ISLAND BREEZE TECHNICIAN CERTIFICATION PROGRAM

Heat Pump Diagnostics

MODULE D29 | DIAGNOSTICS | PREREQ C19, D24

A heat pump fails two ways at once: it breaks like any split system, and it breaks in ways no straight-cool system can. The first kind you already know how to chase. The second kind is this module, and it is where good split-system techs condemn good compressors, miss leaking reversing valves, and tell customers their perfectly healthy heat pump is junk because the supply air felt lukewarm on a cold morning.

C19 gave you the healthy machine: the reversing valve mechanism, the defrost sequence, the balance point. D24 gave you the refrigerant circuit triangle, the discipline of separating charge, airflow, and metering before touching a gauge port. This module is where they collide. You will learn the 2 degree test that catches a reversing valve leaking internally, the full defrost diagnostic from board to sensor to forced cycle, what a healthy heat pump actually looks like at low ambient so you stop condemning winter operation, and how to chase auxiliary heat faults all the way to the power bill complaint they cause.

Short Version

Heat pump diagnosis is split-system diagnosis plus three new suspects: the reversing valve, the defrost system, and the auxiliary heat strips. A reversing valve that leaks internally bypasses hot discharge gas into the suction stream, which shows on the gauges as low head and high suction, the exact same signature as a weak compressor. The discriminator is temperature: the valve is supposed to be a pass-through on the suction side, so measure the suction line entering the valve from the active coil and the suction line leaving the valve to the compressor. More than about 2 to 3 degrees of warming across that pass-through means hot gas is leaking inside the valve. Pass the valve, and the compressor inherits the blame, which you confirm with the D26 condemnation sequence, never with a guess. Defrost faults split two ways: a defrost that never runs builds ice armor over the outdoor coil, and a defrost that runs constantly wastes capacity and scares customers. Test the sensor, force a cycle, watch all four actions, and check how it terminates. Charge checks in heating mode use weigh-in or the manufacturer's heat mode chart, never cooling targets, and never within an hour of a defrost. And before you condemn anything in winter, know what normal looks like at 35 degrees outdoor: low suction, lukewarm supply air, light frost, all of it healthy.

Key Values

VALUE	NUMBER	WHY IT MATTERS
2 degree test pass	Less than 2 F rise across the valve's suction pass-through	The valve is just a tube here; suction gas should not warm up inside it
2 degree test fail	More than about 3 F rise	Hot discharge gas is leaking past the slide into the suction stream

VALUE	NUMBER	WHY IT MATTERS
Touch test, discharge line	Hottest line on the unit, well over 150 F	Reference point for every other line temperature
Stuck mid-shift signature	Head and suction converge toward each other, capacity collapses	Discharge and suction are talking to each other inside the valve
Valve leakage cost (NIST)	About 70 W capacity lost per 1 percent fault severity at 47 F, COP down about 0.022 per percent	Worst single fault NIST measured; small leaks cost real heat
Defrost stat behavior	Closes near 30 F coil, opens 50 to 80 F coil	The test points for ohming the sensor in place
Defrost termination	Sensor opens (50 to 80 F) or 10 minute limit	Termination on time instead of temperature means the coil never warmed
Timer pins	30, 60, or 90 minutes compressor run time	Wrong pin in dry air means nuisance defrosts
Post-defrost stabilization	About 60 minutes	Readings are noise inside that window; do not judge charge
Healthy capacity vs ambient (NIST)	8,441 W at COP 3.46 at 47 F; 5,275 W at COP 2.26 at 17 F	About 37 percent capacity loss is physics, not a fault
Normal suction at 35 F outdoor	Roughly 62 to 78 psig (10 to 20 F saturation, R-410A)	Coil runs 15 to 25 F below ambient; this is not undercharge
Normal head at 35 F outdoor	Roughly 317 to 365 psig (100 to 110 F saturation)	Indoor coil condenses against 70 F return air
Normal supply air, heat pump	Roughly 90 to 105 F; near 90 F at low ambient	Feels cool to a 98.6 F hand and is completely healthy
Strip bank amp draw	A 5 kW bank pulls about 21 A at 240 V	Staging verification and stuck-strip detection by clamp meter
Strip heat output	3,412 BTU per hour per kW	Sizing the aux contribution you should see

Field Checklist

Heat pump no-heat or weak-heat call, in order, usable from a phone at the unit:

- [ ] **Listen to the complaint for the fault class:** lukewarm air in both modes points at the valve, ice armor points at defrost, a shocking power bill points at the strips, weak heat that tracks cold weather may be physics.

- [ ] **Run the D24 triangle first, translated to heating mode:** charge, airflow, metering, before blaming any heat pump part. The indoor coil is the condenser now; dirty filters show up as high head, not low suction.
- [ ] **Confirm the mode is real:** verify the O or B signal is present and correct for the brand before diagnosing anything downstream.
- [ ] **Touch test all four reversing valve lines:** discharge hottest, the active coil's hot gas line nearly as hot, the suction pair distinctly cooler and close to each other.
- [ ] **Run the 2 degree test:** strap probes on the suction line entering the valve and the suction line leaving it. Less than 2 F rise passes. More than about 3 F condemns the valve for internal leakage.
- [ ] **Gauges showing low head and high suction:** do not condemn the compressor until the valve passes the 2 degree test. Both faults share that gauge signature.
- [ ] **Valve passed, compressor suspect:** run the D26 condemnation sequence, amps against RLA, compression ratio capacity check, the functional test. The compressor proves itself; you never guess it dead.
- [ ] **Inspect the defrost system every visit:** board type, timer pins, sensor seated on the correct return bend, clean spades.
- [ ] **Test the defrost sensor,** ohms open at room temperature for a defrost stat, resistance against the chart for a thermistor.
- [ ] **Force a defrost and watch all four actions:** valve shifts, outdoor fan stops, compressor keeps running, strips energize. Note how it terminates.
- [ ] **Verify aux staging with a clamp meter:** banks step on in sequence, and every amp of strip draw disappears when the call ends.
- [ ] **Check for stuck strips:** any strip amp draw with no W2 or defrost call is a failed sequencer or relay and a power bill complaint in progress.
- [ ] **Judging charge:** weigh-in or the manufacturer heat mode chart only, and never within 60 minutes of a defrost.

