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COURSE 9 OF 10
FIRST EDITION 2026

HEAT PUMP TRAINING PROGRAM

Course 9 — Service, Maintenance and Troubleshooting

One of ten vendor-neutral courses, with worked examples, P&IDs, a quiz and a glossary, written for Indian conditions.

Values marked "typical", "approximate" or "illustrative" are not test data; check them against manufacturers' manuals and current standards before use.

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9 Service, Maintenance and Troubleshooting

Level 3 · Field Practice

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LEVEL 3 · FIELD PRACTICE

Course 9 — Service, Maintenance and Troubleshooting

Powered by Sunniva. This Level 3 course is for service technicians who already know the refrigeration cycle and heat pump components. After it you will be able to: (1) plan and record preventive maintenance for air-source and water-source heat pumps; (2) clean coils, descale plate heat exchangers and control water quality; (3) follow a systematic method to find faults, including high-pressure and low-pressure trips; and (4) trace compressor, leak, electrical and control faults to their root cause.

9.1 Preventive maintenance schedule and service records

Key idea: A heat pump that is checked on a fixed schedule and logged every time rarely fails without warning.

Preventive maintenance (PM) means planned checks done before something breaks. Breakdown maintenance means repairing after a failure. PM costs less because small problems such as a dirty filter are fixed before they trip the compressor.

Think of a pressure cooker. You check the gasket and the whistle before cooking, not after the lid blows. A heat pump works the same way. Most failures start as a slow drift in a pressure, temperature or current.

A service record is the written history of a unit. Each visit you note readings, work done and parts changed. Over months the record shows trends, like a slowly rising discharge temperature, that a single visit cannot.

