ISLAND BREEZE TECHNICIAN CERTIFICATION PROGRAM

Heat Pumps: Reversing Valves and Defrost

MODULE C19 | CORE SYSTEMS | PREREQ C17

It is a 38 degree January morning and a customer calls in a panic: her outdoor unit is pouring steam like it is on fire, the fan on top has stopped, and the air inside went cold for a few minutes. Nothing is broken. Her heat pump is defrosting itself, exactly as designed, and by the end of this module you will be able to explain every second of what she saw, predict it before it happens, and know the difference between a healthy defrost and a system that is about to ice into a block.

A heat pump is not a new machine. It is the same four-job refrigeration cycle from F4 with one added valve that lets it run the loop in either direction. Learn that valve, learn what swaps when the direction swaps, and learn the defrost system that keeps the outdoor coil alive in cold weather, and you own heat pumps.

Short Version

A heat pump is an air conditioner with a reversing valve. In cooling it moves heat from the house to the outdoors, exactly like every system you have studied. In heating it redirects the compressor's hot discharge gas to the indoor coil instead, so the indoor coil becomes the condenser and the outdoor coil becomes the evaporator, pulling heat out of cold outdoor air and dumping it into the house. The reversing valve does the redirecting: a pilot solenoid uses the system's own pressure difference to slide an internal sleeve that swaps which coil gets discharge gas. In heating below about 40 degrees the outdoor coil runs below freezing and frosts up, so a defrost board periodically flips the valve back to cooling for a few minutes, stops the outdoor fan, and runs the electric heat strips so the house does not feel the cold blast. Below the balance point, the outdoor temperature where heat pump capacity equals the house load, the strips stage in as backup. Same cycle, new direction, plus the housekeeping that direction requires.

Key Values

VALUE	NUMBER	WHY IT MATTERS
Reversing valve center pipe (three-port side)	Always suction back to the compressor	The orientation rule for tracing any heat pump in any mode
Single pipe (one-port side)	Always discharge from the compressor	Hot in both modes, never changes
O terminal convention	Solenoid energized in COOLING	Carrier, Bryant, Trane, Lennox, Goodman, Amana, York
B terminal convention	Solenoid energized in HEATING	Rheem and Ruud

VALUE	NUMBER	WHY IT MATTERS
Frost conditions	Below about 40 F outdoor with humidity	Outdoor coil runs 15 to 25 F colder than the air, so it drops below 32 F
Time-temperature defrost timer pins	30, 60, or 90 minutes of compressor run time	Board only checks for defrost when the timer expires AND the coil sensor is closed
Defrost termination	Coil sensor opens (50 to 80 F coil, per manufacturer) or 10 minute max	Both ends of every defrost are sensor or clock, nothing else
Heat mode gauges on a 40 F day (R-410A)	Suction about 90 psig (25 F sat), head about 317 to 340 psig (100 to 105 F sat)	Low side tracks outdoor air, high side tracks the indoor coil now
Electric strip output	3,412 BTU per hour per kW; a 5 kW bank is about 17,000 BTU per hour	Sizing aux heat and tempering defrost air
Capacity loss with cold (NIST test unit)	8,441 W at COP 3.46 at 47 F down to 5,275 W at COP 2.26 at 17 F, about 37 percent capacity loss	Why balance point exists
Post-defrost stabilization	About 60 minutes before readings settle	Never judge charge right after a defrost

Field Checklist

Heat pump arrival checks, both modes, usable from a phone at the unit:

- [ ] **Identify it as a heat pump:** reversing valve visible near the compressor (a brass cylinder with one pipe on one side, three on the other, and a small solenoid with thin tubes), an accumulator on the suction line, a defrost board in the panel.
- [ ] **Trace the valve before assuming anything:** single pipe side is discharge, center pipe of the three is suction. Always.
- [ ] **Confirm the O or B convention** for the brand before touching thermostat wiring. Wrong terminal means heat on a cooling call.
- [ ] **In cooling mode:** everything from F4 applies unchanged. Fat line cold and sweating, thin line warm, hot air off the top.
- [ ] **In heating mode:** the fat insulated line is now HOT, it carries discharge gas to the house. The air off the outdoor fan blows COLD, colder than the day. Both are correct and healthy.
- [ ] **Switch modes and listen:** a healthy reversing valve shifts with one decisive whoosh and pressure swing. Repeated swooshing or a half-shift hiss is a problem for the diagnostics track.
- [ ] **Check the defrost board settings:** timer pin position, sensor or thermostat seated on the correct return bend, no corroded spades.
- [ ] **Force a test defrost** using the board's test pins and watch the full sequence: valve shifts, outdoor fan stops, strips energize, steam rises, normal termination.

- [ ] **In heat mode, charge by manufacturer heat-mode data or weigh-in only.** Cooling-mode subcooling targets do not transfer.

> **IB STANDARD**
>
> Every heat pump maintenance visit verifies all three behaviors: cooling mode, heating mode, and a forced defrost cycle, every visit, regardless of season. A heat pump that cools perfectly in October and has a dead defrost sensor will become a January no-heat call. We find it in October.

Full Breakdown

One machine, two directions

Recall the heart of F4: an air conditioner does not make cold, it moves heat, and it moves it by controlling pressure. Boil refrigerant at low pressure where you want to absorb heat, condense it at high pressure where you want to reject heat. Nothing in that sentence says which coil has to do which job.

