

Start Here: What Is in a Heat Pump, What Breaks, and How to Find It

YES Electric • Arc Workforce Academy HVAC Apprenticeship

Draft 1 (October 2026). This lesson is under review. Videos are made by other companies, not YES Electric; follow this lesson and your journeyman where they differ. Boxes marked "Shop photo coming" will get real photos from our shop in a later version.

Unit 0 • Start Here • Read this before Lesson 1.1 Class time: ~3 hrs (1 reading + 2 at the shop unit with the panels off)

1. What you'll be able to do

By the end of this chapter you will be able to:

- Stand at a residential heat pump with electric heat strips and **name every main part**, inside and outside, and say what it does in plain words.
- Say **what usually breaks** on each part, what that looks like on a service call, and roughly how big the repair is.
- Walk a dead or misbehaving system through the **five-question diagnosis flowchart** and land on the part most likely at fault.
- Know which repairs are quick electrical swaps and which ones mean recovering refrigerant and soldering.

This chapter is written in plain language on purpose. The lessons after it go deep on each part. If you read nothing else before your first ride-along, read this.

2. Tools & materials

- The shop heat pump with the outdoor panel and the air handler door off
- Multimeter with AC volts, ohms, and capacitance (μF)
- Clamp amp meter
- Flashlight, 1/4" and 5/16" nut drivers, screwdriver
- Safety glasses

3. The main parts

Think of the whole system as a machine that moves heat from one place to another, like a bucket brigade for warmth. In winter it carries heat from the outside air into the house. In summer it carries heat from the house to the outside air.

Outdoor unit (the condenser or heat pump)

Part	What it does, in plain words
Compressor	The pump and the heart of the system. It squeezes the refrigerant gas hard, which makes it hot, and pushes it around the loop. No compressor, no heating or cooling.
Outdoor coil and fan	The coil is thin metal fins with tubes through them. The fan blows outside air across it. In summer it dumps house heat outside. In winter it grabs heat from the outdoor air, even when the air feels cold, because the refrigerant inside is colder than the air.
Reversing valve	A switch for the refrigerant. It flips the direction the hot gas flows, so the same machine heats in winter and cools in summer. A small electric magnet called a solenoid moves it.
Accumulator	A small tank on the suction line that catches liquid refrigerant before it reaches the compressor. The compressor only likes gas. Liquid would break it, like trying to squeeze water in a bicycle pump.
Metering device (TXV or piston)	A tiny opening that lets only a little refrigerant squirt through at a time. The refrigerant gets very cold as it passes through, like a can of spray air turning cold in your hand.
Defrost board and sensor	In winter the outdoor coil gets so cold that frost builds up like a freezer. The sensor notices, and the board flips the system to cooling for a few minutes to melt it. That is why you see steam coming off the unit sometimes.
Contactor	A big electric switch. The thermostat sends a small 24 V signal, and the contactor closes to let the big 240 V power through to the compressor and fan.
Capacitor	A can that gives the motors a push to start and keeps them running smoothly. The dual capacitor serves both the compressor (HERM) and the fan (FAN).
Pressure switches	Safety switches. If the refrigerant pressure gets too high or too low, they shut the compressor off before it hurts itself.
Crankcase heater	A small warmer on the compressor shell. It keeps the oil warm so refrigerant does not soak into it while the unit sits off in cold weather.
Service valves	Ports where you hook up gauges, like the air valve on a tire. The caps are part of the seal.

Indoor unit (the air handler)

Part	What it does, in plain words
Indoor coil	Fins and tubes inside the house. In summer it is cold and pulls heat out of the air blowing across it. In winter it is hot and warms the air.
Indoor metering device	Same job as the outdoor one, used in cooling mode. A check valve lets refrigerant go around it the other way in heating mode.
Blower	The big fan. It pulls air from the house through the filter, pushes it across the coil and the heat strips, and sends it back out through the ducts.
Electric heat strips	Wire coils that glow hot when power runs through them, like a giant toaster. They come on when it is too cold outside for the heat pump to keep up, during defrost so you do not feel cold air, or as the only heat in Emergency mode. Sequencers turn them on one at a time. Limit switches shut them off if they get too hot.
Control board	The small computer that listens to the thermostat and decides when to run the blower and when to bring on the heat strips.
Transformer	Turns the 240 V house power into a safe 24 V for the thermostat and control wires.
Drain pan and drain line	In summer water drips off the cold coil like a cold glass of lemonade. The pan catches it and the line carries it outside. The float switch shuts the system off if the drain clogs so water does not pour through the ceiling.
Filter	Catches dust and hair before the air reaches the coil and blower.

