CHAPTER 19

Troubleshooting and Diagnostics

Learning Objectives

Upon completion of this chapter, students will be able to:

1. Apply systematic troubleshooting methodology to diagnose gas equipment problems
2. Select and use diagnostic tools appropriately for various testing requirements
3. Diagnose common heating system problems using logical sequences
4. Troubleshoot water heater issues efficiently and safely
5. Identify and resolve gas supply problems at various system points
6. Diagnose venting problems and their effects on equipment operation
7. Test and verify control system components systematically
8. Read and interpret wiring diagrams for troubleshooting purposes
9. Apply advanced diagnostic techniques for complex problems
10. Recognize when problems exceed scope of practice and require referral

19.1 Systematic Troubleshooting Approach

Successful troubleshooting requires a methodical approach that eliminates guesswork and ensures efficient problem resolution.

The Diagnostic Process

A systematic approach saves time, reduces callbacks, and ensures customer satisfaction.

Overview of Systematic Troubleshooting

Key Principles:

1. **Never assume** - Verify every piece of information
2. **One change at a time** - Isolate variables
3. **Document everything** - Create a clear record
4. **Safety first** - Never bypass safety devices
5. **Understand before acting** - Know the system
6. **Verify the repair** - Ensure complete resolution

Benefits of Systematic Approach:

- Faster diagnosis
- Fewer parts changed unnecessarily
- Better customer communication
- Reduced liability
- Professional reputation

- Training documentation

Common Mistakes to Avoid:

- Jumping to conclusions
- Changing multiple parts
- Ignoring customer input
- Skipping verification
- Poor documentation
- Not testing after repair

Gathering Information

The foundation of accurate diagnosis is comprehensive information gathering.

Customer Interview

Essential Questions:

1. **Problem Description:**
    - "What exactly is happening?"
    - "When did it start?"
    - "Has it happened before?"
    - "What were you doing when it occurred?"
    - "Have you noticed any patterns?"
2. **System History:**
    - "How old is the equipment?"
    - "When was last service?"
    - "Any recent repairs?"
    - "Any other work done recently?"
    - "Has it always worked this way?"
3. **Environmental Factors:**
    - "Any unusual sounds?"
    - "Any strange odors?"
    - "Changes in utility bills?"
    - "Other appliances affected?"
    - "Recent weather events?"

Visual Inspection

Initial Observations:

- Equipment condition
- Installation quality
- Obvious damage
- Modifications

- Environmental conditions
- Safety hazards

Detailed Inspection Points:

Component	Check For
Furnace exterior	Rust, damage, labels
Venting	Corrosion, gaps, slope
Gas piping	Leaks, support, sizing
Electrical	Burn marks, loose connections
Filters	Condition, type, fit
Thermostat	Level, location, settings
Combustion area	Soot, debris, damage
Drainage	Clogs, traps, slope

Equipment History Review

Documentation Sources:

- Service records
- Installation manual
- Previous invoices
- Warranty information
- Equipment data plate
- Error code history

Critical Information:

- Model and serial numbers
- Manufacturing date
- BTU rating
- Electrical requirements
- Gas type
- Previous problems

Understanding Normal Operation

Cannot diagnose abnormal without understanding normal.

Sequence of Operation Knowledge

Standard Furnace Sequence:

1. **Thermostat Call:**

    - R to W closed
    - 24V to control board
    - Board initiates sequence
2. **Inducer Start:**
    - Inducer motor energized
    - Pressure switch proves
    - Pre-purge period
3. **Ignition Sequence:**
    - Igniter energized
    - Gas valve opens
    - Flame detected
    - Igniter de-energized
4. **Blower Operation:**
    - Blower-on delay
    - Speed selection
    - Continuous operation
    - Blower-off delay
5. **Satisfied Call:**
    - Gas valve closes
    - Inducer continues
    - Post-purge
    - Blower-off delay

Normal Operating Parameters

Typical Values:

Parameter	Normal Range
Temperature rise	40-70°F
Supply temperature	110-140°F
Return temperature	65-75°F
Gas pressure (NG)	7" W.C.
Manifold pressure	3.5" W.C.
Draft pressure	-0.02" to -0.05" W.C.
Flame sensor	2-6 μA DC
Inducer amp draw	80% of nameplate

Normal Sounds:

- Inducer startup whoosh
- Igniter clicking or glow
- Gas valve click
- Burner ignition whoosh
- Blower motor hum

- Expansion/contraction ticking

Normal Timing:

- Inducer pre-purge: 30-60 seconds
- Igniter warm-up: 15-45 seconds
- Trial for ignition: 4-7 seconds
- Blower-on delay: 30-90 seconds
- Blower-off delay: 60-180 seconds

Isolating the Problem

Systematic isolation narrows the possibilities.

Problem Classification

Categories:

1. **No Operation:**
    - Complete failure
    - No response
    - Dead system
2. **Partial Operation:**
    - Starts but stops
    - Intermittent operation
    - Some functions work
3. **Poor Performance:**
    - Inadequate heating
    - High bills
    - Comfort issues
4. **Safety Issues:**
    - CO production
    - Gas odors
    - Electrical problems

Isolation Techniques

Divide and Conquer:

1. **System Level:**
    - Power supply OK?
    - Gas supply OK?
    - Thermostat calling?
2. **Circuit Level:**
    - Control voltage present?
    - Safety circuit complete?

    - Operating controls functioning?
3. **Component Level:**
    - Individual component tests
    - Resistance checks
    - Voltage measurements

Using Process of Elimination:

- List all possibilities
- Test easiest first
- Eliminate confirmed good
- Focus on remaining
- Verify assumptions

Voltage Testing Path:

1. Line voltage at disconnect
2. Line voltage at unit
3. Transformer primary
4. Transformer secondary
5. Through safety circuit
6. To operating controls
7. To loads

Testing Hypotheses

Develop and test theories systematically.

Hypothesis Development

Based on Symptoms:

Symptom	Possible Causes
No heat, no blower	No power, bad transformer
Blower only	No gas, failed ignition
Cycles on limit	Airflow, gas pressure
Short cycles	Thermostat, flame sensor
Won't ignite	Gas valve, igniter

Prioritizing Tests:

1. **Most likely** based on symptoms
2. **Easiest to test** first
3. **Least invasive** tests
4. **Most dangerous** last

5. **Most expensive** last

Test Procedures

Safe Testing Practices:

- Lock out/tag out
- Verify meter operation
- Use proper PPE
- One hand rule
- Insulated tools
- Know escape route

Component Testing:

1. **Visual inspection**
2. **Mechanical operation**
3. **Electrical continuity**
4. **Resistance values**
5. **Voltage presence**
6. **Current draw**
7. **Functional test**

Recording Results:

- Test performed
- Expected value
- Actual value
- Pass/fail
- Time/date
- Conditions

Making Repairs

Execute repairs professionally and safely.

Repair Preparation

Parts Acquisition:

- Verify correct part
- Check availability
- Consider upgrades
- Have backup plan
- Price approval

Customer Communication:

- Explain problem clearly
- Describe solution
- Provide options
- Get authorization
- Set expectations

Safety Considerations:

- Shut off power
- Close gas valve
- Allow cooling
- Ventilate area
- Protect property

Repair Execution

Best Practices:

1. **Follow manufacturer procedures**
2. **Use correct tools**
3. **Take photos before**
4. **Label wires/connections**
5. **Clean as you go**
6. **Check related components**

Common Repair Procedures:

Component	Key Points
Flame sensor	Clean with steel wool
Igniter	Handle carefully, check position
Gas valve	Don't force, check voltage
Pressure switch	Check tubing first
Blower motor	Check capacitor too
Transformer	Verify voltage rating

Quality Control:

- Proper torque
- Secure mounting
- Wire routing
- No gas leaks
- Electrical safety
- Clean work area

Verification

Confirm complete problem resolution.

Operational Verification

Complete Test Cycle:

1. **Initial Power-Up:**
    - Check for errors
    - Listen for abnormal sounds
    - Watch sequence
    - Verify ignition
    - Monitor operation
2. **Full Cycle Test:**
    - Normal startup
    - Steady operation
    - Proper temperatures
    - Normal shutdown
    - Post-purge completion
3. **Multiple Cycles:**
    - Three minimum
    - Consistent operation
    - No error codes
    - Proper timing
    - Customer satisfaction

Performance Verification

Measurements Required:

- Temperature rise
- Gas pressure
- Manifold pressure
- Amp draws
- Combustion analysis
- Draft test
- CO in space

Comparing to Specifications:

Parameter	Specification	Actual	Pass/Fail
Temp rise	40-70°F	55°F	Pass
Gas pressure	7" W.C.	7.2"	Pass
CO	<100 ppm	35 ppm	Pass

Safety Verification

Critical Checks:

- All safeties operational
- No gas leaks
- Proper venting
- Electrical safety
- CO levels safe
- Proper combustion

Documentation

Complete records protect everyone involved.

Service Report Contents

Required Information:

1. **Customer Data:**
    - Name and address
    - Phone numbers
    - Email address
    - Account number
    - Service address
2. **Equipment Data:**
    - Make and model
    - Serial number
    - Age
    - Location
    - Accessories
3. **Problem Description:**
    - Customer complaint
    - Symptoms found
    - Diagnostic steps
    - Root cause
    - Contributing factors
4. **Work Performed:**
    - Parts replaced
    - Adjustments made
    - Cleaning done
    - Tests performed
    - Results achieved
5. **Recommendations:**
    - Additional repairs
    - Maintenance needs

    - Safety concerns
    - Upgrade options
    - Follow-up required

Technical Documentation

Test Results:

- Before and after readings
- All measurements taken
- Combustion analysis
- Electrical values
- Temperature readings
- Pressure measurements

Parts Information:

- Part numbers
- Descriptions
- Warranty status
- Cost
- Source

Photos/Diagrams:

- Problem areas
- Before repair
- After repair
- Model/serial plates
- Unusual conditions

Legal Documentation

Liability Protection:

- Work authorization
- Safety notifications
- Code violations noted
- Recommendations declined
- Warranty terms
- Payment received

Follow-Up Requirements:

- Warranty registration
- Callback scheduled

- Parts ordered
- Permits required
- Inspection needed
- Customer training

19.2 Diagnostic Tools and Their Use

Professional diagnostic tools are essential for accurate troubleshooting.