PM schedule

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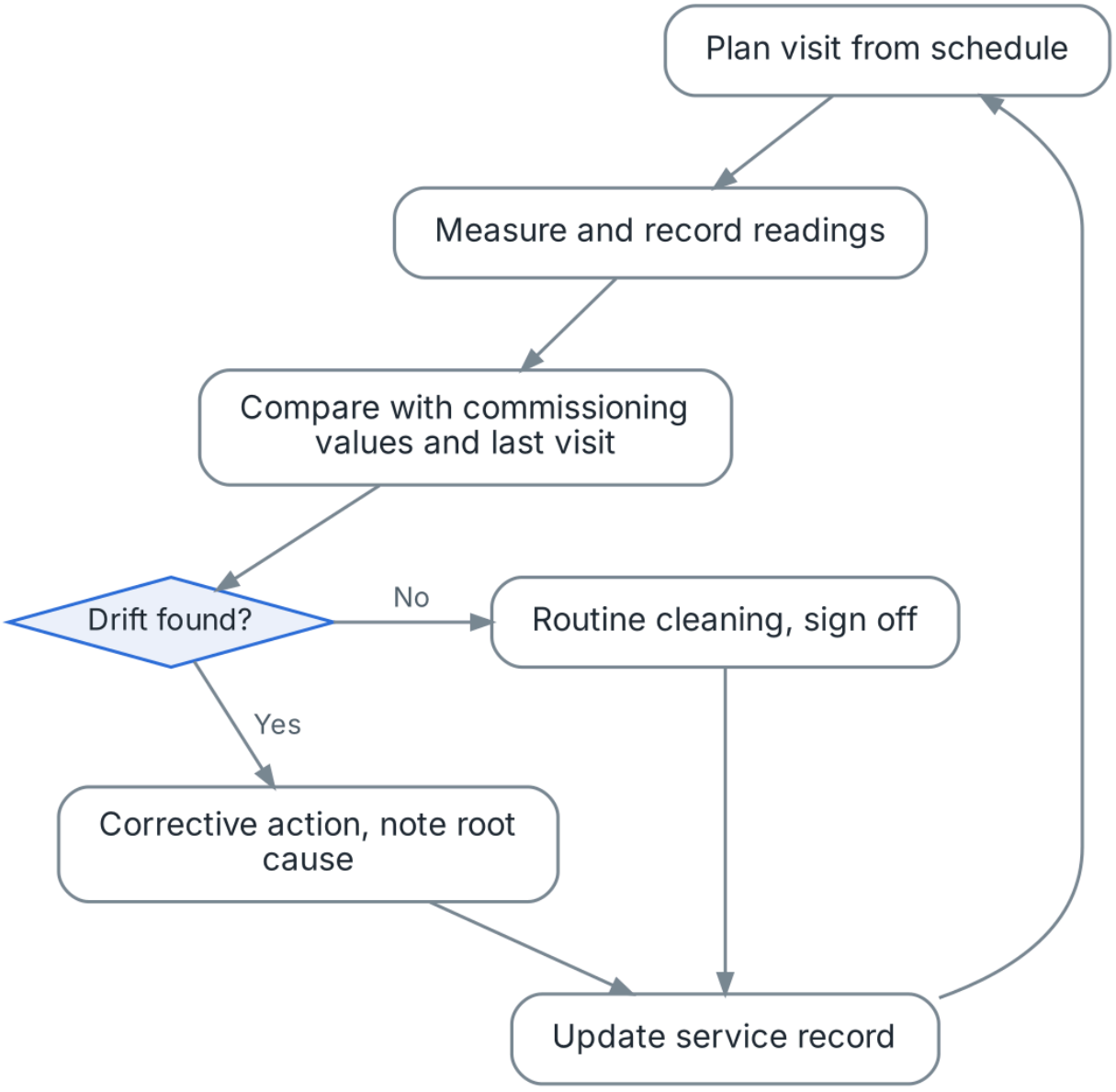
Frequency	Who	Check	What "good" looks like
Daily	Operator	Unit running, no alarms on controller	No active alarm; set point reached
Daily	Operator	Supply and return water temperature	Difference (ΔT) typically 3–7 °C
Daily	Operator	Unusual noise, vibration, water drips	None
Monthly	Technician	Clean Y-strainer on water inlet	Mesh clear; pressure drop back to normal
Monthly	Technician	Clean air-coil fins (light wash)	Fins clear of dust, leaves, lint
Monthly	Technician	Condensate drain and tray	Free-flowing, no algae
Monthly	Technician	Water system pressure and air vents	Pressure as commissioned; no trapped air
Quarterly	Technician	Suction and discharge pressures, superheat, subcooling	Within commissioning values
Quarterly	Technician	Compressor and fan current on each phase	Within nameplate; phases balanced within about 2–3 %
Quarterly	Technician	Tighten electrical terminals, inspect contactors	No burnt marks, no pitting
Quarterly	Technician	Leak check on brazed joints and flare nuts	No oil stains, detector silent
Quarterly	Technician	Water quality test (hardness, TDS, pH)	Within limits of lesson 9.3
Yearly	Technician	Descale plate heat exchanger (more often in hard water)	Approach temperature back to commissioning value
Yearly	Technician	Deep coil clean with coil cleaner	Full air flow restored
Yearly	Technician	Insulation resistance test of compressor and fan motors	Above 1 MΩ minimum at 500 V DC (healthy compressors usually read well above 2 MΩ; follow the manufacturer's manual)
Yearly	Technician	Calibrate or verify sensors and safety switches	Readings match reference instrument; HP/LP switches trip at set point
Yearly	Technician	Expansion vessel pre-charge, safety valve, pump bearings	Pre-charge as designed; valve not passing

What a service record must contain

Field	Example
Date, site, unit serial	12-03-2026, Hotel, Pune, serial XXXX
Ambient and water temperatures	Ambient 34 °C; water in 48 °C, out 54 °C
Suction and discharge pressure (R410A)	15.0 bar(g) / 35.0 bar(g)
Superheat and subcooling	6 K / 5 K
Compressor current (R/Y/B)	18.2 / 18.4 / 18.1 A
Alarms in log since last visit	None
Work done, parts used	Strainer cleaned; coil washed
Next action	Descale PHE at next quarterly visit

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The preventive maintenance cycle



The preventive maintenance cycle

Remember

- PM is planned; breakdown repair is unplanned and costs more.
- Record readings every visit so you can see trends.
- Compare against commissioning values, not just "looks fine".
- Hard water and dusty sites need shorter intervals.

