# Millivolt Systems – Magnetism and Thermogeneration


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Part Two of Electricity Basics
Millivolt gas hearth systems have been the industry standard for many years. Understanding how "self-powered" systems produce their electricity and how that voltage creates magnetism is the foundation for understanding millivolt troubleshooting. This session will tie in concepts from Part One, discuss the nature of the various components of millivolt systems, and provide a clear path for diagnosing and fixing both common and complex issues.



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# ELECTRICITY BASICS PART 2

## ELECTROMAGNETISM & THERMOGENERATION

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# PURPOSES AND LIMITATIONS

# REMINDER

Do not perform any work that you are not qualified or licensed to perform. The information provided during this presentation does not in any way encourage anyone to risk their professional status or personal health by engaging in work that they are unqualified to do. Merely attending this presentation will not make someone qualified to do electrical work.

Working with electricity can be extremely dangerous. Do not put yourself or others at risk by doing work that you shouldn't.

# OVERVIEW

The ability to troubleshoot hearth products has become increasingly dependent on an understanding of electricity and electronics. Some technicians have tried to avoid those aspects of our work because of a lack of confidence or outright fear. Knowledge and experience will allow any technician to successfully troubleshoot the electronic systems we encounter.

That being said, we are going to try to cram years worth of information into 60 minutes . . .

# OVERVIEW

Terminology (Part 1)

Common issues with 120VAC circuits (Part 1)

Concepts we use in hearth products (mostly gas)

**Millivolt systems**

Electronic ignition (Part 3)

# OVERVIEW

- It is important to have a basic understanding of these topics:
  - The relationship between voltage, current and resistance (part 1)
  - Electromagnetism & the Seebeck effect
  - Open and closed circuits
  - Electronic flame sensing (part 3)
  - How to use basic diagnostic tools

# TERMINOLOGY

Electricity is the movement of free atomic particles – electrons – through materials. The ability of a material to let electrons flow freely is **conductivity**.

Some materials are very conductive: gold, copper, steel, etc.

Some are not: glass, ceramic, silicone (insulators).

In some cases, dirt, corrosion, oxidation, condensation and other foreign matter can make conductive materials less conductive *and vice versa*.

# TERMINOLOGY

A **source** is the power supply, either alternating current (AC) or direct current (DC).

A wall outlet is AC, a battery pack is DC, a transformer can be either one.

**Voltage** is the *force* that drive the electrons, analogous to water ***pressure***.

Low voltage can be handled safely because it does not have the strength to overcome the resistance of our skin.

Line voltage (110-120VAC) is powerful enough to break the skin resistance and give a person a shock.

High voltage (thousands of volts) can jump through the air, as in a piezo ignitor or other spark ignition.

A millivolt is one thousandth of a volt, so 500 MV = ½ volt

# TERMINOLOGY

**Current** is the volume of electricity, measured in amperes.

Amperage is analogous to water ***volume***. Trying to get 1500 gallons per minute through a garden hose is pretty much impossible, but a firehose should be able to handle it.

Likewise, small gauge wiring cannot carry high amperage. It will overheat, causing other issues.

# DIGITAL MULTIMETER

- Need Direct Current **volts.** down to millivolts (tc, tp)
- Need Alternating Current **volts** (house current, transformers)
- Need **Ohms** (resistance)
- Continuity is nice (audible)
- Rarely need Amps (current) except for HSI systems

# MILLIVOLT SYSTEMS

- Millivolt systems provide their own power, so do not require outside battery power or line voltage to operate. Millivolt systems have been the industry standard for decades, and are in some ways simpler to troubleshoot than electronic ignition systems.
- The electrical/scientific basis for millivolt systems is the Seebeck effect and electromagnetism.