> **IB STANDARD**
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> Every heat pump diagnostic visit records the 2 degree test result, pass or fail, with both temperatures written on the ticket, whenever the complaint involves capacity, comfort, or efficiency in either mode. The test takes two probes and three minutes, and a documented pass today is the baseline that catches a creeping leak next season.

Full Breakdown

Why split-system habits fail on heat pumps

Everything you learned chasing straight-cool systems still works on a heat pump, and that is exactly the trap. The habits work just well enough to walk you into the wrong conclusion.

Three examples of split-system thinking that fails here. First: low head and high suction means a weak compressor. On a straight-cool system that is a strong lead, and D26 taught you how to prove it. On a heat pump there is a second component that produces the identical gauge signature, the reversing valve, because an internal valve leak and worn compressor valves both let discharge gas sneak back to suction. Condemn the compressor without testing the valve and you sell a customer the most expensive repair on the menu to fix the wrong part.

Second: cold supply air means a broken heater. A gas furnace delivers 120 to 140 degree supply air, and a tech raised on furnaces puts a hand over a heat pump register, feels 92 degree air, and starts looking for the failure. There is no failure. Heat pump supply air runs roughly 90 to 105 degrees, and at low ambient the bottom of that range is normal. Air at 92 degrees is heating the house just fine and still feels cool against skin at 98.6 degrees. The thermometer decides, never the hand.

Third: frost on a coil means a refrigerant problem. In cooling, ice on the evaporator sends you down the low-charge and low-airflow paths. In heating, a light frost coat on the outdoor coil below 40 degrees is the machine working as designed, with the defrost system handling housekeeping. The fault is not frost. The fault is frost that never gets removed, or defrosts that run when there is nothing to remove.

The fix for all three is the same: learn what a healthy heat pump looks like in heating mode, then diagnose against that baseline instead of the cooling-season one in your head.

The triangle still comes first

Recall D24: before condemning any component, separate the three refrigerant circuit suspects, charge, airflow, and metering, because they imitate each other on the gauges. That discipline does not change on a heat pump. It just needs translating, because the coils have swapped jobs.

In heating mode the indoor coil is the condenser. So the classic indoor airflow problems, a clogged filter, a matted blower wheel, closed registers, now show up as high head pressure and high discharge temperature, not as a starving low side. The outdoor coil is the evaporator, so a dirty or blocked outdoor coil now starves the low side: low suction, heavy frosting, and capacity loss. NIST put numbers on that one: 30 percent outdoor coil blockage at 17 degrees outdoor cost about 26 percent capacity and 24 percent COP. Cleaning the outdoor coil is a heating-season repair, not just a summer one.

Metering swaps too. The outdoor metering device is the active one in heating, with the indoor device bypassed through its check valve. A restricted outdoor metering device or a stuck indoor check valve produces heating-only symptoms on a system that cools perfectly, which is one of the genuinely heat-pump-shaped faults: the season selects which half of the plumbing is being tested.

Run the triangle translated this way first. Only when charge, airflow, and metering are cleared do the heat pump specials, the valve, the defrost system, and the strips, take the stage.

The reversing valve fault menu

C19 taught you the mechanism: a pilot solenoid routes the system's own head pressure to either end cap of a sliding sleeve, and the slide picks which coil gets discharge gas. Every reversing valve failure is a failure of some link in that chain, and the chain gives you the diagnostic order.

The solenoid coil. It is a 24 volt coil and it fails like any 24 volt coil: open winding, shorted winding, or no signal arriving. With the thermostat calling for the energized mode for that brand, O brands energized in cooling, B brands in heating, verify 24 volts at the coil. No voltage is a thermostat, wiring, or board problem, not a valve problem. Voltage present, pull a coil lead and ohm the coil: an open reading condemns the coil, which is a cheap screw-on part, not a valve replacement. A quick field confirmation: hold the tip of a steel screwdriver near the solenoid stem while a helper toggles the call. An energized coil pulls the tip with a noticeable magnetic grab.

The pilot valve. Energized coil, good magnetism, and still no shift means the trouble is mechanical. Listen at the valve while toggling the solenoid with the compressor running: a healthy pilot answers with a faint click and a momentary hiss as it reroutes the capillaries. Inspect the capillary tubes, the pencil-lead lines between pilot and body, for kinks, rubs, and crush damage. A blocked or kinked capillary starves an end cap of the pressure that moves the slide, and the valve sits still with a perfectly good coil clicking away.

The slide itself. The big failures live here: a slide stuck in one position, a slide stuck somewhere in the middle, or a slide that seats but no longer seals, leaking hot gas internally. Stuck and leaking look completely different on the unit and get separate treatment below.

One C19 rule worth repeating, because techs keep paying for forgetting it: the slide moves on pressure difference, and only a running compressor makes one. A valve that does nothing when toggled on a dead or equalized system is behaving correctly. Every shift test happens with the compressor running.