Field tip: Photograph the controller's alarm log and the nameplate at every visit and attach them to the record.

9.2 Cleaning coils and heat exchangers; descaling

Key idea: Dirt on the air side and scale on the water side both act like a blanket, so the heat pump must work harder to move the same heat.

An air coil (finned tube heat exchanger) picks up dust, cotton lint, leaves and oily kitchen fumes. A plate heat exchanger (PHE) is a stack of thin pressed plates; refrigerant flows on one side and water on the other. Scale is a hard layer of calcium and magnesium salts left by hard water when it is heated.

Look inside an old geyser in Delhi or Chennai and you will see white rock on the element. The same rock forms in the PHE water channels. Even a thin layer of scale cuts heat transfer noticeably, because scale conducts heat far worse than steel.

Cleaning the air coil

1. Isolate power and lock out.
2. Brush or vacuum loose dirt from the air-inlet side.
3. Spray coil cleaner (non-acidic, safe for aluminium and copper) and wait for the time on the label.
4. Rinse with low-pressure water from the air-outlet side towards the inlet (back-flush), so dirt goes out the way it came in.
5. Straighten bent fins with a fin comb.

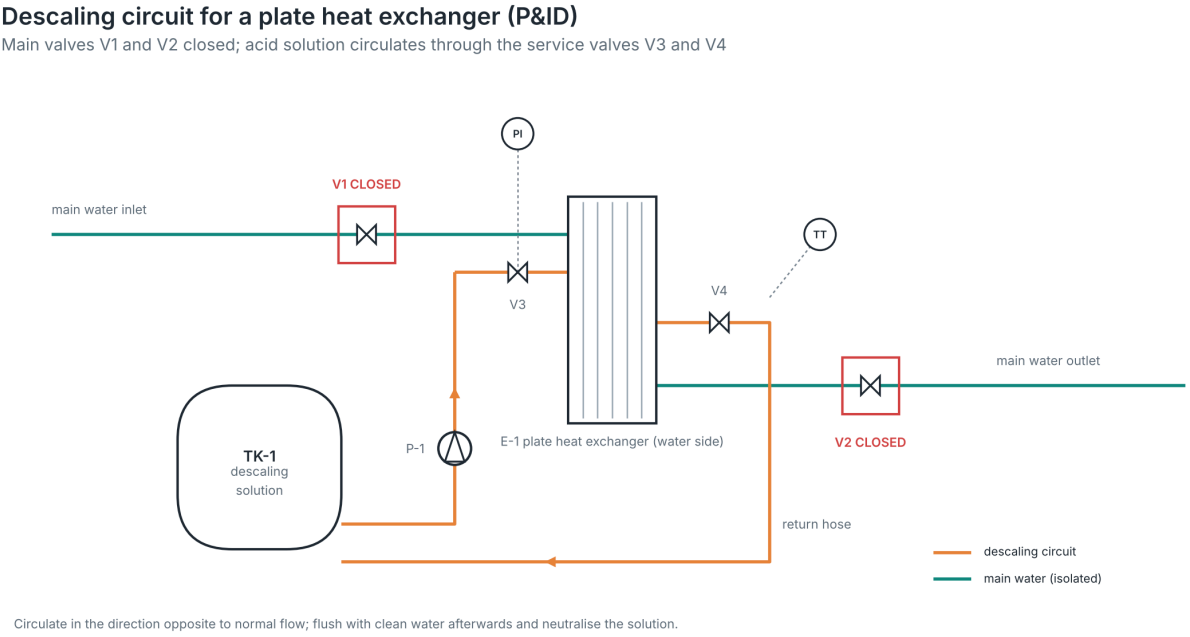
Never use a high-pressure jet close to the fins. It flattens them and blocks air flow.

Descaling a plate heat exchanger

Descaling means circulating a mild acid solution through the water side to dissolve scale. Use a descaling solution suited to stainless steel plates and copper brazing; follow the chemical supplier's strength and time. Typical practice is a weak acid such as citric acid or a proprietary inhibited descaler.