# MILLIVOLT VALVES





Millivolt Valve with 3 terminals labeled TPTH - TP - TH

TH = thermostat (switch)    TP = thermopile    THTP= common

# MILLIVOLT VALVES

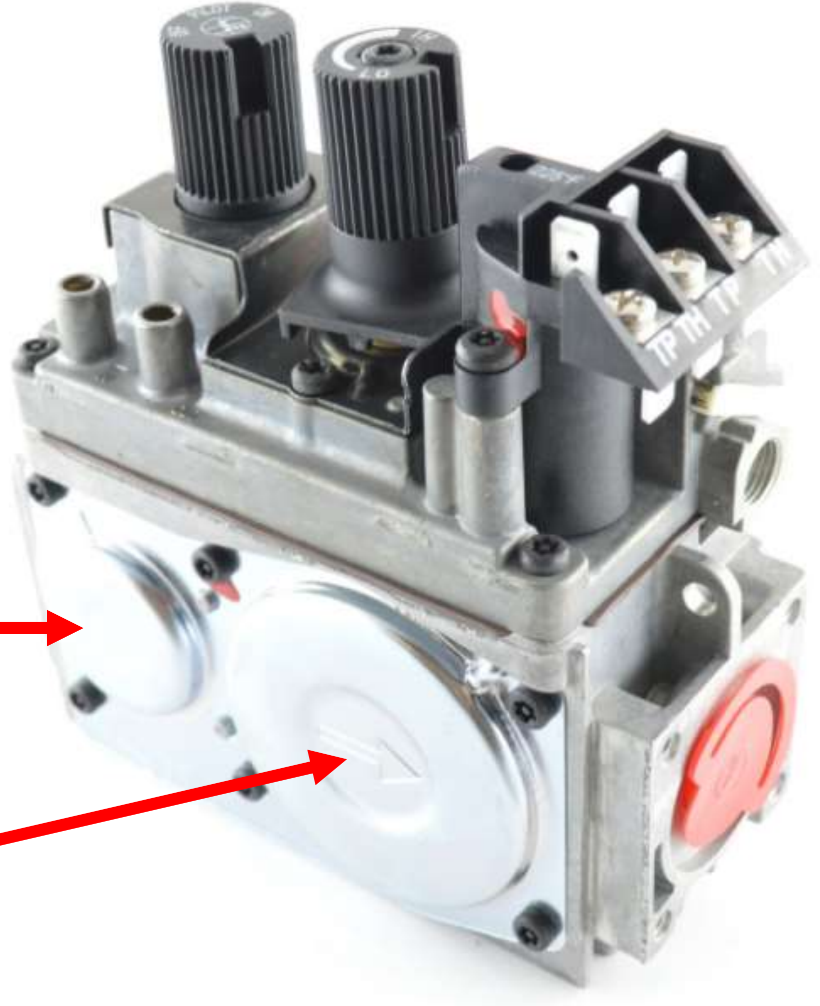
Black
EPU wire

# MILLIVOLT VALVES

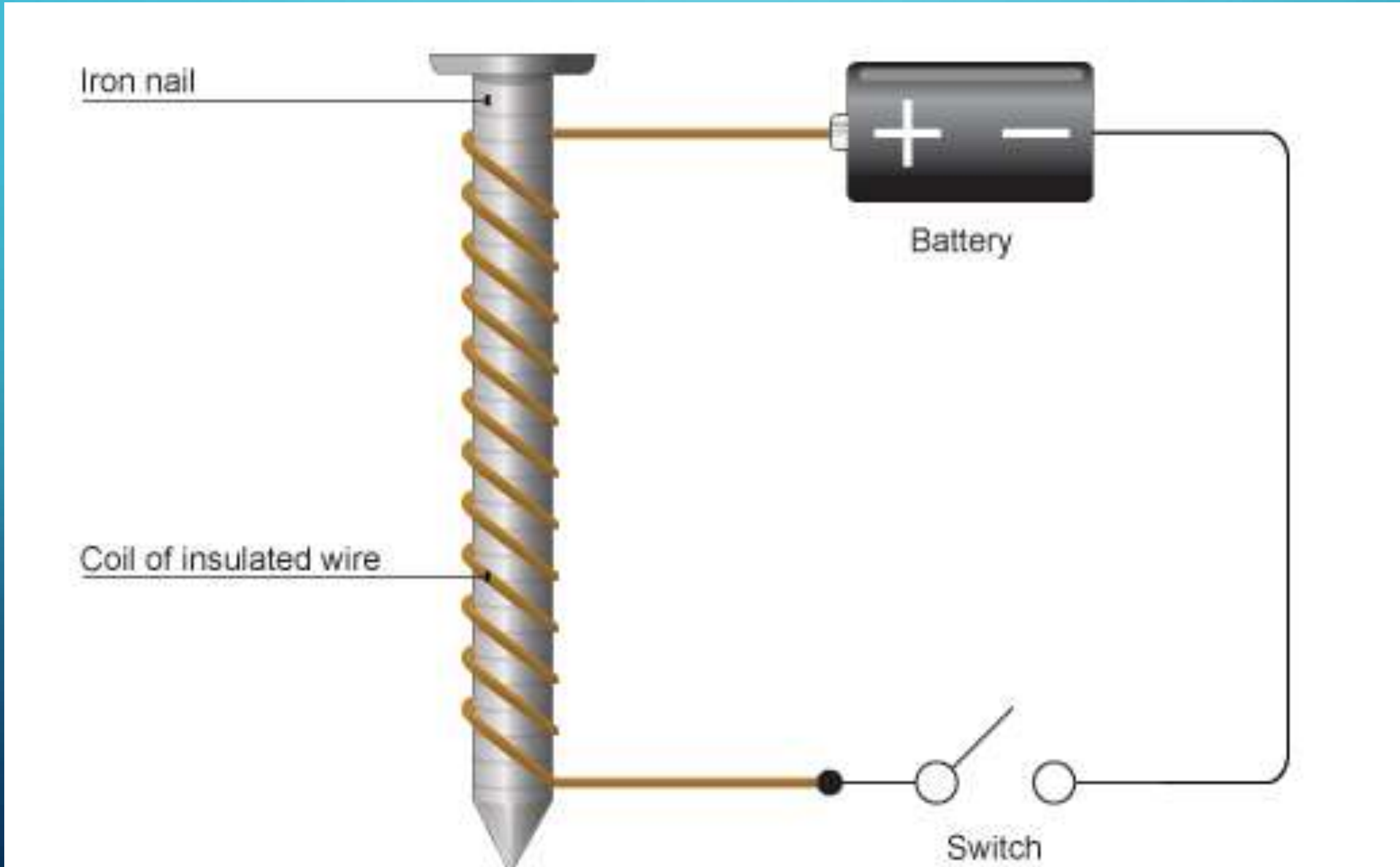
Valve contains two electromagnetics

Pilot side – “keeper”
Energized by thermocouple

Main burner – operator head
Energized by thermopile



# ELECTROMAGNETISM



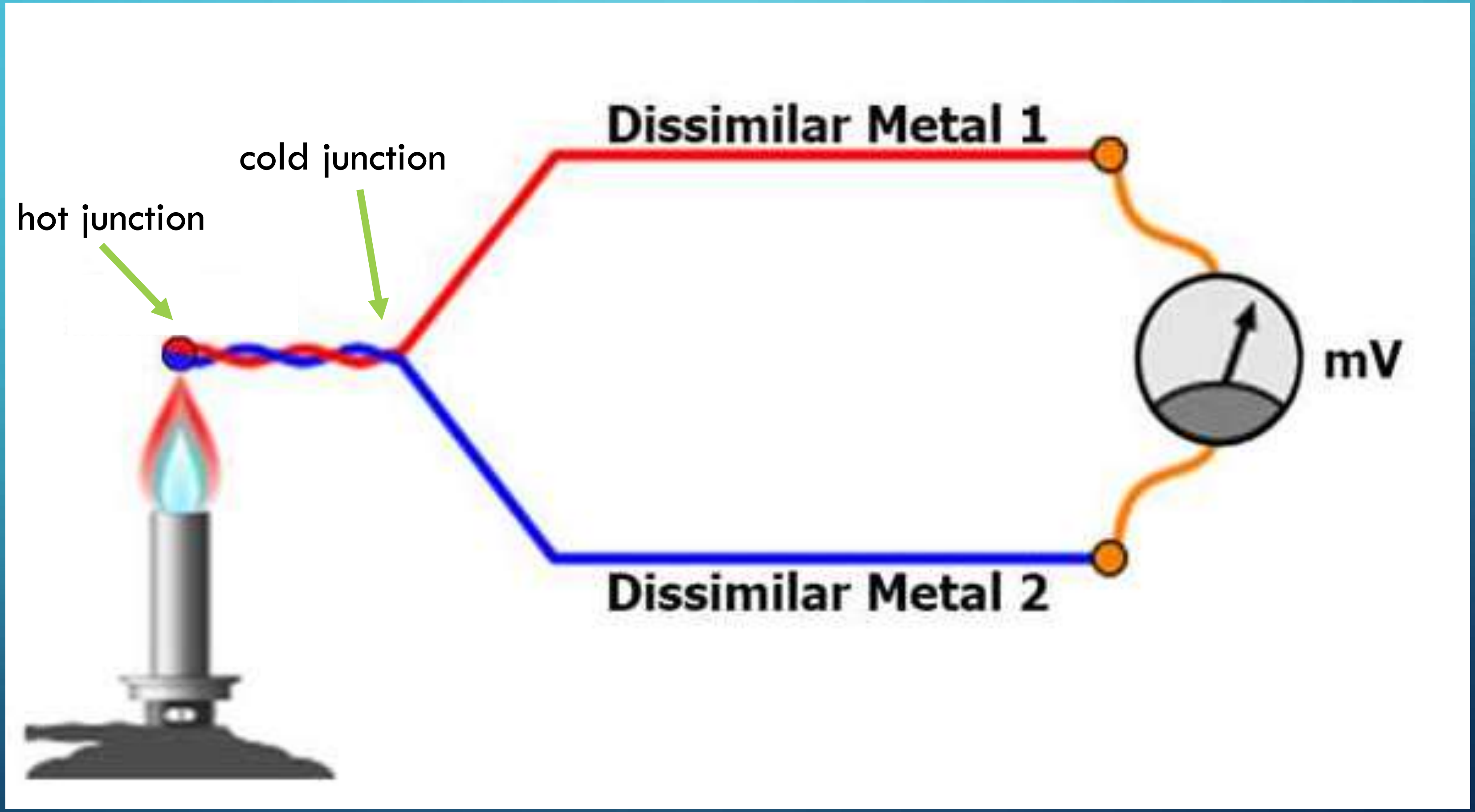
# ELECTROMAGNETS

- Danish scientist Hans Christian Ørsted discovered in 1820 that electric currents create magnetic fields. British scientist William Sturgeon invented the electromagnet in 1824.
- Sturgeon's first electromagnet was a horseshoe-shaped piece of iron that was wrapped with about 18 turns of bare copper wire (insulated wire didn't exist yet). The iron was varnished to insulate it from the windings. When a current was passed through the coil, the iron became magnetized and attracted other pieces of iron; ***when the current was stopped, it lost magnetization***.