That is the entire idea of a heat pump. In summer, the indoor coil boils refrigerant and absorbs the house's heat, and the outdoor coil condenses it and rejects that heat to the yard. In winter, swap the assignments: let the outdoor coil boil refrigerant so it absorbs heat from the cold outdoor air, and let the indoor coil condense so it rejects that heat into the living room.

Hold on, absorb heat from 40 degree air? Yes, and you already know why. Heat flows from hotter to colder, and 40 degree air is hotter than refrigerant boiling at 25 degrees. There is real, usable heat energy in cold air all the way down to absolute zero. The heat pump just has to run its boiling temperature below whatever the outdoor air is doing, and pressure control does exactly that. Cold air is not empty of heat. It is a low-grade heat source, and the cycle pumps that heat uphill into the house the same way it pumps living room heat uphill into a 95 degree backyard all summer.

So a heat pump heats your house with heat that was already outside. The electricity does not become the heat, the electricity moves the heat. That is why the NIST test unit delivered 8,441 watts of heat at 47 degrees while drawing far less than that in electrical power: a coefficient of performance, COP, of 3.46, meaning about three and a half units of heat delivered per unit of electricity consumed. An electric strip heater can never beat a COP of 1, because resistance heat only converts, it never pumps. Hold that comparison, it comes back at the balance point.

Three pieces of hardware distinguish a heat pump from the straight-cool systems you have worked so far: the reversing valve, the defrost system, and the accumulator. The rest of this module is those three, in that order.

Reversing valve anatomy

Find the brass cylinder mounted near the compressor, about the size of a flashlight, lying on its side. Four pipes connect to it. One side has a single pipe. The other side has three.

The single pipe is the compressor discharge line. Hot gas from the compressor enters here in both modes, always. The valve body itself is therefore always full of hot, high pressure gas, which is why the whole valve is hot to the touch whenever the system runs.

On the three-pipe side, the center pipe is the suction line back to the compressor. Always. This is the single most useful orientation rule in heat pump work: center pipe of the three, suction, no exceptions, any brand, any mode. The two outer pipes run to the two coils, one to the outdoor coil, one to the indoor coil by way of the line set.

Inside the body, a sliding sleeve, usually just called the slide, sits over the three ports. The slide is a small upside-down cup that covers the center suction port and exactly one of the two outer ports, connecting those two together underneath itself, sheltered from the hot gas filling the rest of the body. Whichever coil port the slide connects to suction becomes the low side coil, the evaporator. The other outer port is left exposed to the discharge gas filling the body, so that coil becomes the high side coil, the condenser.

Slide left: outdoor coil gets the hot gas, indoor coil connects to suction. That is cooling. Slide right: indoor coil gets the hot gas, outdoor coil connects to suction. That is heating. One sleeve sliding maybe an inch is the entire difference between July and January operation.

How the shift actually happens: the pilot solenoid

Here is the part that surprises people: the solenoid does not move the slide. The slide sits in hundreds of psi of gas, and the little 24 volt coil bolted to the valve could never drag it across directly. Instead, the solenoid operates a tiny pilot valve, and the pilot valve aims the system's own pressure at the job.

Look closely at the valve and you will see the small solenoid connected to the main body by three or four capillary tubes, thin lines the diameter of pencil lead. One capillary taps the high pressure gas inside the main body. One connects to suction. The others run to the two end caps of the main valve body, the chambers at either end of the slide.

The pilot valve is a switchyard for those capillaries. In one solenoid position, it feeds high pressure gas to the left end cap and bleeds the right end cap off to suction. Now the left end of the slide has high pressure behind it and the right end has low pressure, and that pressure difference shoves the slide to the right. Energize the solenoid and the pilot swaps the connections: high pressure to the right cap, bleed the left, slide shoves left. The system's own head pressure does the heavy lifting. The solenoid just decides which end gets it.

Two field consequences fall straight out of that design:

First, the valve only shifts while the compressor is running, because only a running compressor creates the pressure difference that moves the slide. Energize the solenoid on a dead unit and you will hear the faint click of the pilot, but the main slide stays put until pressures build. A system that has been off long enough to equalize cannot shift until it runs.

Second, a valve can be electrically perfect and still fail to shift. If the slide is stuck, if the pilot capillaries are kinked or plugged, or if a worn compressor cannot build enough pressure difference, the solenoid clicks and nothing changes. Telling a lazy valve apart from a weak compressor is a real diagnostic skill, and it has its own module: D29 teaches the measurement method, including the 2 degree temperature test across the valve. Here you only need to understand the mechanism that test is checking.

O versus B: which brands energize when

The solenoid needs a 24 volt signal, and the thermostat terminal that supplies it is named O or B depending on the convention the manufacturer chose.

O convention: the solenoid is energized in COOLING. De-energized, the valve rests in heating. This is the majority position: Carrier, Bryant, Trane, Lennox, Goodman, Amana, and York all energize in cooling. The thermostat's O terminal goes hot on a cooling call and stays hot through the cooling season.

B convention: the solenoid is energized in HEATING. De-energized, the valve rests in cooling. Rheem and Ruud are the B brands you will meet.

Notice what "de-energized position" really means: it is the mode the system fails into if the solenoid circuit dies. An O-brand heat pump with a broken O wire is stuck in heating. A B-brand with a broken B wire is stuck in cooling. Keep that in your pocket for diagnostics: a heat pump blowing the wrong temperature in both thermostat modes often has a reversing valve that never received, or never obeyed, its signal.

Nearly every thermostat has both an O and a B terminal, or one configurable O/B terminal. Connect the valve wire to the wrong one, or set the configuration backward, and the system runs heat on a cooling call and cooling on a heating call, perfectly, in the wrong direction. This is one of the most common heat pump installation mistakes in existence, and it is pure setup, no broken parts at all. Verify the convention for the equipment in front of you from its wiring diagram, the way F9 taught you, before assuming.

