensure ignition wire does not touch any metal surface.

Inspect Connections

Connections to the module and the igniter-sensor must be clean and tight.

Test Wire Continuity

Ignition wire must provide good electrical continuity.

Proper installation and maintenance of the hot surface ignition system components is essential for reliable operation. Any issues with wiring or connections can lead to ignition failures or inconsistent performance.

Checking System Grounding for Hot Surface Ignition

Nuisance shutdowns are often caused in hot surface ignition systems by a poor or erratic ground. A common ground is required for the module, igniter, flame sensor, and main burner.

1 Check Metal-to-Metal Contact

Check for good metal-to-metal contact between the igniter bracket and the main burner.

2 Inspect Ground Lead

Check the ground lead from the GND (burner) terminal on the module to the igniter bracket.

3 Replace Damaged Wire

If the wire is damaged or deteriorated, replace it with No. 14 or 18-gauge, moisture-resistant, thermoplastic insulated wire with 105°C (221°F) minimum rating.

4 Protect from Heat

Use a shield, if necessary, to protect the ground wire from radiant heat.

5 Check Temperature

Check the temperature at the igniter ceramic or flame sensor insulator. Excessive temperature will permit leakage to ground.

Testing Integrated Control Modules

Expanded Functionality

Just like the previous ignition control modules, integrated controls are solid state devices that do not only control the appliance ignition but also manage all other aspects of the appliance.

For a furnace, these could include two-stage burner operation, variable fan speed, variable induced blower speed, electronic air cleaner, and humidifier.

Boiler Controls

For a boiler, these could be such things as room temperatures, outdoor air temperature, boiler water temperature, return water temperature, firing rate, domestic hot water, boiler pump, system pumps, and zone water temperatures.

The troubleshooting skills used previously on older wiring circuits are still relevant for modern electronic controls as the problem will often be with one of the external switches, sensors, or loads that are connected to the module.

Troubleshooting Integrated Controls

Common Misconceptions

Far too often, the first assumption is that the module is at fault when in fact there is simply a bad connection to one of the external devices, or a wiring short has caused a fuse to burn out.

Fault Analysis

One of the additional benefits of microprocessor control is their ability to continually monitor the appliances operation. When an error occurs, it can communicate the fault analysis to the operator via fault LEDs or a code displayed on a user interface.

Testing Features

Often the module will test pins for checking the flame current as well as a fault code retrieval push button. Depending on the complexity of the equipment, the number of potential faults can vary greatly.

Fault Code Display Methods

LED Flash Codes

Some modules will display faults using a single LED with multiple flashes. If the list of errors is short, they can be shown right on the module.

For appliances with more complex operations and/or additional external components, the list of codes will increase. LED Flash code tables show that the LED changes color to give normal status indicators as well as faults.

Digital Displays

More advanced systems may use digital displays or user interfaces to show detailed fault information. These can provide more specific information about the nature of the fault and potential solutions.

Some systems store multiple fault codes in memory, allowing technicians to see a history of issues that have occurred over time.

Recalibrating and Replacing Components

Most controls are factory set or set upon installation of appliances according to manufacturer's instructions. For this reason, never disturb settings unless you have definitely determined that the appliance malfunction is due to an improper setting.

Readjustment and Recalibration

Some controls may be recalibrated or readjusted on the owner's premises. Some examples include room thermostats, heat anticipators, oven thermostats, improperly operating gas valves, spark ignition electrode gaps, some pilots, and some solid-state control elements.

Most electronic controls cannot be field calibrated and must be returned to the manufacturer or replaced.

When recalibrating or readjusting controls, always follow manufacturer's instructions.

Replacement

Field repair of controls is often not practical. In many cases, it is cheaper and safer to replace controls than to repair them. This depends, of course, on the nature of the control and the repair required.

The solenoid may be replaced on a solenoid valve for instance, but a broken expansion bulb thermostat could be replaced for less expense than a repair would cost.

Most electronic controls are not repairable and must be replaced.

Replacing Electronic Control Modules

Verify the Fault

If the fault is in fact the control module and it needs replacement, make sure it is a manufacturer-approved matching component.