- Electromagnetism is useful because it can produce mechanical movement with electrical power, and *vice versa*. And it can be turned on and off.

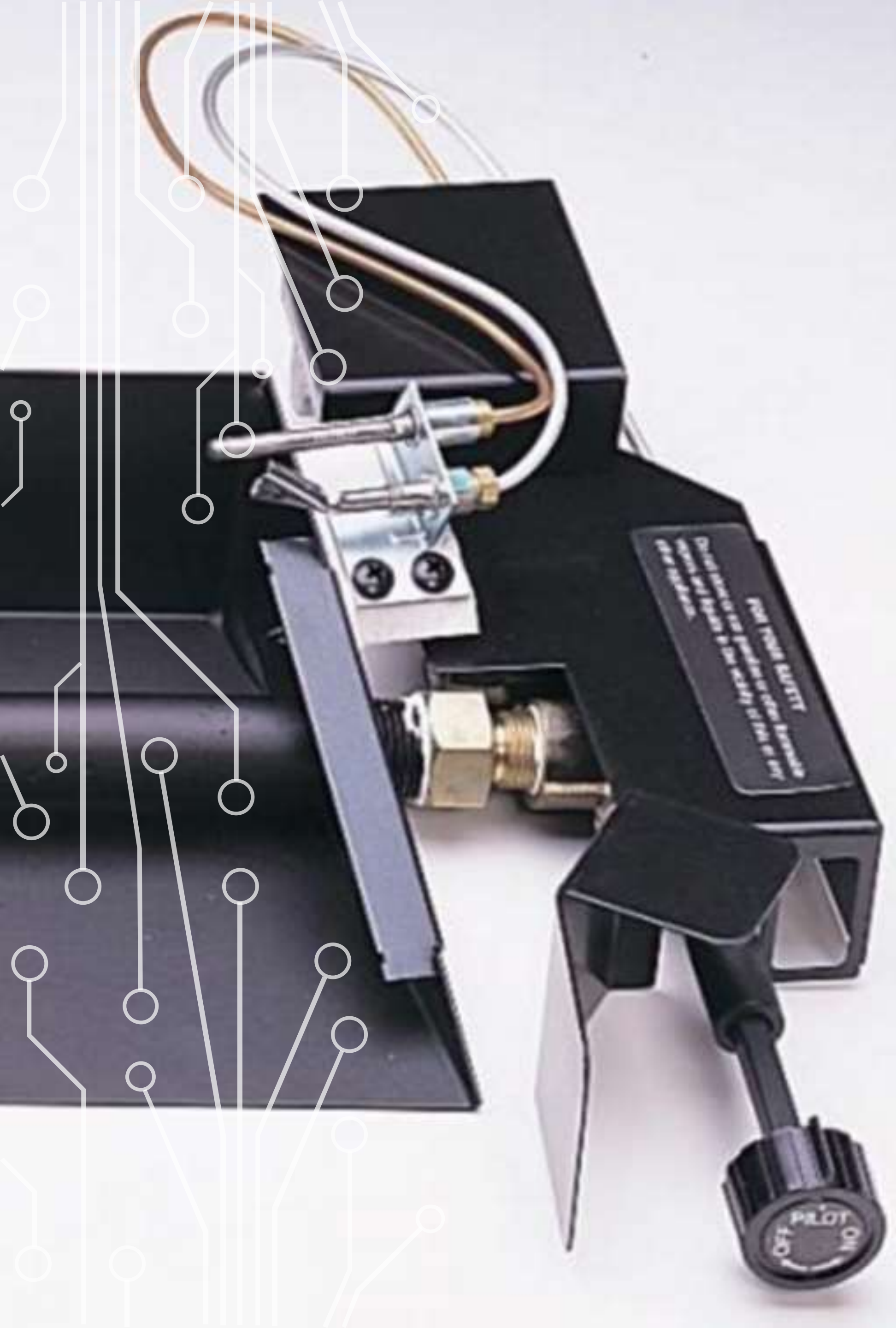
# THE OTHER HALF OF THE EQUATION: THE SEEBECK EFFECT

- In the 1820's, Thomas Johann Seebeck found that a circuit made from two dissimilar metals, with junctions at different temperatures would deflect a compass magnet. Seebeck initially believed this was due to magnetism induced by the temperature difference and thought it might be related to the Earth's magnetic field. However, it was quickly realized that a "Thermoelectric Force" induced an electrical current, which deflects the magnet. More specifically, the temperature difference produces and electric potential (voltage) which can drive an electric current in a closed circuit. Today, this is known as the Seebeck effect.
- The voltage produced is ***proportional to the temperature difference*** between the two junctions. The proportionality constant (S or a) is known as the Seebeck coefficient, and often referred to as "thermopower" even though it is more related to potential (voltage) than power.

