Cotten's Services

HVAC Technician Troubleshooting Handbook

Core Edition

This full handbook combines the complete section-by-section technician training material developed for Cotten's Services. It is written as a practical troubleshooting help book, not just a checklist. Each topic explains what the technician is checking, why it matters, how to perform the test, what normal readings look like, what bad readings mean, and what to do next.

SECTION 1 - HVAC Electrical Diagnostics Fundamentals

Chapter 1

Electrical Safety & Diagnostic Mindset

Why Electrical Diagnostics Matter

Nearly every HVAC system failure involves one of these:

- Loss of power
- Failed electrical component
- Open safety
- Bad connection
- Voltage issue
- Control board logic problem
- Improper grounding
- Failed motor
- Failed capacitor
- Communication failure

Good technicians do not guess. They follow a repeatable diagnostic process.

The Technician Diagnostic Mindset

Never Start By Replacing Parts

New technicians often:

- replace capacitors randomly,
- condemn compressors too quickly,
- guess at boards,
- or assume refrigerant issues first.

Professional technicians diagnose first.

Proper Diagnostic Order

Always Diagnose In This Order

1. Verify Power

2. Verify Control Voltage

3. Verify Safety Circuit

4. Verify Sequence of Operation

5. Verify Mechanical Operation

6. Verify Refrigeration Operation

Skipping steps creates callbacks and misdiagnosis.

Electrical Safety

WARNING

HVAC systems contain:

- 120V
- 208V
- 230V
- 240V
- 277V
- 480V
- High voltage capacitors
- Stored electrical energy

These voltages can kill you.

Basic Electrical Safety Rules

Rule 1

Never trust a disconnect. Always verify voltage with a meter.

Rule 2

Capacitors hold charge after power removal. Always discharge safely.

Rule 3

Never work energized unless absolutely necessary for testing.

Rule 4

One hand rule whenever possible. Avoid becoming a path to ground.

Rule 5

Wear safety glasses. Arc flashes happen instantly.

Essential Electrical Tools

Multimeter

The multimeter is the most important HVAC diagnostic tool.

A good HVAC meter should read:

- AC voltage
- DC voltage
- Resistance
- Continuity
- Capacitance
- Frequency
- Microamps
- Temperature

Clamp Meter

Used for:

- motor amperage,
- compressor amperage,
- blower diagnostics,
- locked rotor testing.

Non-Contact Voltage Tester

Quick verification only. Never trust it as your primary test method.

Manometer

Critical for:

- pressure switches,
- gas pressure,
- static pressure diagnostics.

Understanding Voltage

What Is Voltage?

Voltage is electrical pressure. Think of it like water pressure in a pipe. Higher voltage = more electrical force.

Common HVAC Voltages

Voltage	Common Use
24V	Thermostat/control
120V	Furnaces/air handlers
208/230V	Condensers/heat pumps
240V	Residential equipment
480V	Commercial equipment

Understanding Low Voltage vs High Voltage

Low Voltage (24V)

Controls:

- thermostat,
- contactor,
- relays,
- boards,
- safeties.

Low voltage tells equipment what to do.

High Voltage

Actually powers:

- compressors,
- motors,
- heaters,
- blowers.

Transformer Basics

What Does A Transformer Do?

A transformer converts 120V or 240V down to 24V control voltage.

Most HVAC transformers:

- 40VA
- 50VA

- 75VA

Transformer Terminals

Terminal	Meaning
Primary	Incoming high voltage
Secondary	Outgoing 24V
R	24V power
C	Common

How To Test A Transformer

Step 1

Verify incoming voltage to primary side.

Example:

- 120V present

Step 2

Measure secondary voltage.

Expected:

- 24V-28V AC

Bad Transformer Symptoms

- Blank thermostat
- No control voltage
- Blown low voltage fuse
- Intermittent operation
- Burned smell
- Overheating

Important Technician Note

If transformer failed, do not immediately replace it. Find why it failed.

Usually:

- shorted thermostat wire,
- grounded contactor coil,
- shorted float switch,
- failed reversing valve coil.

Understanding Continuity

What Is Continuity?

Continuity means electricity can flow through a circuit. A closed switch has continuity. An open switch does not.

How To Test Continuity

IMPORTANT

POWER MUST BE OFF.

Never test resistance or continuity on energized circuits.

Meter Setup

Set meter to:

- continuity,

OR

- resistance (ohms)

Continuity Examples

Component	Normal Reading
Closed switch	Continuity
Open switch	OL
Good fuse	Continuity
Blown fuse	OL

Understanding Resistance

What Is Resistance?

Resistance opposes electrical flow. Measured in ohms.

Common Resistance Checks

Component	Purpose
Compressor windings	Check damage
Motor windings	Check condition
Sensors	Temperature reading

Component	Purpose
Heating elements	Integrity
Contactor coils	Coil condition

Understanding Ground Faults

What Is A Ground Fault?

Electricity is leaking to ground instead of staying in the circuit. Grounded components often trip breakers, destroy boards, blow fuses, and cause intermittent failures.

How To Check For Ground Fault

Step 1

Disconnect power.

Step 2

Remove wires from component.

Step 3

Measure terminal to ground.

Expected: OL

If continuity exists: Component is grounded.

Common Grounded Components

- Compressors
- Condenser fan motors
- Blower motors
- Heater elements
- Reversing valve coils

Understanding Sequence of Operation

What Is Sequence of Operation?

The exact order equipment operates.

Example:

1. Thermostat calls
2. Board responds
3. Inducer starts
4. Pressure switch closes
5. Igniter energizes
6. Gas valve opens
7. Flame proven
8. Blower starts

Understanding sequence of operation is everything in HVAC diagnostics.

If sequence stops, the failed component is usually near that stopping point.

Critical Technician Rule

Never Skip Ahead

If the inducer never starts, do not troubleshoot flame sensor yet. Always follow the sequence logically.

Understanding HVAC Wiring Diagrams

Two Main Diagram Types

Type	Purpose
Ladder Diagram	Electrical sequence
Pictorial Diagram	Physical wiring locations

Reading Ladder Diagrams

Power flows top to bottom or left to right. Follow switches, safeties, relays, and loads.

Common Wiring Diagram Symbols

Symbol	Meaning
M	Motor
COMP	Compressor
C	Capacitor/Common
NO	Normally Open
NC	Normally Closed

Symbol	Meaning
OL	Overload
TSTAT	Thermostat

Important Technician Habit

Never panic looking at wiring diagrams. Break them into sections:

- power supply,
- controls,
- safeties,
- loads.

Then trace operation step-by-step.

Voltage Drop

What Is Voltage Drop?

Loss of voltage due to weak connections, undersized wire, burned terminals, or loose connections.

Symptoms Of Voltage Drop

- contactor chatter,
- dim boards,
- overheating motors,
- hard starting,
- intermittent failures.

How To Find Voltage Drop

Measure across connections, switches, and contactors while energized.

Good closed switch: Near 0 volts across it.

High voltage across closed switch: Bad connection.

Common Electrical Failures In HVAC

Failure	Most Common Cause
No cooling	Capacitor
Dead unit	Breaker/disconnect
Intermittent blower	Loose low voltage

Failure	Most Common Cause
Repeated fuse blowing	Shorted thermostat wire
Compressor won't start	Capacitor/contactor
Random board failures	Poor grounding
Inverter faults	Dirty power

Technician Field Tip

Most intermittent problems are:

- loose wires,
- weak connections,
- grounding issues,
- or airflow-related.

Not bad boards.

End of Section 1

SECTION 2 - Capacitors, Contactors, Relays & Motor Diagnostics

Chapter 2

Capacitor Diagnostics

What A Capacitor Does

A capacitor stores and releases electrical energy to help motors:

- start,
- run efficiently,
- produce torque,
- reduce amperage draw.

Without proper capacitance:

- motors overheat,
- compressors struggle,
- amperage increases,
- efficiency drops.

Types Of HVAC Capacitors

Type	Purpose
Run Capacitor	Helps motor run continuously
Start Capacitor	Assists startup only
Dual Run Capacitor	Runs compressor and fan

Understanding Dual Capacitors

Most residential condensers use one dual capacitor. It contains a compressor capacitor, fan capacitor, and common terminal.

Capacitor Terminal Markings

Terminal	Meaning
C	Common
FAN	Condenser fan
HERM	Hermetic compressor

Common Capacitor Ratings

Examples:

- 35/5 uF
- 45/5 uF
- 55/7.5 uF

First number: Compressor side.

Second number: Fan side.

Capacitor Voltage Ratings

Common ratings:

- 370V
- 440V

IMPORTANT

A 440V capacitor may replace a 370V capacitor. A 370V capacitor should not replace a 440V capacitor.

Symptoms Of Weak Capacitors

Compressor Side Symptoms

- hard starting,
- loud humming,
- breaker trips,
- overheated compressor,
- locked rotor trips,
- high amp draw,
- intermittent cooling.

Fan Side Symptoms

- fan blade spins slowly,
- fan stops intermittently,
- overheating condenser,
- high head pressure,
- compressor overheating.

Physical Signs Of Failure

Replace capacitor if you see:

- swollen top,
- leaking oil,
- rust expansion,
- burned terminals,
- melted wires.

Even if capacitance is close.

Tools Needed

- Multimeter with capacitance
- Insulated screwdriver
- Needle nose pliers

Safety Procedure

WARNING

Capacitors can hold dangerous voltage after power removal. Always discharge before handling.

How To Safely Discharge Capacitor

Step 1

Shut off disconnect.

Step 2

Verify power is off.

Step 3

Use insulated screwdriver.

Bridge:

- C to FAN
- C to HERM

Some technicians prefer resistor discharge tools.

How To Test A Capacitor

Step 1

Label wires if needed.

Step 2

Remove all wires.

Step 3

Set meter to capacitance.

Step 4

Measure:

- C to FAN
- C to HERM

Example Reading

45/5 capacitor:

Side	Expected
Compressor	45 uF
Fan	5 uF

Acceptable Range

Most capacitors: +/- 6%

Example Calculation

45 uF capacitor:

- 45 x .06 = 2.7

Acceptable:

- 42.3 to 47.7

Below: Replace.

Important Technician Note

Weak capacitors often still run motors. Do not assume "running" means "good."

Hard Start Kits

What Is A Hard Start Kit?

A start capacitor and relay combination used to:

- increase startup torque,
- reduce startup strain,
- assist weak compressors,
- help generator startup.

Common Uses

- long line sets,
- older compressors,
- low voltage areas,
- generators,
- high head pressure conditions.

WARNING

Hard start kits do not fix:

- grounded compressors,
- locked compressors,
- mechanical damage.

Chapter 3

Contactor Diagnostics

What A Contactor Does

A contactor is an electrically controlled switch. 24V control voltage energizes the coil and closes contacts to allow high voltage to flow to compressor, condenser fan, and electric heaters.