Connecting pieces

Part	What it does, in plain words
Line set	Two copper pipes between the inside and outside units. The fat insulated one carries cold gas, the skinny one carries warm liquid.
Thermostat	The brain on the wall. You set the temperature, and it tells the system to heat, cool, run the fan, or call for the heat strips. A heat pump thermostat has an O/B terminal for the reversing valve, W2/Aux for the strips, and E for emergency heat.
Low-voltage wiring	The thin 18-gauge wires carrying the thermostat's messages to the indoor and outdoor units.
Disconnects	Big switches next to each unit so you can shut the power off safely before working on it.
Breakers and wires	The heavy wires from the panel that feed the units. Heat strips use a lot of power, so they get their own big breakers, sized from the nameplate MCA and MOP.
Grounding	A safety wire that gives electricity a safe path back to the panel if something goes wrong, so it does not go through a person instead.
Ductwork	The tubes in the walls and attic that carry air from the blower to each room and bring it back again.
Pad or brackets	What the outdoor unit sits on so it stays level and out of the mud.

How the pieces work together

In winter the refrigerant goes outside, gets very cold, soaks up heat from the air, comes back inside, gets squeezed hot by the compressor, and gives that heat to the air blowing through your ducts. In summer the reversing valve flips everything and it works backward. When it is too cold outside for that trick to work well, the heat strips kick in like a giant toaster and warm the air directly. The defrost board periodically reverses the system to cooling for a few minutes to melt ice off the outdoor coil, which is why the outdoor fan stops and steam rises off the unit in winter.

4. What goes wrong with each part, and what the fix looks like

Outdoor unit

- **Compressor.** The worst thing that can break. It can burn out its motor windings, lock up so it will not spin, or lose its ability to squeeze when the valves inside wear out. You hear it hum and not start, or the breaker trips, or it runs but the house never gets warm or cool. The fix means recovering all the refrigerant, cutting the old compressor out with a torch, brazing a new one in, pulling a vacuum, and refilling. It takes most of a day and costs a lot. On an old unit most people replace the whole outdoor unit instead.
- **Outdoor coil and fan.** The coil gets clogged with grass, cottonwood fluff, and dirt so it cannot breathe. Fix is washing it with a hose and coil cleaner. The coil can also spring a leak from rubbing or corrosion. Small leaks sometimes get patched, but a bad coil usually means a new outdoor unit. The fan motor wears out its bearings and gets noisy or stops. Fix is unbolting the top of the unit, swapping the motor and blade, and wiring it back. About an hour.
- **Reversing valve.** It can stick halfway so refrigerant leaks between the two sides, or the solenoid coil burns out so it will not flip. The system blows warm air when it should be cold, or the other way around. A bad solenoid coil is a quick swap. A stuck valve means recovering refrigerant and brazing in a new valve, which is a big repair.
- **Accumulator.** Rarely fails, but it can rust through and leak. Replacing it is a cut-and-braze job with refrigerant recovery.
- **Metering device.** The tiny hole plugs with dirt or sludge, or the TXV's sensing bulb loses its charge and the valve stops opening. The system runs but freezes up or barely cools. A plugged piston gets pulled and cleaned or replaced. A bad TXV gets cut out and a new one brazed in.
- **Defrost board and sensor.** The board can fail so the unit never defrosts and the outdoor coil turns into a block of ice, or it defrosts constantly. The sensor can read wrong. Both are plug-in parts. Pull the old board off its standoffs, move the wires one at a time, clip a new sensor on the coil. Under an hour.
- **Contactors.** The contacts get pitted and burned from switching so many times. They stick closed so the unit never shuts off, or burn open so it never starts. Ants and bugs get crushed in them too. Replacing it is two screws and a handful of wires. About 15 minutes.