# THERMOGENERATION



# THERMOCOUPLES



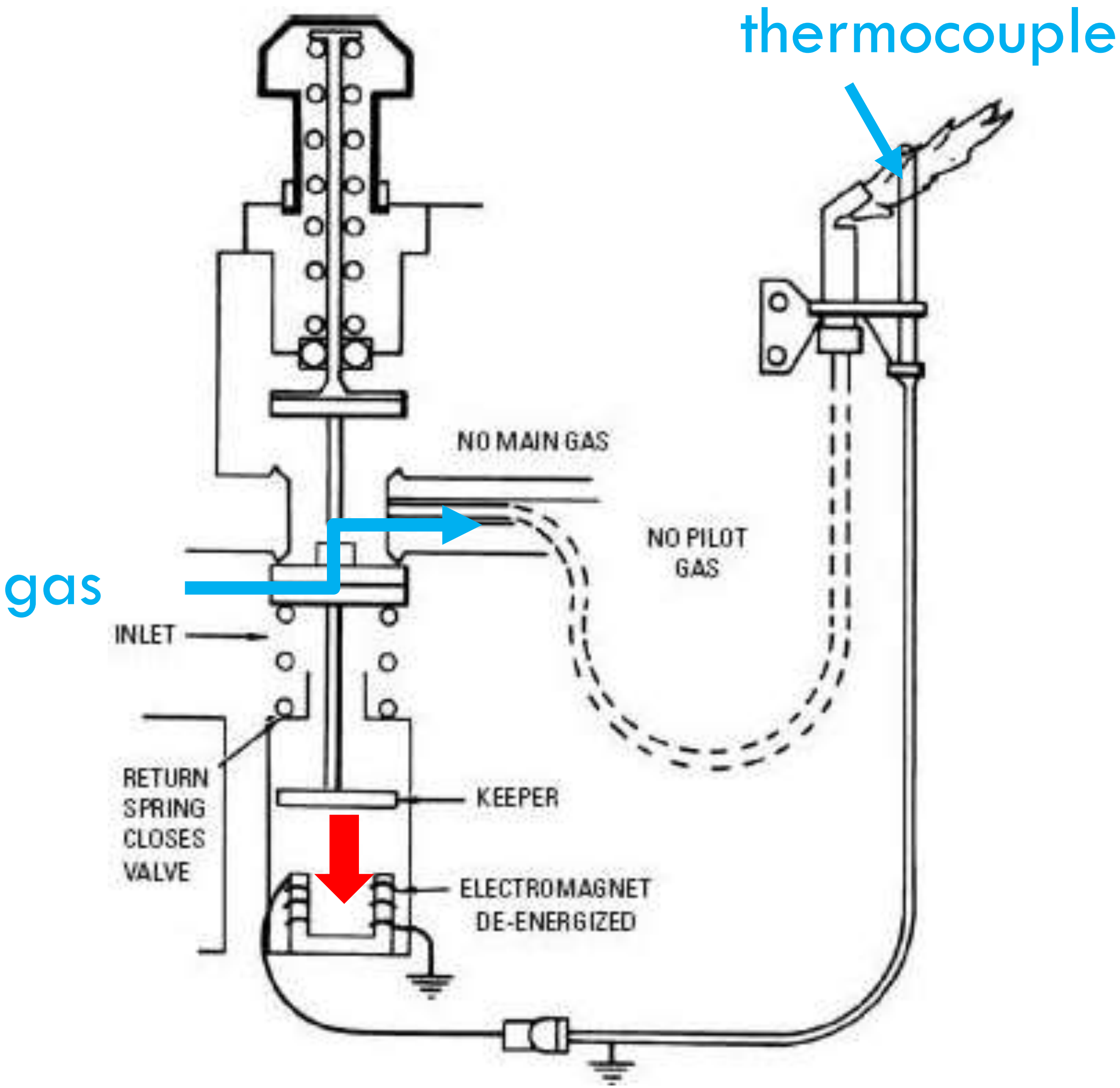

# MANUAL MILLIVOLT

By NFI definition, this is a manual control, but the millivolts in the thermocouple are a key to the required safety pilot device

(standing pilot not legal in CA)

# PILOT OPERATION

- User presses keeper against electromagnet while allowing gas to flow through.
- Pilot light is lit.
- Thermocouple heats up and energizes electromagnet.
- User releases button, keeper is held against electromagnet, gas continues to flow to pilot, and is available for main burner