Main Parts Of A Contactor

Part	Function
Coil	Magnetic control
Contacts	Carry high voltage
Plunger	Pulls contacts closed
Line side	Incoming power
Load side	Outgoing power

How A Contactor Works

Thermostat calls for cooling:

1. 24V sent to contactor coil
2. Coil becomes magnetic
3. Plunger pulls in
4. Contacts close
5. High voltage reaches compressor/fan

Common Contactor Failures

- burned contacts,
- weak coil,
- pitted contacts,
- welded contacts,
- ant infestation,
- buzzing coil,
- voltage drop.

Symptoms Of Bad Contactors

- outdoor unit won't start,
- loud chattering,
- intermittent cooling,
- buzzing,
- overheated wires,
- voltage loss,
- welded closed contacts.

How To Test A Contactor

Step 1

Verify 24V across coil.

Expected: 24-28V AC

Step 2

Check if plunger pulls in.

If 24V present but no pull-in: Bad coil.

Step 3

Measure voltage across contacts while energized.

Good contacts: Near 0 volts.

IMPORTANT

If you measure significant voltage across closed contacts, contacts are damaged.

Example

Closed contactor:

- 8V measured across contacts

This indicates high resistance and burned contacts. Replace contactor.

Voltage Drop Rule

Good closed switch: Near 0V across switch.

High voltage across switch: Resistance problem.

Common Technician Mistake

Replacing capacitor when contactor is actually dropping voltage.

Contact Welding

What Is Welded Contacts?

Contacts melt together. Compressor continues running even when thermostat stops calling.

Symptoms

- condenser won't shut off,
- frozen evaporator,
- constant compressor operation.

Ant Problems

In southern climates, ants frequently destroy contactors. Dead ants prevent contact closure.

Technician Tip

Always inspect contactor physically before condemning expensive components.

Chapter 4

Relay & Sequencer Diagnostics

What Is A Relay?

A relay is a smaller electrically controlled switch.

Used for:

- blower motors,
- fan relays,
- electric heat staging,
- isolation controls.

Relay Basics

Low voltage energizes a coil. Coil closes switch contacts. Switch controls another circuit.

Normally Open vs Normally Closed

Type	Meaning
Normally Open	Open until energized
Normally Closed	Closed until energized

Sequencers

What Is A Sequencer?

Electric heat timing device. Stages electric heaters on gradually to reduce amperage spikes, light dimming, and breaker stress.

Symptoms Of Bad Sequencer

- no electric heat,
- partial heat,
- blower not running,
- heat strips stuck on,
- high electric bills.

How To Test Sequencer

Step 1

Verify 24V control signal.

Step 2

Verify contacts close after time delay.

Step 3

Check continuity through load side.

Important Note

Sequencers intentionally delay operation. Do not misdiagnose normal timing as failure.

Chapter 5

PSC Motor Diagnostics

What Is A PSC Motor?

Permanent Split Capacitor motor. Uses run capacitor and fixed speed windings.

Common in older blowers, condenser fans, and budget equipment.

Common PSC Failures

- weak capacitor,
- overheated bearings,
- grounded windings,
- open windings,
- overheating,
- low airflow damage.

Symptoms

- overheating,
- noisy bearings,
- weak airflow,
- slow startup,

- excessive amperage.

How To Test PSC Motor

Step 1

Verify proper voltage.

Step 2

Verify capacitor. Never condemn motor before testing capacitor.

Step 3

Check amperage. Compare to FLA rating.

Step 4

Check winding resistance.

Open winding: OL reading.

Grounded winding: Continuity to ground.

Bearing Failure Symptoms

- squealing,
- grinding,
- overheating,
- shaft play.

Chapter 6

ECM Motor Diagnostics

What Is An ECM Motor?

Electronically Commutated Motor. Variable speed DC motor controlled electronically.

Used in high efficiency systems, inverter systems, and communicating systems.

ECM Advantages

- lower energy usage,
- airflow control,
- quieter operation,
- humidity control,
- variable speed operation.

ECM Problems Most Techs Miss

ECMs hate:

- high static pressure,
- overheating,
- voltage spikes,
- dirty power.

High Static Pressure Kills ECMs

This is extremely important.

ECMs attempt to maintain airflow. When static pressure rises, the motor increases torque. This overheats modules.

Symptoms Of High Static

- surging blower,
- noisy airflow,
- failed ECM module,
- intermittent blower,
- excessive watt draw.

ECM Diagnostic Basics

Step 1

Verify proper voltage.

Step 2

Verify low voltage communication.

Step 3

Verify airflow restrictions.

Step 4

Check static pressure.

IMPORTANT

Many ECM motors are replaced unnecessarily. The real problem is often:

- plugged filter,
- undersized return,
- dirty evaporator,
- restrictive duct system.

Technician Field Tip

Always check airflow before condemning ECM motors.

End Of Section 2

SECTION 3 - Refrigeration Cycle Fundamentals & Refrigerant Diagnostics

Chapter 7

Understanding The Refrigeration Cycle

The Most Important Concept In HVAC

Air conditioning does not create cold air. HVAC systems remove heat from inside and move it outside.

Understanding heat transfer is the foundation of refrigeration diagnostics.

The Four Main Refrigeration Components

Component	Function
Compressor	Pumps refrigerant
Condenser Coil	Rejects heat
Metering Device	Controls refrigerant flow
Evaporator Coil	Absorbs heat

Refrigerant State Changes

Refrigerant constantly changes between liquid, vapor, high pressure, and low pressure. These pressure changes allow heat movement.

Basic Refrigeration Flow

Cooling Mode

1. Compressor

Takes low-pressure vapor and compresses it into high-pressure, high-temperature vapor.

2. Condenser Coil

Outdoor coil rejects heat. Refrigerant changes from vapor to liquid.

3. Metering Device

Pressure drop occurs. Liquid refrigerant enters low-pressure side.

4. Evaporator Coil

Indoor coil absorbs heat. Refrigerant boils into vapor. Cycle repeats.

Important Technician Rule

Refrigerant does not get used up. If charge is low, there is a leak.

Heat Always Moves Toward Cold

Heat moves from warmer area to cooler area. The refrigeration cycle manipulates pressure to control this heat movement.

Saturation Temperature

What Is Saturation?

The temperature where refrigerant changes state: liquid to vapor or vapor to liquid.

Why Saturation Matters

Pressure and temperature are directly related. Higher pressure means higher saturation temperature. Lower pressure means lower saturation temperature.

Example

R-410A:

- 118 PSI is about 40°F saturation

That means refrigerant boils at 40°F at that pressure.

Technician Understanding

Your gauges are actually temperature tools disguised as pressure tools.

Superheat

What Is Superheat?

Temperature above refrigerant boiling point. Measured on suction line after evaporator.

Why Superheat Matters

Superheat confirms refrigerant fully boiled off and compressor protected from liquid floodback.

How To Measure Superheat

Step 1

Connect suction gauge.

Step 2

Read suction pressure.

Step 3

Convert pressure to saturation temperature using PT chart.

Step 4

Measure actual suction line temperature.

Step 5

Subtract: Actual line temp minus saturation temp = Superheat

Example

Suction Pressure: 118 PSI R-410A

Saturation: 40°F

Actual Suction Line Temp: 55°F

Calculation: 55°F - 40°F = 15°F superheat

What High Superheat Means

High superheat usually means:

- low refrigerant,
- evaporator starving,
- restriction,
- airflow problem,
- underfeeding TXV.

What Low Superheat Means

Low superheat may indicate:

- overcharge,
- flooding evaporator,
- failed TXV,
- low airflow,
- liquid floodback danger.

Important Technician Rule

Never diagnose refrigerant charge before verifying airflow. Airflow problems drastically affect superheat.

Subcooling

What Is Subcooling?

Temperature below condensing saturation temperature. Measured on liquid line leaving condenser.

Why Subcooling Matters

Confirms condenser properly filled with liquid refrigerant and TXV receiving solid liquid column.

How To Measure Subcooling

Step 1

Connect liquid gauge.

Step 2

Read liquid pressure.

Step 3

Convert to saturation temperature.

Step 4

Measure liquid line temperature.

Step 5

Subtract: Saturation temp minus actual liquid line temp = Subcooling

Example

Liquid Pressure: 377 PSI R-410A

Saturation: 110°F

Actual Liquid Line Temp: 98°F

Calculation: 110°F - 98°F = 12°F subcooling

High Subcooling Causes

- overcharge,
- restricted metering device,
- backed-up condenser,
- excessive refrigerant.

Low Subcooling Causes

- undercharge,
- flashing liquid,
- low refrigerant mass,
- condenser starvation.

TXV Systems vs Fixed Orifice Systems

System Type	Primary Charging Method
TXV	Subcooling
Fixed Orifice/Piston	Superheat

Why TXVs Change Diagnosis

TXV regulates evaporator feeding automatically. Superheat becomes less reliable for charging. Subcooling becomes primary charging method.

Metering Devices

Type	Characteristics
Fixed Orifice	Simple, inexpensive
Piston	Fixed bore
TXV	Variable flow
EEV	Electronic control

Fixed Orifice Systems

Flow depends on pressure difference. Charge is critically important.

TXV Systems

TXV automatically adjusts refrigerant flow based on evaporator outlet temperature.

TXV Bulb Operation

Sensing bulb monitors suction line temperature. TXV attempts to maintain target superheat.

Common TXV Failures

- stuck closed,
- stuck open,
- lost bulb charge,
- plugged inlet screen,
- poor bulb mounting,
- external equalizer problems.

Symptoms Of Restricted TXV

- high superheat,
- low suction pressure,
- starving evaporator,
- poor cooling,
- flashing liquid.

Symptoms Of Flooding TXV

- low superheat,
- floodback,
- sweating compressor,
- low suction line temperature.

Flash Gas

What Is Flash Gas?

Liquid refrigerant prematurely boiling before metering device. Usually caused by low subcooling, restriction, excessive pressure drop, or undercharge.

Symptoms

- poor cooling,
- unstable TXV operation,
- noisy liquid line,
- erratic pressures.

Floodback

What Is Floodback?

Liquid refrigerant returning to compressor. Compressors are designed to compress vapor, not liquid.

Symptoms

- sweating compressor,
- slugging,
- oil dilution,
- noisy compressor,
- broken valves.

Causes

- low airflow,
- failed TXV,
- overcharge,
- dirty evaporator,
- blower failure.

Slugging

What Is Slugging?

Large amounts of liquid entering compressor. Liquid cannot compress. Mechanical damage occurs.

Symptoms

- violent compressor noise,
- broken reeds,
- damaged valves,
- locked compressor.

Compression Ratio

What Is Compression Ratio?

Discharge pressure divided by suction pressure. High compression ratio increases heat, amperage, and compressor strain.

Causes Of High Compression Ratio

- dirty condenser,
- low suction pressure,
- overcharge,
- restrictions,
- high ambient temperature.

Understanding Compression Cooling

The compressor is cooled partly by returning suction vapor. Low suction vapor causes poor compressor cooling.

Refrigerant Restrictions

Common Restriction Points

Location	Common Cause
TXV inlet screen	Debris
Filter drier	Moisture/debris
Piston	Contamination
Liquid line	Kink
Service valve	Partial closure

Restriction Symptoms

- high superheat,
- low suction,
- high subcooling,

- flashing,
- temperature drop across restriction.