Multimeters

The most versatile diagnostic tool for HVAC technicians.

Types and Features

Digital Multimeters (DMM):

Essential Features:

- Auto-ranging
- True RMS
- Min/Max recording
- Backlight
- CAT III 600V minimum
- Temperature probe capability

Measurements Capabilities:

- AC/DC voltage
- AC/DC current
- Resistance
- Continuity
- Capacitance
- Frequency
- Temperature
- Diode test

Specialty Features:

- Clamp-on amp probe
- Data logging
- Wireless connectivity
- Ghost voltage elimination
- Low impedance mode
- Non-contact voltage

Proper Use Procedures

Safety First:

1. **Inspect before use:**
    - Leads not damaged
    - Probes intact
    - Display functional
    - Battery good
    - Correct CAT rating
2. **Test on known source:**
    - Verify operation
    - Correct reading
    - Proper function
    - Lead continuity
3. **Select correct function:**
    - Voltage type (AC/DC)
    - Expected range
    - Proper terminals
    - Special functions

Voltage Measurements:

AC Voltage Testing:

- Set to AC voltage
- Start high range
- Black to neutral/ground
- Red to hot
- Read display
- Note ghost voltages

DC Voltage Testing:

- Set to DC voltage
- Observe polarity
- Common HVAC: 24VDC controls
- Flame sensors: microamps DC
- Some motors: DC

Testing Sequence:

1. Power supply voltage
2. Transformer primary
3. Transformer secondary
4. Control voltage

5. Load voltage
6. Voltage drops

Resistance Testing:

Safety Critical:

- POWER OFF
- Discharge capacitors
- Isolate component
- Zero meter if needed

Common Tests:

Component	Expected Resistance
Transformer primary	5-50Ω
Transformer secondary	0.5-5Ω
Gas valve coil	10-50Ω
Igniter (hot surface)	40-200Ω
Flame sensor	Open (clean)
Limit switch	0Ω (closed)
Pressure switch	0Ω (closed)

Continuity Testing:

- Audible beep helpful
- Less than 1Ω typical
- Check switches
- Verify fuses
- Test wiring
- Find opens

Current Measurements:

Clamp-On Method:

- Single conductor only
- Perpendicular to wire
- Centered in jaws
- Away from other fields
- Stable reading

In-Line Method:

- Break circuit
- Series connection
- Proper range
- Start high
- Safety precautions

Common Current Draws:

Component	Typical Amps
Inducer motor	0.5-2.0A
Blower motor	3.0-15.0A
Hot surface igniter	3.5-5.5A
Gas valve	0.5-1.0A

Manometers

Essential for pressure measurements in gas systems.

Types of Manometers

U-Tube Manometer:

- Simple and reliable
- No calibration needed
- Reads directly
- Limited range
- Fragile

Inclined Manometer:

- More sensitive
- Easier reading
- Draft measurements
- Portable
- Moderate cost

Digital Manometer:

- High accuracy
- Multiple scales
- Data logging
- Differential pressure
- Easy reading

Magnehelic Gauge:

- Analog display
- Permanent installation
- Various ranges
- Reliable
- No power needed

Pressure Measurements

Gas Pressure Testing:

Equipment Setup:

1. Select proper port
2. Install test fitting
3. Connect tubing
4. Zero gauge
5. Open test port
6. Read pressure

Test Points:

Location	Purpose	Expected
Meter outlet	Supply pressure	7" W.C. (NG)
Appliance inlet	After regulator	7" W.C.
Manifold	Burner pressure	3.5" W.C.
Propane tank	Tank pressure	Varies

Testing Procedures:

1. **Static Pressure:**
    - All appliances off
    - Maximum available
    - Identify restrictions
2. **Operating Pressure:**
    - All appliances on
    - Actual working pressure
    - Identify undersizing
3. **Lockup Pressure:**
    - Appliance cycles off
    - Regulator performance
    - Should match static

Draft Measurements:

Natural Draft:

- Over-fire draft
- Breach draft
- Stack draft
- Room pressure
- Typical: -0.02" to -0.05" W.C.

Induced Draft:

- Pressure switch setting
- Heat exchanger pressure
- Venting pressure
- Combustion air pressure

Static Pressure Testing:

Supply Static:

- Before filter
- After filter
- After coil
- At furthest register
- Calculate total

Return Static:

- At grille
- Before filter
- At furnace
- Total return
- Compare to specs

Total External Static:

- Supply + Return
- Compare to blower table
- Identify restrictions
- Verify airflow

Combustion Analyzers

Critical for safety and efficiency testing.

Analyzer Components

Basic Features:

- O_2 sensor
- CO sensor
- Temperature probes
- Draft measurement
- Calculated values

Advanced Features:

- NO/NOx sensors
- CO_2 direct measurement
- Printer capability
- Data logging
- Wireless connectivity

Sensor Types:

Sensor	Life Expectancy	Calibration
O_2	2-4 years	Annual
CO	3-5 years	Annual
NO	2-3 years	Annual
Temperature	5+ years	As needed

Combustion Testing Procedures

Test Preparation:

1. **Equipment Warmup:**
    - Analyzer on 5 minutes
    - Auto-zero in fresh air
    - Check battery
    - Verify calibration date
    - Print header
2. **Appliance Preparation:**
    - Run 10 minutes minimum
    - Steady state operation
    - Drill test holes if needed
    - Seal around probe
    - Record conditions

Sampling Locations:

Appliance Type	Sample Point
Natural draft	Above draft hood
Induced draft	Before inducer

Appliance Type	Sample Point
Condensing	Exhaust terminal
Power vent	Before vent motor

Test Procedure:

1. Insert probe
2. Wait for stable reading
3. Record all values
4. Test multiple rates
5. Print results
6. Seal test holes

Interpreting Results

Acceptable Ranges:

Parameter	Natural Draft	Induced	Condensing
O_2	6-9%	5-9%	4-7%
CO	<100 ppm	<100 ppm	<100 ppm
CO_2	6-9%	7-9.5%	8-10%
Efficiency	75-80%	78-83%	90-98%
Stack temp	350-500°F	300-450°F	80-120°F

Problem Indicators:

Reading	Indicates
High O_2	Excess air, leaks
Low O_2	Insufficient air
High CO	Incomplete combustion
Low efficiency	Needs service
High stack temp	Scale, soot

Adjustments:

- Air shutter position
- Gas pressure
- Baffle position
- Inducer speed
- Orifice sizing

Temperature Measurement

Various methods for different applications.

Temperature Measurement Tools

Thermometers Types:

Digital Pocket:

- Quick checks
- ±1°F accuracy
- Supply/return air
- Water temperature
- Ambient readings

Infrared (IR):

- Non-contact
- Surface temperature
- Spot ratio important
- Emissivity affects
- Quick scanning

Thermocouple Meters:

- Type K common
- Wide range
- Fast response
- Multiple inputs
- Data logging

Clamp-On Pipe:

- Pipe surface
- No penetration
- Insulate sensor
- Allow stabilization
- Good contact essential

Measurement Applications

Air Temperatures:

Location	Purpose	Typical Range
Return air	System input	65-75°F
Supply air	System output	100-140°F

Location	Purpose	Typical Range
Room ambient	Comfort check	68-78°F
Outside air	Reference	Varies
Mixed air	Economizer	Calculated

Surface Temperatures:

- Heat exchanger
- Refrigerant lines
- Pipe temperatures
- Motor housing
- Electrical connections

Temperature Rise Calculation:

- Supply - Return = Rise
- Compare to nameplate
- Indicates airflow
- Affects efficiency

Example:

- Supply: 120°F
- Return: 70°F
- Rise: 50°F
- Nameplate: 45-75°F
- Status: Normal

Amp Meters

Essential for motor and electrical diagnostics.

Clamp-On Amp Meters

Features:

- AC/DC capability
- Auto-ranging
- Peak hold
- Inrush current
- Min/Max recording

Proper Use:

1. Select AC or DC

2. Zero if needed
3. Open jaws fully
4. Center conductor
5. Close completely
6. Read display

Applications:

Component	Measurement Purpose
Blower motor	Verify operation, check load
Inducer motor	Confirm operation
Compressor	Check operation
Electric heat	Verify elements
Transformers	Check loading

Current Analysis

Motor Diagnostics:

Normal vs. Abnormal:

Condition	Current Draw
Normal	80-100% FLA
Overloaded	>110% FLA
Worn bearings	105-115% FLA
Low voltage	>100% FLA
High voltage	<100% FLA
Single phasing	150-200% FLA

Locked Rotor Amps:

- Starting current
- 4-6× running
- Duration important
- Hard start conditions
- Capacitor problems

Power Factor:

- Watts ÷ (Volts × Amps)
- Normal: 0.7-0.9
- Low indicates problems
- Capacitor issues

- Motor problems

Gas Leak Detectors

Critical safety equipment for gas technicians.