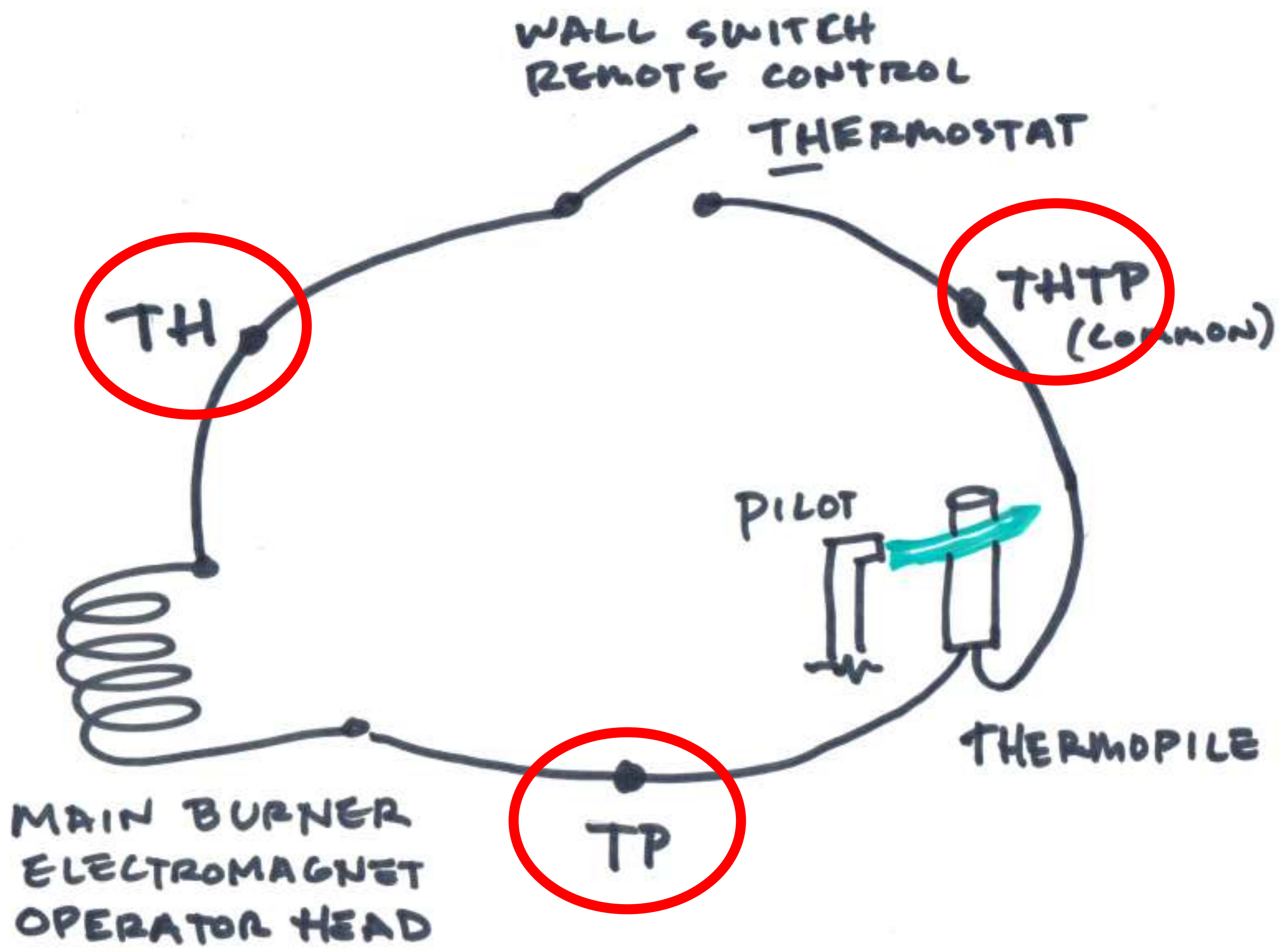
# TESTING THERMOCOUPLES

- Clamp to positive (silver end) and other lead to ground (copper outer shield)
- If the thermocouple has a plastic outer shield, clamp to chassis ground – like the valve mounting bracket
- Light the pilot
- Keep the valve on/off/pilot knob held in while taking the voltage

15 mv – 25 mv typical

# MAIN VALVE OPERATION

- Gas is already available because pilot is on.
- Thermopile generates enough voltage to open operator head after about thirty seconds
- Switching device closes circuit to energize operator head.



# THERMOPILES

A thermopile is simply dozens of thermocouples connected in series.

A typical thermopile output is 500-750 mv.

# MEASURE THERMOPILE VOLTAGE

disconnected

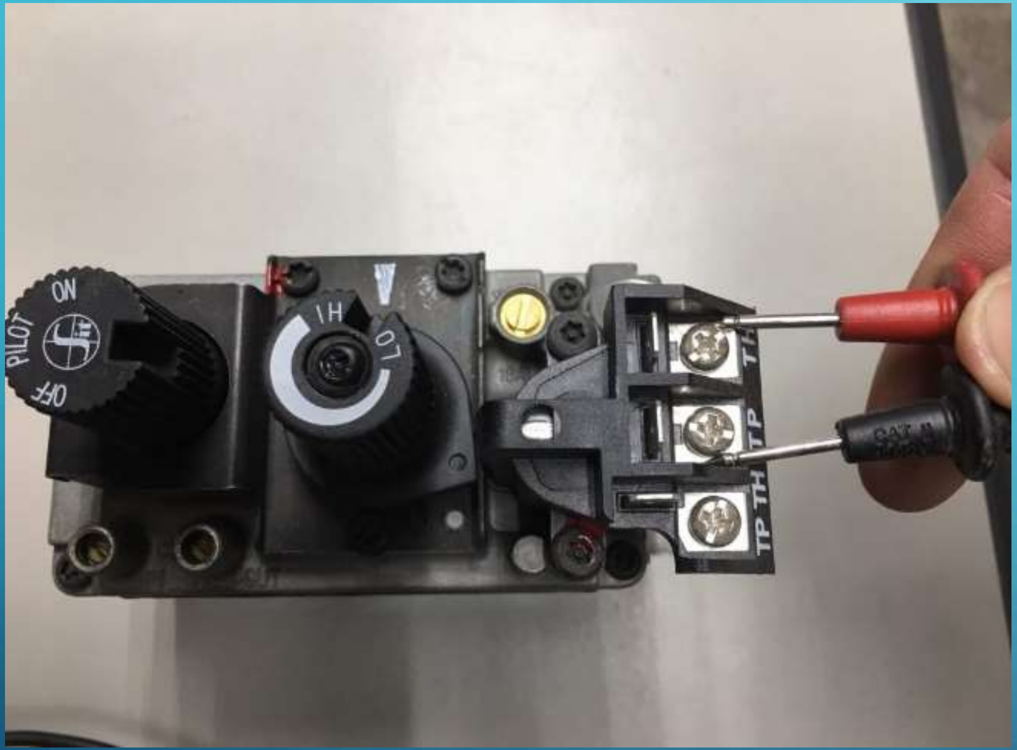
- **Isolate** - Remove one thermopile lead to get accurate voltage (no sneak paths)
- Set meter to DCV, low range

# MILLIVOLT CIRCUIT RESISTANCE

- Millivolt circuits can be problematic if any of the components provide too much resistance.
- Components that may cause too much resistance:
  - Old wall switch (cross wires to test)
  - Switch wire too long (check specification in manual)
  - Switch wire gauge too small (check specification in manual)
  - Oxidation on terminals
  - Valve operator coil

> 16", 18", 24" and 30" Gas Logs (Millivolt) thermopile is self powered gas valve and does not require 110 volts. See Figure 22 to provide optional wall switch, thermostat, or remote control. Maximum length of 20 feet of 16 AWG to conductor wires is to be used with all optional switches.