How To Find Restrictions

Use temperature probes. Restrictions create temperature drop.

Example

Filter drier:

- inlet 95°F
- outlet 72°F

Major restriction likely present.

Refrigerant Charging Procedures

Proper Charging Steps

Step 1

Verify airflow first.

Step 2

Verify clean coils.

Step 3

Verify blower speed.

Step 4

Connect gauges.

Step 5

Measure superheat, subcooling, line temperatures, amp draw, and temperature split.

Never Charge By Pressure Alone

Pressure alone means very little without temperatures, airflow, and load conditions.

Typical Temperature Split

Most systems: 16-22°F split

Measured at return air and supply air.

Low Temperature Split Causes

- low charge,
- high airflow,
- compressor problems,
- duct leakage.

High Temperature Split Causes

- low airflow,
- dirty filter,
- restricted evaporator,
- blower issues.

Technician Field Tip

Always think of the system as airflow plus refrigeration working together. Most refrigerant misdiagnosis is actually airflow related.

End Of Section 3

SECTION 4 - Advanced Refrigerant Diagnostics, Leak Detection & System Commissioning

Chapter 8

Advanced Refrigerant Diagnostics

The Difference Between Beginners And Advanced Technicians

Beginner technicians read pressures, guess at charge, and replace parts. Advanced technicians understand system relationships, heat transfer, airflow interaction, compressor behavior, and refrigerant state changes.

The goal is not: "what is the pressure?" The goal is: "why is the pressure that way?"

System Conditions Always Affect Each Other

Every refrigeration reading affects another reading.

Example:

- low airflow lowers suction pressure,
- low suction affects superheat,
- high superheat affects compressor temperature,
- compressor temperature affects discharge temperature.

Everything is connected.

The 5 Main Refrigeration Readings

Reading	What It Tells You
Suction Pressure	Evaporator condition
Head Pressure	Condenser condition
Superheat	Evaporator feeding
Subcooling	Condenser liquid reserve
Temperature Split	Overall system performance

Reading System Behavior

Example 1

Low Suction + High Superheat + Low Subcooling

Usually indicates undercharge, leak, or starving evaporator.

Example 2

Low Suction + Low Superheat

Usually indicates low airflow, dirty evaporator, or blower problem.

Example 3

High Head + High Subcooling

Usually overcharge, restriction, or backed-up condenser.

Example 4

High Head + Low Subcooling

Usually condenser airflow problem, dirty condenser, or condenser fan issue.

Example 5

Normal Pressures + Poor Cooling

Possible causes: duct leakage, airflow bypass, compressor inefficiency, or reversing valve leakage.

Compressor Diagnostics

What The Compressor Does

The compressor circulates refrigerant, creates pressure difference, and drives the refrigeration cycle.

Types Of Compressors

Type	Common Use
Reciprocating	Older systems
Scroll	Modern residential
Rotary	Mini splits
Inverter Rotary	Variable speed systems

Scroll Compressor Basics

Scroll compressors are smooth, efficient, and quiet. Common today in R-410A systems, inverter systems, and heat pumps.

Common Scroll Failures

- overheating,
- floodback damage,
- internal bypass,
- grounded windings,
- locked rotor,
- oil loss.

Symptoms Of Weak Compressors

- poor temperature split,
- low amp draw,
- equalized pressures,
- low compression ratio,
- poor capacity.

Important Technician Note

A compressor can run and still be bad. Running does not equal pumping properly.

Compressor Amp Draw

Why Amp Draw Matters

Amp draw shows compressor workload.

High Amp Draw Causes

- high head pressure,
- overcharge,
- dirty condenser,
- low voltage,
- failing compressor.

Low Amp Draw Causes

- undercharge,

- inefficient compressor,
- low load,
- internal bypassing.

Locked Rotor Amps (LRA)

What Is LRA?

Maximum startup amperage if compressor cannot start. LRA is extremely high.

Example:

- 140 amps,
- 160 amps,
- 200+ amps.

Hard Starting Symptoms

- lights dim,
- loud humming,
- breaker trips,
- delayed startup,
- high startup amps.

Causes Of Hard Starting

- weak capacitor,
- voltage drop,
- high head pressure,
- mechanical wear,
- flooded starts.

Discharge Temperature

Why Discharge Temperature Matters

High discharge temperature destroys compressors.

Causes Of High Discharge Temp

- high superheat,
- undercharge,

- restrictions,
- low suction cooling,
- dirty condenser.

General Rule

Discharge line temperatures above about 225°F become dangerous.

Condenser Diagnostics

Purpose Of Condenser

Reject heat absorbed indoors plus compressor heat.

Dirty Condenser Symptoms

- high head pressure,
- high amp draw,
- poor cooling,
- overheated compressor,
- high discharge temperature.

Cleaning Condensers Properly

IMPORTANT

Do not only spray from outside inward. Push debris out the way it entered.

Proper Cleaning Procedure

Step 1

Disconnect power.

Step 2

Remove top carefully. Avoid stressing fan wires.

Step 3

Wash from inside outward.

Step 4

Straighten damaged fins if needed.

Common Cleaning Mistakes

- bending fins,
- using excessive pressure,
- damaging coil coating,
- washing debris deeper into coil.

Evaporator Diagnostics

Purpose Of Evaporator

Absorb indoor heat.

Dirty Evaporator Symptoms

- low airflow,
- low suction pressure,
- low superheat,
- freezing,
- poor humidity removal.

Ice Formation Causes

Cause	Why
Low airflow	Coil too cold
Low refrigerant	Low saturation temp
Blower failure	Lack of heat load
Dirty filter	Reduced airflow

IMPORTANT

Ice is not automatically low refrigerant. Airflow causes more freezing than leaks.

Refrigerant Leak Detection

Refrigerant Never Gets Used Up

Low charge always means a leak or improper installation.

Common Leak Locations

Location	Common Cause
Schrader cores	Vibration
Evaporator coils	Corrosion
Brazed joints	Poor workmanship
TXVs	Vibration
Condenser coils	Formic corrosion
Service valves	Wear

Leak Detection Methods

Method	Accuracy
Soap bubbles	Excellent
Electronic detector	Excellent
Nitrogen pressure test	Excellent
UV dye	Sometimes useful

Soap Bubble Testing

Still one of the best methods. Apply generously. Watch for continuous bubbling.

Electronic Leak Detectors

Move slowly. Fast movement misses leaks.

Common False Positives

- cleaners,
- solvents,
- drain chemicals,
- gasoline fumes.

Nitrogen Pressure Testing

Why Nitrogen?

Dry nitrogen is safe, inert, and moisture free. Used for leak testing, pressure testing, and brazing purge.

NEVER Use Oxygen

Oxygen plus oil plus pressure can explode violently.

Pressure Testing Procedure

Step 1

Recover refrigerant.

Step 2

Pressurize with nitrogen.

Step 3

Monitor pressure stability.

Step 4

Use bubbles/electronic detector.

Standing Pressure Tests

Pressure should remain stable. Temperature changes slightly affect readings.

Vacuum Procedures

Why Pull Vacuum?

Remove moisture, air, and non-condensables.

Moisture Is Extremely Dangerous

Moisture creates acids, restrictions, oil damage, and compressor failure.

Micron Gauge

Never pull vacuum by gauges alone. Use a micron gauge. Manifold gauges are not accurate for evacuation depth.

Target Vacuum

Proper deep vacuum: 500 microns or lower.

Triple Evacuation

Used on contaminated systems, burnout repairs, and major repairs.

Vacuum Decay Test

Purpose

Verify no leaks and no moisture remaining.

Procedure

After reaching target vacuum, isolate pump and watch micron rise.

Rapid rise indicates leak, moisture, or contamination.

System Commissioning

What Is Commissioning?

Final verification system operates properly. Many callbacks happen because commissioning was skipped.

Commissioning Checklist

Verify:

- airflow,
- blower speed,
- temperature split,
- refrigerant charge,
- condensate drainage,
- thermostat operation,
- amp draws,
- static pressure,
- voltage,
- safety operation.

Condensate Drain Diagnostics

Common Problems

- improper trap,
- clogged drain,
- double trapping,
- no vent,
- poor pitch.

Float Switches

Purpose: prevent water damage. They open low voltage circuit when drain backs up.

Common Float Switch Problems

- incorrect wiring,
- poor mounting,
- intermittent sticking.

Non-Condensables

What Are Non-Condensables?

Air or gases trapped inside system.

Symptoms

- high head pressure,
- unstable pressures,
- poor efficiency,
- high compression ratio.

Cause

Usually improper evacuation or improper charging procedures.

Technician Field Tip

A properly installed system rarely has problems. Most major failures begin with poor evacuation, poor airflow, improper charging, contamination, or bad electrical connections.

End Of Section 4

SECTION 5 - Airflow Diagnostics, Static Pressure & Duct System Troubleshooting

Chapter 9

Understanding Airflow

Airflow Is The Most Misdiagnosed Problem In HVAC

Most technicians focus on refrigerant pressures, compressors, and electrical parts.

But airflow problems cause:

- freezing coils,
- overheating furnaces,
- high electric bills,
- poor humidity removal,
- compressor failures,
- ECM motor failures,
- cracked heat exchangers,
- poor comfort.

HVAC Is A Heat Transfer System

Refrigerant moves heat. Airflow delivers heat to and from the refrigerant. Without proper airflow, the refrigeration cycle cannot operate correctly.

The 400 CFM Rule

Most residential cooling systems target:

CFM = Tons x 400

Example

System Size	Target Airflow
2 Ton	800 CFM
3 Ton	1200 CFM
4 Ton	1600 CFM
5 Ton	2000 CFM

Exceptions To 400 CFM

Condition	Typical CFM
High humidity climates	350-375 CFM/Ton
Heat pump heating	400-450 CFM/Ton
Dry climates	Higher airflow acceptable

What Happens With Low Airflow

Low airflow causes colder evaporator, lower suction pressure, ice formation, reduced efficiency, high compressor superheat, and poor capacity.

What Happens With High Airflow

High airflow causes warmer evaporator, higher suction pressure, poor dehumidification, low temperature split, and possible water blowoff.

Symptoms Of Airflow Problems

Symptom	Possible Airflow Issue
Frozen coil	Low airflow
Hot furnace limit trips	Low airflow
Loud return grille	Restriction
Weak supply airflow	Duct restriction
High electric bills	Airflow imbalance
ECM surging	High static pressure
Uneven temperatures	Air distribution

Chapter 10

Static Pressure Diagnostics

What Is Static Pressure?

Static pressure is resistance to airflow inside the duct system. Think of it as blood pressure for HVAC airflow.

Why Static Pressure Matters

High static pressure kills ECM motors, reduces airflow, lowers efficiency, increases noise, and overheats equipment.

External Static Pressure (ESP)

Most residential systems are designed for:

- 0.5" WC total external static pressure

Some variable speed systems tolerate 0.8" WC or occasionally higher, but lower is always better.

What WC Means

WC = Water Column. Used because HVAC pressure is very small.

Tools Needed

- Digital manometer
- Static pressure probes
- Drill with step bit
- Rubber test port plugs

Where To Drill Test Ports

Return Pressure Port

Drill between filter and blower.