Types of Detectors

Electronic Combustible Gas:

- Semiconductor sensor
- Heated element
- PPM sensitivity
- Audible/visual alarm
- Requires warmup

Ultrasonic:

- Detects turbulence
- Works all gases
- No calibration
- Noisy environments difficult
- Expensive

Bubble Solution:

- Visual confirmation
- Pinpoints exact location
- No false positives
- Temperature limited
- Time consuming

Proper Use Procedures

Electronic Detector Use:

1. **Calibration:**
    - Fresh air zero
    - Test with known source
    - Adjust sensitivity
    - Verify battery
2. **Search Pattern:**
    - Start at meter
    - Work toward appliances
    - Check all joints
    - Test valves

    - Include flex connectors
3. **When Leak Found:**
    - Verify with bubbles
    - Mark location
    - Determine severity
    - Take appropriate action
    - Document

Leak Classification:

Class	Reading	Action
Grade 1	>1% gas	Immediate repair
Grade 2	<1% gas, hazardous	Scheduled repair
Grade 3	<1% gas, not hazardous	Monitor

Safety Protocol:

- No ignition sources
- Ventilate area
- Evacuate if needed
- Call gas company
- Document everything

19.3 Common Heating System Problems

Understanding common failures speeds diagnosis and repair.

No Heat Calls

The most common service call requires systematic diagnosis.

Power Supply Issues

Electrical Problems:

No Power:

- Tripped breaker
- Blown fuse
- Disconnect off
- Emergency switch off
- Power outage

Diagnostic Steps:

1. Check breaker/fuse
2. Verify disconnect on
3. Test line voltage
4. Check door switch
5. Test transformer primary

Low Voltage:

- Affects performance
- Increased amp draw
- Motor overheating
- Control problems
- Voltage drop calculations

Control Power Problems

Transformer Failures:

Testing:

1. Primary voltage present
2. Secondary voltage output
3. VA rating adequate
4. Proper grounding
5. No shorts

Common Causes:

- Shorted secondary
- Overloaded
- Primary voltage high
- Age/heat damage
- Water damage

Fuse Issues:

- 3-5 amp typical
- Automotive type
- Check holder
- Proper rating
- Find short cause

Thermostat Problems

No Call for Heat:

- Dead batteries
- Programming error
- Set to cooling
- Temperature satisfied
- Anticipator problem

Testing:

1. Jump R to W
2. Check voltage R-C
3. Verify W output
4. Test cable continuity
5. Check programming

Safety Circuit Opens

Common Safety Switches:

Switch	Purpose	Test Method
Limit	Overheat protection	Continuity, temperature
Rollout	Flame rollout	Continuity, manual reset
Pressure	Vent blockage	Tubing, continuity
Door	Cover interlock	Continuity, adjustment

Diagnostic Process:

1. Identify which safety
2. Test continuity
3. Determine why open
4. Fix root cause
5. Test operation

Insufficient Heat

System runs but doesn't maintain temperature.

Sizing Issues

Undersized Equipment:

- Heat loss exceeds capacity
- Runs continuously
- Never reaches setpoint
- High utility bills
- Comfort complaints

Calculations:

- Perform heat loss
- Compare to output
- Check actual input
- Verify altitude derating
- Consider additions/changes

Airflow Problems

Restricted Airflow Causes:

Filter Issues:

- Dirty filter
- Wrong size
- Collapsed filter
- Missing filter
- Restrictive type

Duct Problems:

- Closed dampers
- Crushed flex
- Disconnected runs
- Undersized ducts
- Blocked registers

Blower Issues:

- Wrong speed
- Dirty wheel
- Belt slipping
- Motor weak
- Capacitor bad

Testing Airflow:

Method	Application
Temperature rise	Quick check
Static pressure	Detailed analysis
Anemometer	Actual CFM
Flow hood	Register flow

Gas Pressure Problems

Low Gas Pressure:

Symptoms:

- Yellow flames
- Delayed ignition
- Low input
- Poor heating
- Flame lifting

Causes:

- Meter/regulator problem
- Undersized piping
- Other loads operating
- Supply issue
- Restrictions

Testing:

1. Static pressure test
2. Operating pressure
3. Manifold pressure
4. Multiple appliances
5. Document readings

Short Cycling

Frequent on/off cycling indicates problems.

Thermostat-Related Causes

Location Issues:

- Near supply register
- On outside wall
- Near heat source
- Drafty location
- Direct sunlight

Anticipator Problems:

- Set too low (mechanical)
- Cycles per hour (digital)
- Swing setting
- Differential adjustment

- Smart recovery

Solutions:

- Relocate thermostat
- Adjust anticipator
- Change CPH setting
- Increase differential
- Disable smart features

Limit Switch Trips

High Limit Causes:

Airflow Restriction:

- Dirty filter
- Blocked returns
- Closed registers
- Duct problems
- Blower failure

Overfiring:

- High gas pressure
- Wrong orifices
- Altitude issues
- Improper conversion

Testing:

1. Check temperature rise
2. Measure static pressure
3. Verify gas pressure
4. Test limit operation
5. Inspect heat exchanger

Flame Sensor Issues

Weak Signal:

- Dirty sensor
- Poor ground
- Wrong position
- Wire problems
- Control board issue

Testing:

- Measure microamps
- Clean sensor
- Check ground
- Test wire
- Replace if needed

Normal: 2-6 µA DC

Blower Problems

Critical for heat distribution and system protection.

Motor Failures

Types of Motors:

Type	Characteristics	Common Problems
PSC	Single speed, capacitor	Capacitor, bearings
ECM	Variable speed, efficient	Module, programming
Shaded pole	Simple, low power	Bearings, overheating

Diagnostic Tests:

1. **Electrical:**
    - Voltage present
    - Amp draw
    - Capacitor test
    - Winding resistance
    - Ground test
2. **Mechanical:**
    - Free spinning
    - Bearing noise
    - Shaft play
    - Balance
    - Coupling

Belt Drive Issues

Belt Problems:

- Loose belt
- Worn belt
- Wrong size

- Misalignment
- Pulley wear

Adjustment:

- 1/2" deflection
- Proper tension
- Parallel alignment
- Same plane
- Correct belt type

Bearing Failures

Symptoms:

- Noise
- High amp draw
- Hot running
- Vibration
- Intermittent operation

Testing:

- Spin freely
- Lateral play
- End play
- Temperature
- Sound

Lubrication:

- Oil type
- Oil amount
- Frequency
- Over-oiling problems
- Sealed bearings

Ignition Failures

Various ignition types require different diagnostics.

Hot Surface Igniter Problems

Testing HSI:

Test	Specification
Resistance	40-200Ω
Amp draw	3.5-5.5A
Voltage	120VAC
Position	1/4" from burner
Condition	No cracks

Common Failures:

- Cracked element
- Contamination
- Wrong position
- Voltage problems
- Control board issue

Spark Ignition Issues

Spark Problems:

- No spark
- Weak spark
- Wrong gap
- Grounding issue
- Module failure

Testing:

1. Gap: 1/8" typical
2. Spark rate: 1-2/second
3. Ground: Good connection
4. Insulator: Not cracked
5. Wire: Good condition

Direct Ignition Problems

System Components:

- Igniter/sensor combo
- Control module
- Gas valve
- Flame sensing circuit

Diagnostics:

- Spark present

- Gas valve opens
- Flame established
- Sensing circuit works
- Proper timing

Flame Sensor Issues

Critical for safe operation and preventing nuisance shutdowns.

Flame Sensing Principles

Flame Rectification:

- AC applied to sensor
- Flame conducts to ground
- DC component created
- Microamp signal generated
- Control board detects

Requirements:

- Good ground
- Clean sensor
- Proper position
- Adequate flame
- Control board function

Common Problems

Dirty Sensor:

- Carbon buildup
- Oxidation
- Contamination
- Silicon coating
- Corrosion

Cleaning:

- Steel wool
- Fine sandpaper
- No chemicals
- Gentle pressure
- Check porcelain

Position Issues:

- Too far from flame
- Too close
- Wrong angle
- Loose mounting
- Bent sensor

Proper Position:

- In flame path
- 1/2" typical
- Stable mounting
- Good flame contact
- Away from metal

Testing and Measurement

Microamp Testing:

1. Meter in series
2. DC microamps scale
3. Burner operating
4. Read display
5. Compare to spec

Specifications:

Condition	Reading
Good	4-6 μA
Marginal	2-4 μA
Replace	<2 μA

Improving Signal:

- Clean sensor
- Check ground
- Verify gas pressure
- Adjust position
- Replace if needed

Limit Switch Trips

Safety device protecting against overheating.

Types of Limit Switches

Primary Limit:

- Main high limit
- Auto reset typical
- 160-200°F typical
- Bimetal or bulb
- Series with gas valve

Secondary Limit:

- Backup protection
- Manual reset often
- Higher temperature
- Redundant safety
- Code required

Rollout Switch:

- Flame rollout protection
- Manual reset
- Multiple locations
- Very high temp
- Serious problem indicator

Diagnostic Procedures

Why Limit Trips:

1. **Restricted Airflow:**
    - Most common cause
    - Filter/duct/register
    - Blower problems
    - High static pressure
2. **Overfiring:**
    - Gas pressure high
    - Wrong orifices
    - Improper conversion
3. **Heat Exchanger:**
    - Restricted passages
    - Scaled/sooted
    - Damaged baffles

Testing:

1. Check temperature rise
2. Measure static pressure

3. Verify blower operation
4. Test actual limit temp
5. Inspect heat exchanger

Resetting Procedures

Auto Reset:

- Cools down automatically
- Resets itself
- Find root cause
- Don't bypass

Manual Reset:

- Push button reset
- Must cool first
- Investigation required
- Document cause
- Safety concern

Never Bypass Limits!

Inducer Motor Problems

Critical component for safe venting and combustion.