What changes in heating mode

Flip the valve to heating and walk the loop again, because several things you learned as fixed facts in F4 quietly trade places.

The coils swap job titles. The indoor coil is now the condenser: hot discharge gas arrives from the line set, rejects heat into the blower air, and condenses to liquid. The outdoor coil is now the evaporator: liquid meters into it, boils at a temperature below outdoor ambient, and absorbs heat from the outdoor air. The physical coils never move. Their roles do. From this module forward, prefer the role names that do not lie: indoor coil and outdoor coil, rather than evaporator and condenser, unless the mode is stated.

The pressures move house. Head pressure now lives indoors and suction pressure lives outdoors. Hang gauges at the outdoor unit in heat mode and the high side gauge is reading a coil that is inside the building, condensing against 70 degree return air, while the low side gauge reads the coil right in front of you, boiling against the winter air. On a 40 degree day a healthy R-410A heat pump runs the outdoor coil at roughly 25 degrees saturation, which is 90 psig, while the indoor coil condenses around 100 to 105 degrees, which is 317 to 340 psig. Compare that to the cooling numbers from F4, 130 suction and 365 head on a 95 degree day, and notice the low side is dramatically lower in winter. The whole low side follows the outdoor air down.

The big line runs hot. The fat insulated line you have always called the suction line carries the compressor discharge to the indoor coil in heating mode. It will be over 150 degrees. The correct mode-neutral name is the vapor line, and the burn you avoid by knowing this is your own. The thin liquid line still carries liquid in both modes, just in opposite directions.

Two metering devices, each with a bypass. Each coil needs metering when it is the evaporator and needs to be left alone when it is the condenser, so a heat pump carries a metering device at each coil with a check valve that lets refrigerant skip around it in the wrong direction, or a bi-flow TXV that does both jobs internally. In cooling, the indoor metering device works and the outdoor one is bypassed. In heating, the outdoor metering device works and the indoor one is bypassed. When you trace refrigerant on a real unit, find both devices and both check valves and say out loud which pair is active in the current mode.

The accumulator earns its keep. Between the reversing valve and the compressor suction inlet sits the accumulator, a steel tank that catches liquid refrigerant and feeds the compressor vapor only, with oil returning through a small metered orifice. F4 taught you why: liquid does not compress, and liquid arriving at a compressor is how compressors die. Heat pumps need this protection more than straight-cool systems for two reasons. In low ambient heating, the outdoor coil can struggle to boil off everything fed to it, sending wet vapor back. And every reversing valve shift, including every defrost in and out, momentarily upends the pressures and can sling a slug of liquid toward the compressor. The accumulator is the catcher's mitt for both.

Charging and gauge readings in heat mode

C17 taught you to charge a TXV system to subcooling and a fixed orifice system to superheat, using targets that assume cooling mode. Heat mode breaks those assumptions, and you need to know how and why.

In heating, the condenser is the indoor coil, sized and ducted for its summer job as an evaporator, now condensing against a fixed 70 degree indoor environment instead of swinging outdoor weather. The evaporator is the outdoor coil drinking from whatever the sky offers. Charge distribution through the circuit is different, the active metering device is different, and the familiar cooling targets, subcooling 8 to 12 and TXV superheat 10 plus or minus 5, were never promised to apply here.

So the heat mode charging rules are:

1. **Weigh-in is king.** A weighed charge per the nameplate plus line set adjustment, the C17 method, is correct in any season. When in doubt, recover and weigh in.
2. **If charging by readings, use the manufacturer's heat mode charging chart**, found on the panel or in the install manual. These typically plot discharge or liquid pressure against outdoor temperature, and they are equipment-specific by design.
3. **Never apply cooling-mode subcooling or superheat targets to a system running in heat mode.** The numbers will be off and the conclusion will be wrong.
4. **Never judge charge within an hour of a defrost.** NIST measured a heat pump after defrost events and found readings, especially superheat entering the indoor coil, fluttering for roughly 60 minutes while two-phase refrigerant cleared the vapor line. A tech who gauges up ten minutes after a defrost is reading noise.

One more NIST result worth carrying: in heating mode, subcooling was the most sensitive indicator of undercharge, and compressor discharge temperature was the most sensitive indicator of overcharge. You will use both in the diagnostics track. For now the takeaway is that heat mode has its own fingerprints, and they are learnable.

Why the outdoor coil ices

Run the heating numbers again. On a 40 degree day, the outdoor coil boils refrigerant around 25 degrees, generally 15 to 25 degrees colder than the air, because it needs that temperature difference to pull heat in, the same way the indoor coil ran 30 degrees colder than the room in cooling.

A coil surface at 25 degrees is below freezing. Outdoor air carries moisture. When that air touches a below-freezing surface, the moisture does not just condense the way it does on a summer evaporator, it freezes. Frost forms on the fins.

Frost is a double thief. It is an insulating blanket between the air and the refrigerant, and it physically chokes the airflow path through the fins. Less heat absorbed means the refrigerant boils even colder, which makes the coil colder, which builds frost faster. The process feeds itself, and an unchecked coil rolls downhill from a white dusting to a solid block of ice that absorbs almost nothing. NIST watched this happen on instrumented equipment at 36 degrees and 68 percent humidity: frost built over roughly two hours between defrosts, with capacity sagging as it grew.

So every heat pump needs a planned, automatic way to melt the coil. That is defrost.