The 2 degree test, step by step

Here is the idea that makes the whole test. In either mode, two of the valve's four lines are on the suction side: the line returning from whichever coil is the evaporator, and the center line out to the compressor. Inside the valve those two are connected under the slide, sheltered from the hot gas that fills the rest of the body. The valve is supposed to be nothing but a short tube between those two points. Gas does not warm up flowing through a tube. So the temperature entering and the temperature leaving should match.

If the slide no longer seals, hot discharge gas leaks underneath it and mixes into the suction stream, and the gas leaving the valve runs warmer than the gas entering it. The size of that rise is the size of your evidence.

The procedure:

1. **Run the system at least 10 to 15 minutes in a steady mode,** and never within 60 minutes of a defrost. You need stable line temperatures, and post-defrost flutter will lie to you.
2. **Identify the two suction-side lines for the current mode.** The center pipe of the three is always suction to the compressor, every brand, every mode. The active coil return is the outer pipe currently running cool: in heating it is the line from the outdoor coil, in cooling the line from the indoor coil. Confirm with the touch test before strapping probes.
3. **Strap a probe on each line,** two to four inches from the valve body, on clean bare copper with good contact, and insulate over both probes. Radiant heat from the hot valve body and discharge line will corrupt a bare probe.
4. **Let the readings settle, then compare.** Less than 2 degrees of rise from coil-return to compressor-suction is a passing valve. Two to 3 degrees is a gray zone: reseat the probes, give it ten more minutes, and retest. More than about 3 degrees is internal bypass leakage, and the bigger the spread the worse the leak.

Read the result alongside the gauges. A leaking valve also pushes suction pressure up and head pressure down, drops the compressor's amp draw below normal for conditions, and bleeds capacity out of the system. NIST measured this fault class as the most expensive per percent of severity of any fault in the study: about 70 watts of heating capacity lost per 1 percent fault at 47 degrees, with COP falling about 0.022 per percent. A valve leaking enough to fail the 2 degree test decisively is not a watch-and-wait item.

Two cautions. First, severity scales the signature: a small leak shows 4 or 5 degrees of rise with mild gauge symptoms, and a gross leak can show 10 or more with the system barely heating. Second, the test is directional but not surgical: it tells you hot gas is reaching suction inside the valve, which condemns the valve, but on a system with a stuck-open pilot or damaged body the repair is the same anyway. The valve gets replaced, a brazing job from C16 with the body wrapped and heat-blocked per the manufacturer.

Stuck mid-shift: the equalization signature

A slide that stalls partway between positions is the most dramatic valve failure and the easiest to recognize once you know it. Mid-shift, the slide seals nothing: discharge and suction are partially connected to each other and to both coils at once. The compressor is pumping in a circle.

The signature: head pressure falls, suction rises, and the two converge toward each other far closer than any healthy operating spread. Capacity does not just sag, it collapses, and the supply air runs barely different from return air. Compressor amps drop because the machine is doing almost no real work. And the touch test goes strange: lines that should be cool run warm, because hot gas is reaching places it never should.

It usually happens at a shift: a mode change, or entering or leaving defrost. The history fits the complaint: the system worked, the weather turned, the first defrost of the season ran, and now it will not heat.

Before condemning, try to complete the shift. With the compressor running, toggle the solenoid a few times from the thermostat and let head pressure build between attempts, since pressure difference is what throws the slide. A light tap on the valve body with a screwdriver handle while toggling sometimes frees a slide that is hung on debris. If it seats and the system recovers, run the 2 degree test before you leave: a slide that stuck once may be damaged, and the test result on the ticket is your baseline. If it will not seat, the valve is done.

Leaking valve or weak compressor: the discrimination

Now the call this module is named for. The gauges show low head and high suction. Capacity is weak. Amps are below normal. Two components produce exactly this picture: a reversing valve leaking internally, and a compressor with worn or broken valves recirculating gas inside its own shell. Both are letting compressed gas sneak back to the low side. The gauges cannot tell you which side of the suction line the crime is on.

The discrimination is a two-step, and the order matters because one test is three minutes and the other is a sequence.

Step one: the valve speaks first. Run the 2 degree test. The valve's leak path runs through the suction pass-through you are measuring, so a leaking valve cannot hide from the probes. A clear fail, more than about 3 degrees of rise with corroborating gauge symptoms, condemns the valve and the compressor walks. Do not let anyone, including you, condemn a compressor on a heat pump without this test on the ticket.

Step two: the compressor proves itself. A clean pass on the 2 degree test does not directly condemn the compressor, it just removes the alternative. The compressor still gets the full D26 treatment before anyone orders one: amp draw compared against RLA for the conditions, the compression ratio and capacity check, and the functional test that makes the compressor demonstrate what it can build. Recall the D26 rule: a compressor is condemned by evidence it cannot perform, never by the absence of another suspect.

Two corroborating details help at the margins. Discharge temperature rises in both faults, because both feed the compressor pre-heated suction gas, so it does not discriminate, do not let it. And a stuck-mid-shift valve is the extreme case of the valve branch: if the pressures have converged hard and capacity has collapsed, work the mid-shift procedure before anything else.

> **PHOENIX FIELD NOTE**
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> Phoenix heat pumps spend ten months a year in cooling, so a valve that leaks slightly often gets noticed first in summer, as a cooling complaint: capacity down, head down, suction up, on a system the customer swears was fine last year. The 2 degree test works identically in cooling mode, the suction pair is just the indoor coil return and the center pipe. Run it on summer capacity complaints too, before the compressor conversation starts.