Motor Types and Issues

Shaded Pole:

- Simple design
- Low cost
- Limited life
- Bearing problems
- Not repairable

PSC Motor:

- Capacitor run
- More efficient
- Repairable
- Bearing/capacitor issues

ECM Motor:

- Variable speed
- High efficiency
- Module problems
- Expensive
- Programming issues

Common Failures

Mechanical:

Problem	Symptoms
Bearings	Noise, binding
Wheel damage	Vibration, reduced flow
Housing cracks	Leaks, CO risk
Coupling	Slipping, noise
Water damage	Corrosion, freezing

Electrical:

- Open windings
- Shorted windings
- Capacitor (PSC)
- Module (ECM)
- Connections

Testing Procedures

Electrical Tests:

1. Voltage to motor
2. Amp draw test
3. Resistance check
4. Capacitor test (PSC)
5. Ground test

Mechanical Tests:

1. Free spinning
2. End play
3. Bearing condition
4. Wheel integrity
5. Housing seal

Pressure Switch Test:

1. Tubing clear
2. Port clean
3. Proper vacuum
4. Switch contacts
5. Electrical continuity

19.4 Common Water Heater Problems

Water heater diagnosis requires understanding of various systems.

No Hot Water

Complete lack of hot water indicates major component failure.

Gas Supply Issues

No Gas Flow:

- Shut-off closed
- Meter off
- Propane empty
- Service interrupted
- Locked valve

Diagnostic Steps:

1. Verify pilot lit
2. Check shut-off valve
3. Test gas pressure
4. Check other appliances
5. Call gas company if needed

Pilot System Problems

Pilot Won't Light:

Causes:

- No gas
- Air in line
- Thermocouple bad
- Dirty orifice
- Wrong gas type

Lighting Procedure:

1. Turn to pilot
2. Push button down
3. Light pilot
4. Hold 30-60 seconds
5. Release slowly
6. Turn to ON

Pilot Won't Stay Lit:

Problem	Test	Solution
Thermocouple bad	Millivolt test	Replace
Loose connection	Tighten	Secure
Dirty pilot	Visual	Clean
Drafts	Observe	Shield
Gas valve	Replace valve	New valve

Electronic Ignition Failures

Hot Surface Ignition:

- Igniter cracked
- No voltage
- Control board
- Sensor problems
- Wiring issues

Testing:

1. Voltage to igniter
2. Resistance test
3. Visual inspection
4. Amp draw
5. Control outputs

Spark Ignition:

- No spark
- Weak spark
- Gap issues
- Ground problems
- Module failure

Control Problems

Thermostats:

- Contacts stuck open
- Wrong setting
- Wiring problems
- Digital failure
- Programming error

Gas Valve:

- Coil open
- Mechanical failure
- No voltage
- Safety lockout
- Regulator problem

Testing:

- Voltage to valve
- Coil resistance
- Manual operation
- Inlet pressure
- Outlet flow

Inadequate Hot Water

System produces some hot water but not enough.

Capacity Issues

Undersized Tank:

- Family size increased
- Usage patterns changed
- Added fixtures
- Simultaneous use

Calculations:

Family Size	Tank Size (Gas)
1-2	30-40 gallons
2-3	40 gallons
3-4	50 gallons
4+	75+ gallons

First Hour Rating:

- Tank capacity
- Plus recovery
- More accurate sizing
- Matches peak demand

Recovery Problems

Low BTU Input:

Causes:

- Low gas pressure
- Dirty burner
- Wrong orifice
- Altitude derating
- Improper air

Testing:

1. Clock gas meter
2. Calculate BTU/hr
3. Compare to rating
4. Check gas pressure
5. Inspect burner

Recovery Rates:

BTU Input	Gallons/Hour (100°F rise)
30,000	30
40,000	40
50,000	50
75,000	75

Temperature Settings

Thermostat Issues:

- Set too low
- Out of calibration
- Sensing bulb problem
- Differential too wide
- Scale buildup

Proper Settings:

- 120°F recommended
- 140°F maximum residential
- Check with thermometer
- Both thermostats same
- Adjust as needed

Dip Tube Problems

Broken Dip Tube:

- Cold water short-circuits
- Reduced hot water
- Plastic particles
- Common in certain years
- Replace required

Symptoms:

- Short draws OK
- Long draws cold
- Intermittent temperature
- Plastic in aerators
- Age 5-15 years

Pilot Problems

Pilot issues are common in older water heaters.

Pilot Outages

Common Causes:

Cause	Test Method	Solution
Drafts	Observe flame	Shield pilot
Condensation	Check venting	Improve venting
Thermocouple	Millivolt test	Replace
Gas pressure	Manometer	Adjust/repair
Dirty pilot	Visual	Clean assembly

Thermocouple Testing

Millivolt Test:

1. Remove from gas valve
2. Heat with pilot

3. Measure DC millivolts
4. Should read 20-30 mV
5. Under 20 mV replace

Resistance Test:

- Should read <1Ω
- Open = bad
- High resistance = bad

Pilot Assembly Service

Cleaning Procedure:

1. Turn off gas
2. Remove assembly
3. Clean orifice
4. Clean hood
5. Check thermocouple
6. Reassemble
7. Adjust flame

Proper Pilot Flame:

- Blue cone
- Soft blue mantle
- Wraps thermocouple
- Steady flame
- 1-1.5" total height

Burner Issues

Main burner problems affect heating efficiency.

Delayed Ignition

Causes:

- Dirty burner ports
- Low gas pressure
- Improper air mixture
- Pilot position
- Control valve slow

Dangers:

- Mini explosion
- Flame rollout
- Component damage
- CO production
- Safety hazard

Solutions:

- Clean burner
- Adjust gas pressure
- Check pilot position
- Service control valve
- Verify venting

Flame Characteristics

Normal Flame:

- Soft blue
- Minimal yellow tips
- Even distribution
- Stable flame
- No lifting

Abnormal Flames:

Appearance	Cause	Solution
Yellow	Lack of air	Clean, adjust
Lifting	Excess air	Reduce air
Loud	Resonance	Adjust
Flashback	Low pressure	Increase

Burner Maintenance

Cleaning:

1. Remove burner
2. Brush ports clean
3. Clear venturi
4. Check for rust
5. Reinstall properly
6. Test operation

Relief Valve Discharge

T&P valve discharge indicates serious conditions.

Temperature Relief

Causes:

- Thermostat stuck on
- Excessive temperature
- High inlet temperature
- Closed system expansion
- Solar heating

Testing:

- Check water temperature
- Test thermostat operation
- Verify elements/burner off
- Check mixing valves
- Monitor cycling

Pressure Relief

Causes:

- Thermal expansion
- High supply pressure
- Water hammer
- Closed system
- PRV failure

Solutions:

Problem	Solution
Thermal expansion	Install expansion tank
High pressure	Install/adjust PRV
Water hammer	Install arrestors
Closed system	Add expansion tank

Valve Testing

Manual Test:

- Lift lever
- Water should flow
- Release lever

- Flow should stop
- If not, replace

Never Plug Relief Valve!

Temperature Control Problems

Maintaining proper temperature is critical for safety and comfort.

Thermostat Failures

Gas Valve Thermostat:

Testing:

1. Check continuity
2. Test at temperature
3. Verify differential
4. Check ECO function
5. Calibration check

Problems:

- Contacts stuck
- Out of calibration
- Sensing bulb leak
- Capillary damage
- Mechanical failure

Electric Thermostat:

Testing:

1. Continuity test
2. Temperature test
3. Check both stats
4. ECO function
5. Manual reset test

Stack Temperature Issues

High Stack Temperature:

Causes:

- Scale buildup

- Baffle missing
- Soot accumulation
- Overfiring
- Poor heat transfer

Effects:

- Low efficiency
- High bills
- Premature failure
- Venting problems
- Safety issues

Testing:

- Measure stack temp
- Normal: 350-450°F
- High: >500°F
- Calculate efficiency
- Inspect flue baffle

Mixing Valve Problems

Thermostatic Mixing Valves:

Purpose:

- Prevent scalding
- Maintain temperature
- Increase capacity
- Safety device
- Code required (commercial)

Problems:

- Stuck valve
- Wrong setting
- Failed element
- Check valve stuck
- Debris blockage

Testing:

1. Check inlet temps
2. Verify outlet temp
3. Adjust setting

4. Flow test
5. Service/replace

19.5 Gas Supply Problems

Gas pressure and delivery issues affect all gas appliances.

Low Gas Pressure

Insufficient pressure causes poor performance and safety issues.

Symptoms of Low Pressure

Visual Indicators:

- Yellow flames
- Lazy flames
- Delayed ignition
- Flame lifting
- Incomplete combustion

Performance Issues:

- Low input
- Poor heating
- Long recovery
- Pilot outages
- Intermittent operation

Causes at Various Points

Utility Supply:

- System problems
- Peak demand
- Regulator issues
- Service interruption
- Meter problems

Building System:

Location	Common Causes
Meter	Undersized, regulator
Piping	Undersized, long runs
Regulators	Failed, wrong setting

Location	Common Causes
Valves	Partially closed
Appliance	Blocked orifice

Diagnostic Procedures

Systematic Testing:

1. **Utility Supply:**
    - Test at meter outlet
    - Static pressure
    - All appliances off
    - Should be 7" W.C. (NG)
    - Document reading
2. **Operating Pressure:**
    - All appliances on
    - Test at each appliance
    - Calculate pressure drop
    - Should maintain 5" minimum
    - Identify restrictions
3. **Individual Appliance:**
    - Test at appliance inlet
    - Appliance operating
    - Compare to requirement
    - Check manifold pressure
    - Verify orifice size

Problem Identification:

Test Result	Indicates
Low static	Utility problem
Static OK, operating low	Piping/meter issue
Gradual drop	Undersized piping
Sudden drop	Restriction
One appliance only	Local problem

High Gas Pressure

Excessive pressure creates dangerous conditions.