Defrost logic: time-temperature versus demand

The melting method is brilliant in its simplicity: the machine already knows how to make the outdoor coil hot. Run cooling mode. Defrost is a few minutes of deliberate cooling operation that turns the outdoor coil back into a condenser and lets 200 degree discharge gas melt the frost from the inside out.

What needs intelligence is the decision of when, and that lives on the defrost board, a control board in the outdoor unit. Two generations of logic exist, and you will service both.

Time-temperature defrost is the classic approach. Two inputs: a timer counting compressor run time, with pins you set to 30, 60, or 90 minutes, and a defrost thermostat or sensor clamped to a return bend of the outdoor coil that closes when the coil drops to roughly 30 degrees. When the timer expires, the board checks the sensor. Sensor closed, coil is cold enough to be frosting, run a defrost. Sensor open, coil is fine, restart the timer and keep heating. The timer cannot trigger anything by itself, and neither can the sensor. It takes both.

The weakness is that time and coil temperature are stand-ins for frost, not measurements of it. A coil can be cold without frosting in dry air, and time-temperature boards will defrost it anyway, wasting heat and cycling the valve for nothing. Pin choice matters too: 30 minute pins in a dry climate mean three times as many needless defrosts as 90 minute pins.

Demand defrost is the modern approach: the board measures conditions that indicate actual frost, typically by comparing an outdoor ambient sensor against the coil sensor. A clean coil holds a predictable temperature difference below ambient. As frost insulates and chokes the coil, the coil temperature falls further below ambient than the clean baseline allows, and that widening gap is the board's evidence of real frost. Demand boards defrost only when the coil genuinely needs it, which can cut defrost events dramatically, and every needless defrost avoided is heating capacity kept.

PHOENIX FIELD NOTE

Heat pumps dominate Phoenix new installs, which makes this module daily bread even though our winters are gentle. Defrost events here are genuinely rare, a handful of cold, damp winter mornings a year, and that rarity is exactly the trap: a mis-set timer pin, a fallen-off coil sensor, or a corroded board spade can hide for years because defrost is almost never asked to run. Then the one freezing-fog morning arrives, the coil blocks solid, and the customer has a no-heat call in January. Rare-event systems must be tested deliberately, because Phoenix weather will not test them for you.

The defrost cycle, step by step

When the board decides to defrost, four things happen at essentially the same moment. Learn them as a package, because seeing all four together is how you recognize a healthy defrost, and seeing one missing is how you catch a fault.

1. **The reversing valve shifts to cooling.** The board energizes or de-energizes the solenoid as the brand requires. Hot discharge gas floods the outdoor coil and starts melting frost from the tubing outward. You will hear the whoosh of the shift and often a brief growl as pressures reorganize.
2. **The outdoor fan stops.** This looks wrong and is exactly right. The fan's whole job is moving heat away from the coil, and right now we want heat to stay in the coil. A dead-still fan during defrost is correct operation. The frost melts faster, and the rising heat turns the meltwater and damp coil into the dramatic steam plume customers mistake for smoke.
3. **The compressor keeps running.** It is the heat source. Defrost is cooling mode, not off mode.
4. **The board calls for auxiliary heat.** The system is now air conditioning the house in winter, so the board closes a circuit to W and brings on the electric heat strips to temper the supply air. With strips running, the registers blow roughly neutral air instead of cold, and most homeowners never notice a defrost happening. Undersized or failed strips are why some customers report a blast of cold air every hour or two in winter.

Termination mirrors initiation: the defrost ends when the coil sensor warms to its opening temperature, somewhere between 50 and 80 degrees depending on the manufacturer, proof the ice is gone, or when a maximum time limit hits, typically 10 minutes, whichever comes first. The board then shifts the valve back to heating, restarts the outdoor fan, and drops the strips. A defrost that always runs the full 10 minutes and terminates on time rather than temperature is telling you the coil never got warm, and that is a clue worth writing down.

Auxiliary and emergency heat

The strips deserve their own treatment, because they serve two different masters and a thermostat wire for each.

The hardware is electric resistance elements mounted in the air handler, downstream of the indoor coil, sold in banks rated in kilowatts: 5, 8, 10, 15, 20 kW packages are common. Every kilowatt makes 3,412 BTU per hour, so a 10 kW package adds about 34,000 BTU per hour, real furnace-scale heat at COP 1, the most expensive heat the system can make. Larger packages are split into stages so the elements step on in sequence rather than slamming a 60 plus amp load onto the service in one hit. Sequencers or staged relays bring banks on a few seconds apart, and you will see that staging as stepped amp draw if you clamp the air handler feed.

Auxiliary heat is the strips helping the running heat pump. Recall the F9 thermostat terminals: W2 is the second stage heat call. When the heat pump alone cannot hold setpoint and the indoor temperature keeps sagging, the thermostat closes W2 and the strips run alongside the compressor. Compressor plus strips together. This is normal cold-snap operation, and the strips drop back out when the heat pump catches up. The defrost board's tempering call lands on this same strip circuit during defrost.

Emergency heat is the strips replacing the heat pump. The E terminal, selected by the homeowner at the thermostat, locks the compressor out entirely and heats with strips alone. It exists for one situation: the heat pump is broken and the family needs heat tonight while they wait for you. Teach your customers that EM HEAT is a limp-home switch, not a comfort setting. A thermostat parked on emergency heat all winter generates shocking electric bills with a perfectly healthy heat pump sitting idle outside.