Defrost diagnosis: boards, sensors, forced cycles

Recall the C19 logic. Time-temperature boards defrost when a run-time timer expires and the coil sensor confirms a cold coil, both conditions, never one. Demand boards compare coil temperature to outdoor ambient and defrost when the gap says real frost. Termination is the same on both: the coil sensor warms to its opening point, 50 to 80 degrees per the manufacturer, or a 10 minute limit forces the issue.

Diagnosis works the chain in order: board type, sensor, forced cycle, termination.

Identify the board and its settings. The panel sticker or board silkscreen names the type. On a time-temperature board, check the pin: a 30 minute pin means a defrost check every half hour of compressor run, and in dry air that is three times the needless defrosts of a 90 minute pin. Find the test pins now, while the panel is open, because you will want them in a minute.

Test the sensor where it lives. First, look: the sensor or defrost stat must be clamped on the manufacturer's specified return bend with solid contact. A sensor dangling in air reads air, and air is warmer than a frosting coil, so the board never sees the cold coil and never defrosts. That single unseated clamp is one of the quietest serious faults on a heat pump.

Then test electrically. A defrost stat is a bimetal switch: it should ohm open at room temperature and close near 30 degrees, which you can prove with freeze spray or an ice-water bath against its face. A thermistor sensor gets its resistance compared to the manufacturer's temperature chart, and the fast field check is plausibility: does the reading move the right direction when you warm it in your hand? An open sensor circuit on a time-temperature board silently disables defrost. Demand boards usually flag an open sensor with a fault code, but verify rather than trust.

Force a cycle. Per the board's instructions, short the test pins to collapse the timer, and jumper the sensor circuit if the coil is not actually cold, telling the board the coil is frozen. Then watch for the full four-part signature from C19: valve shifts, outdoor fan stops, compressor keeps running, strips energize. Any missing limb is a finding: no valve shift sends you back to the valve chain above, no fan stop is a board relay, no strips points into the aux heat section below.

Watch the termination. Pull the sensor jumper partway through so the board can see the real coil, or test on a genuinely frosted coil. Termination on temperature, the sensor opening between 50 and 80 degrees, is the healthy ending: the coil provably got warm. Termination on the 10 minute clock means the coil never reached opening temperature, and that is a finding too: weak charge, a tired compressor, a leaking valve bleeding away the hot gas, or a sensor that opens too high. Pull the jumpers when you are done, every time, and show your own eyes the board restored.

Failed defrost versus nuisance defrost

Both directions of defrost failure have a face. Learn both.

Defrost that never runs builds ice armor. Without melting cycles, frost grows through accumulation into glaze ice: the coil face packs solid, ice climbs the cabinet and caps the top panel, and in bad cases the fan blades chew into it. Airflow through the coil approaches zero, suction pressure dives, capacity goes with it, and the strips quietly take over the house at three times the energy per unit of heat. The classic causes: an open or unseated sensor, a dead board, a failed timer, or a valve that cannot shift into cooling when commanded. Ice armor is never weather. Healthy defrost handles any Phoenix winter morning; armor means the system stopped defending itself, and your job is to find which link broke.

Clear it before you diagnose: kill the cooling call and run the indoor blower, or force defrost cycles if the machine still can. Never chip ice off a coil; fins and tubing lose that fight.

Defrost that runs constantly is a nuisance defrost. A sensor stuck closed, a sensor reading colder than the coil truly is, a 30 minute pin in dry air, or a confused demand board will defrost a coil that has nothing on it. Each event is a few minutes of air conditioning the house in winter with the strips burning to cover it, so the cost is capacity, efficiency, and customer alarm: steam plumes, whooshing valve shifts, and lukewarm air every half hour. The complaint sounds like "it keeps doing something weird" rather than "no heat." Catch it by checking defrost frequency against conditions: a system defrosting hourly on a 55 degree dry afternoon has a defrost initiation fault, full stop.

> **PHOENIX FIELD NOTE**
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> Mild, dry winters mean defrost barely runs here, and that is precisely why defrost faults in Phoenix hide for years. A disconnected sensor or a dead board costs nothing for fifty weeks, then the one cold damp morning arrives and the coil armors over while the customer sleeps. Heat pumps dominate our installed base, which makes the forced defrost check on every maintenance visit, the C19 IB standard, our only realistic way of finding these faults before January does.

Charge checks in heating mode

This is recall from C19, kept short and sharpened for diagnosis, because charge mistakes in heating mode are a leading source of false condemnations.

The rules: weigh-in is correct in any season. If charging or checking by readings, use the manufacturer's heat mode charging chart, which typically plots discharge or liquid pressure against outdoor temperature for that specific equipment. Cooling targets, subcooling 8 to 12 and TXV superheat 10 plus or minus 5, do not transfer to heating mode and were never meant to. And no charge judgment within 60 minutes of a defrost, because NIST measured readings fluttering that long while two-phase refrigerant cleared the vapor line.

Two NIST sensitivities worth carrying into diagnosis. Undercharge shows first in subcooling at the outdoor service valve, which collapsed 87.7 percent at 30 percent undercharge, long before capacity told the story; capacity holds within a few percent until roughly 25 percent of the charge is gone. Overcharge shows first in compressor discharge temperature. So in heating mode, subcooling whispers undercharge and discharge temperature whispers overcharge, and both whisper before the gauges shout.