Dangers of High Pressure

Safety Hazards:

- Flame lifting
- Delayed ignition
- Flashback
- CO production
- Component damage
- Fire risk

Equipment Effects:

- Overfiring
- Overheating
- Limit trips
- Valve damage
- Control problems
- Noise

Causes and Solutions

Regulator Problems:

Type	Problem	Solution
Meter regulator	Failed open	Utility repair
Line regulator	Adjustment wrong	Readjust
Appliance reg	Bypassed	Reinstall
Vent blocked	Can't relieve	Clear vent

Testing:

1. Check at meter
2. Test at appliances
3. Monitor during operation
4. Check relief function
5. Verify venting

Maximum Pressures:

- Residential: 14" W.C.
- Appliance rating: 13.9" W.C.
- Test pressure: 14" W.C.
- Relief setting: 2 psi typical

Regulator Failures

Critical component requiring proper diagnosis.

Types of Failures

Failed Closed:

- No gas flow
- Complete outage
- Diaphragm ruptured
- Spring broken
- Frozen

Failed Open:

- High pressure
- No regulation
- Dangerous condition
- Immediate attention
- Shut off gas

Creeping:

- Pressure rises slowly
- Lock-up pressure high
- Seat damage
- Debris problem
- Replace regulator

Diagnostic Tests

Lock-Up Test:

1. Install gauge downstream
2. Flow gas briefly
3. Shut off appliance
4. Monitor pressure
5. Should stabilize

Acceptable:

- Stable pressure
- Slight rise OK
- Within 1" W.C.
- No continuous rise

Vent Test:

- Check for blockage

- Screen clear
- Proper termination
- No back pressure
- Winter icing

Relief Valve Test

Internal Relief:

- Part of regulator
- Token relief typical
- Should not discharge
- Indicates problem
- Limited capacity

External Relief:

- Separate device
- Full capacity
- Set above normal
- Below maximum
- Required certain sizes

Testing:

1. Slowly increase pressure
2. Monitor relief point
3. Should open at setting
4. Full flow capability
5. Reseats properly

Piping Restrictions

Flow restrictions cause pressure drop and poor performance.

Common Restrictions

Physical Blockages:

Location	Cause
Pipe	Debris, scale
Valves	Partially closed
Fittings	Undersized
Flex connectors	Kinked
Meters	Internal problems

Identification Methods

Pressure Drop Testing:

1. Test multiple points
2. Identify where drop occurs
3. Calculate drop per section
4. Compare to calculations
5. Find problem area

Visual Inspection:

- Kinked connectors
- Valve positions
- Fitting types
- Pipe condition
- Support issues

Flow Testing:

- Clock meter
- Calculate CFH
- Compare to requirements
- All appliances on
- Identify bottleneck

Solutions

Remedies:

Problem	Solution
Undersized pipe	Replace section
Kinked connector	Replace
Valve issue	Open fully/replace
Debris	Clean or replace
Too many fittings	Redesign

Meter Problems

Gas meter issues affect entire system.

Meter Sizing Issues

Undersized Meter:

- Pressure drop excessive
- All appliances on
- Exceeds capacity
- Utility problem
- Upgrade required

Meter Ratings:

Meter Size	Capacity CFH
AC-175	175
AC-250	250
AL-425	425
AL-800	800

Calculation:

- Total all appliances
- Convert BTU to CFH
- Add future loads
- Compare to meter
- Request upgrade if needed

Internal Problems

Meter Failures:

- Regulator problems
- Internal restrictions
- Mechanical issues
- Age-related
- Contamination

Symptoms:

- Pressure variations
- Noise
- No flow
- Erratic pressure
- Complete failure

Testing:

- Can't repair
- Utility responsibility
- Document symptoms

- Request replacement
- Temporary issues

19.6 Venting Problems

Proper venting is critical for safety and efficiency.

Spillage and Backdrafting

Dangerous conditions requiring immediate attention.

Causes of Spillage

House Depressurization:

Exhaust Devices:

Device	CFM	Effect
Range hood	100-1200	Major
Bath fan	50-150	Minor
Dryer	150-200	Moderate
Attic fan	1000-4000	Severe
Whole house fan	3000-5000	Severe

Building Tightness:

- Weatherization
- New windows/doors
- Air sealing
- Vapor barriers
- Modern construction

Vent System Problems:

- Blocked vent
- Improper termination
- Inadequate size
- Wrong configuration
- Deterioration

Detection Methods

Visual Tests:

- Match test

- Smoke test
- Mirror test
- Feel for spillage
- Look for staining

Instrumented Tests:

Worst-Case Depressurization:

1. Close all windows/doors
2. Turn on all exhaust
3. Open door to combustion area
4. Measure pressure difference
5. Should be > -5 Pa

Spillage Test:

1. Run appliance 5 minutes
2. Test at draft hood
3. Use smoke or CO
4. Should draft continuously
5. No spillage allowed

Solutions and Corrections

Remedies:

Problem	Solution
Depressurization	Combustion air, sealed combustion
Blocked vent	Clean, repair
Undersized vent	Resize per tables
Poor termination	Correct termination
Deteriorated vent	Replace vent

Combustion Air:

- Direct openings
- Ducted air
- Mechanical air
- Sized properly
- Code compliant

Condensation Issues

Condensation in vents causes deterioration and blockages.

Causes of Condensation

Oversized Venting:

- Too large diameter
- Slow velocity
- Cool flue gases
- Long residence time
- Condensation forms

Equipment Efficiency:

- Higher efficiency
- Lower stack temp
- More moisture
- Reaches dew point
- Condensation occurs

Long Runs:

- Heat loss
- Temperature drops
- Exterior runs worst
- Uninsulated chase
- Cold climates

Effects and Damage

Vent Deterioration:

Material	Effect
Galvanized	Rust through
Single wall	Rapid failure
Masonry	Spalling, blockage
B-vent	Longer life

Operational Problems:

- Blockages
- Spillage
- Freeze-ups
- Odors
- Staining

Prevention Methods

Solutions:

Vent Sizing:

- Proper sizing
- Per manufacturer
- Use tables
- Consider all factors
- Professional design

Vent Materials:

- AL29-4C stainless
- PVC (Category IV)
- Plastic (condensing)
- Special materials
- Proper category

Insulation:

- Exterior runs
- Cold spaces
- Vent wraps
- Maintain clearances
- Vapor barriers

Liners:

- Stainless steel
- Aluminum
- Plastic
- Proper sizing
- Professional installation

Inadequate Draft

Poor draft affects combustion and safety.

Measuring Draft

Test Points:

Location	Expected Reading
Over fire	-0.02" to -0.04"
Breach	-0.02" to -0.03"

Location	Expected Reading
At barometer	-0.04" to -0.06"
Stack	-0.04" to -0.08"

Test Procedure:

1. Equipment at temperature
2. All doors closed
3. Measure at breach
4. Stable reading
5. Document results

Causes of Poor Draft

Vent Problems:

- Undersized
- Too many elbows
- Horizontal runs
- Poor termination
- Blockages

Environmental:

- Wind effects
- Stack effect
- Temperature differential
- Altitude
- Barometric pressure

Equipment:

- Overfired
- Underfired
- Heat exchanger fouled
- Improper baffling
- Wrong fuel

Improving Draft

Methods:

Solution	Application
Resize vent	Undersized
Add height	Marginal draft

Solution	Application
Reduce elbows	Too many turns
Clean vent	Blockages
Wind cap	Wind problems
Barometric damper	Oil equipment
Power venter	Difficult situations

Blocked Vents

Obstructions prevent proper venting and create hazards.

Common Blockages

Types:

Blockage	Location	Season
Birds nests	Termination	Spring
Animals	Horizontal runs	Year-round
Ice	Termination	Winter
Debris	Any	Year-round
Deterioration	Joints	Year-round

Detection Methods

Inspection:

- Visual inspection
- Mirror on stick
- Flashlight
- Camera inspection
- Feel for flow

Testing:

- Draft test
- Spillage test
- CO test
- Temperature test
- Pressure test

Clearing Procedures

Safe Removal:

1. Shut off appliance
2. Allow cooling
3. Access vent
4. Remove carefully
5. Inspect damage
6. Clean thoroughly
7. Install screen
8. Test operation

Prevention:

- Proper caps
- Screens (where allowed)
- Regular inspection
- Proper termination
- Maintenance schedule

Improper Terminations

Vent termination affects safety and performance.

Code Requirements

Minimum Heights:

Type	Requirement
B-vent	1 foot above roof
Within 10 feet horizontal	2 feet above
Steep roof	2 feet above ridge
Flat roof	1 foot minimum

Clearances:

- 4 feet below opening
- 4 feet horizontally
- 1 foot above opening
- 10 feet from corner
- 3 feet above forced air intake

Common Problems

Installation Errors:

Error	Effect
Too short	Downdrafts

Error	Effect
Wrong cap	Rain entry
No cap	Debris entry
Too close to opening	CO entry
In alcove	Recirculation

Environmental Issues:

- Wind effects
- Snow coverage
- Ice formation
- Vegetation growth
- Adjacent buildings

Correction Methods

Solutions:

- Extend height
- Install proper cap
- Relocate if needed
- Add wind protection
- Maintain clearances
- Regular maintenance

19.7 Control System Failures

Controls coordinate all system operations and safety functions.

Thermostat Problems

The most common control issue and often easiest to diagnose.