On a service call, the distinction tells you where to look. Aux running constantly with the compressor means the heat pump side is underperforming: low charge, failing valve, iced coil, dying compressor. The house surviving on E means the compressor side is down outright.

The balance point

Two curves decide a heat pump's winter, and where they cross is the most important number in heat pump application.

The capacity curve falls as it gets colder. The colder the outdoor air, the less heat per hour the machine can pump out of it. The suction pressure follows the falling outdoor temperature down, the compressor moves less refrigerant per stroke at the worse compression ratio, and frost losses pile on near freezing. The NIST test unit is the concrete example: 8,441 watts of heat at 47 degrees outdoors, 5,275 watts at 17 degrees. Thirty degrees colder cost 37 percent of capacity, with the compressor drawing more power for less output, COP sliding from 3.46 to 2.26.

The load curve rises as it gets colder. The colder it is outside, the faster the house leaks heat and the more heat per hour it takes to hold 70 inside. From F3, heat flow scales with temperature difference.

Falling capacity, rising load. The outdoor temperature where the two lines cross is the **thermal balance point**: the temperature at which the heat pump's full output exactly equals the house's need. Above it, the heat pump carries the house alone with capacity to spare. Below it, the heat pump runs continuously and still loses ground, and the gap between the two lines must be filled by auxiliary heat. The thermostat does the filling automatically through W2. A typical residential balance point lands somewhere in the 25 to 35 degree range, but it is a property of the specific equipment matched to the specific house, not a constant.

There is a second balance point that has nothing to do with capacity. The **economic balance point** is the outdoor temperature where the heat pump stops being the cheaper way to make heat, set by efficiency and energy prices rather than physics of capacity. Against electric strips the comparison is simple: the strips are locked at COP 1, and a running heat pump beats COP 1 at any temperature it can operate, so against strips the heat pump is always the cheaper heat and the economic balance point effectively does not bind. The concept earns its keep on dual fuel systems, where the backup is a gas furnace and there is a real crossover temperature, set by gas and electric rates, below which burning gas costs less than pumping heat. Dual fuel controls lock the compressor out below that point. Know both balance points by name and never blur them: thermal is about capability, economic is about cost.

> **PHOENIX FIELD NOTE**
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> Phoenix equipment is selected for the 112 F cooling design day, which makes it generously sized against our mild heating loads. Balance points here commonly fall at or below our coldest winter nights, which means many Phoenix heat pumps can carry their house all winter with the strips touching only defrost tempering duty. So when you find strips cycling regularly on aux in a Phoenix January, do not shrug it off as winter being winter. Mild-climate aux runtime is a symptom: low charge, a leaking reversing valve, a frost problem, or a failing compressor is stealing capacity from a machine that should have plenty.

Low ambient heating and where this leads

Everything in this module assumed the single-speed equipment that fills Phoenix neighborhoods, and single-speed physics is blunt: capacity falls with outdoor temperature, period. The compressor is a fixed-displacement pump taking whatever density the cold suction gas offers, and at low ambient that is not much. Deep-winter performance for these machines is the balance point story plus strips, and there is no trick that changes it.

What changes it is changing the compressor. Inverter-driven variable speed heat pumps can spin the compressor faster as the temperature falls, moving more refrigerant to compensate for the thinner gas, and modern cold-climate designs hold their rated capacity to far lower outdoor temperatures while pushing balance points down dramatically. That technology, how it works and how it changes everything you measure, is module A33. And the dark side of this module, reversing valves that leak instead of shift, defrost boards that lie, and the discrimination test between a bad valve and a bad compressor, is module D29. This module gave you the healthy machine. Those give you the broken ones and the advanced ones.

Common Mistakes

- **Wiring or configuring O when the equipment wants B, or the reverse.** The system heats on cool calls and cools on heat calls with zero failed parts. Always verify the convention from the equipment wiring diagram, not from habit. Rheem and Ruud energize in heating; most everything else energizes in cooling.
- **Condemning a reversing valve with the system off.** The slide moves on pressure difference, which exists only with the compressor running. A solenoid that clicks on a dead unit and "does nothing" is behaving correctly. Test shifts on a running system.
- **Grabbing the fat line in heat mode out of summer habit.** The vapor line carries 150 degree plus discharge gas to the house in heating. The reflex that the big insulated line is the cold one is a cooling-mode fact, and it will burn you exactly once.
- **Calling a healthy defrost a failure.** Steam pouring off the unit, the outdoor fan dead still, and a few minutes of cool supply air is the design working. Know the four-part defrost signature cold, and teach it to customers before winter so the panicked call never happens.
- **Charging a heat pump in heat mode with cooling targets.** Subcooling 8 to 12 and superheat 10 are cooling-mode numbers. In heat mode: weigh-in, or the manufacturer's heat mode chart. And never within an hour of a defrost, the readings are still settling.
- **Ignoring the defrost system in a mild climate.** Rarely-used systems fail silently. A wrong timer pin or unseated coil sensor costs nothing in October and the whole night's heat in a January cold snap. Force a defrost on every maintenance and watch it complete.
- **Letting a customer winter on emergency heat.** EM HEAT at the thermostat locks out a possibly healthy compressor and heats the house at COP 1. If the bill complaint arrives in February, check the thermostat mode before anything else.
- **Treating aux heat runtime as normal in a mild climate.** Strips covering for a heat pump that should carry the load alone are a capacity-loss symptom. Find out what is stealing the capacity instead of admiring the strips for working.