Supply Pressure Port

Drill after evaporator coil and before supply plenum branches.

IMPORTANT

Do not drill into heat exchanger, coil tubing, drain pan, or electrical wiring. Always inspect before drilling.

How To Measure Static Pressure

Step 1

System running at full airflow.

Step 2

Insert return probe. Return pressure usually negative.

Example: -0.22" WC

Step 3

Insert supply probe. Supply pressure positive.

Example: +0.31" WC

Step 4

Add absolute values.

TESP = |Return| + Supply

Example

Reading	Value
Return	-0.22
Supply	+0.31

Calculation: 0.22 + 0.31 = 0.53" WC

Interpreting Static Pressure

Static Pressure	Meaning
Under 0.5	Good
0.5-0.8	Marginal
Over 0.8	Restrictive
Over 1.0	Severe restriction

High Return Static Causes

- plugged filter,
- undersized return,
- restrictive filter grille,
- collapsed flex duct,
- dirty evaporator.

High Supply Static Causes

- undersized supply ducts,
- closed dampers,
- restrictive registers,
- dirty coil,
- kinked flex duct.

Important Technician Note

Many bad blower motors are actually victims of high static pressure.

Chapter 11

Duct System Diagnostics

Duct Systems Matter More Than Most Technicians Realize

A perfect HVAC unit connected to poor ductwork will still perform poorly.

Common Duct Problems

Problem	Result
Undersized return	High static
Poor supply layout	Hot/cold rooms
Leaky ducts	Capacity loss
Crushed flex duct	Airflow restriction
Poor insulation	Heat gain/loss
Unbalanced airflow	Comfort problems

Flex Duct Problems

Most Common Flex Duct Mistakes

- excessive length,
- sharp bends,
- compression,
- sagging,
- kinks.

IMPORTANT

Flex duct should be stretched tight, supported properly, and use gradual turns only. Compressed flex drastically reduces airflow.

Duct Leakage

Symptoms

- poor airflow,
- dusty house,
- attic smells,
- humidity problems,
- high energy bills.

Common Leak Locations

- plenum connections,
- return boxes,
- boots,
- air handler seams,
- flex connections.

Detecting Duct Leaks

Methods:

- visual inspection,
- smoke testing,
- pressure testing,
- thermal imaging.

Return Air Problems

Undersized Returns Cause

- noisy systems,
- high static,
- reduced airflow,
- overheating,
- coil freezing.

Rule Of Thumb

Return air is usually more important than supply air sizing. A system cannot deliver air it cannot receive.

Air Balancing Basics

Purpose

Deliver proper airflow to each room.

Symptoms Of Poor Balancing

- one room too hot,
- one room too cold,
- weak airflow,
- pressure imbalances.

Balancing Methods

- damper adjustment,
- register adjustment,
- duct resizing,
- adding returns.

Chapter 12

Filter Diagnostics

Filters Affect EVERYTHING

A restrictive filter can freeze coils, trip limits, damage ECM motors, and reduce efficiency.

Common Filter Mistakes

- too restrictive,
- wrong size,
- double filtering,
- neglected replacement.

MERV Ratings

Higher MERV means more restriction.

IMPORTANT

Ultra-high MERV filters in weak duct systems often create airflow problems.

Filter Pressure Drop

Good filters should have low pressure drop. Measure pressure before and after filter.

Dirty Evaporator Coils

Symptoms

- low airflow,
- freezing,
- high static,
- poor cooling,
- high superheat.

Causes

- poor filtration,
- return leaks,
- neglected maintenance.

Coil Cleaning

IMPORTANT

Evaporator fins are delicate. Use approved cleaners, low pressure, and proper rinsing.

Condensate Drain Issues

Dirty evaporators often create slime buildup, overflow, and float switch trips.

Chapter 13

Blower Speed Diagnostics

Why Blower Speed Matters

Incorrect blower speed affects humidity, temperature split, refrigerant pressures, comfort, and heat exchanger temperatures.

Cooling Mode Airflow

Typical target: 350-400 CFM per ton.

Heating Mode Airflow

Gas furnaces often require higher airflow to control temperature rise.

Temperature Rise

What Is Temperature Rise?

Difference between return air and supply air.

Furnace Example

Return: 70°F

Supply: 125°F

Temperature rise: 55°F

IMPORTANT

Always compare to manufacturer rating plate.

High Temperature Rise

Usually low airflow.

Low Temperature Rise

Usually high airflow.

ECM Blower Programming

Modern systems may use dip switches, Bluetooth setup, communicating controls, or board programming.

Technician Field Tip

Never adjust blower speed blindly. Always verify static pressure, temperature rise, and refrigerant conditions.

Chapter 14

Airflow & Refrigeration Relationship

Critical HVAC Understanding

Airflow and refrigerant readings are directly connected.

Low Airflow Effects

Reading	Effect
Suction Pressure	Drops
Superheat	May drop
Coil Temp	Drops
Ice Risk	Increases

High Airflow Effects

Reading	Effect
Suction Pressure	Rises
Temp Split	Drops
Humidity Removal	Reduced

IMPORTANT TECHNICIAN RULE

Before adjusting refrigerant charge, verify airflow first.

End Of Section 5

SECTION 6 - Gas Furnace Diagnostics & Heating System Troubleshooting

Chapter 15

Understanding Gas Furnace Operation

The Furnace Sequence Of Operation

Understanding sequence of operation is the key to furnace diagnostics. Most furnace problems are solved by identifying where the sequence stopped.

Typical Gas Furnace Sequence

Step 1

Thermostat calls for heat.

Step 2

Control board energizes inducer motor.

Step 3

Pressure switch proves venting.

Step 4

Igniter energizes.

Step 5

Gas valve opens.

Step 6

Burners ignite.

Step 7

Flame sensor proves flame.

Step 8

Indoor blower starts after delay.

Step 9

Heating cycle continues until thermostat satisfies.

Step 10

Burners shut off.

Step 11

Blower continues through fan-off delay.

Critical Technician Rule

When troubleshooting, follow the sequence. Where operation stops is usually near the failed component.

Chapter 16

Thermostat & Low Voltage Heat Calls

Heat Call Basics

Most furnaces use 24V control circuits.

Common Thermostat Terminals

Terminal	Function
R	24V power
W	Heat call
G	Indoor blower
Y	Cooling
C	Common

Heat Call Operation

When thermostat calls for heat, R connects to W. This sends 24V to furnace control board.

How To Verify Heat Call

Step 1

Set thermostat to heat.

Step 2

Raise setpoint above room temperature.

Step 3

Measure voltage R to C.

Expected: 24-28V AC

Step 4

Measure W to C.

Expected during heat call: 24V

Common Thermostat Problems

- dead batteries,
- broken subbase,
- loose wire,
- incorrect programming,
- failed thermostat relay.

Intermittent Thermostat Issues

Often caused by loose low voltage connections, weak transformer, or broken thermostat wire.

Chapter 17

Inducer Motor Diagnostics

What The Inducer Does

The inducer motor removes combustion gases, creates draft, and proves venting safety.

Why Draft Matters

Without proper draft, dangerous combustion gases may enter the home.

Common Inducer Problems

Problem	Symptoms
Seized bearings	Loud noise
Weak motor	Pressure switch failure
Cracked wheel	Poor draft
Water damage	Corrosion
Restricted vent	Intermittent pressure switch

Inducer Startup

The inducer should start immediately after heat call.

If Inducer Does NOT Start

Check:

- voltage to inducer,
- control board output,
- inducer capacitor if equipped,
- seized motor,
- loose wiring.

Voltage Test

Most residential inducer motors: 120V.

Example

Board sending 120V to inducer but motor not running: Likely bad inducer.

Important Technician Note

Always spin wheel by hand with power off. Seized bearings are common.

Chapter 18

Pressure Switch Diagnostics

What A Pressure Switch Does

Pressure switches verify proper inducer draft exists.

Pressure Switch Operation

Inducer creates negative pressure. Pressure switch senses this vacuum. When proper draft exists, switch closes.

Important Safety Note

Pressure switches are safety devices. Never permanently bypass them.

Common Pressure Switch Problems

Cause	Result
Plugged condensate drain	Won't close
Cracked tubing	Pressure loss
Weak inducer	Low draft
Blocked vent	Intermittent operation
Failed switch	Open circuit

How To Test Pressure Switch

Step 1

Verify inducer running.

Step 2

Inspect tubing for cracks, water, and blockage.

Step 3

Measure continuity across switch.

During proper draft: switch should close.

Measuring Draft

Use manometer.

Example

Switch rated: -1.20" WC

Inducer must create at least 1.20" negative pressure.

Condensate Problems

High efficiency furnaces commonly fail due to plugged traps, blocked drains, and water-filled tubing.

Important Technician Tip

Many bad pressure switches are actually drainage problems.

Chapter 19

Igniter Diagnostics

Types Of Igniters

Type	Description
Hot Surface Igniter	Silicon carbide/nitride
Spark Ignition	Arc ignition
Standing Pilot	Older systems

Hot Surface Igniters

Modern furnaces commonly use silicon nitride and silicon carbide igniters. They glow orange/white hot before ignition.

Important Technician Warning

Igniters are fragile. Never touch element with bare fingers. Oil contamination shortens lifespan.

Common Igniter Failures

- cracked element,
- improper voltage,
- weak glow,
- open circuit,
- delayed ignition.

How To Test Igniter

Step 1

Verify furnace sequence reaches ignition stage.

Step 2

Measure voltage to igniter.

Step 3

Inspect for cracks.

Step 4

Measure resistance.

Typical Resistance

Varies by manufacturer. Always compare to specs.

Important Technician Note

Open igniter: OL reading.

Delayed Ignition

Symptoms

- loud boom,
- rough ignition,
- rollout concerns.

Causes

- dirty burners,
- low gas pressure,
- weak igniter,
- crossover blockage.

Delayed ignition can crack heat exchangers over time.

Chapter 20

Gas Valve Diagnostics

What The Gas Valve Does

Controls gas flow to burners.

Gas Valve Operation

Board sends 24V to gas valve. Valve opens. Gas flows to burners.

How To Test Gas Valve

Step 1

Verify 24V at valve during ignition sequence.

Step 2

If voltage present but no gas flow, possible failed valve.

Step 3

Verify inlet gas pressure.

Step 4

Verify manifold pressure.

Typical Gas Pressures

Fuel	Typical Pressure
Natural Gas	3.5" WC
LP Gas	10-11" WC

LP Conversion Problems

Incorrect LP setup causes soot, rollout, overheating, and delayed ignition.

Important Technician Note

Always verify correct orifices, regulator adjustment, and conversion kit installation.

Chapter 21

Flame Sensor Diagnostics

One Of The Most Misunderstood Components In HVAC

What The Flame Sensor Does

Proves flame exists. Without proof, gas valve shuts down.

Flame Rectification

Flame conducts tiny DC current. Board measures this current through flame sensor.

Typical Flame Sensor Reading

Usually 1-10 microamps DC. Most systems: 2-6 uA common.