# CHECK OPERATOR HEAD RESISTANCE




Measure across “TP” and “TH” terminals

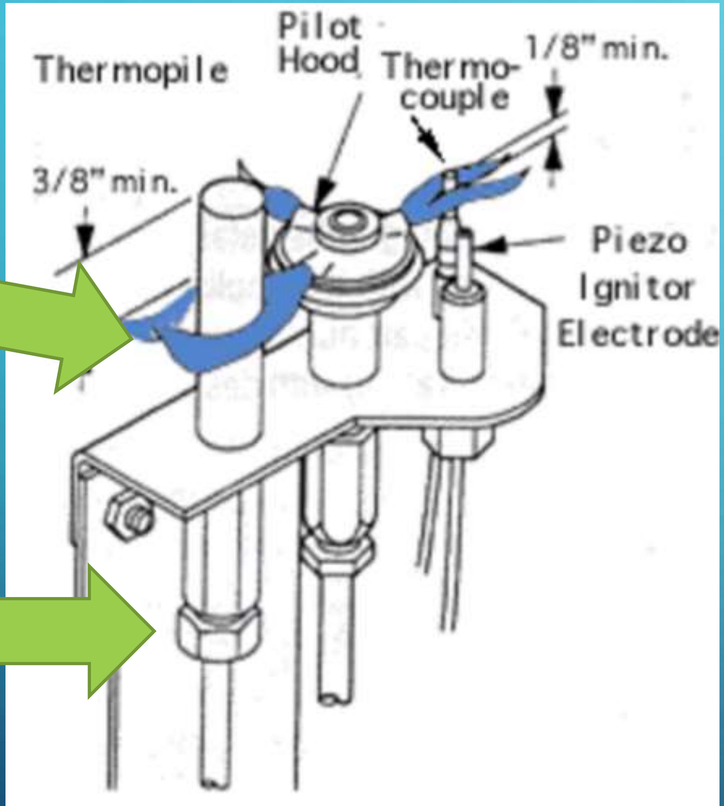
- SIT 820 valve -1.75 to 2.75 Ω
- Honeywell valve (disc.) -3.1 to 3.6 Ω
- Robert Shaw/Dexen – 1.5 to 1.7 Ω

- “OL” means out of limits or over limits, infinite resistance, open circuit. Translation: broken