Digital Thermostat Issues

Power Problems:

- Dead batteries
- No common wire
- Transformer issues
- Voltage too low
- Power stealing problems

Testing:

1. Check batteries
2. Measure R-C voltage
3. Should be 24-28VAC
4. Check C wire
5. Test under load

Programming Errors:

Issue	Check
Wrong day/time	Reset clock
Schedule wrong	Review program
Override active	Clear override
Vacation mode	Check settings
Wrong system type	Reconfigure

Communication Issues:

- WiFi connection
- App problems
- Cloud service
- Updates needed
- Compatibility

Mechanical Thermostat Problems

Anticipator Issues:

Heat Anticipator:

- Wrong setting
- Contacts dirty
- Out of adjustment
- Wire broken
- Affects cycling

Setting:

- Match to amp draw
- Typically 0.4-0.8A
- Longer cycles = higher
- Shorter cycles = lower

Mercury Bulb:

- Level critical

- Contacts dirty
- Bulb cracked
- Lost mercury
- Replace thermostat

Bimetal Issues:

- Out of calibration
- Mechanical damage
- Dirt/dust
- Corrosion
- Age related

Wiring Problems

Common Issues:

Wire	Function	Problem Effect
R	24V power	No operation
C	Common	Digital issues
W	Heat call	No heat
Y	Cool call	No cooling
G	Fan	No fan

Testing:

1. Check connections
2. Test continuity
3. Look for shorts
4. Verify color code
5. Check splice points

Limit Switch Issues

Safety devices preventing overheating.

Types and Functions

Primary Limit:

Type	Reset	Temperature
Disc	Auto	160-200°F
Bulb	Auto	Variable
Electronic	Auto	Programmable

Auxiliary Limits:

- Secondary limit
- Manual reset
- Rollout switches
- High limit
- Backup protection

Testing Procedures

Continuity Test:

1. Power off
2. Remove wires
3. Test continuity
4. Should be closed
5. If open, check temp

Temperature Test:

1. Check actual temp
2. Compare to rating
3. Should be below limit
4. If at limit, find cause
5. Don't bypass

Calibration Check:

- Heat with torch
- Monitor opening temp
- Should open at rating
- Cool down
- Should reset (auto)

Common Failures

Failure Modes:

Mode	Symptom
Stuck open	No heat
Stuck closed	No protection
Opens early	Short cycles
Opens late	Overheating
Won't reset	Manual only

Root Causes:

- Airflow problems
- Overfiring
- Duct restrictions
- Blower failures
- Filter issues

Never Bypass Safety Limits!

Pressure Switch Failures

Proves proper venting and combustion air flow.

How Pressure Switches Work

Operating Principle:

- Diaphragm senses pressure
- Inducer creates vacuum
- Switch closes on vacuum
- Allows ignition sequence
- Opens if pressure lost

Typical Settings:

Furnace Type	Switch Setting
80% efficiency	-0.5" to -0.8" W.C.
90% efficiency	-0.3" to -1.5" W.C.
Two-stage	Multiple settings

Testing Methods

Electrical Test:

1. Check for 24V to switch
2. Test continuity when closed
3. Should be <1Ω
4. Open when no vacuum
5. Infinite resistance

Pressure Test:

1. Connect manometer
2. Tee into tubing

3. Run inducer
4. Check vacuum level
5. Compare to switch rating

Tube Test:

1. Remove tube
2. Check for water
3. Clear blockages
4. Check for cracks
5. Verify connections

Common Problems

Failure Causes:

Cause	Test	Solution
Blocked tube	Blow through	Clear tube
Water in tube	Visual	Drain, reroute
Vent blockage	Check vent	Clear vent
Inducer weak	Amp test	Replace motor
Switch failed	Continuity	Replace switch
Wrong switch	Check rating	Correct switch

Valve Problems

Gas valves control fuel flow and safety.

Gas Valve Types

Standing Pilot Valves:

- Thermocouple operated
- Millivolt systems
- Manual control
- Simple design
- Reliable

Intermittent Pilot:

- Electronic ignition
- Pilot lights each cycle
- Proves before main
- More efficient
- Complex controls

Direct Ignition:

- No pilot
- Direct burner ignition
- HSI or spark
- Most efficient
- Electronic controls

Smart Valves:

- Integrated controls
- Self-diagnostic
- Modulating capable
- Communication bus
- Advanced features

Testing Procedures

Voltage Tests:

Test Point	Expected
Input voltage	24VAC
Pilot valve	24VAC
Main valve	24VAC
Common	0V

Resistance Tests:

- Power off
- Isolate coil
- Test resistance
- 10-50Ω typical
- Infinity = open
- 0Ω = shorted

Pressure Tests:

1. Inlet pressure
2. Outlet pressure
3. Regulated pressure
4. Should match specs
5. Adjust if possible

Common Failures

Failure Types:

Type	Symptom	Test
Coil open	No operation	Resistance
Stuck closed	No gas flow	Tap valve
Stuck open	Won't shut off	Manual close
Regulator	Wrong pressure	Pressure test
Solenoid	Intermittent	Voltage/resistance

Safety Concerns:

- Never bypass
- No jumpers
- Replace if questionable
- Test thoroughly
- Document tests

Sensor Failures

Various sensors provide feedback to controls.

Temperature Sensors

Types:

Type	Application	Resistance
Thermistor	Digital controls	Varies with temp
RTD	Precise measurement	100Ω at 0°C
Thermocouple	Flame sensing	Millivolts
Bimetal	Limits, stats	Switch action

Testing Thermistors:

1. Disconnect sensor
2. Measure resistance
3. Check temperature
4. Compare to chart
5. Should match ±5%

Temperature/Resistance:

Temperature	10K Thermistor
32°F	32,650Ω

Temperature	10K Thermistor
70°F	10,000Ω
100°F	5,827Ω

Flame Sensors

Flame Rectification:

- Single rod sensor
- AC voltage applied
- DC microamps returned
- 2-6 μA typical
- Proves flame

Testing:

1. Clean sensor
2. Check position
3. Measure microamps
4. Verify ground
5. Check connections

Problems:

- Carbon buildup
- Cracked porcelain
- Wrong position
- Poor ground
- Wire problems

Wiring Issues

Electrical problems cause many control failures.

Common Wiring Problems

Connection Issues:

Problem	Symptom	Test
Loose wire	Intermittent	Wiggle test
Corroded	High resistance	Visual/ohm
Wrong terminal	Wrong operation	Verify diagram
Pinched wire	Short/open	Continuity
Burnt wire	No continuity	Visual/ohm

Troubleshooting Method

Systematic Approach:

1. **Visual inspection**
2. **Wiggle test**
3. **Continuity check**
4. **Voltage verification**
5. **Load test**
6. **Replace if needed**

Wire Identification:

Color Codes:

Color	Typical Use
Black	Hot (L1)
White	Neutral/Hot (L2)
Red	24V power
White (low V)	Common
Yellow	Cooling
Green	Fan
Blue	Common (C)

Repair Procedures:

- Proper wire nuts
- Correct gauge
- Good connections
- Strain relief
- Proper routing
- Avoid hot surfaces

19.8 Using Wiring Diagrams for Troubleshooting

Wiring diagrams are roadmaps for electrical troubleshooting.

Following Circuit Paths

Understanding how to trace circuits on diagrams.

Types of Diagrams

Ladder Diagrams:

- Left to right flow
- Line 1 to Line 2
- Parallel circuits
- Easy to follow
- Most common

Schematic Diagrams:

- Component layout
- Physical representation
- Connection points
- More complex
- Installation reference

Connection Diagrams:

- Terminal strips
- Wire routing
- Color codes
- Harness layout
- Field connections

Reading Techniques

Circuit Tracing:

1. **Start at power source**
2. **Follow through controls**
3. **Through safeties**
4. **To loads**
5. **Back to common**

Symbols:

Symbol	Component
—[ ]—	Switch (open)
—[/]—	Switch (closed)
—(@)—	Coil/load
—[M]—	Motor
—>	<—
—[===]—	Heater

Path Analysis:

- Identify complete path

- Find all controls in series
- Note parallel paths
- Understand interlocks
- Locate test points

Voltage Tracing

Using diagrams to systematically check voltages.

Procedure

Step-by-Step:

1. **Verify input voltage**
    - At disconnect
    - At unit
    - Proper voltage
    - Both legs (240V)
2. **Through controls**
    - Each switch/control
    - Should have voltage
    - Both sides when closed
    - One side when open
3. **To loads**
    - Motor terminals
    - Valve connections
    - Heating elements
    - Control boards
4. **Complete circuit**
    - Back to neutral/L2
    - Through load
    - Complete path
    - Measure drops

Test Point Selection

Strategic Points:

Test Point	Information Gained
Transformer primary	Line voltage present
Transformer secondary	24V available
After thermostat	Call for heat
After safeties	Safety circuit complete
At gas valve	Valve should open

Documentation:

- Mark diagram
- Note voltages
- Circle problems
- Plan repairs
- Keep for reference

Identifying Open Circuits

Open circuits prevent current flow and operation.

Symptoms

Indicators:

- No voltage past point
- Component won't operate
- Infinite resistance
- No current flow
- Dead circuit section

Testing Methods

Continuity Testing:

1. Power OFF
2. Isolate circuit
3. Test across component
4. Should read 0-1Ω
5. Infinity = open

Voltage Testing:

1. Power ON
2. Test before component
3. Test after component
4. Voltage before, not after = open
5. Voltage both sides = closed

Half-Split Method:

1. Test middle of circuit
2. If voltage, problem downstream
3. No voltage, problem upstream
4. Split again

5. Quickly isolates problem

Common Opens

Locations:

Component	Test Method
Fuse	Visual/continuity
Circuit breaker	Reset/continuity
Switch	Continuity closed
Wire	Continuity end-to-end
Connection	Wiggle/continuity
Control	Internal test

Finding Short Circuits

Shorts cause excessive current and blown fuses.