Symptoms Of Bad Flame Sensor

- burners light then shut off,
- repeated ignition attempts,
- lockout codes,
- intermittent heating.

How To Test Flame Sensor

Step 1

Connect meter in series. Meter must read DC microamps.

Step 2

Run furnace.

Step 3

Observe microamp reading.

Weak Reading Causes

- dirty sensor,
- poor grounding,
- weak flame,
- cracked porcelain,
- board issue.

Cleaning Flame Sensors

Use fine steel wool or a dollar bill. Avoid aggressive sanding.

Important Technician Note

Many flame sensors are replaced unnecessarily. Cleaning often fixes issue.

Grounding Is Critical

Flame rectification depends heavily on proper furnace grounding. Poor ground causes weak flame signal.

Chapter 22

Limit Switch Diagnostics

What Limit Switches Do

Protect furnace from overheating.

Causes Of High Temperature

- dirty filter,
- blower failure,
- low airflow,
- undersized ductwork,
- dirty evaporator coil.

Symptoms Of Open Limit

- burners shut off early,
- blower runs continuously,
- overheating,
- short cycling.

Important Technician Rule

Never simply replace limit switch. Find why furnace overheated.

Rollout Switches

What Is Rollout?

Flame leaving burner area. Extremely dangerous.

Causes Of Rollout

- blocked heat exchanger,
- cracked heat exchanger,
- blocked vent,
- delayed ignition.

Rollout Switches Are Manual Reset

If rollout trips, investigate thoroughly. Never bypass.

Chapter 23

Blower Operation In Heating Mode

Blower Delay

Indoor blower starts after heat exchanger warms up. This prevents blowing cold air.

Fan-Off Delay

Blower continues after burners shut off. This removes remaining heat from exchanger.

Blower Problems

Problem	Result
Low speed	High temperature rise
High speed	Low temperature rise
Weak capacitor	Overheating
Dirty wheel	Reduced airflow

Measuring Temperature Rise

Temperature Rise = Supply Temp - Return Temp

Example

Reading	Temp
Return	70°F
Supply	125°F

Temperature rise: 55°F

Always Compare To Rating Plate

Too high: low airflow.

Too low: excessive airflow.

Chapter 24

Heat Exchanger Diagnostics

The Most Important Safety Component

The heat exchanger separates combustion gases from breathing air.

Cracked Heat Exchanger Symptoms

- rollout,
- soot,
- flame disturbance,
- CO concerns,

- repeated limit trips.

Inspection Methods

- visual inspection,
- combustion analysis,
- camera inspection,
- flame observation.

Flame Disturbance Test

Blower starts. If flames move excessively, possible exchanger crack.

IMPORTANT

This is not a definitive test alone.

Carbon Monoxide Concerns

Incomplete combustion creates CO. Potentially deadly.

Combustion Analysis

Professional combustion analyzers measure O2, CO2, CO, efficiency, and draft.

Technician Field Tip

Many furnace component failures are airflow problems in disguise. Always verify filter, blower, ductwork, and evaporator cleanliness before condemning major components.

End Of Section 6

SECTION 7 - Heat Pump Diagnostics & Defrost System Troubleshooting

Chapter 25

Understanding Heat Pump Operation

What Makes A Heat Pump Different

A heat pump is an air conditioner that can operate in reverse. It can cool a house in summer and heat a house in winter.

Basic Heat Pump Concept

In cooling mode:

- indoor coil absorbs heat,
- outdoor coil rejects heat.

In heating mode:

- outdoor coil absorbs heat,
- indoor coil rejects heat.

Heat Pumps Move Heat

Even cold outdoor air still contains heat energy. The heat pump extracts that heat and moves it indoors.

Major Heat Pump Components

Component	Purpose
Compressor	Circulates refrigerant
Reversing Valve	Changes refrigerant direction
Outdoor Coil	Condenser or evaporator
Indoor Coil	Condenser or evaporator
Defrost Board	Controls defrost cycle
Auxiliary Heat	Backup heat source

Reversing Valve Basics

What The Reversing Valve Does

Changes refrigerant flow direction. This determines heating mode and cooling mode.

Common Control Methods

Type	Energized In
O terminal	Cooling
B terminal	Heating

IMPORTANT TECHNICIAN NOTE

Many Nortek/Nordyne systems use Y & B logic, not Y & O. Always verify wiring diagrams.

Symptoms Of Reversing Valve Problems

- poor heating,
- poor cooling,
- equalized pressures,
- lukewarm air,
- stuck mode operation.

Reversing Valve Diagnostics

Step 1

Verify thermostat output.

Step 2

Verify solenoid energized.

Step 3

Check coil magnetism. Use screwdriver test.

Step 4

Listen for valve shift. Often audible whoosh.

Important Technician Note

A solenoid can energize while valve itself remains mechanically stuck.

Stuck Reversing Valve Symptoms

- high suction pressure,
- low head pressure,
- poor temperature difference,
- compressor runs continuously.

Heat Pump Heating Pressures

Heating pressures differ greatly from cooling mode. Do not compare them directly.

Typical Heating Mode Conditions

Outdoor coil becomes evaporator. Indoor coil becomes condenser.

Frost Formation

Frost Is Normal

When outdoor temperatures drop, the outdoor coil may frost.

Why Frost Forms

Outdoor coil operates below freezing. Moisture freezes onto coil surface.

Why Frost Is Dangerous

Heavy frost blocks airflow and reduces capacity, efficiency, and airflow.

Chapter 26

Defrost System Operation

Purpose Of Defrost

Remove frost buildup from outdoor coil.

How Defrost Works

During defrost:

1. Heat pump temporarily switches to cooling mode
2. Outdoor coil heats up
3. Frost melts
4. Auxiliary heat prevents cold air indoors

Important Technician Understanding

The outdoor unit may appear to steam, hiss, or smoke during defrost. This is normal.

Defrost Components

Component	Function
Defrost board	Controls timing
Coil sensor	Detects coil temp
Ambient sensor	Outdoor temp reference
Reversing valve	Switches mode
Auxiliary heat	Indoor comfort

Defrost Initiation Methods

Method	Description
Time-temperature	Most common
Demand defrost	Smart systems
Sensor based	Advanced systems

Time-Temperature Defrost

Most older systems check coil every 30/60/90 minutes and initiate defrost if coil cold enough.

Demand Defrost

Advanced systems analyze coil temperature, ambient conditions, and runtime efficiency. They only defrost when needed.

Symptoms Of Defrost Problems

Problem	Result
No defrost	Ice-covered coil
Stuck in defrost	Cold house
Sensor failure	Improper timing
Board failure	Erratic operation

How To Test Defrost Operation

Step 1

Verify frost accumulation.

Step 2

Verify sensors.

Step 3

Check board timing.

Step 4

Force defrost manually if board allows.

During Proper Defrost

You should observe reversing valve shift, outdoor fan stop (often), coil warming, and steam production.

IMPORTANT

Steam during defrost is normal. Do not misdiagnose as smoke or fire.

Defrost Sensor Diagnostics

Coil Sensor

Monitors outdoor coil temperature.

Failed Coil Sensor Symptoms

- excessive icing,
- short defrost cycles,
- no defrost.

Sensor Testing

Most sensors are thermistors. Resistance changes with temperature.

How To Test Thermistors

Step 1

Disconnect sensor.

Step 2

Measure resistance.

Step 3

Compare to manufacturer chart.

IMPORTANT

Always know actual sensor temperature while testing.

Chapter 27

Auxiliary Heat Diagnostics

What Is Auxiliary Heat?

Backup heating source. Usually electric heat strips, sometimes gas or dual fuel.

When Auxiliary Heat Operates

- low outdoor temperatures,
- defrost cycles,
- emergency heat,
- large temperature demand.

Heat Strip Operation

Electric heaters stage on using relays, sequencers, or boards.

Common Heat Strip Problems

- burned elements,
- failed sequencers,
- stuck relays,
- airflow restrictions,
- overheating.

Symptoms Of Failed Heat Strips

- cold air during defrost,
- poor heat output,
- thermostat aux heat warning.

Symptoms Of Stuck Heat Strips

- extremely high electric bills,
- overheating,
- breakers tripping,
- strips energized during cooling.

How To Test Heat Strips

Step 1

Verify airflow.

Step 2

Verify sequencer operation.

Step 3

Measure amperage.

Step 4

Measure resistance.

Important Technician Rule

Never energize heat strips without blower airflow. Dangerous overheating can occur.

Emergency Heat Mode

What Is Emergency Heat?

Disables compressor and runs only backup heat.

Used For

- compressor failure,
- severe weather,
- service operation.

Important Technician Note

Emergency heat greatly increases electrical usage.

Chapter 28

Heat Pump Refrigerant Diagnostics

Heat Pumps Behave Differently In Heating

Outdoor temperatures heavily affect pressures, superheat, subcooling, and discharge temperature.

Common Heating Mode Symptoms

Symptom	Possible Cause
Poor heat	Low charge
Frosting	Defrost issue
Cold air	Aux heat failure
High head pressure	Indoor airflow restriction
Low suction	Outdoor airflow restriction

Indoor Airflow In Heating

Indoor coil becomes condenser. Poor indoor airflow now raises head pressure.

Outdoor Airflow In Heating

Outdoor coil becomes evaporator. Restricted outdoor airflow lowers suction pressure.

Important Technician Understanding

A heat pump in heating mode may show very low suction pressures. This can be normal depending on outdoor temperature.

Chapter 29

Inverter Heat Pump Diagnostics

What Makes Inverter Systems Different

Inverter systems vary compressor speed continuously instead of simple on/off operation.

Advantages

- efficiency,
- quieter operation,
- low ambient performance,
- stable temperatures.

Inverter Systems Depend Heavily On Electronics

Including DC inverter boards, sensors, communication wiring, and power quality.

Important Technician Note

Traditional gauge diagnostics alone are often insufficient.

Common Inverter Problems

Problem	Cause
Communication errors	Wiring/polarity
Random shutdowns	Voltage problems
DC fan failures	Board issues

Problem	Cause
High amp faults	Compressor problems
Generator issues	Dirty power

Power Quality Is Critical

Inverter systems hate voltage imbalance, surging, harmonics, unstable generators, and weak neutral connections.

Generator Operation Issues

Many generators produce unstable voltage, poor frequency control, and harmonic distortion. This can damage inverter systems.

AVR Importance

Automatic Voltage Regulation helps stabilize voltage, startup surges, and power quality.

Symptoms Of Dirty Power

- nuisance faults,
- communication errors,
- inverter lockouts,
- board failures.

Communication Wiring

Mini split and inverter systems often use serial communication and DC signaling.

Wiring Mistakes Cause Major Problems

Common issues:

- reversed polarity,
- poor grounding,
- loose terminals,
- wire damage.

Important Technician Rule

Always follow manufacturer wiring diagrams exactly, especially on inverter systems.

Chapter 30

Heat Pump Airflow & Balance Point

What Is Balance Point?

Outdoor temperature where heat pump alone can no longer maintain indoor temperature.

Below Balance Point

Auxiliary heat becomes necessary.