Set capacity expectations from the anchors before you blame charge at all: the NIST test unit delivered 8,441 watts at COP 3.46 at 47 degrees and 5,275 watts at COP 2.26 at 17 degrees. About 37 percent of capacity gone over that 30 degree fall, on a healthy, correctly charged machine. Weak heat on the coldest night of the year is, first, physics.

Low ambient normal: stop condemning healthy systems

Here is the picture of a healthy single-speed R-410A heat pump on a 35 degree Phoenix morning, the baseline that should be in your head before any gauge goes on.

Suction is low and that is correct. The outdoor coil boils 15 to 25 degrees below ambient, so at 35 degrees outdoor the coil saturates around 10 to 20 degrees, roughly 62 to 78 psig. A tech who carries the cooling-season reflex that suction belongs near 118 to 130 psig sees 70 psig and reaches for the undercharge story. The low side follows the outdoor air down. That is the machine, not a leak.

Head is moderate and steady. The indoor coil condenses against fixed 70 degree return air, around 100 to 110 degrees saturation, 317 to 365 psig. Head pressure barely cares about the weather in heating mode; if head is far off, look indoors, at airflow across the indoor coil, before anything else.

Supply air is lukewarm to the hand and right on target. Expect roughly 90 to 100 degrees at this ambient, a 20 to 30 degree rise over return. It will not feel like a furnace because it is not one. Measure rise with a thermometer, compare to the equipment's data, and put the hand away.

Light frost is normal. A thin white coat on the lower rows between defrost cycles is routine operation near and below 40 degrees with humidity. The judgment line is glaze and growth: clear ice, frost bridging the fins solid, or accumulation the defrost cycles never fully clear.

Some strip runtime is normal in cold snaps, and defrost tempering is always strips. Brief aux assists on a cold morning and strip heat during every defrost are by design. Strips carrying the house continuously on a Phoenix winter day are not; recall the C19 balance point note, our oversized-for-cooling equipment should hold this climate nearly alone, so constant aux runtime here is a capacity-theft symptom, and the thieves are this module's suspects.

The discipline is the same one D24 taught for the triangle: define normal for the conditions first, then call only the deviations faults. A heat pump at low ambient is supposed to read like a system a summer tech would worry about. Knowing that is the difference between a diagnosis and a healthy system condemned in January.

Aux heat diagnostics: staging, stuck strips, and wiring faults

The strips are simple hardware, resistance elements behind sequencers or relays, and that simplicity is why their faults are mostly switching and wiring. Three diagnostics cover nearly everything.

Verify staging with a clamp meter. Clamp the air handler feed, force a W2 call, and watch the steps. Blower draw comes first, then each strip bank lands as its sequencer times in, a few seconds to a half minute apart. A 5 kW bank at 240 volts adds about 21 amps per step, so a 10 kW package reads as two distinct 21 amp stairs. A missing stair is a dead bank: a failed sequencer, an open element, or a blown fuse link, and the customer's symptom is weak aux heat on the coldest nights, exactly when it matters. Confirm the count matches the nameplate kW, and confirm every stair drops back out when the call ends.

Hunt stuck strips by amp draw, not by faith. A sequencer or relay with welded contacts leaves its bank running with no call at all. The complaint arrives as a power bill, often double or worse, on a system that "works fine." The house holds temperature, because the thermostat simply runs less compressor while the strips secretly carry the load at COP 1. Diagnosis is one clamp reading: with the thermostat satisfied and no defrost in progress, the air handler feed should carry blower amps at most. Twenty extra amps with no W2 call is a welded contact, and you just solved the bill. In cooling season the same fault shows as supply air warmer than it should be and cooling that struggles, strips fighting the air conditioner in the same airstream.

Chase W2 and E wiring faults at the thermostat. Recall the F9 terminals: W2 stages the strips in alongside the running compressor, E runs strips alone with the compressor locked out. The classic faults: a thermostat configured as a conventional furnace instead of a heat pump, so every first stage heat call lands on W and runs strips as the primary heat, compressor idle, bill enormous, house perfectly warm; E and W2 crossed or jumpered so routine staging locks the compressor out; and a customer thermostat parked on EM HEAT since the last cold snap, which is a settings visit, not a repair. The screening question for every winter high-bill complaint on a heat pump is the same: who is making the heat, the compressor or the strips? A clamp meter at the air handler and condenser answers it in under a minute.

> **IB STANDARD**
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> Every winter high-bill complaint on a heat pump gets the full strip audit before any refrigerant-side work: thermostat mode and configuration verified, amp draw at the air handler with the stat satisfied, staging stepped and released under a forced W2 call, and the findings written on the ticket. Most of these calls are solved at the thermostat or the sequencer, and the customer deserves that answer before anyone opens a gauge port.

Common Mistakes

- **Condemning a compressor without running the 2 degree test.** Low head and high suction is a two-suspect signature on a heat pump. The valve test takes three minutes; the wrong compressor takes the customer's money and leaves the fault in the system. The test goes on the ticket every time.
- **Running the 2 degree test on dirty lines, bare probes, or too soon.** Probe contact and radiant heat from the valve body can fake several degrees either way, and post-defrost flutter lasts an hour. Clean copper,

strapped and insulated probes, 10 to 15 stable minutes minimum, never inside the 60 minute defrost window.