Types of Shorts

Dead Short:

- Direct path to ground
- Immediate fuse blow
- Zero resistance
- Complete short
- Easy to find

Partial Short:

- High resistance short
- Intermittent operation
- Warm components
- Reduced performance
- Harder to find

Ground Fault:

- Current to ground
- Through unintended path
- Safety hazard
- GFCI trips
- Dangerous condition

Detection Methods

Resistance Testing:

1. Power OFF
2. Disconnect load
3. Test to ground
4. Should be infinity
5. Any reading = problem

Visual Inspection:

- Burnt insulation
- Melted wires
- Discoloration
- Damaged components
- Pinched wires

Isolation Testing:

1. Disconnect sections
2. Test each separately
3. Find problem section
4. Further isolate
5. Locate exact short

Common Short Locations

Problem Areas:

Location	Cause
Motor windings	Insulation failure
Wiring	Rubbing, heat
Capacitors	Internal short
Transformers	Winding short
Controls	Component failure

Component Verification

Using diagrams to verify component operation.

Test Procedures

Individual Component Tests:

1. **Locate on diagram**
2. **Identify terminals**

3. **Determine test type**
4. **Perform test**
5. **Compare to specs**
6. **Document results**

Verification Methods

Operational Tests:

Component	Test	Expected
Relay	Coil voltage	Contacts close
Contactor	Pull-in voltage	75-85% rated
Motor	Running amps	Below FLA
Capacitor	Microfarads	±10% rating
Transformer	Output voltage	24VAC ±10%

Substitution Testing:

- Temporary replacement
- Known good component
- Verify operation
- Identify failure
- Order correct part

Sequential Testing:

1. Follow operation sequence
2. Test each step
3. Verify timing
4. Check interlocks
5. Confirm safety operation

19.9 Advanced Diagnostic Techniques

Complex problems require sophisticated diagnostic methods.

Sequence of Operation Verification

Understanding and verifying proper operational sequence.

Standard Sequences

Heating Sequence:

1. **Thermostat calls** (0 sec)

2. **Inducer starts** (0 sec)
3. **Pressure switch closes** (2-5 sec)
4. **Igniter energizes** (30 sec)
5. **Gas valve opens** (34 sec)
6. **Flame proven** (35 sec)
7. **Blower starts** (45-60 sec)
8. **Heating continues** (varies)
9. **Thermostat satisfied** (varies)
10. **Gas valve closes** (immediate)
11. **Inducer runs** (15-30 sec post)
12. **Blower runs** (90-180 sec post)

Cooling Sequence:

1. Thermostat calls (Y)
2. Contactor pulls in
3. Compressor starts
4. Condenser fan runs
5. Blower operates
6. Cooling continues
7. Satisfied, shuts down

Verification Methods

Timing Tests:

- Use stopwatch
- Note each event
- Compare to specs
- Document variations
- Identify problems

LED Codes:

Flash Pattern	Typical Meaning
1 flash	Normal operation
2 flashes	Pressure switch stuck closed
3 flashes	Pressure switch open
4 flashes	Limit open
5 flashes	Flame sense
6 flashes	Rollout switch
7 flashes	Gas valve

Control Board Diagnostics:

- LED indicators
- Error codes
- History codes
- Test modes
- Communication ports

Timing Measurements

Critical for identifying control problems.

Important Timings

Pre-Purge:

- Clears heat exchanger
- 30-60 seconds typical
- Safety requirement
- Must complete
- No bypass allowed

Trial for Ignition:

- Time to prove flame
- 4-7 seconds typical
- Multiple attempts
- Lockout after failures
- Reset procedures

Post-Purge:

- Clears combustion products
- 15-30 seconds
- After gas stops
- Safety requirement
- Prevents odors

Blower Delays:

Delay	Time	Purpose
On delay	30-90 sec	Heat exchanger warmup
Off delay	90-180 sec	Heat removal
Cool delay	30 sec	Coil drainage

Measuring Techniques

Tools:

- Digital stopwatch
- Data logger
- Oscilloscope
- Chart recorder
- Smartphone apps

Procedure:

1. Start at initiation
2. Record each event
3. Note exact times
4. Multiple cycles
5. Average results
6. Compare to specs

Current Draw Analysis

Electrical consumption reveals component condition.

Motor Analysis

Measurements:

Motor Type	Normal Draw
PSC blower	70-80% FLA
ECM blower	Varies with load
Inducer	80-90% FLA
Condenser fan	70-80% FLA

Problem Indicators:

Current	Indicates
High	Mechanical bind, low voltage
Low	Coupling slip, high voltage
Fluctuating	Bearing problem
Very high	Locked rotor
Zero	Open winding

Compressor Analysis

RLA Testing:

- Rated Load Amps
- Should not exceed
- Indicates problems
- High = overload
- Low = loss of charge

LRA Testing:

- Locked Rotor Amps
- Starting current
- 4-6× running
- Brief duration OK
- Extended = problem

Power Quality:

- Voltage balance
- Power factor
- Harmonic distortion
- Voltage drop
- Frequency stability

Temperature Differential Testing

Temperature measurements diagnose performance issues.

Heating Differentials

Air Temperature Rise:

Formula: Supply - Return = Rise

Example:

- Supply: 120°F
- Return: 70°F
- Rise: 50°F
- Spec: 45-75°F
- Status: Good

What Rise Indicates:

Rise	Indicates
Too high	Low airflow
Too low	High airflow, low input

Rise	Indicates
Normal	Proper operation
Fluctuating	Cycling problem

Water Temperature Rise:

- Boilers: 20-40°F typical
- Tankless: 35-77°F
- Storage: Recovery rate
- Measure supply/return
- Calculate BTU output

Cooling Differentials

Air Temperature Drop:

- Should be 15-22°F
- Depends on humidity
- Indoor wetbulb affects
- Measure after 15 minutes
- Stable operation

Superheat/Subcooling:

Measurement	Target
Superheat (fixed)	20-25°F
Superheat (TXV)	8-12°F
Subcooling	8-12°F
Delta T	15-22°F

Combustion Analysis Interpretation

Understanding combustion readings ensures safety and efficiency.

Key Parameters

Critical Measurements:

Parameter	Good	Marginal	Poor
CO	<50 ppm	50-100 ppm	>100 ppm
O_2	5-9%	4-5%, 9-11%	<4%, >11%
CO_2	8-10%	6-8%, 10-11%	<6%, >11%
Efficiency	>78%	75-78%	<75%

Problem Diagnosis:

Reading	Indicates	Solution
High CO	Incomplete combustion	Adjust air/gas
High O_2	Excess air	Reduce air
Low O_2	Insufficient air	Increase air
Low efficiency	Poor combustion	Service needed

Adjustment Procedures:

1. Run 10 minutes
2. Insert probe
3. Read values
4. Adjust air
5. Retest
6. Document
7. Seal holes

Safety Limits:

- CO: <100 ppm air-free
- CO ambient: <35 ppm
- Never exceed 400 ppm
- Evacuate if high
- Find and fix source

19.10 When to Refer Work

Recognizing limitations protects technicians and customers.

Scope of Practice Limitations

Understanding legal and technical boundaries.

License Limitations

Gas Technician Scope:

License	Can Do	Cannot Do
G3	Appliances to 400K BTU	Over 400K
G2	Any appliance	Complex systems
G1	Complex systems	Nothing excluded

Trade Boundaries:

- Electrical: 120V limits
- Plumbing: Water/drain
- HVAC: Refrigeration
- Sheet metal: Ductwork
- Controls: Specialized

Electrical Work Requiring Electrician

Knowing when electrical work exceeds gas technician scope.

Permitted Electrical Work

Gas Technicians Can:

- Replace like-for-like
- Low voltage wiring
- Plug-in connections
- Control wiring
- Thermostat wiring

Within Appliance:

- Component replacement
- Internal wiring
- Safety controls
- Gas valve wiring
- Thermostat installation

Requiring Electrician

High Voltage Work:

Work Type	Why Electrician
New circuit	Permit required
Panel work	Licensed only
Outlet installation	Code requirements
Service upgrade	Utility coordination
240V work	Special requirements

Complex Controls:

- BMS integration
- Variable frequency drives
- Phase monitors
- Power quality

- Motor controls

HVAC System Modifications

Recognizing when work requires HVAC technician.

Refrigeration Work

Requires HVAC License:

- Refrigerant handling
- Compressor replacement
- Refrigerant piping
- Charging procedures
- Recovery requirements

Ductwork Modifications

Major Changes:

- System redesign
- Trunk lines
- Complete replacement
- Zoning systems
- Major rebalancing

Gas Tech Can Do:

- Minor adjustments
- Register changes
- Filter modifications
- Simple dampers
- Basic cleaning

Structural Issues

Building problems beyond equipment repair.

Foundation Problems

Indicators:

- Equipment not level
- Stress on piping
- Vent separation
- Door alignment

- Cracks visible

Actions:

- Document condition
- Notify owner
- Recommend engineer
- Don't attempt repair
- Safety concerns first

Building Envelope

Issues:

Problem	Referral To
Insulation	Contractor
Air sealing	Energy auditor
Moisture	Remediation
Ventilation	HVAC designer
Structural	Engineer

Code Authority Involvement

When to involve inspectors and code officials.