Module Visuals

AUX HEAT STAGING

Strip Heat: Who Calls It and When

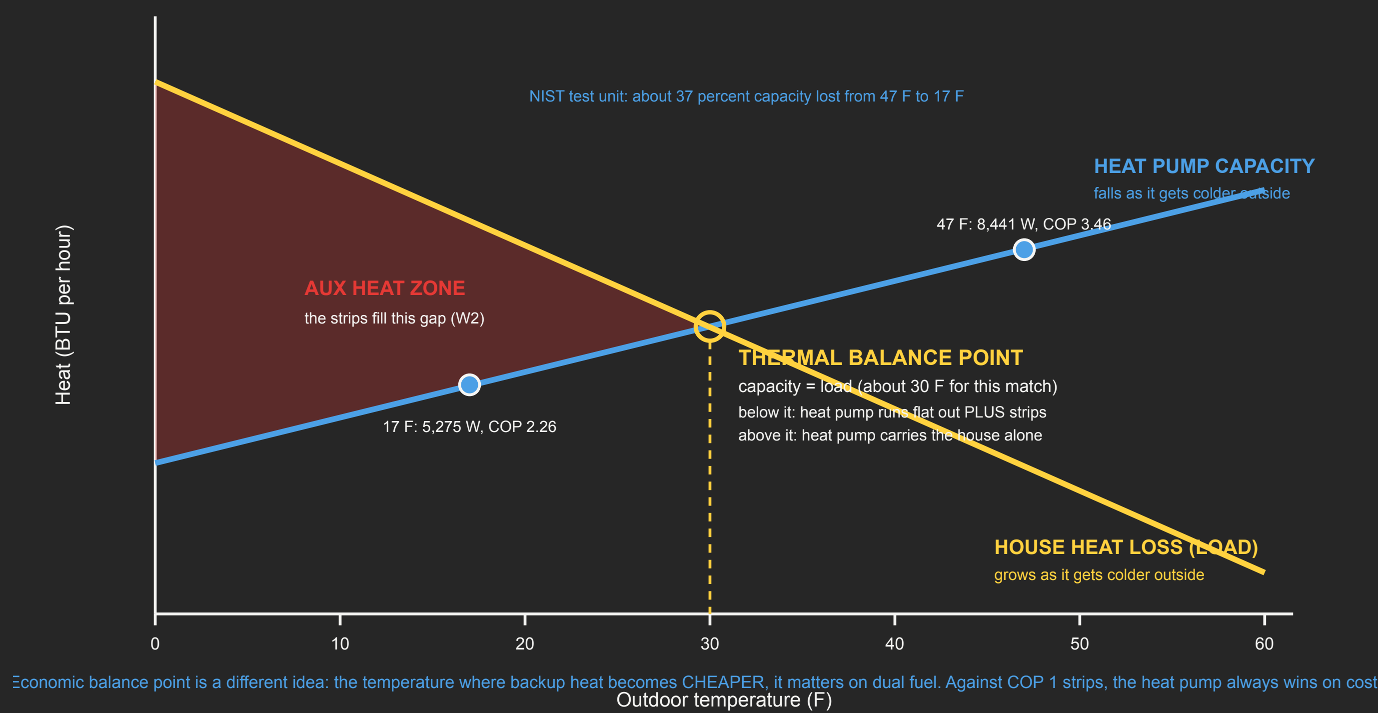
Four situations, one strip package. Each kW of strip = 3,412 BTU per hour, at COP 1, the most expensive heat in the system.

SITUATION	TERMINAL (F9 recall)	COMPRESSOR	STRIP BANKS (10 kW = 2 x 5 kW)
Mild day, above balance point heat pump alone	W2 open, E open	ON	BANK 1 off / BANK 2 off cheapest heat: COP about 3 in mild weather
Cold snap, below balance point AUX: strips help the pump	W2 CLOSED	ON	BANK 1 ON / BANK 2 ON sequencer steps banks in seconds apart, no inrush slam
Defrost cycle (a few minutes) strips temper the cold blast	defrost board board drives W, not the stat	ON (running in cooling, melting the coil)	BANK 1 ON / BANK 2 ON
EMERGENCY HEAT (homeowner selects) heat pump is broken: limp home	E CLOSED	LOCKED compressor out of the circuit	BANK 1 ON / BANK 2 ON

10 kW package delivers about 34,000 BTU per hour. A thermostat parked on EM HEAT all winter = a shocking electric bill with a healthy heat pump idle outsi