- **Capacitor.** The most common failure of all. It swells on top like a soda can left in a hot car, or just loses strength. The fan or compressor hums and will not start, or starts slowly. Check it with the meter's μF setting, unplug the old one, plug in the new one. Ten minutes.
- **Pressure switches.** They can fail and keep the unit off when nothing else is wrong, or chatter on and off. Replacing one usually means recovering refrigerant and brazing unless it sits on a Schrader port.
- **Crankcase heater.** It burns out. You usually find out when the compressor has a hard start on a cold morning. Unwrap the old one and strap on a new one.
- **Service valves.** The Schrader cores leak slowly and the caps go missing. New core or cap, like fixing a tire valve.

Indoor unit

- **Indoor coil.** It gets coated with dirt when filters are skipped, and it can corrode and leak refrigerant. Formicary corrosion makes tiny pinhole leaks in copper. A dirty coil gets pulled and cleaned. A leaking coil gets swapped, which means recovery, cutting it out, brazing a new one in, vacuum, and recharge.
- **Indoor metering device.** Same failures and same repair as the outdoor one.
- **Blower.** The motor wears out, the capacitor fails on PSC motors, or the electronic module dies on ECM motors. The wheel gets caked with dirt and goes out of balance. You hear it rattle, or air stops moving while the coil freezes. Replacing the motor means pulling the blower assembly out, swapping the motor in the housing, and sliding it back in. One to two hours.
- **Electric heat strips.** Elements break like a burnt toaster wire, so you get less heat or none. Sequencers stick so some strips never come on or never go off. Limit switches trip from a dirty filter or a weak blower. Fuses or breakers on the kit blow. Pull the kit out of the air handler, replace the broken element or sequencer, slide it back in. Sometimes the whole kit gets replaced.
- **Control board.** Relays fail, solder joints crack, or a power surge fries it. The blower will not run, or runs nonstop, or the strips never come on. Move the wires one at a time to a new board. Under an hour.
- **Transformer.** It burns out, usually because a thermostat wire shorted. Everything goes dead and the thermostat screen is blank. It is a small bolt-on part, but you have to find the short first or the new one burns too.
- **Drain pan and drain line.** The line clogs with slime and water backs up. The float switch shuts the system off, or without one, water drips through the ceiling. The pan can rust through or crack. Blow out or vacuum the line, pour in cleaner, replace a bad pan.
- **Filter.** It clogs. That starves the system for air, freezes the coil, trips limit switches, and burns up blower motors. A new filter every one to three months prevents a lot of the problems above.

Connecting pieces

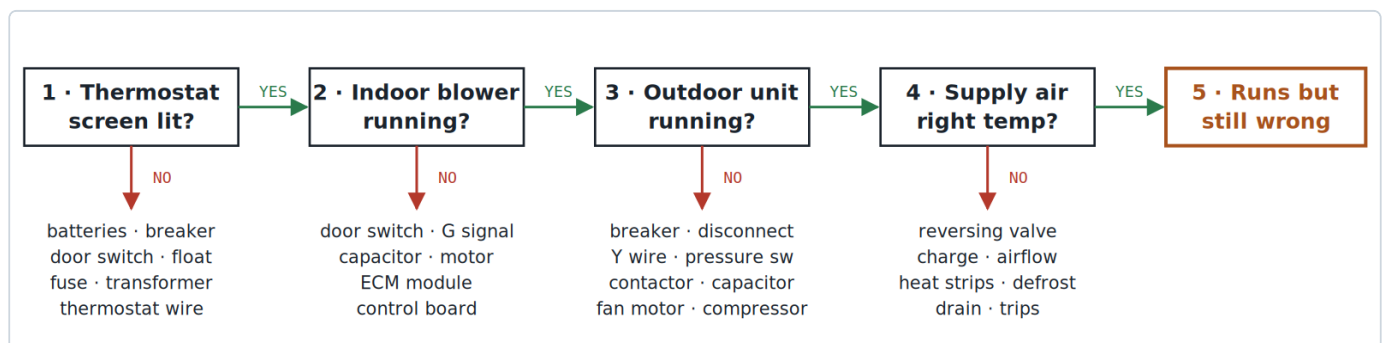
- **Line set.** It rubs through on something and leaks, or the insulation rots off in the sun so the pipe sweats. Leaks get brazed or the line set gets replaced. Rotten insulation gets peeled off and new foam slid on.