- **Condemning a reversing valve that was never told to shift, or never could.** Verify 24 volts at the solenoid and the O or B convention before touching the valve chain, and remember the slide only moves with the compressor running. Half of "bad valves" are signals and setups.
- **Calling low suction at low ambient an undercharge.** At 35 degrees outdoor, 62 to 78 psig suction is a healthy R-410A heat pump. The low side follows the sky. Check charge by weigh-in or the heat mode chart before adding a single ounce, because refrigerant added to a winter reading becomes an overcharge in May.
- **Condemning lukewarm supply air by hand.** Ninety degree air feels cool to skin and heats a house fine. Measure the rise, compare to the data, and educate the customer instead of the gauge manifold.
- **Chipping ice off an armored coil.** Fins and tubing lose. Kill the call, run the blower or force defrost cycles, let heat do the work, then find the dead link in the defrost chain, because armor always means a link is dead.
- **Leaving defrost jumpers in the board.** A jumpered sensor circuit tells the board the coil is frozen forever, and the system you just fixed will nuisance-defrost until someone finds your jumper. Pull them, then look again before the panel goes on.
- **Treating defrost frequency as personality instead of data.** Hourly defrosts in dry mild air are an initiation fault; a defrost that always rides the 10 minute clock to termination never got the coil warm. Both belong on the ticket with the cause chased down.
- **Skipping the strip audit on a high-bill complaint.** Welded sequencers, furnace-configured thermostats, and EM HEAT settings make more shocking winter bills than refrigerant faults do. One clamp reading at the air handler with the stat satisfied screens all of it.

DARREL FIELD WISDOM (to be recorded)

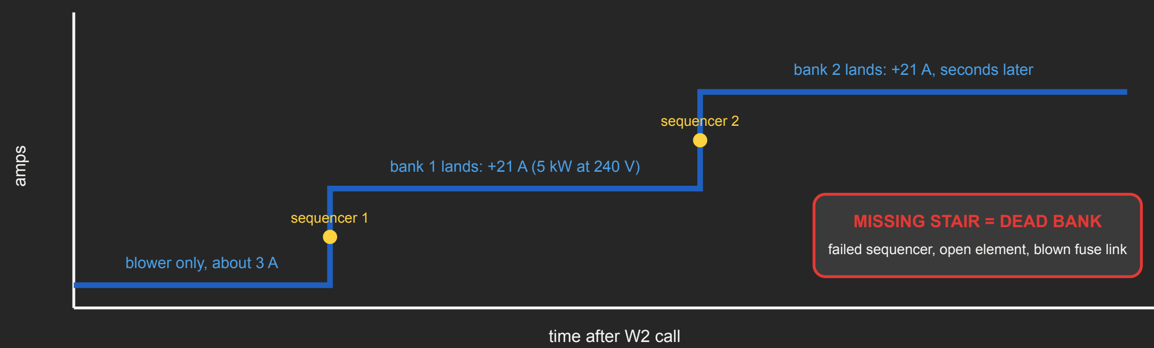
1. Tell the story of a reversing valve call that fooled you early on. What did the gauges say, what did you almost condemn, and what finally told you it was the valve?
2. Walk through the no-heat patterns you see in a Phoenix winter. When the cold week finally hits, what actually broke, and how much of it had been broken since summer without anyone noticing?
3. Tell a strip-heat power bill story: the highest winter bill a customer ever showed you, what the clamp meter found, and what the fix cost compared to what they had been paying the utility.
4. How do you talk a customer down when they have been told by another company that their heat pump compressor is dead, and your 2 degree test says the valve is leaking instead?
5. What is your personal routine for defrost checks on maintenance visits, and have you ever found ice armor on a Phoenix unit? What had failed, and for how long?

Module Visuals

AUX HEAT STAGING FAULTS

Aux Heat: Verify the Staircase, Then Hunt the Faults

Clamp the air handler feed and force W2. A 10 kW package reads as two 21 amp stairs on top of the blower.



Count the stairs against nameplate kW. Then confirm every stair DROPS OUT when the call ends.

The Power Bill Fault Lineup

STUCK-ON STRIPS

welded sequencer or relay contacts. House holds temp, bill doubles, system "works fine." In cooling: warm supply air.

TEST: stat satisfied, no defrost. Feed should read blower amps only. 20 extra amps with no call = found it.

THERMOSTAT CONFIG FAULT

stat set up as conventional furnace, not heat pump: every first stage call lands on W. Strips run as PRIMARY heat, compressor idle.

House warm, bill enormous, nothing "broken." Verify config and O/B setting before any refrigerant-side work.

W2 / E WIRING FAULTS

W2 = strips ALONGSIDE the compressor. E = strips ALONE, compressor locked out. Crossed or jumpered: staging kills the pump.