Compare Components

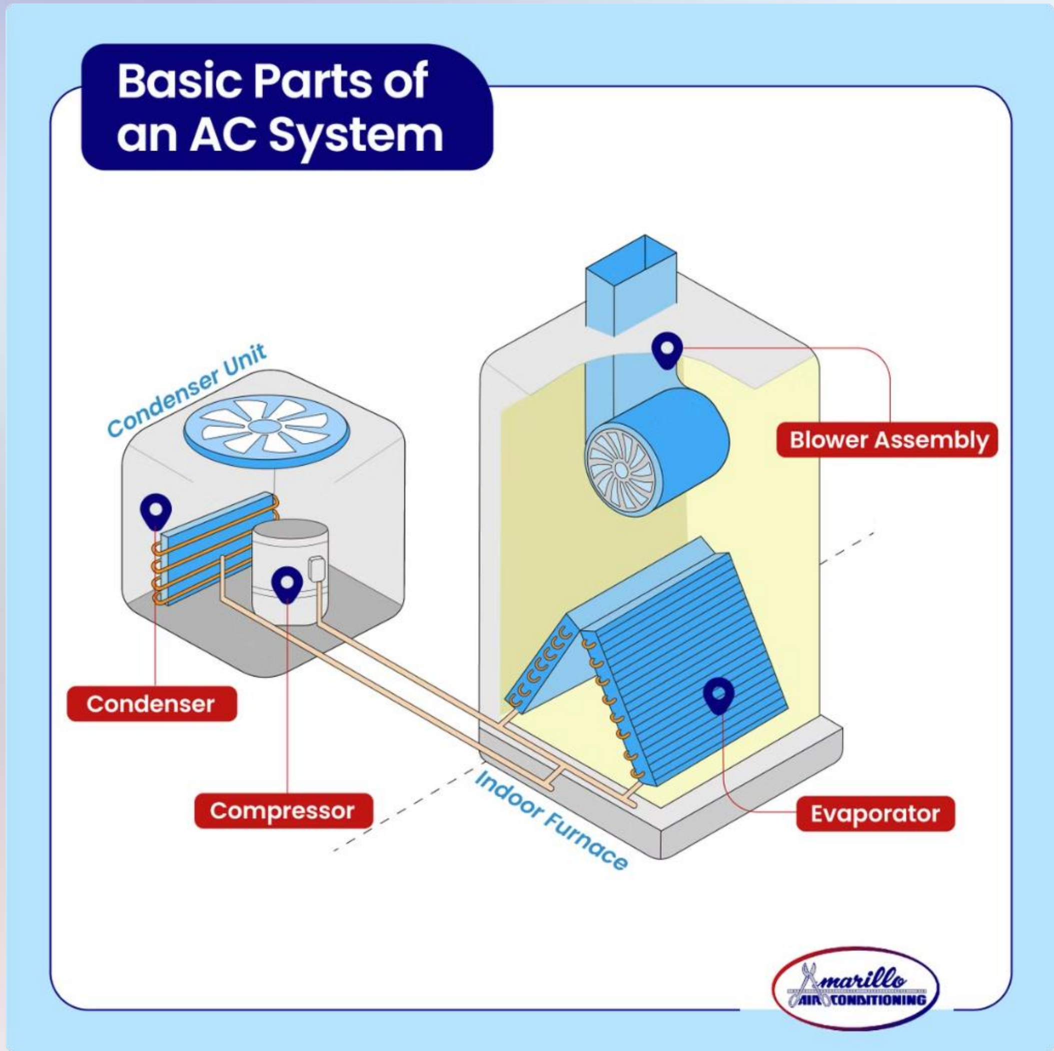
When it has been unpackaged, compare it to the existing unit to ensure the connections are a match.

Label Wires

Label all the wires before disconnecting them from the old module. Taking a picture can be helpful.

Match Settings

Check the DIP switch settings on the new module to match the old one.



Replacement Component Options

Like-for-Like Replacement

Although this is the simplest solution, the component may be outdated and difficult to locate.

Universal Component

The advantages of universal components are that you can keep a supply of the most standard ones in your van and you will also become familiar with their installation and operation, thus increasing your efficiency on the job.

System Upgrade

This option, although more expensive initially for the customer, may well save them money in the long run. Moreover, standards continue to improve, and so the homeowner will benefit from current safety standards as well as current research and manufacturing technology.

Considerations for Component Selection

When replacing components, review CSA B 149.3 for the field acceptance of ignition systems (e.g., from standing pilot to automatic ignition), automatic safety shut-off valves, pilot-operated safety shut-off valves, and miscellaneous requirements.

Purpose of Operation

The component must serve the same function

Sequence of Operation

Must fit into the existing control sequence

Mechanical Characteristics

Physical operation must be compatible

Electrical Characteristics

Switching actions and amperage ratings must match

Differential Settings

Control ranges must be appropriate

Physical Dimensions

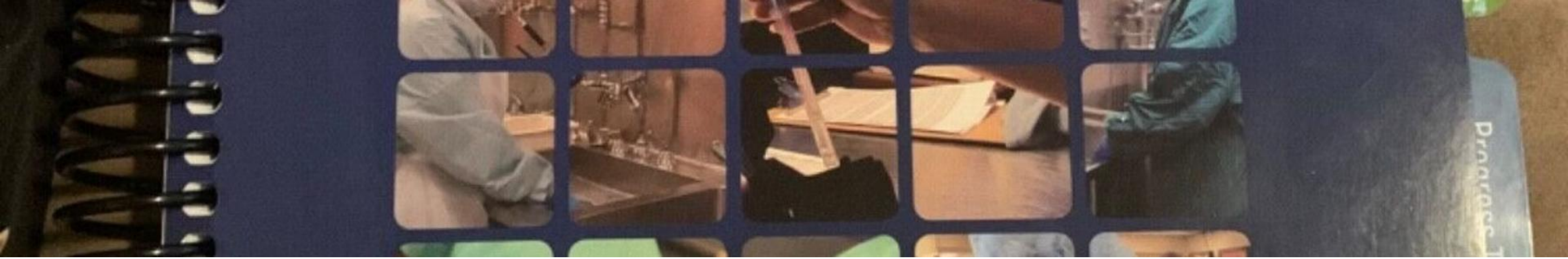
Mounting characteristics and size must fit

Resets

Manual or automatic reset as required

Availability

Parts must be obtainable in a timely manner



Final Considerations for Component Replacement

Ensure Proper Operation

To ensure proper and safe operation of the mechanical equipment, it is necessary that field replacement controls and wiring corrections provide the same operation and protection as was originally intended.

Consult Manufacturer

Always consult the manufacturer for an approved replacement.

Follow Safety Standards

Adhere to all applicable codes and standards when replacing components to ensure safe and reliable operation.

Proper component selection and installation is critical for both safety and performance. Taking shortcuts or using unapproved parts can lead to dangerous conditions and equipment failure. Always prioritize safety and manufacturer specifications when servicing gas equipment.