- **Thermostat.** Batteries die, the screen goes blank, it gets wired wrong, or loses its settings. New batteries, or a new thermostat wired to the same letters.
- **Low-voltage wiring.** A wire gets chewed by a critter, nicked by a weed eater, or corrodes at the terminal. Find the break with a meter and splice or run new wire.
- **Disconnects.** The pull-out corrodes or the clips get loose and arc. New disconnect box on the wall, about a half hour.
- **Breakers and wires.** Breakers wear out and trip for no reason, or terminals get loose and overheat. New breaker, or tighten and clean the connections.
- **Grounding.** The ground wire comes loose or was never connected. Nothing looks wrong until something shorts and the case becomes live. Reconnect it properly.
- **Ductwork.** Joints come apart, flex duct gets crushed or chewed, and air leaks into the attic. Reconnect and seal with mastic, or replace a run.
- **Pad or brackets.** The pad sinks and the unit tilts, which strains the line set. Lift the unit and level or replace the pad.

The big picture on repairs. Small electrical parts like capacitors, contactors, boards, and sensors are quick swaps measured in minutes. Anything that holds refrigerant, like coils, compressors, reversing valves, and metering devices, means recovering refrigerant, cutting and brazing, pulling a vacuum, and recharging, which takes hours and costs much more. On a unit over 12 to 15 years old, a refrigerant-side repair often costs enough that replacing the whole unit makes more sense.

5. The diagnosis flowchart

Start at question 1 and answer each one with what you can see, hear, and read on a meter. Every NO sends you to a fix list. Every YES drops you to the next question. Work in order, because a problem up top makes everything below it look broken too.



Before you touch anything. Pull the outdoor disconnect and flip the air handler breaker before putting hands inside either cabinet. Capacitors hold a charge after power is off, so short the terminals with an insulated screwdriver before handling one. Heat strip terminals carry 240 V. Refrigerant work (coils, compressor, reversing valve, TXV) needs a recovery machine, a vacuum pump, and an EPA 608 card, which you earn in Unit 5. This chart tells you when you are there. It does not walk you through it.

Question 1 — Is the thermostat screen lit?

Blank screen means no 24 V control power or dead batteries. Lit screen means the transformer and the wire to the thermostat are fine.

If NO, find the missing 24 volts:

1. **Batteries.** If the thermostat takes batteries, put new ones in. Lit now? Go to question 2.
2. **Air handler breaker.** Tripped? Reset it once. Trips again right away? Go to box 5F. Do not keep resetting.
3. **Blower door switch.** The door has to be fully on to press the switch.
4. **Float switch.** A drain pan full of water lifts the float and kills power on purpose. Pan full? Go to box 5E, then come back.
5. **Board fuse.** Meter across R and C on the air handler board. No 24 V? Pull the 3 A or 5 A blade fuse. Blown means a thermostat wire is shorted somewhere (chewed, pinched, nicked at the outdoor unit). Find the short first, then put a new fuse in.
6. **Transformer.** Fuse good but still no 24 V? Check 240 V going into the transformer. Power in, nothing out means a dead transformer.
7. **Thermostat wire.** 24 V at the board but not at the thermostat means a broken wire in between. Find the break, splice or run new wire.

If YES, set the thermostat 5° past room temperature and wait up to 5 minutes for any delay.

Question 2 — Does the indoor blower run when you call for heat or cool?

Put a hand at a supply vent.

If NO, get the blower moving:

1. **Fan switch to ON.** Runs now? The motor is fine. The problem is the G call from the thermostat or the board's auto logic. Check 24 V on G at the board during a call.
2. **Hum but no spin (PSC motor).** Check the run capacitor in μF . Swollen top or more than 6 percent under its rating means replace it.
3. **Stiff wheel.** Power off, spin the blower wheel by hand. Drags or grinds means motor bearings. Replace the motor.
4. **Silent ECM motor.** Confirm 240 V on the motor's power plug and 24 V on its signal plug during a call. Power and signal present, no spin means the motor module is dead.
5. **Nothing at all.** 24 V on G at the board but no voltage leaving the blower relay means a bad control board.