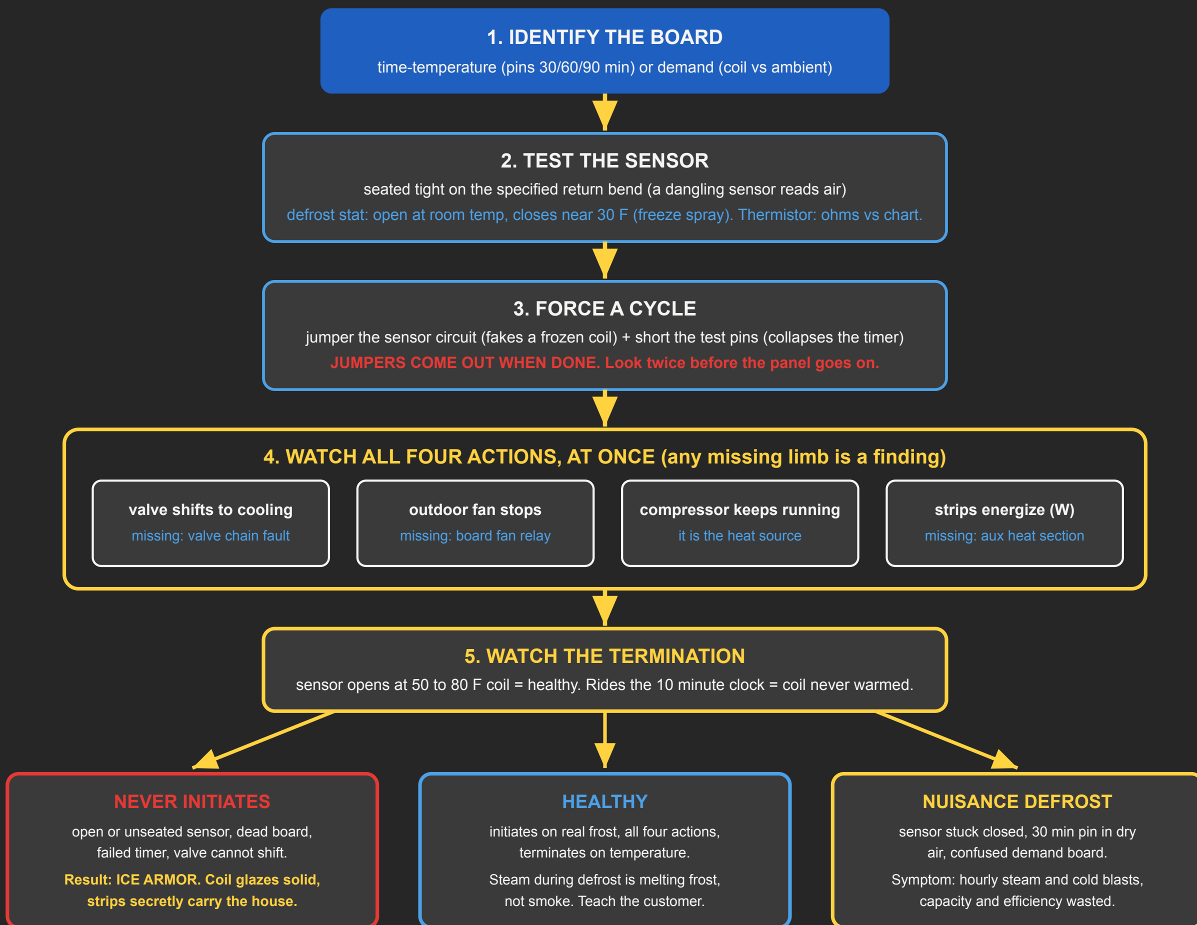
Also check: customer parked on EM HEAT since the last cold snap. That is a settings visit, not a repair.

The screening question for every winter high-bill complaint:
WHO is making the heat, the compressor or the strips?

Strips make heat at COP 1, about three times the energy per unit of heat. One clamp reading answers the question in under a minute.

DEFROST DIAGNOSIS FLOW

Defrost Diagnosis: Work the Chain in Order



Phoenix trap: dry mild winters mean defrost faults hide for years. Force a cycle on every maintenance visit.

LOW AMBIENT NORMAL READINGS

Winter Normal: Healthy R-410A Heat Pump, 35 F Outdoor

Load this baseline before any gauge goes on. Every value below is a HEALTHY system.

SUCTION: 62 to 78 psig

coil saturates 10 to 20 F, running 15 to 25 F below the outdoor air.

NOT an undercharge.

the low side follows the sky down

HEAD: 317 to 365 psig

indoor coil condenses at 100 to 110 F against fixed 70 F return air.

Head barely cares about weather.

head far off? check indoor airflow first

SUPPLY AIR: 90 to 100 F

a 20 to 30 F rise over return. Feels cool to a 98.6 F hand.

Measure the rise. Put the hand away.

a heat pump is not a 120 F furnace

LIGHT FROST: NORMAL

thin white coat on lower rows between defrosts, below about 40 F with humidity.

FAULT LINE: glaze ice, bridged fins, buildup defrost never clears

STRIPS: BRIEF ASSISTS ONLY

defrost tempering and cold-snap W2 staging are by design.

FAULT LINE: strips carrying a Phoenix house continuously = capacity theft

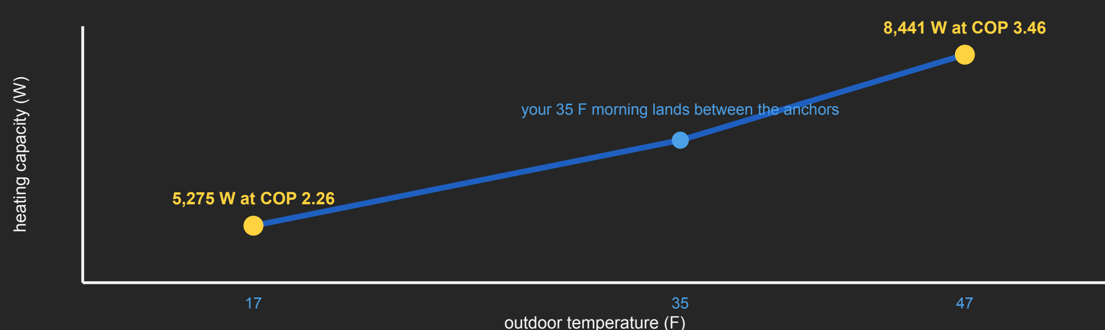
AFTER A DEFROST: WAIT

readings flutter for about 60 minutes while two-phase gas clears the vapor line.