Mandatory Reporting

Must Report:

- Immediate hazards
- CO incidents
- Gas leaks (major)
- Fire hazards
- Illegal installations

Red Tag Situations:

- Imminent danger
- Code violations
- Unsafe conditions
- Must shut down
- Authority notified

Permit Requirements

Work Requiring Permits:

Work Type	Permit Needed
New installation	Yes
Replacement	Usually
Repairs	Sometimes
Maintenance	No
Emergency	After-the-fact

Inspector Relations:

- Professional conduct
- Clear communication
- Documentation ready
- Corrections promptly
- Learn from feedback

Documentation:

- Written reports
- Photos
- Test results
- Communication records
- Follow-up required

Chapter Review

Summary

This chapter covered comprehensive troubleshooting and diagnostic procedures:

Systematic Approach:

- Information gathering critical
- Understanding normal operation essential
- Logical problem isolation
- Hypothesis testing
- Proper repair execution
- Complete verification required
- Thorough documentation protects

Diagnostic Tools:

- Multimeter most versatile
- Manometer for pressures

- Combustion analyzer for safety
- Temperature measurement critical
- Amp readings reveal problems
- Leak detection essential

Common Problems:

- No heat calls most frequent
- Systematic diagnosis required
- Safety switches protect equipment
- Flame sensors need maintenance
- Limits indicate other problems
- Venting issues cause many failures

Control Systems:

- Thermostats often problematic
- Safeties must never be bypassed
- Sensors provide critical feedback
- Wiring problems common
- Proper diagnosis essential

Advanced Techniques:

- Sequence verification
- Timing measurements
- Current analysis
- Temperature differentials
- Combustion interpretation

Professional Judgment:

- Know your limitations
- Refer appropriately
- Protect license
- Ensure safety
- Document everything

Key Diagnostic Principles:

1. Safety always first
2. One problem at a time
3. Never assume
4. Test, don't guess
5. Fix cause, not symptom
6. Verify repairs

7. Document thoroughly
8. Learn from each call
9. Maintain tools properly
10. Continue education

Troubleshooting Case Studies

Case Study 1: No Heat - Intermittent

Complaint: "Heat works sometimes"

Information Gathered:

- 5-year-old furnace
- Problem 2 weeks
- No pattern noticed
- Previous service last year
- No error codes

Diagnosis Steps:

1. Run furnace - operates normally
2. Wait for failure - stops after 10 minutes
3. Check flame sensor - 1.8 μA
4. Clean sensor - 4.5 μA
5. Run multiple cycles - consistent

Solution: Marginal flame signal

Case Study 2: Short Cycling on Limit

Complaint: "Furnace runs briefly"

Findings:

- Starts normally
- Runs 3-5 minutes
- Limit light flashes
- Dirty filter found
- Static pressure 0.8" W.C.

Resolution:

- Replace filter
- Check all registers - 3 closed
- Open registers

- Static now 0.4" W.C.
- Temperature rise normal

Case Study 3: Yellow Flames

Complaint: "Flames look funny"

Testing:

- Gas pressure 7.2" W.C.
- Manifold 3.5" W.C.
- CO reading 450 ppm
- O_2 at 3%

Diagnosis:

- Primary air restricted
- Burner ports dirty
- Spider webs in venturi

Repair:

- Clean burners thoroughly
- Clear venturi
- Adjust air shutters
- CO now 35 ppm

Case Study 4: Pilot Won't Stay Lit

Complaint: "Have to relight daily"

Tests:

- Thermocouple 18 mV
- Pilot flame small
- Gas pressure OK
- Draft normal

Solution:

- Replace thermocouple
- Clean pilot orifice
- Adjust pilot flame
- Now 28 mV

Case Study 5: Water Too Hot

Complaint: "Scalding water"

Findings:

- Thermostat set 120°F
- Actual temp 150°F
- Gas valve doesn't shut off
- Burner continuous

Diagnosis:

- Thermostat contacts stuck
- ECO not tripping

Repair:

- Replace gas valve/thermostat
- Test ECO function
- Set to 120°F
- Verify cycling

Case Study 6: Pressure Switch Error

Complaint: "Three blinks on board"

Testing:

- Pressure switch open
- -0.3" W.C. at switch
- Switch rated -0.6" W.C.
- Inducer running

Found:

- Water in pressure tube
- Condensate trap full
- Drain partially blocked

Solution:

- Clear drain
- Empty trap
- Reroute tubing
- Add second trap

Case Study 7: Random Lockouts

Complaint: "Requires reset weekly"

Observation:

- Ignition failures
- Intermittent problem
- Worse on windy days
- Flame sensor OK

Discovery:

- Vent termination low
- Downdraft affecting
- Pressure switch marginal

Fix:

- Extend vent 2 feet
- Add wind cap
- No more lockouts

Case Study 8: High Gas Bills

Complaint: "Bills doubled"

Testing:

- Input correct
- Efficiency 79%
- Temperature rise OK
- Thermostat accurate

Found:

- Humidifier solenoid stuck
- Running constantly
- Hot water into drain

Resolution:

- Replace solenoid
- Check operation
- Bills return normal

Case Study 9: Blower Won't Stop

Complaint: "Fan runs constantly"

Checks:

- Thermostat fan AUTO
- G terminal no voltage
- Board shows fan on
- Heat works normally

Diagnosis:

- Board relay stuck
- Contacts welded

Solution:

- Replace control board
- Check for cause
- Found high static
- Address duct issues

Case Study 10: CO Alarm Activation

Complaint: "CO detector beeping"

Immediate Actions:

- Evacuate occupants
- Test with analyzer
- 45 ppm in basement
- Shut down equipment

Investigation:

- Water heater backdrafting
- Exhaust fans running
- House depressurized

Correction:

- Install combustion air
- Add powered vent
- Retest - 0 ppm
- Education provided

Diagnostic Procedure Exercises

Exercise 1: No Heat Diagnosis

Create diagnostic flowchart for no heat call:

1. Power present? → No → Check breaker
2. ↓ Yes
3. Thermostat calling? → No → Check thermostat
4. ↓ Yes
5. Inducer running? → No → Check control board
6. ↓ Yes
7. Pressure switch closed? → No → Check venting
8. ↓ Yes
9. Igniter operating? → No → Check igniter
10. ↓ Yes
11. Gas valve open? → No → Check gas valve
12. ↓ Yes
13. Flame proven? → No → Check sensor

Exercise 2: Temperature Rise Calculation

Given:

- Return air: 68°F
- Supply air: 135°F
- Nameplate: 40-70°F rise

Calculate:

- Rise = 135 - 68 = 67°F
- Within specifications
- Indicates normal airflow
- No adjustment needed

Exercise 3: Pressure Drop Test

System:

- 150 feet equivalent length
- 200,000 BTU/hr load
- 1" pipe installed

Test:

- Inlet: 7" W.C.
- Appliance: 5.8" W.C.
- Drop: 1.2" W.C.

Analysis:

- Excessive pressure drop
- Pipe undersized
- Need 1¼" minimum
- Recommend repipe

Tool Use Demonstrations

Manometer Setup

Procedure:

1. Zero in atmosphere
2. Install test fitting
3. Connect tubing
4. Open test port slowly
5. Allow stabilization
6. Read pressure
7. Close port
8. Remove fitting
9. Seal opening

Combustion Analyzer

Steps:

1. Warm up analyzer
2. Zero in fresh air
3. Check calibration date
4. Install probe in vent
5. Seal penetration
6. Run appliance 10 minutes
7. Record all readings
8. Print results
9. Seal test hole

Multimeter Safety

Checks:

1. Inspect leads
2. Verify CAT rating
3. Test on known source
4. Select proper function
5. Start high range

6. One hand rule
7. Stand on insulation
8. Never bypass safety

Problem Identification Scenarios

Scenario 1:

Symptoms: Furnace starts, runs 30 seconds, stops

Diagnosis: Flame sensor problem

Tests: Microamp test shows 0.8 μA

Solution: Clean or replace sensor

Scenario 2:

Symptoms: Loud boom on ignition

Diagnosis: Delayed ignition

Cause: Dirty burners, low pressure

Solution: Clean burners, check pressure

Scenario 3:

Symptoms: Furnace cycles on/off rapidly

Diagnosis: Overheating on limit

Tests: High temperature rise

Solution: Improve airflow

Key Terms and Definitions

Anticipator: Device in thermostat controlling cycle rate.

CAZ: Combustion Appliance Zone where combustion equipment located.

Continuity: Complete electrical path, measured in ohms.

Delta T: Temperature difference across system.

FLA: Full Load Amps - motor rating.

Flame Rectification: DC signal proving flame presence.

Ghost Voltage: Induced voltage, not real power.

Lockout: Safety shutdown requiring manual reset.

Microamps: Flame signal measurement (μA).

Open Circuit: Broken electrical path.

Pressure Switch: Proves proper venting/air flow.

RLA: Running Load Amps for motors.

Short Circuit: Unintended current path.

Spillage: Combustion products entering space.

Temperature Rise: Supply minus return temperature.

Trial for Ignition: Time allowed to prove flame.

Worst-Case Depressurization: Test for spillage potential.

End of Chapter 19

This comprehensive chapter on Troubleshooting and Diagnostics provides essential skills for diagnosing and repairing gas equipment safely and efficiently. The systematic approach presented ensures thorough problem resolution while protecting both technician and customer.

Students should master the diagnostic sequence from information gathering through verification, use diagnostic tools properly and safely, recognize common failure patterns, understand control system operations, and know when to refer work beyond their scope. Regular practice with these techniques builds confidence and competence.

As technology advances, diagnostic methods evolve, but the fundamental principle remains: systematic, logical troubleshooting based on understanding normal operation. Continuous education, proper tool maintenance, and thorough documentation ensure professional service delivery and career success in gas fitting.