Factors Affecting Balance Point

Factor	Effect
Home insulation	Major
Outdoor temperature	Major
Heat pump size	Major
Air leakage	Major
Wind exposure	Moderate

Low Ambient Heat Pumps

Modern inverter systems can operate well below freezing. Some maintain heating below -5°F, -10°F, or lower.

Technician Field Tip

Many heat pump complaints are actually airflow issues, thermostat setup problems, auxiliary heat staging problems, or poor defrost operation. Not refrigerant issues.

End Of Section 7

SECTION 8 - Mini Split & Inverter System Troubleshooting

Chapter 31

Understanding Mini Split Systems

What Makes Mini Splits Different

Mini splits are ductless, inverter driven, electronically controlled, variable capacity systems. Unlike conventional systems, they constantly adjust operation.

Main Mini Split Components

Component	Function
Outdoor inverter board	Compressor control
Indoor head unit	Air handling
Electronic expansion valve (EEV)	Refrigerant control
DC fan motors	Variable airflow
Thermistors	Temperature sensing
Communication wiring	Data exchange

Mini Split Advantages

- high efficiency,
- zoning,
- low ambient heating,
- quiet operation,
- variable speed operation.

Why Mini Splits Confuse Technicians

Traditional HVAC systems mostly use simple on/off logic. Mini splits use DC voltage, PWM signals, serial communication, electronic expansion valves, and inverter frequency control.

IMPORTANT TECHNICIAN NOTE

Mini split pressures constantly change. Do not expect steady conventional readings.

Chapter 32

Mini Split Electrical Fundamentals

Inverter Power Conversion

Mini splits convert AC power into DC power. Then the inverter board creates variable-frequency AC for compressor control.

Why This Matters

Because compressor speed changes constantly, amperage, pressures, and temperatures change.

Main Electrical Sections

Section	Purpose
Incoming AC	Main power
Rectifier	Converts AC to DC
Capacitor bank	Smooths DC voltage
Inverter module	Creates variable frequency
Compressor drive	Powers compressor

Important Safety Warning

Mini split inverter boards contain high DC voltage, often 300-400+ volts DC, even after power removal.

IMPORTANT

Always allow capacitor discharge time. Some systems retain dangerous charge.

Common Mini Split Electrical Failures

- inverter board failure,
- capacitor failure,
- communication errors,
- thermistor faults,
- DC fan motor failures,
- power supply instability.

Chapter 33

Communication Wiring Diagnostics

Why Communication Wiring Matters

Mini splits depend on constant communication between indoor unit and outdoor unit. If communication fails, system shuts down.

Common Communication Wiring

Usually 2 wire, 3 wire, or 4 wire systems. May include power, communication, and grounding.

Common Wiring Problems

Problem	Result
Reversed polarity	Communication fault
Loose wire	Intermittent errors
Poor ground	Random faults
Incorrect wire size	Voltage drop
Shared voltage interference	Communication loss

Important Technician Rule

Always match terminal numbers exactly: 1 to 1, 2 to 2, 3 to 3. Never assume wire colors are correct.

Voltage Drop Problems

Long wire runs can create communication instability, intermittent shutdowns, and startup failures.

Shielded Communication Wiring

Some systems require shielded cable. Improper shielding causes noise interference.

IMPORTANT

Never run communication wiring tightly alongside high voltage wiring, motors, or generators. Electrical interference can corrupt communication.

Chapter 34

Thermistor Diagnostics

What Is A Thermistor?

Temperature-sensitive resistor. Mini splits rely heavily on thermistors.

Common Thermistor Locations

Sensor	Purpose
Indoor air sensor	Room temperature
Coil sensor	Coil protection
Outdoor ambient	Outdoor conditions
Discharge sensor	Compressor protection
Suction sensor	Refrigerant monitoring

How Thermistors Work

As temperature changes, resistance changes.

Symptoms Of Failed Thermistors

- false temperature readings,
- random shutdowns,
- icing,
- poor heating,
- poor cooling,
- communication faults.

How To Test Thermistors

Step 1

Disconnect sensor.

Step 2

Measure resistance.

Step 3

Measure actual sensor temperature.

Step 4

Compare to manufacturer resistance chart.

IMPORTANT

Temperature accuracy matters. A sensor at 70°F must be compared against 70°F resistance values.

Common Thermistor Mistakes

- testing without temperature reference,
- poor probe contact,
- condemning board before sensor.

Chapter 35

Electronic Expansion Valve (EEV) Diagnostics

What Is An EEV?

Electronic Expansion Valve. Mini split version of a TXV.

EEV Advantages

Allows extremely precise refrigerant control, variable capacity operation, and efficiency improvements.

EEV Operation

Controlled electronically by outdoor board. Adjusts refrigerant flow constantly.

Symptoms Of EEV Problems

Problem	Symptoms
Stuck closed	Low suction
Stuck open	Flooding
Hunting	Pressure instability
Wiring issue	Communication errors

EEV Sounds

Ticking or clicking during startup may be normal. Valve is positioning itself.

Important Technician Understanding

Mini splits constantly adjust EEV position. Pressures may appear unstable compared to traditional systems.

Chapter 36

Mini Split Refrigerant Diagnostics

Mini Splits Are Charge Critical

Most mini splits use very precise refrigerant charges. Even small charge errors matter.

IMPORTANT

Always weigh in charge. Do not charge mini splits by pressure alone.

Why Pressure Alone Fails

Inverter systems constantly vary compressor speed, EEV position, and load conditions. Pressure changes constantly.

Proper Charging Procedure

Step 1

Recover refrigerant if necessary.

Step 2

Pull deep vacuum.

Step 3

Verify vacuum decay.

Step 4

Weigh in factory charge exactly.

Step 5

Add line set adjustment if required.

Common Refrigerant Problems

Problem	Result
Undercharge	Poor capacity
Overcharge	High amps
Moisture contamination	EEV issues
Non-condensables	High pressures
Restriction	Sensor faults

Mini Split Ice Formation

Often caused by low airflow, dirty blower wheel, dirty coil, low charge, or failed thermistor.

Chapter 37

DC Fan Motor Diagnostics

Mini Splits Use DC Fan Motors

Unlike PSC motors, DC motors use electronic control.

Advantages

- variable airflow,
- quiet operation,
- efficiency.

Common DC Fan Problems

- board failure,
- motor module failure,
- bearing failure,
- communication problems.

Symptoms

- fan surging,

- intermittent operation,
- startup failure,
- unusual speed changes.

Important Technician Note

Some DC motors require feedback signals to operate properly. Voltage alone does not confirm good operation.

Chapter 38

Mini Split Error Codes

Error Codes Are Clues, Not Final Diagnoses

Never replace parts solely from error codes. Codes indicate where to begin diagnosis.

Common Error Categories

Category	Typical Meaning
Communication	Wiring/board
Thermistor	Sensor issue
Compressor overload	Refrigeration/electrical
DC fan fault	Motor/board
High pressure	Airflow/charge
Low pressure	Charge/restriction

IMPORTANT

One failed component may trigger multiple codes.

Example

Low airflow may cause coil freezing, thermistor fault, compressor overload, and communication instability.

Chapter 39

Generator & Power Quality Issues

Inverter Systems Are Sensitive To Power Quality

Mini splits often fail on generators because of voltage instability, harmonic distortion, and poor frequency control.

Symptoms Of Generator Problems

- startup failures,
- random lockouts,
- communication faults,
- board damage,
- nuisance trips.

Proper Generator Requirements

Requirement	Importance
Stable frequency	Critical
Stable voltage	Critical
Proper grounding	Critical
Clean sine wave	Important

AVR Systems

Automatic Voltage Regulators help stabilize voltage swings and startup fluctuations.

Harmonic Distortion

Dirty generator waveforms confuse inverter electronics.

IMPORTANT

Many conventional generators are unsuitable for sensitive inverter systems without proper conditioning.

Chapter 40

Mini Split Maintenance Diagnostics

Dirty Mini Splits Lose Efficiency Fast

Especially indoor blower wheels.

Dirty Blower Wheel Symptoms

- reduced airflow,
- ice formation,
- poor cooling,
- water leakage,
- odor complaints.

Cleaning Procedures

Indoor Coil

Use approved evaporator cleaner.

Blower Wheel

Often requires partial disassembly.

Drain Pan

Clean thoroughly.

Condensate Drain

Flush properly.

Condensate Problems

Mini splits commonly suffer algae buildup, improper pitch, and clogged drains.

Water Leakage Causes

Cause	Result
Dirty blower	Water blowoff
Clogged drain	Overflow
Poor pitch	Improper drainage
Low airflow	Ice melt overflow

Chapter 41

Advanced Inverter Diagnostics

Advanced Technicians Analyze System Behavior

Instead of single readings, observe:

- compressor frequency,
- fan modulation,
- EEV response,
- thermistor values,
- amperage trends.

Important Technician Rule

Inverter systems constantly adapt. Short observations may mislead diagnosis. Allow systems time to stabilize.

Common Misdiagnosis

Many technicians condemn boards and compressors when the actual problem is airflow, sensors, wiring, or power quality.

Technician Field Tip

Mini split systems reward patience, careful observation, and proper procedure. Guessing becomes extremely expensive on inverter equipment.

End Of Section 8

SECTION 9 - Advanced Electrical Diagnostics, Control Boards & Communication Systems

Chapter 42

Advanced HVAC Electrical Diagnostics

Why Advanced Electrical Diagnostics Matter

Modern HVAC systems now depend heavily on electronics, communication networks, sensors, DC voltage circuits, inverter logic, and smart thermostats.

Technicians must understand more than: "does it have voltage?"

They must understand signal flow, board logic, sequencing, voltage quality, and communication integrity.

Electrical Troubleshooting Philosophy

Never Guess At Boards

Control boards are frequently replaced unnecessarily. Most board replacements are caused by poor diagnosis, loose wiring, failed safeties, grounding issues, bad sensors, and voltage instability.

Proper Board Diagnosis

Before condemning a board verify incoming power, transformer output, low voltage integrity, grounding, safeties, thermostat signals, and sensor values.

Chapter 43

Understanding HVAC Control Boards

What Control Boards Do

Boards manage timing, sequencing, safety monitoring, blower delays, communication, and diagnostics.

Common Board Functions

Function	Purpose
Fan timing	Blower delays
Safety monitoring	Limit protection
Ignition sequence	Furnace operation
Defrost logic	Heat pump control
Communication	Smart system operation

Common Board Failures

- burned traces,
- failed relays,
- moisture damage,
- lightning damage,
- voltage spikes,
- grounding problems.

Visual Inspection

Always inspect for burned areas, swollen capacitors, cracked solder joints, overheated relays, and corrosion.

IMPORTANT

A visibly damaged board is failed. But a clean board can still be defective.

Intermittent Board Problems

Often temperature related. Symptoms include works cold, fails hot, random lockouts, and intermittent outputs.

Chapter 44

Low Voltage Circuit Diagnostics

Understanding 24V Circuits

Low voltage circuits control relays, contactors, boards, safeties, and thermostats.