No charge judgment inside the window.

weigh-in or heat mode chart only (C19)

Capacity Falls With Ambient on a HEALTHY Unit (NIST test data)

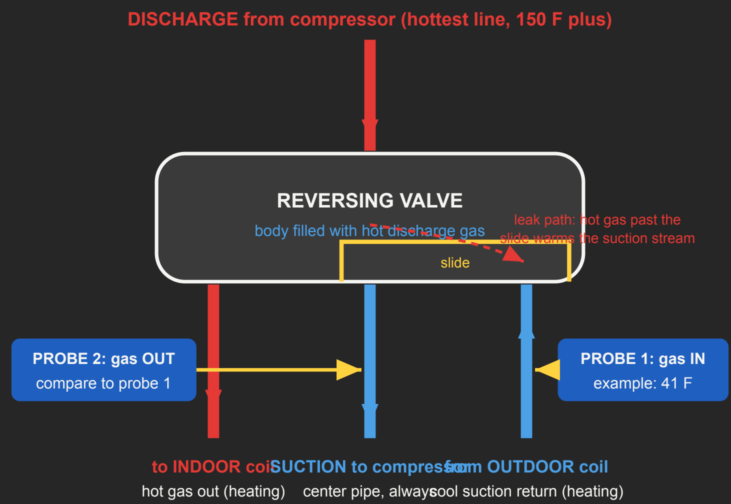


About 37 percent of capacity gone from 47 F to 17 F with NOTHING wrong. Weak heat on the coldest night is, first, physics.

TWO DEGREE TEST

The 2 Degree Test: Suction In vs Suction Out

Heating mode shown. The valve is a pass-through on the suction side. Gas should NOT warm up inside it.



Read the rise: Probe 2 minus Probe 1

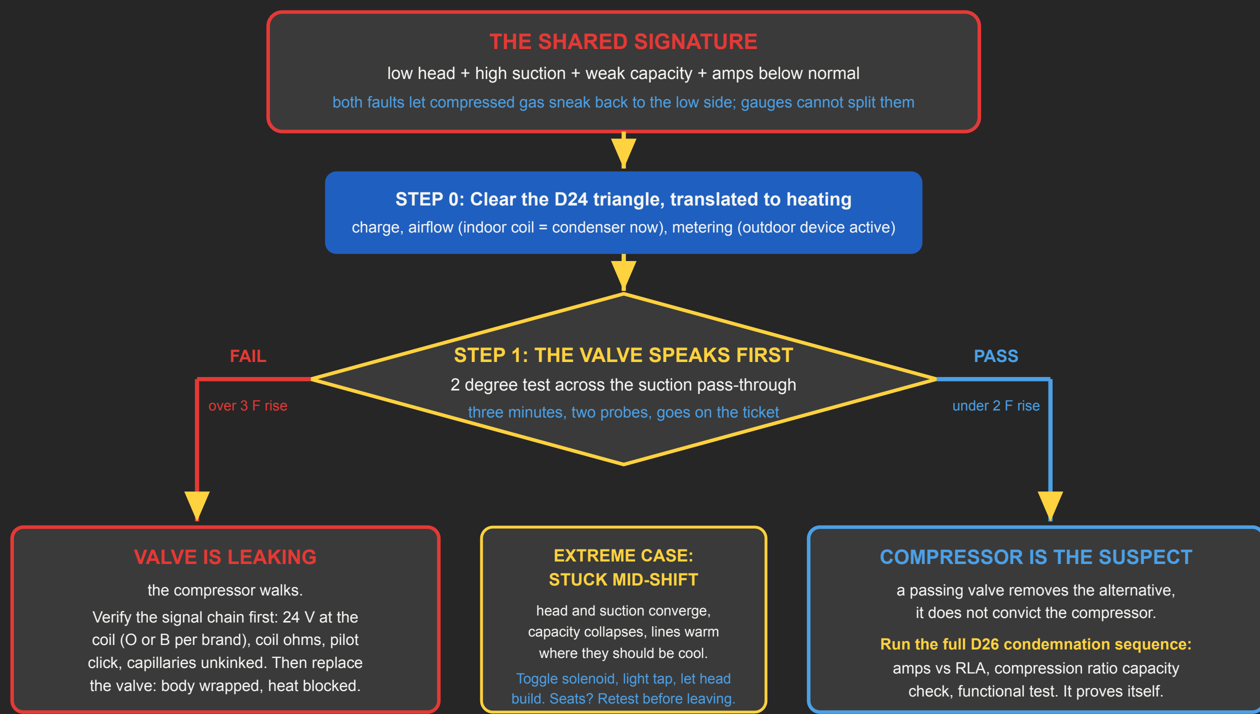
UNDER 2 F: PASS	2 TO 3 F: GRAY ZONE	OVER 3 F: FAIL
valve seals; suspect moves on	reseat probes, run 10 more min, retest	internal bypass leak; condemn valve

Run 10 to 15 steady minutes first. Never within 60 minutes of a defrost. Clean copper, strapped and insulated probes.

Works in cooling mode too: the suction pair becomes the indoor coil return plus the center pipe. Both temps go on the ticket.

VALVE VS COMPRESSOR DISCRIMINATION

Valve or Compressor: Same Gauges, One Discriminator



DOES NOT DISCRIMINATE: discharge temperature

both faults preheat the suction gas, so discharge temp rises either way. Only the valve temperature signature splits them.

NIST: valve/compressor leakage is the worst fault per percent severity, about 70 W lost per 1 percent at 47 F.

IB rule: no compressor is condemned on a heat pump without a documented 2 degree test result on the ticket.