BALANCE POINT GRAPH

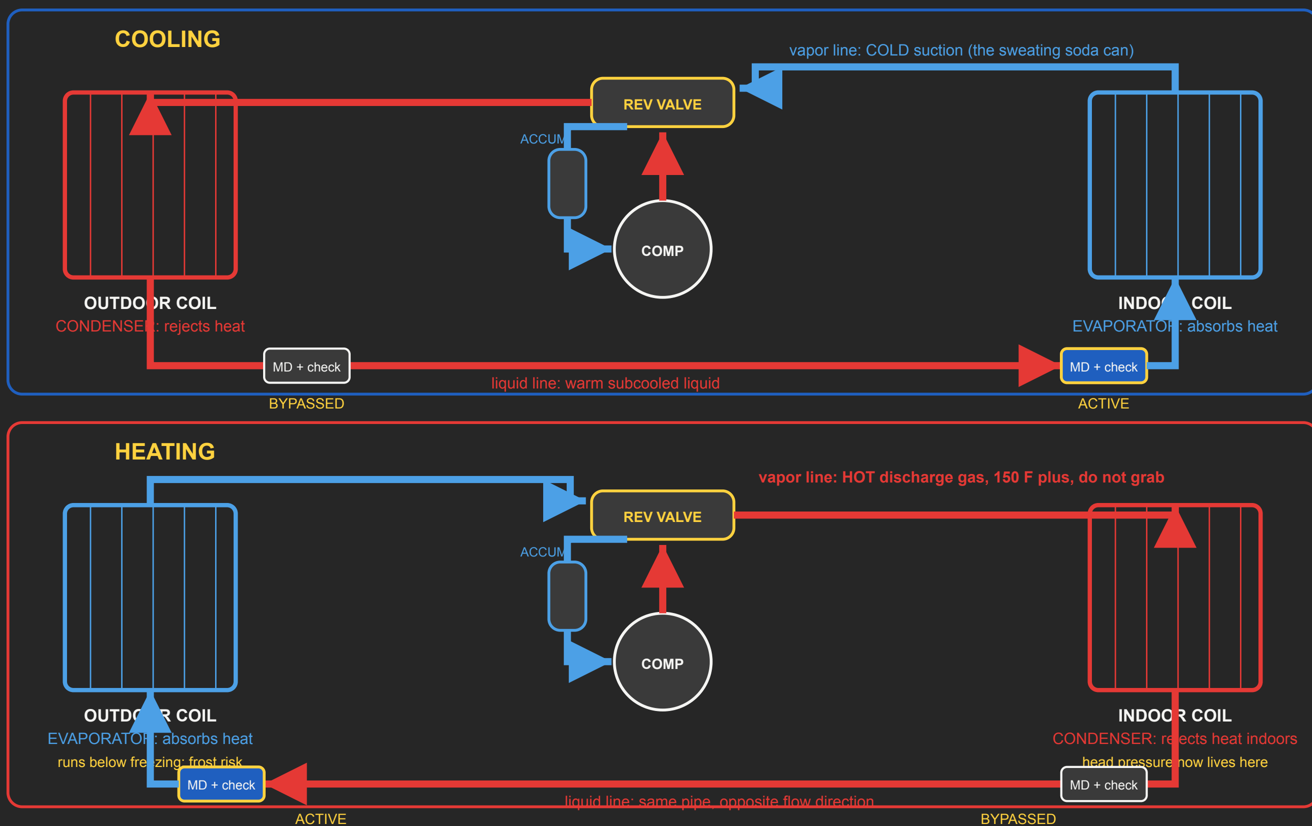
The Balance Point: Where Capacity Meets Load