Common Low Voltage Problems

Problem	Result
Short circuit	Blown fuse

Problem	Result
Open circuit	No operation
Weak transformer	Intermittent issues
Loose connection	Random failures

Low Voltage Fuse Diagnostics

Most boards use 3A or 5A blade fuses.

If Fuse Blows Repeatedly

Do not simply replace fuse repeatedly. Find short.

Common Short Locations

- thermostat wire rubbed through,
- contactor coil,
- float switch wiring,
- reversing valve coil,
- damaged low voltage cable.

How To Find Low Voltage Shorts

Step 1

Disconnect all low voltage loads.

Step 2

Replace fuse.

Step 3

Reconnect loads individually.

When fuse blows, last connected component is likely faulty.

Thermostat Wire Problems

Common Issues

- staples through wire,
- rodent damage,
- UV deterioration,
- weed eater damage,
- water intrusion.

Intermittent Shorts

Often occur when wire moves, during rain, or during vibration.

Chapter 45

Relay Logic & Signal Tracing

Understanding Signal Flow

Advanced technicians trace what should happen, when it should happen, and why it failed.

Example Cooling Call

Sequence

1. Thermostat closes R to Y
2. Board receives cooling call
3. Board energizes blower
4. Contactor energized
5. Compressor starts

Signal Tracing Method

Start at thermostat. Then move through safeties, boards, relays, and outputs.

Important Technician Rule

Never assume the board failed because output is missing. The board may be intentionally withholding output because a safety is open, sensor fault exists, or communication failure is present.

Chapter 46

Voltage Drop Diagnostics

One Of The Most Overlooked Problems

Voltage drop causes overheated motors, chattering contactors, board instability, hard starting, and nuisance faults.

Voltage Drop Basics

Electricity loses pressure through resistance, poor connections, loose terminals, and undersized wiring.

How To Measure Voltage Drop

Measure across connection while energized.

Important Rule

Good closed switch: near 0 volts across it.

Example

Contactor closed: 4 volts measured across contacts.

This indicates high resistance. Replace contactor.

Common Voltage Drop Locations

Location	Common Cause
Disconnects	Burned lugs
Breakers	Weak contacts
Contactors	Pitted contacts
Wire nuts	Loose connection
Grounds	Corrosion

Symptoms Of Voltage Drop

- dim lights,
- intermittent boards,
- compressor overheating,
- relay chatter,
- low motor torque.

Chapter 47

Grounding & Neutral Problems

Grounding Is Extremely Important

Poor grounding creates communication issues, flame sensor problems, inverter faults, and nuisance lockouts.

Neutral Problems

Loose neutrals create unstable voltage, board failures, and strange intermittent behavior.

Common Neutral Symptoms

- flickering lights,
- random shutdowns,
- overvoltage,
- low voltage,
- inverter communication faults.

Ground Testing

Measure ground to neutral. Should be very low voltage.

IMPORTANT

Floating grounds can destroy inverter equipment.

Chapter 48

Smart Thermostat Diagnostics

Modern Thermostats Are Computers

They may control staging, airflow, humidity, Wi-Fi communication, and inverter operation.

Common Smart Thermostat Problems

Problem	Result
Power stealing	System instability
Poor Wi-Fi	Communication issues

Problem	Result
Improper programming	Comfort issues
Incorrect setup	Equipment damage

C-Wire Importance

Many smart thermostats require common wire for stable power.

Symptoms Of Missing C-Wire

- rebooting,
- screen flicker,
- intermittent operation,
- random system behavior.

IMPORTANT

Do not assume thermostat compatibility. Always verify equipment support.

Chapter 49

Communicating Systems

What Is A Communicating System?

Components exchange digital information instead of simple on/off signals.

Advantages

- efficiency,
- diagnostics,
- precise control,
- variable capacity operation.

Communication Failures

Most caused by polarity errors, poor grounds, voltage instability, and damaged wiring.

Common Communication Symptoms

- no operation,
- intermittent faults,
- mismatched equipment errors,
- sensor failures,
- lockouts.

Daisy Chain Communication

Many systems use serial communication loops. One bad connection affects the entire system.

Chapter 50

Sensor Diagnostics

Modern HVAC Systems Depend On Sensors

Boards constantly monitor temperatures, pressures, airflow, voltage, and humidity.

Common Sensor Types

Sensor	Purpose
Thermistor	Temperature
Pressure transducer	Pressure
Float switch	Water safety
Flame sensor	Flame proving
Limit switch	Overheat protection

Thermistor Basics

Resistance changes with temperature.

Pressure Transducers

Convert pressure into electrical signal. Used heavily in inverter systems.

Float Switch Diagnostics

Float switches open low voltage circuit when water rises.

Common Float Switch Problems

- improper wiring,
- algae buildup,
- stuck float,
- intermittent opening.

Chapter 51

Advanced Motor Diagnostics

Motors Often Fail From External Causes

Not internal defects.

Common External Causes

Cause	Result
High static	Overheating
Low voltage	High amp draw
Weak capacitor	Overheating
Poor airflow	Motor stress
Dirty blower wheel	Excess load

Motor Winding Tests

Check winding continuity, resistance balance, and ground faults.

Megohm Testing

Used on compressors, large motors, and moisture diagnostics.

IMPORTANT

Megohm testing can damage sensitive electronics. Disconnect boards first.

Chapter 52

Electrical Noise & Interference

Electrical Interference Is Increasing

Especially with inverter systems, generators, smart homes, and solar systems.

Sources Of Interference

- generators,
- VFDs,
- loose grounds,
- fluorescent lighting,
- shared wiring.

Symptoms

- communication loss,
- random lockouts,
- unstable sensors,
- nuisance trips.

Shielding & Separation

Keep communication wiring away from high voltage, motors, and compressor wiring.

Chapter 53

Surge Protection & Power Quality

Power Quality Matters

Especially for inverter systems, communicating systems, ECM motors, and smart thermostats.

Common Power Problems

Problem	Effect
Surges	Board damage
Low voltage	Motor overheating
Harmonics	Communication faults
Frequency instability	Inverter shutdown

Surge Protection Devices (SPDs)

Protect boards from lightning, spikes, and switching surges.

IMPORTANT

One nearby lightning strike can partially damage electronics. Symptoms may appear weeks later.

AVR Systems

Automatic Voltage Regulators stabilize voltage fluctuations and generator output, especially useful with inverter heat pumps and mini splits.

Technician Field Tip

Most mysterious electrical problems are loose connections, grounding issues, airflow problems, or voltage instability. Not failed boards.

End Of Section 9

SECTION 10 - System Commissioning, Startup Procedures & Professional Service Workflow

Chapter 54

Why Proper Commissioning Matters

Most HVAC Problems Begin At Startup

Many callbacks are caused by improper airflow, incorrect charge, loose wiring, poor evacuation, bad thermostat setup, and unverified operation.

What Is Commissioning?

Commissioning means verifying the system operates correctly after installation or repair.

Proper Commissioning Prevents

- compressor failures,
- poor comfort,
- humidity problems,
- nuisance lockouts,
- high electric bills,
- premature equipment failure.

Technician Mindset

Never assume new equipment is correct. Always verify.

Chapter 55

Pre-Startup Inspection

Before Energizing Equipment

Always inspect first.

Indoor Inspection Checklist

Verify:

- blower wheel tight,
- evaporator coil secure,
- drain connected,
- filter installed,
- ductwork connected,
- wiring tight,
- breakers sized properly.

Outdoor Inspection Checklist

Verify:

- fan spins freely,
- service valves open,
- refrigerant lines insulated,
- wiring secure,
- disconnect tight,
- condenser coil clean,
- unit level.

Refrigerant Line Inspection

Look for kinks, rubbing copper, poor brazing, missing insulation, and oil stains.

Electrical Inspection

Verify wire size, breaker size, grounding, torque on lugs, and disconnect condition.

IMPORTANT

Loose lugs create voltage drop, overheating, and nuisance failures.

Chapter 56

Startup Procedures

First Startup Is Critical

Improper startup can destroy equipment immediately.

Before Starting Compressor

Verify airflow, blower operation, refrigerant valves open, and crankcase heater energized if equipped.

Scroll Compressor Warning

Never run scroll compressor in deep vacuum. Damage can occur quickly.

Initial Energizing

Step 1

Energize disconnect.

Step 2

Verify line voltage.

Step 3

Verify low voltage.

Step 4

Verify thermostat operation.

Step 5

Start system.

Observe Carefully

Watch startup amps, fan rotation, blower operation, unusual sounds, vibration, and pressures.

Fan Rotation Verification

Incorrect rotation causes no airflow, overheating, and pressure issues.

Three-Phase Rotation

Commercial systems may rotate backwards if phase order incorrect.

Chapter 57

Airflow Commissioning

Airflow Must Be Verified FIRST

Before adjusting refrigerant charge.

Verify

- filter condition,
- blower speed,
- static pressure,
- temperature rise,
- airflow balance.

Static Pressure Testing

Always measure return static, supply static, and total external static.

High Static Pressure Causes

Cause	Result
Dirty filter	Reduced airflow
Dirty coil	Freeze risk
Undersized return	Motor overload
Closed dampers	Noise/high pressure

Airflow Verification Methods

Method	Accuracy
Static pressure	Excellent
Temperature rise	Good
Fan tables	Excellent
Airflow hood	Best

IMPORTANT

Never charge refrigerant until airflow is correct.

Chapter 58

Refrigerant Commissioning

Proper Refrigerant Charging

Modern systems are charge critical, especially TXV systems, inverter systems, and mini splits.

Verify

- airflow first,
- clean coils,
- correct blower speed,
- stabilized operation.

Measure

- suction pressure,
- liquid pressure,
- superheat,
- subcooling,
- line temperatures,
- compressor amps.

TXV Charging

Charge using subcooling.

Fixed Orifice Charging

Charge using superheat.

IMPORTANT

Outdoor temperature affects readings. Always account for operating conditions.

Target Temperature Split

Most systems: 16-22°F cooling split.

Example

Return	Supply
75°F	56°F

Temperature split: 19°F

Low Split Causes

- low charge,
- high airflow,
- compressor inefficiency.

High Split Causes

- low airflow,
- dirty filter,
- restricted coil.

Chapter 59

Vacuum & Evacuation Procedures

Why Evacuation Matters

Moisture destroys HVAC systems.

Moisture Creates

- acids,
- sludge,
- restrictions,
- oil contamination,
- compressor damage.

Proper Vacuum Procedure

Step 1

Use large vacuum hoses.

Step 2

Remove Schrader cores if possible.

Step 3

Use micron gauge.

Step 4

Pull below 500 microns.

IMPORTANT

Never use manifold hoses for critical evacuation if avoidable. Large hoses evacuate much faster.

Vacuum Decay Test

Purpose

Verify no leaks and no moisture.

Procedure

Isolate vacuum pump. Watch micron rise.

Interpretation

Result	Meaning
Stable vacuum	Good
Rapid rise	Leak/moisture
Slow rise	Remaining moisture

Nitrogen Sweeping

Dry nitrogen helps remove moisture and contamination.

Triple Evacuation

Used for contaminated systems, burnout cleanup, and severe moisture intrusion.