Steps:

1. Switch off the heat pump and the system pump. Isolate power.
2. Close isolation valves V1 and V2 on the main water lines.
3. Connect hoses from the descaling pump to service valves V3 (inlet) and V4 (outlet) on the PHE.
4. Fill the tank with descaling solution. Circulate against the normal flow direction (back-flush) for better scale removal.
5. Watch for foaming. Foaming means the acid is still reacting with scale. When foaming stops and pH stays steady, scale is dissolved.
6. Drain the solution into a container for neutralisation. Never drain acid into a garden or open drain.
7. Flush with clean water until the outlet pH is neutral (about 7).
8. Neutralise if the chemical supplier says so, flush again, reconnect, vent air and restart.
9. Record the approach temperature before and after.



P&ID: descaling circuit for a plate heat exchanger

Legend: TK tank; P pump; V1/V2 isolation ball valves (closed during descaling); V3/V4 service (flushing) valves; E-1 plate heat exchanger; PI pressure indicator; TT temperature transmitter; arrows show back-flush direction (opposite to normal flow).

Item	Symptom of fouling	Clean when
Air coil (heating mode)	Low suction pressure, more frequent defrost	Visibly dirty, or suction falls versus record
Air coil (cooling / heat rejection)	High discharge pressure	Discharge pressure rises versus record
Water-side PHE (condenser)	High discharge pressure, approach temperature rising	Approach rises by about 2–3 K over commissioning (typical)
Water-side PHE (evaporator)	Low suction, freeze-protection alarms	Approach rises over commissioning
Y-strainer	Low flow, flow switch trips	Pressure drop across it rises

Worked example — Is the condenser PHE scaled?

Approach temperature is the difference between the refrigerant condensing temperature and the leaving water temperature.

$$\text{Approach} = T_{cond} - T_{water,out}$$

At commissioning in Ahmedabad: condensing temperature 58 °C, water out 55 °C. Approach = 58 − 55 = 3 K.

One year later, same load: condensing temperature 63 °C, water out 55 °C. Approach = 63 − 55 = 8 K.

The approach has grown by 5 K. Higher condensing temperature means higher compressor work. Descale the PHE.

Remember

- Back-flush coils from outlet side to inlet side, at low pressure.
- Descale against normal flow direction, then flush to neutral pH.
- Use chemicals compatible with stainless steel, copper and brazing.
- Track approach temperature to know when to descale.

Common mistake: Leaving the main isolation valves open, so acid flows into the whole building's pipework.

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9.3 Water treatment and scale prevention

Key idea: Most water-side problems in Indian sites come from hard, dirty or corrosive water, and they are cheaper to prevent than to clean.

Water quality is measured by a few simple numbers. Hardness is the amount of dissolved calcium and magnesium, given as mg/L (ppm) of $CaCO_3$. TDS (total dissolved solids) is all dissolved salts in mg/L. pH shows whether water is acidic (below 7) or alkaline (above 7).

Borewell water in many parts of India is hard. Hardness of several hundred mg/L is common in places like Rajasthan, Gujarat and parts of Bengaluru. A kettle used with such water gets a white crust; a heat pump gets the same crust inside its PHE, and fast, because the water is hot.

Scale forms faster at higher temperatures. That is why hot-water heat pumps above about 55 °C are most at risk. Open systems, where fresh make-up water is added all the time, bring in new hardness every day.

Typical water quality guide for heat pump circuits

Parameter	Typical target (closed loop)	Why it matters
pH	7.5–9.0	Low pH corrodes copper; very high pH can attack aluminium and brazing
Total hardness	Below about 100–150 mg/L as $CaCO_3$ for hot water service (typical)	Scale on PHE
TDS	Below about 500 mg/L (typical)	Scale and corrosion
Chlorides	As low as practical; typically below about 200 mg/L for stainless steel at heat pump temperatures	Pitting of stainless plates
Suspended solids	Filtered by strainer, mesh typically 0.5–1 mm	Blocking of PHE channels