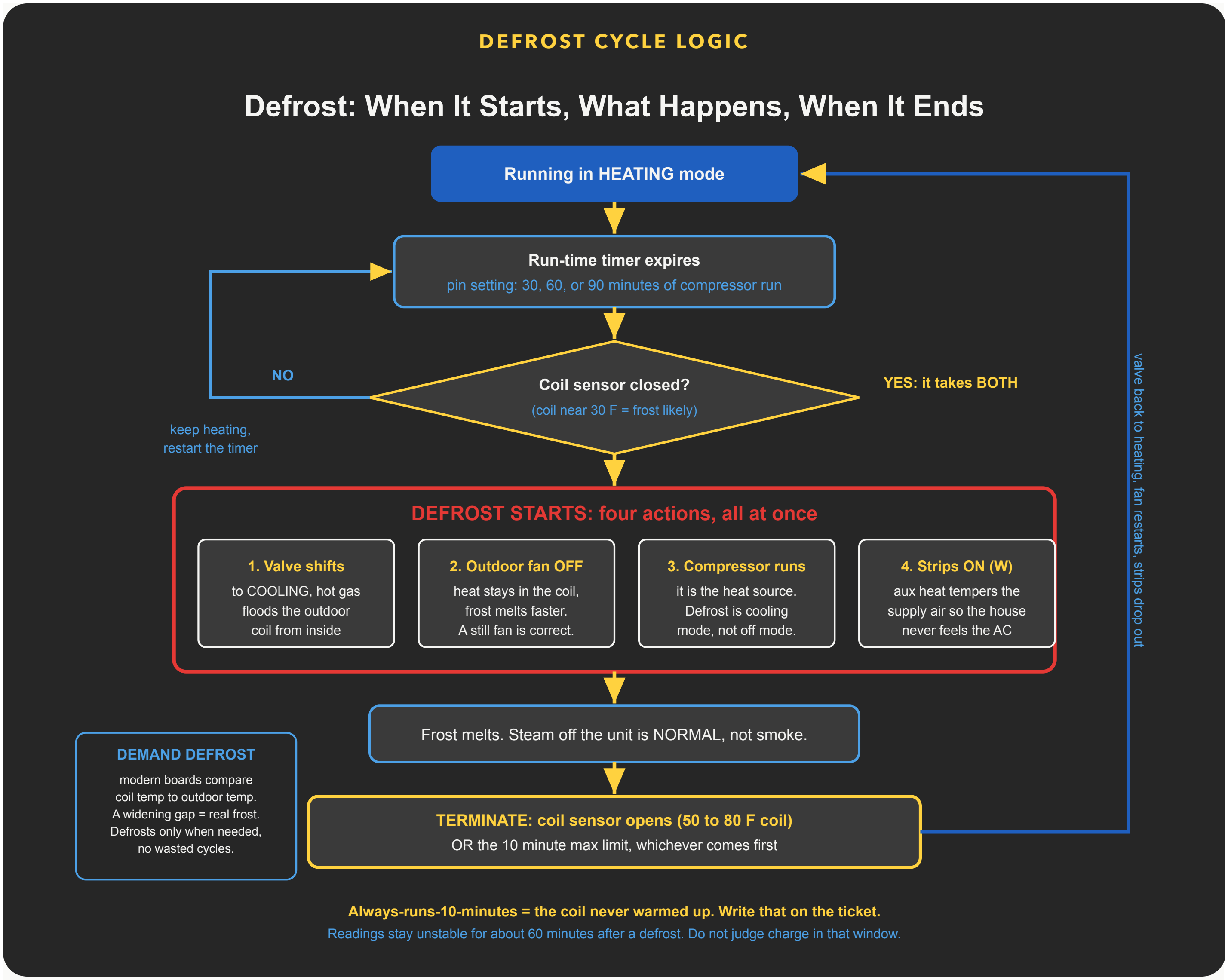


COOLING VS HEATING CIRCUIT

Same Loop, Coils Trade Jobs

Red = high pressure hot, Blue = low pressure cold. Only the reversing valve changed.

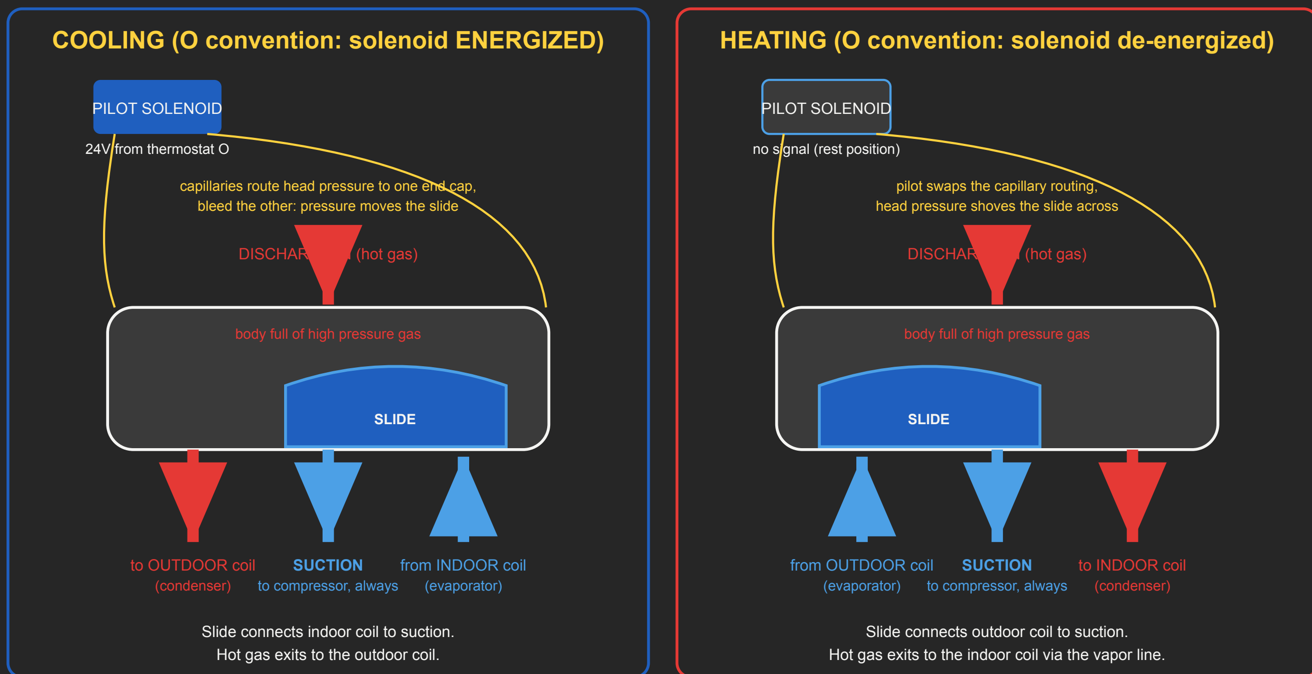



DEFROST CYCLE LOGIC
Defrost: When It Starts, What Happens, When It Ends
Running in HEATING mode
Run-time timer expires
pin setting: 30, 60, or 90 minutes of compressor run
Coil sensor closed?
(coil near 30 F = frost likely)
NO
keep heating, restart the timer
YES: it takes BOTH
DEFROST STARTS: four actions, all at once
1. Valve shifts
to COOLING, hot gas floods the outdoor coil from inside
2. Outdoor fan OFF
heat stays in the coil, frost melts faster. A still fan is correct.
3. Compressor runs
it is the heat source. Defrost is cooling mode, not off mode.
4. Strips ON (W)
aux heat tempers the supply air so the house never feels the AC
Frost melts. Steam off the unit is NORMAL, not smoke.
DEMAND DEFROST
modern boards compare coil temp to outdoor temp. A widening gap = real frost. Defrosts only when needed, no wasted cycles.
TERMINATE: coil sensor opens (50 to 80 F coil)
OR the 10 minute max limit, whichever comes first
valve back to heating, fan restarts, strips drop out
Always-runs-10-minutes = the coil never warmed up. Write that on the ticket.
Readings stay unstable for about 60 minutes after a defrost. Do not judge charge in that window.

REVERSING VALVE FLOW

Reversing Valve: One Slide, Two Directions

Single pipe = discharge, always. Center of the three = suction, always. The slide picks which coil gets which.



O brands (energize in cooling): Carrier, Bryant, Trane, Lennox, Goodman, Amana, York. B brands (energize in heating): Rheem, Ruud.

The slide moves on system pressure difference: the valve can only shift while the compressor is running.

De-energized position = the mode the system fails into if the solenoid circuit dies.