Question 3 — Does the outdoor unit run?

Go outside during the call. You want to see the fan spinning and hear the compressor humming. There are three ways to fail this question.

3A • Nothing runs outside:

1. **Breaker and disconnect.** Outdoor breaker in the panel, then the pull-out at the unit. Tripped? Reset once. Retrips? Go to 5F.
2. **Contactor coil voltage.** Meter across the two small coil wires on the contactor. Should read 24 V during a call. No 24 V? The Y wire is broken, or a pressure switch is open. Meter across each pressure switch. 24 V across an open one means it is tripped. A low-pressure switch open usually means the refrigerant leaked out.
3. **24 V present, contactor not pulled in.** Coil burned out, or a bug jammed in it. Replace the contactor.
4. **Contactor pulled in, no 240 V on the load side.** Burnt contacts. Replace the contactor.
5. **240 V out, still nothing runs.** Check the dual capacitor next. Both motors share it.

3B • Fan runs, compressor does not:

1. **Capacitor.** Check the HERM side in μF . Weak or swollen means replace it. This is the most common fix on the whole chart.
2. **Hums, then clicks off.** The compressor is trying and failing to start. Try a hard-start kit. Still locked? Power off, ohm the three compressor terminals to each other and to the case. An open winding or a reading to the case means the compressor is done. New compressor, or new outdoor unit if it is more than about 12 years old.
3. **Starts, runs a minute, stops.** Pressure switch tripping. Hook up gauges and check charge and airflow.

3C • Compressor runs, fan does not:

1. **Shut it off.** A compressor with no fan builds head pressure fast. Do not leave it running while you work.
2. **Capacitor.** Check the FAN side in μF .
3. **Motor.** Power off, spin the blade by hand. Stiff or wobbly means bearings. Replace the fan motor.

Question 4 — Is the supply air the right temperature for the mode?

After 10 minutes of running, cooling should blow air about 15 to 20°F colder than the return. Heating should blow air warm to the hand, usually 85 to 100°F from the heat pump alone.

If NO:

1. **Backwards.** Warm air in cooling or cool air in heating. Check the reversing valve. Meter the O/B wire at the outdoor unit. Most brands energize O in cooling. No 24 V means a thermostat setting or wire problem. 24 V present? Ohm the solenoid coil on the valve. Open coil means replace the coil. Coil good and the valve still does not shift means the valve is stuck. That is a cut-and-braze refrigerant repair.

2. **Lukewarm both ways.** Hook up gauges. Low pressures and high superheat mean low charge, so find the leak before adding refrigerant. Both sides near equal with the compressor running means the compressor is not pumping.
3. **Weak airflow.** Pull the filter. Look at the indoor coil with a light. Ice on the coil: shut the system off, fan ON, wait for it to thaw, then find why (filter, low charge, dead blower). Dirty coil: pull and clean. Crushed or disconnected duct: reconnect and seal.

Question 5 — Everything runs, but the house is still not right. Match the symptom.

5A • Heat cannot keep up on cold days, or blows cold air for a few minutes at a time

1. **Heat strips not coming on.** Jump W2 (or W) to R at the board and listen for the sequencers to click on one at a time over about a minute.
2. **Heat kit breaker.** The breakers on the kit itself trip separately from the panel.
3. **Elements.** Power off, ohm each element. A reading of a few ohms is good. Open means the element is broken. Replace that element.
4. **Sequencer.** 24 V going in, no 240 V coming out after a minute means a dead sequencer.
5. **Limit switch.** A tripped limit means the air got too hot across the strips. Find the airflow problem (filter, blower) before resetting or replacing it.

5B • Outdoor unit is a block of ice in winter

1. **Defrost board.** Force a defrost with the test pins. No defrost cycle means a bad board.
2. **Defrost sensor.** Clip-on sensor on the outdoor coil. Ohm it and compare to the chart on the board.
3. **Outdoor fan.** A fan that stops or runs slow lets the coil ice over.
4. **Low charge.** Low charge makes the coil run colder than it should and ices it from the bottom up. Gauges, then leak search.