Chapter 60

Combustion Commissioning

Gas Furnace Startup

Always verify gas pressure, temperature rise, combustion quality, venting, and flame stability.

Verify

- manifold pressure,
- inducer operation,
- flame sensor signal,
- limit operation.

Typical Gas Pressures

Fuel	Typical Pressure
Natural Gas	3.5" WC
LP Gas	10-11" WC

Combustion Analysis

Professional startup should include CO testing, oxygen analysis, and efficiency analysis.

IMPORTANT

Never ignore combustion safety.

Chapter 61

Heat Pump Commissioning

Verify Heating & Cooling Operation

Heat pumps must be tested in cooling mode and heating mode.

Verify

- reversing valve operation,
- defrost operation,
- auxiliary heat,
- thermostat staging.

Defrost Verification

Many boards allow forced defrost testing.

During Defrost

Observe steam generation, valve shifting, and auxiliary heat operation.

IMPORTANT

Steam during defrost is normal.

Chapter 62

Mini Split Commissioning

Mini Splits Are Extremely Charge Sensitive

Always weigh in refrigerant.

Verify

- communication wiring,
- polarity,
- grounding,
- drain pitch,
- thermistor operation.

Mini Split Startup

Allow system time to stabilize. Inverter systems constantly adjust.

Common Startup Mistakes

- incorrect flare torque,
- poor evacuation,

- improper communication wiring,
- wrong line set calculations.

Flare Connection Rules

Always deburr carefully, use correct torque, inspect flare surface, and avoid over-tightening.

IMPORTANT

Over-tightened flares leak later.

Chapter 63

Final Operational Verification

Before Leaving Job

Verify thermostat operation, airflow, condensate drainage, amp draws, temperature split, refrigerant readings, and safety operation.

Condensate Verification

Pour water into drain pan if needed. Verify proper drainage.

Safety Testing

Verify operation of float switches, pressure switches, limits, and rollout switches.

IMPORTANT

Never bypass safeties permanently.

Chapter 64

Customer Communication

Good Technicians Educate Customers

Explain filter maintenance, thermostat use, drain care, warning signs, and maintenance intervals.

Important Customer Topics

Topic	Why
Filter changes	Airflow
Drain maintenance	Water damage
Outdoor coil cleaning	Efficiency
Thermostat settings	Comfort
Emergency heat use	Electrical cost

Avoid Technical Overload

Speak clearly. Avoid unnecessary jargon.

Chapter 65

Professional Troubleshooting Workflow

The Best Technicians Follow A Process

Universal HVAC Diagnostic Workflow

Step 1

Interview customer.

Step 2

Verify complaint.

Step 3

Inspect visually.

Step 4

Verify power.

Step 5

Verify airflow.

Step 6

Verify sequence of operation.

Step 7

Measure operating conditions.

Step 8

Confirm diagnosis before replacing parts.

IMPORTANT TECHNICIAN RULE

Never diagnose emotionally. Diagnose logically.

Chapter 66

Preventing Callbacks

Most Callbacks Are Preventable

Common causes:

- loose wires,
- improper charge,
- ignored airflow,
- poor drain setup,
- rushed diagnosis.

Before Leaving Any Job

Double-check electrical connections, refrigerant caps, drain operation, thermostat settings, and filter installation.

Refrigerant Cap Importance

Schrader caps are secondary seals. Loose caps leak refrigerant.

Technician Field Tip

Slow down during final inspection. Five extra minutes prevents many callbacks.

Chapter 67

Technician Professionalism

Great Technicians Build Trust

Professionalism includes honesty, cleanliness, communication, documentation, and proper diagnosis.

Never

- guess,
- scare customers,
- condemn equipment carelessly,
- oversell repairs dishonestly.

Document Everything

Record:

- pressures,
- temperatures,
- amp draws,
- static pressure,
- voltage readings,
- repairs performed.

Good Documentation Protects

- technician,
- company,
- customer.

Final Technician Philosophy

HVAC is not parts changing. HVAC is understanding airflow, heat transfer, electrical operation, mechanical behavior, and system interaction.

The best technicians stay patient, follow sequence, verify readings, think logically, and never stop learning.

End Of Section 10

SECTION 11 - HVAC Quick Reference Charts, PT Tables & Field Diagnostics Quick Guides

Chapter 68

HVAC Electrical Quick Reference

Standard Voltage Ranges

Circuit	Typical Voltage
Thermostat circuit	24-28 VAC
Residential blower	120 VAC
Condenser	208/230 VAC
Commercial	460 VAC

Acceptable Voltage Range

Most equipment: +/- 10%

Example

230V equipment acceptable range:

230V x 0.90 = 207V

230V x 1.10 = 253V

Capacitor Tolerance

Most HVAC capacitors: +/- 6%

Capacitor Quick Chart

Rated	Minimum Acceptable
35 uF	32.9
40 uF	37.6
45 uF	42.3
50 uF	47.0
55 uF	51.7

Contactor Voltage Drop

Condition	Meaning
0-1V across closed contacts	Good
2-5V	Worn
Over 5V	Replace

Transformer Quick Check

Test	Expected
Primary	Rated line voltage
Secondary	24-28 VAC

Chapter 69

Superheat & Subcooling Quick Guide

Superheat Formula

Superheat = Suction Line Temp - Saturation Temp

Subcooling Formula

Subcooling = Saturation Temp - Liquid Line Temp

Typical Superheat Targets

Condition	Typical
Fixed orifice	8-20°F
TXV system	Variable

Typical Subcooling Targets

System	Typical
TXV	8-15°F
Inverter	Manufacturer specific

Quick Diagnostic Reference

Reading Pattern	Possible Cause
High SH + Low SC	Undercharge
Low SH + High SC	Overcharge
Low SH + Low Suction	Low airflow
High Head + High SC	Restriction

Chapter 70

Temperature Split Quick Guide

Temperature Split Formula

Temperature Split = Return Air - Supply Air

Typical Cooling Splits

Condition	Split
Normal	16-22°F
Low airflow	High split
High airflow	Low split

Heating Temperature Rise

Temperature Rise = Supply Temp - Return Temp

Typical Furnace Rise

Furnace Type	Common Range
80% furnace	40-70°F
90+ furnace	35-65°F

Always verify rating plate.

Chapter 71

Static Pressure Quick Guide

Total External Static Pressure Formula

TESP = |Return| + Supply

Typical Static Pressure

Reading	Meaning
Under 0.5	Good
0.5-0.8	Marginal
Over 0.8	Restrictive

High Return Static Causes

- dirty filter,
- undersized return,
- collapsed flex.

High Supply Static Causes

- dirty coil,
- closed dampers,
- restrictive ductwork.

Chapter 72

Refrigerant PT Quick Reference

R-410A PT Reference

Pressure	Saturation Temp
100 PSI	31°F
118 PSI	40°F
143 PSI	50°F
201 PSI	70°F
318 PSI	100°F
377 PSI	110°F

R-22 PT Reference

Pressure	Saturation Temp
58 PSI	32°F
69 PSI	40°F

Pressure	Saturation Temp
84 PSI	50°F
121 PSI	70°F
196 PSI	110°F

IMPORTANT

Always use correct PT chart for refrigerant type.

Chapter 73

Common Refrigerant Diagnostic Patterns

Undercharge Symptoms

Reading	Condition
Low suction	Yes
High superheat	Yes
Low subcooling	Yes
Low amp draw	Often

Overcharge Symptoms

Reading	Condition
High head pressure	Yes
High subcooling	Yes
Low superheat	Sometimes

Low Airflow Symptoms

Reading	Condition
Low suction	Yes
Low superheat	Often
Ice formation	Common

Restriction Symptoms

Reading	Condition
High superheat	Yes

Reading	Condition
High subcooling	Yes
Low suction	Yes

Chapter 74

Gas Furnace Quick Diagnostics

Sequence Of Operation

1. Thermostat calls
2. Inducer starts
3. Pressure switch closes
4. Igniter glows
5. Gas valve opens
6. Burners ignite
7. Flame sensor proves flame
8. Blower starts

If Furnace Stops At

Point	Likely Problem
Inducer	Board/motor
Pressure switch	Draft problem
Igniter	Igniter/board
Flame proving	Flame sensor
Blower startup	Blower/capacitor

Flame Sensor Quick Guide

Reading	Condition
2-6 uA	Normal
Under 1 uA	Weak signal

Gas Pressure Quick Guide

Fuel	Typical
Natural Gas	3.5" WC
LP Gas	10-11" WC

Chapter 75

Heat Pump Quick Diagnostics

Frost Is Normal

Light frost is normal. Solid ice block is a problem.

Defrost Problems

Symptom	Possible Cause
Ice-covered coil	Defrost failure
Frequent defrost	Sensor issue
No auxiliary heat	Heat strip issue

Reversing Valve Symptoms

Symptom	Cause
No cooling	Valve stuck
No heating	Valve stuck
Equal pressures	Internal bypass

Chapter 76

Mini Split Quick Diagnostics

Mini Split Rules

Always:

- weigh charge,
- verify communication,
- verify sensors,
- allow stabilization time.

Common Mini Split Problems

Symptom	Cause
Communication code	Wiring
Random shutdown	Voltage
Ice buildup	Airflow
Water leakage	Drain/blower
High amp fault	Refrigeration

Common Mini Split Mistakes

- charging by pressure,
- poor evacuation,
- incorrect flare torque,
- communication polarity reversal.

Chapter 77

ECM Motor Quick Guide

ECM Motors Hate

- high static,
- dirty filters,
- airflow restrictions,
- unstable voltage.

Symptoms Of High Static

Symptom	Result
Surging blower	High restriction
Loud airflow	Restriction
Failed module	Overheating

IMPORTANT

Most ECM failures begin with airflow problems.

Chapter 78

Compressor Quick Diagnostics

Compressor Electrical Tests

Test	Purpose
Continuity	Winding integrity
Ground test	Short to ground
Amp draw	Load analysis

Scroll Compressor Symptoms

Symptom	Cause
Equalized pressures	Internal bypass
Loud startup	Floodback
High amps	High head pressure

High Discharge Temperature Causes

- low suction cooling,
- high superheat,
- restrictions,
- dirty condenser.

Chapter 79

Vacuum & Evacuation Quick Guide

Proper Evacuation Target

500 microns or lower.

Vacuum Rise Interpretation

Result	Meaning
Stable	Good
Rapid rise	Leak
Slow rise	Moisture

Important Rules

Never:

- evacuate through manifold only,
- use compressor as vacuum pump,
- skip micron gauge.

Chapter 80

HVAC Service Call Workflow Quick Guide

Universal Diagnostic Workflow

1. Verify complaint
2. Visual inspection
3. Verify power
4. Verify airflow
5. Verify sequence
6. Measure readings
7. Confirm diagnosis
8. Repair
9. Re-test operation

Most Important Technician Rule

Never guess, assume, or replace parts emotionally.

Final Technician Principles

Good HVAC technicians:

- understand airflow,
- understand heat transfer,
- understand electrical logic,
- diagnose systematically,
- verify repairs completely.

End Of Section 11

End Of HVAC Technician Troubleshooting Handbook - Core Edition