# VISUAL TROUBLESHOOTING

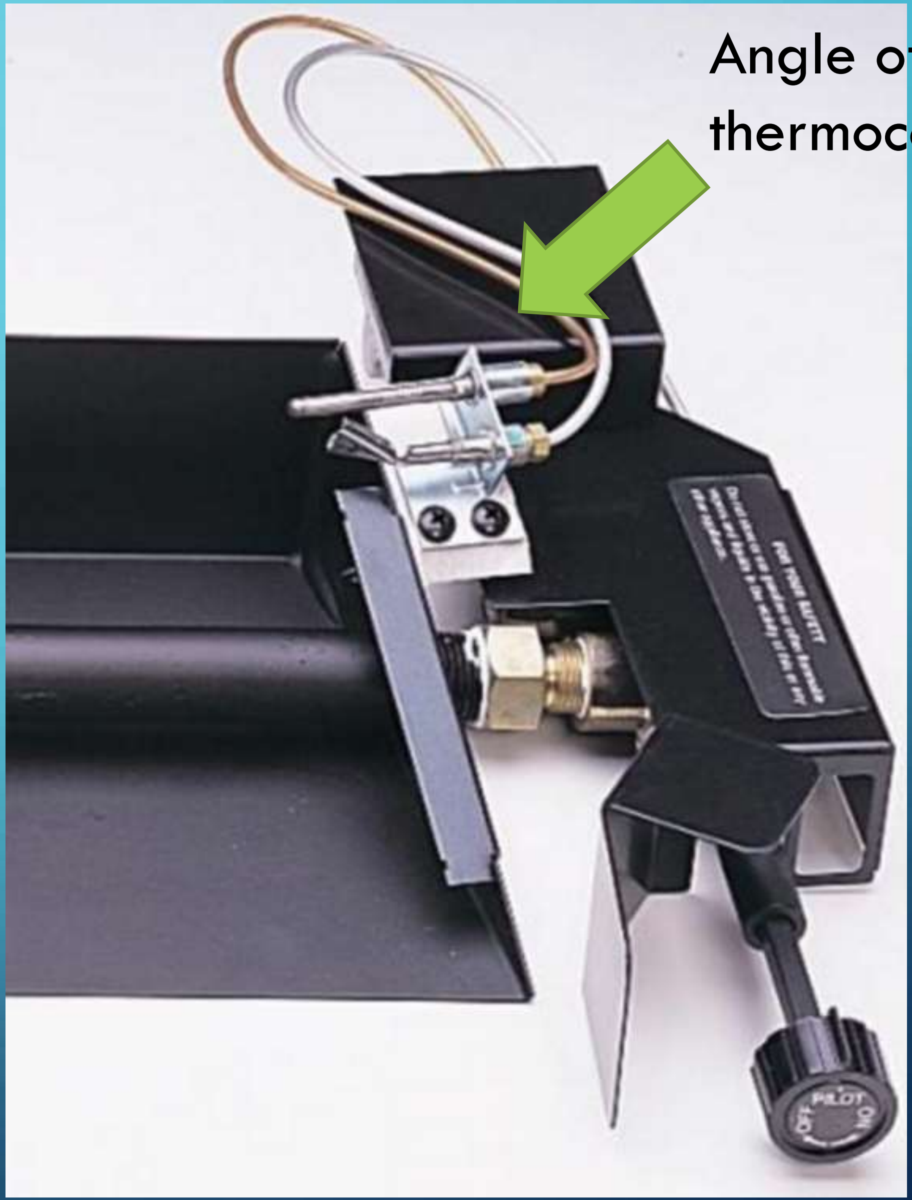
Position of flame

Loose nut




Close up of Thermocouple/Thermopile Assembly

Angle of thermocouple



# MILLIVOLT SYSTEMS ISSUES

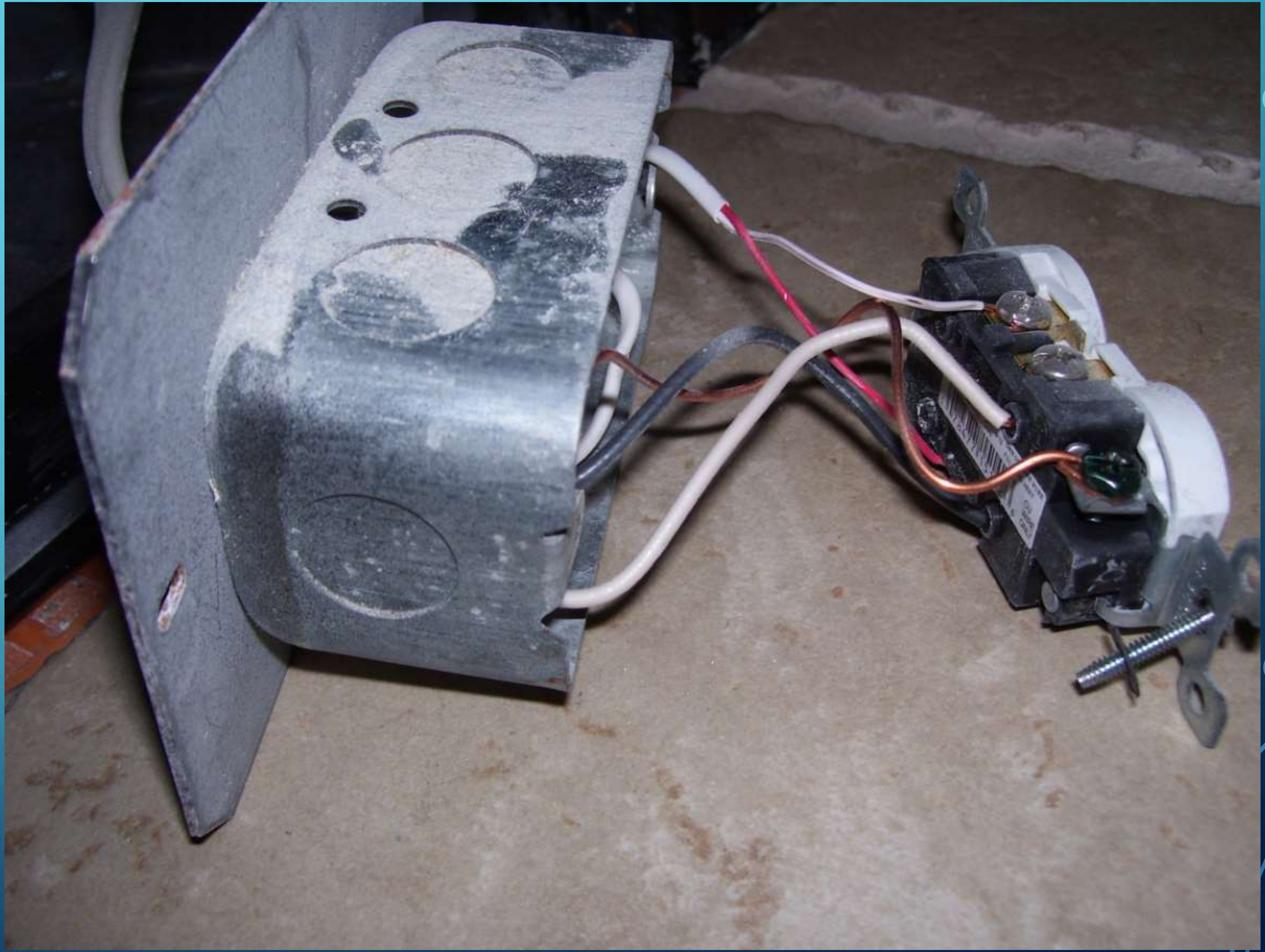
- The low voltages make the system prone to resistance losses due to oxidation (on thermocouple ends or switches)
- Because voltage is dependent on the ***difference*** in temperature ($\Delta$t), if the base of the thermopile or thermocouple heats up, the system can drop out.
- It is hard to convince some people that millivolt systems are self-powered, and we find that electricians will try to connect 120VAC to the millivolt circuit.

# NOPE

# OH, MY.

Wall switch wired to outlet.
What do you think happened when they turned their wall switch on?

The circuit breaker popped, because the wall switch shorted the hot to neutral



# PROCESS OF ELIMINATION

Use jumpers across components to isolate problems by bypassing switches or other components (spill switch)

Connect the jumper in parallel with the component or replace the component with a jumper.

# MILLIVOLT VALVES


TH = thermostat (switch)   TP = thermopile   THTP= common

# TROUBLESHOOTING

- **Weak pilot flame**
  - pressure too low?
    - pilot only?
  - dirty pilot orifice?
    - probably
  - pilot adjustment?
    - hmmm . . .