5C • Runs all the time, never shuts off, high power bill

1. **Contactor stuck closed.** Thermostat satisfied but the outdoor unit still running. Replace the contactor.
2. **Low charge.** The unit cannot make its temperature, so it never satisfies.
3. **Heat strips stuck on.** Clamp the heat kit feed with the thermostat satisfied. Amps means a stuck sequencer or relay.
4. **Duct leaks.** Conditioned air going into the attic.

5D • Short cycles, on and off every few minutes

1. **Thermostat location.** Near a supply vent or in the sun.
2. **Pressure switches.** Tripping on high head (dirty outdoor coil, dead outdoor fan) or low suction (low charge, iced indoor coil).

3. **Oversized unit.** Satisfies in minutes and never dehumidifies. Nothing to repair. Note it for replacement day.

5E • Water on the floor or dripping from the ceiling

1. **Drain line.** Clogged with slime. Vacuum from the outside end or blow it clear, then pour in cleaner.
2. **Pan.** Rusted through or cracked. Replace the pan.
3. **Float switch.** Add one if there is not one. It saves the ceiling next time.
4. **Iced coil melting.** Water in buckets right after an ice-up. Fix the ice cause in question 4.

5F • Breaker trips every time you reset it

1. **Stop resetting.** Something is shorted to ground. Each reset arcs it worse.
2. **Outdoor breaker trips.** Power off, ohm each compressor terminal to the copper line. Any reading to ground means the compressor is grounded. Replace the compressor or the unit. No reading? Check the fan motor the same way, then look for a burnt wire at the contactor.
3. **Air handler breaker trips.** Ohm each heat strip element to the frame. A grounded element is common. Then the blower motor. Then look for a wire pinched under the blower door.
4. **Breaker itself.** Old breakers get weak and trip with nothing wrong. Only decide this after everything above reads clean.

When it is fixed, run it through a full cycle, check amps against the nameplate, and leave the filter new.

6. Readings you will want on hand

What	Where	Good reading
Control power	R to C, air handler board	24 to 28 V AC
Cooling call to outdoor unit	Y to C, contactor coil	24 V AC during a call
Reversing valve signal	O to C (most brands energize in cool)	24 V AC in cooling, 0 V in heating
Line power at contactor	L1 to L2, line side	230 to 250 V AC
Dual capacitor	C to HERM, C to FAN	Within 6 percent of the μF printed on the can
Heat strip element	across each element, power off	About 10 to 20 Ω ; open means broken
Compressor windings	C to S, C to R, S to R	Each reads a few ohms; C to R plus C to S equals S to R; nothing to case
Cooling temperature split	return air minus supply air	15 to 20°F
Running amps	clamp on compressor common	Below the RLA on the nameplate

7. Where each part is taught in depth

Part or skill	Lesson
The refrigeration cycle, the four big components	1.1, 1.2
Reading pressures, superheat, subcooling	1.3, 1.4
Multimeter, 24 V control circuit, transformers	3.2, 3.4
Capacitors, contactors, wiring diagrams	3.5, 3.6, 3.7
Disconnects, breakers, MCA/MOP, lockout	3.8
Brazing, pressure testing, evacuation, leak search	Unit 4
Recovery, charging, EPA 608	Unit 5
Blower motors, thermostats, low-voltage shorts, boards, compressor tests	Unit 6
Reversing valve, defrost, strip heat, heat-mode charging	Unit 8 (coming)
Condensate, airflow, static pressure	Unit 11 (coming)

8. Check yourself

1. In heating mode, which coil is hot, the indoor one or the outdoor one? Which part decides that?
 2. The thermostat screen is blank. Name the first three things you check, in order.
 3. The outdoor fan spins but the compressor only hums. What part do you check first, and what meter setting do you use?
 4. Why do you shut the system off right away when the compressor runs but the outdoor fan does not?
 5. What does the float switch do, and why would it make the whole system look dead?
 6. A customer says the unit blows cold air for a few minutes every so often in winter. Is that normal? What part keeps it from feeling cold?
 7. Name four repairs that take minutes and four that take hours. What separates the two groups?
 8. The breaker trips every time you reset it. What should you never do, and what two parts do you ohm to ground first?
 9. What three things can freeze an indoor coil?
 10. Why do you find the short before you put in a new board fuse?
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