# GOOD PRACTICES

# CHECK BATTERIES

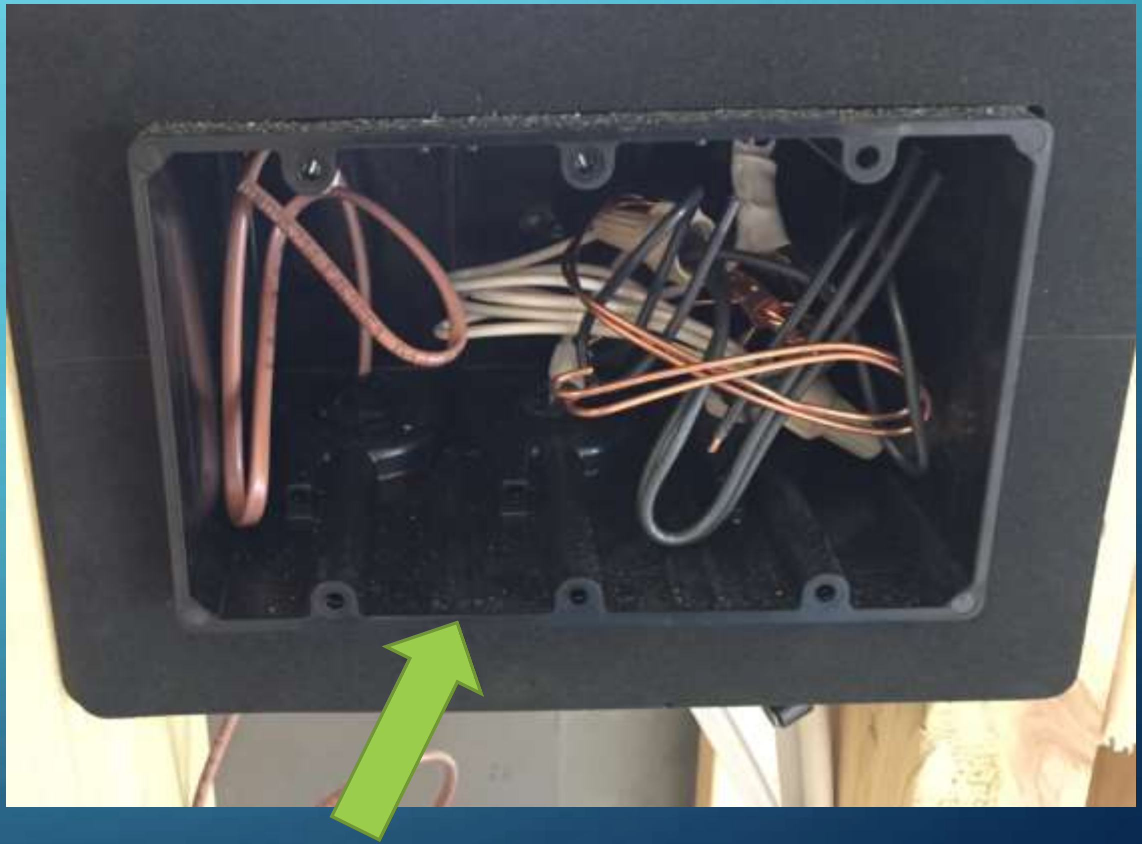
"I just put in new batteries" is just as helpful as "I just had my tank filled"

You need to measure the actual voltage (on every battery) just like you need to check the actual gas pressure.


A brand new single cell is usually about 1.6 volts, and will work until is gets down to about 1.3 volts, but systems vary.

# SEPARATE LOW VOLTAGE AND LINE VOLTAGE

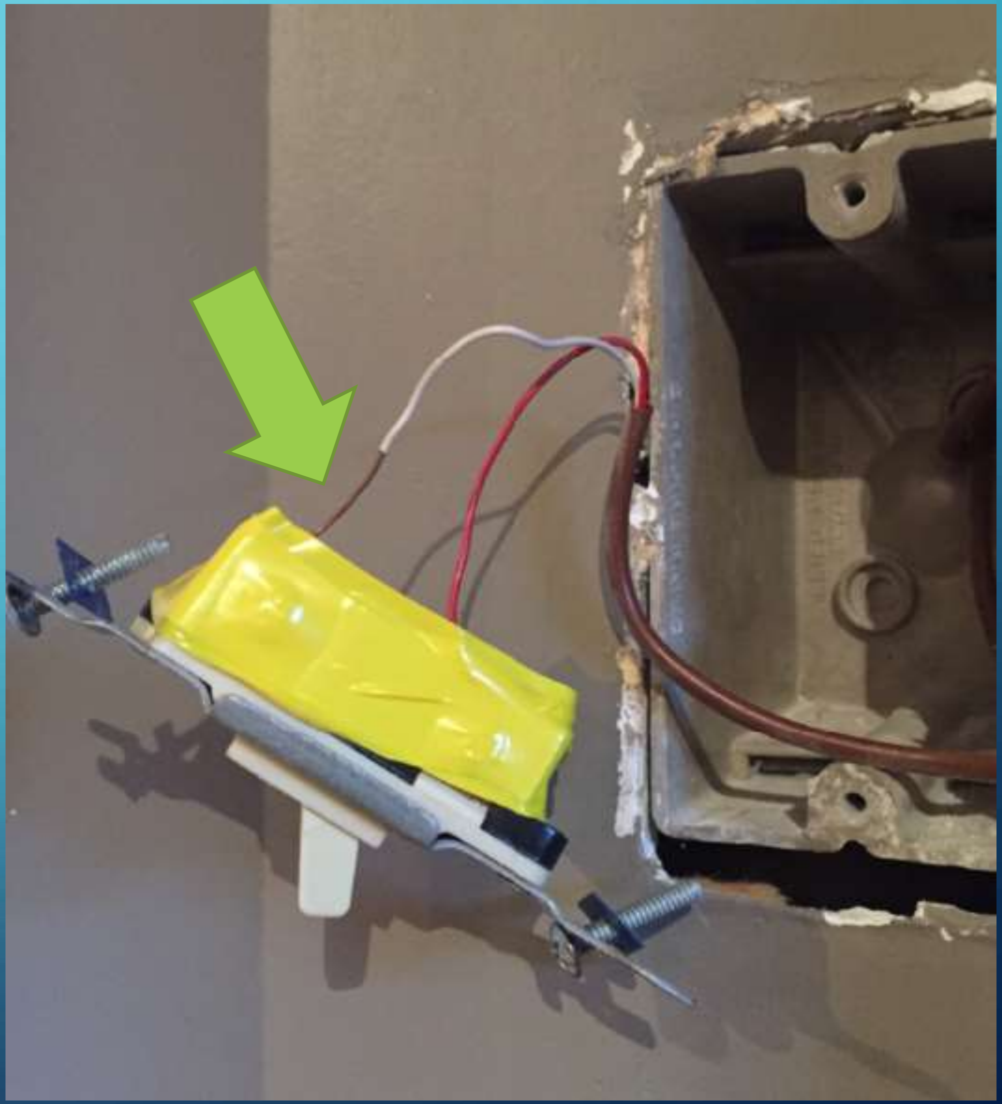
We can't seem to prevent electricians from running low voltage and line voltage next to each other. There is a space for a septum, but there is another thing you can do to prevent shorting your valve to line voltage.



# TAPE SWITCHES & OUTLETS

This is what keeps a $1 switch from destroying a $180 valve.

Tape the bare contacts on the switch (don't strip too much either)



# SUMMARY

- Many professionals in our business are uncomfortable dealing with electrical issues, but most issues are easy to understand and troubleshoot once the concepts are clear.

# SUMMARY

It is important to understand these topics:

- The relationship between voltage, current and resistance
- Electromagnetism & the Seebeck effect (thermogeneration)
- Electronic flame sensing
- How to use basic diagnostic tools

# QUESTIONS?