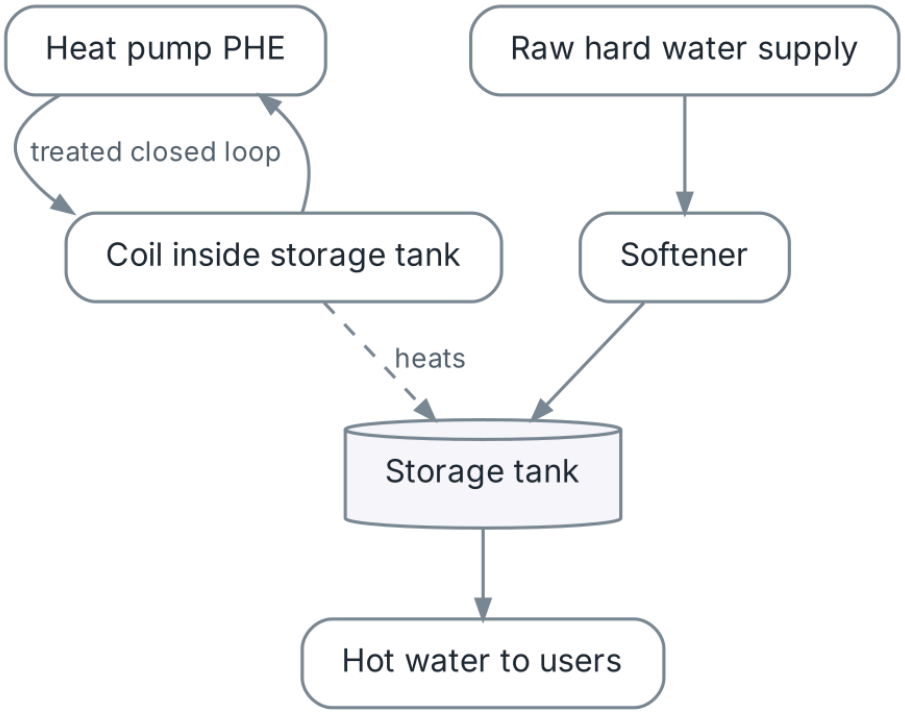
These are typical values. Always use the limits in the unit's manual where available.

Ways to prevent scale

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Method	How it works	Good for	Limits
Closed loop with indirect PHE	Hard water never touches the heat pump PHE	Most sites with hard water	Needs a second heat exchanger in the tank
Water softener (ion exchange)	Swaps calcium and magnesium for sodium	Domestic and hotel hot water	Needs regular salt and regeneration
Reverse osmosis (RO)	Removes most dissolved salts	Small flows, very bad water	Wastes water; RO water can be corrosive, so adjust pH
Polyphosphate dosing	Keeps hardness in suspension	Moderate hardness	Must be food-safe for drinking water
Lower hot water set point	Less scaling at lower temperature	Where use allows	Check hygiene needs (legionella)
Y-strainer and dirt separator	Catches sand and rust	All systems	Must be cleaned monthly

A closed loop protects the heat pump from hard water



A closed loop protects the heat pump from hard water

Worked example — How much scale comes in?

A hotel in Jaipur uses 5,000 L of hot water a day. Hardness is 300 mg/L as $CaCO_3$. If even a tenth of this hardness drops out as scale:

$$m_{scale} = V \times H \times f$$

V = 5,000 L, H = 300 mg/L, f = 0.1 m = 5,000 × 300 × 0.1 = 150,000 mg = 150 g per day.

Over a year: 150 g × 365 ≈ 55 kg of potential scale. Even if most leaves with the water, some will settle in the PHE. This is why open systems on hard water need a softener or an indirect loop.

Remember

- Test hardness, TDS and pH at commissioning and every quarter.
- Hot water above about 55 °C scales fastest.
- An indirect closed loop is the best protection on hard water.
- Clean strainers monthly.

Field tip: Carry a simple hardness test kit and TDS meter; a reading takes two minutes.

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9.4 A systematic troubleshooting method

Key idea: Find faults by measuring and comparing, not by guessing and replacing parts.

Troubleshooting is the process of finding the root cause of a fault. A root cause is the first thing that went wrong; a symptom is what you see. A tripped compressor is a symptom. A blocked strainer that starved the condenser of water may be the root cause.

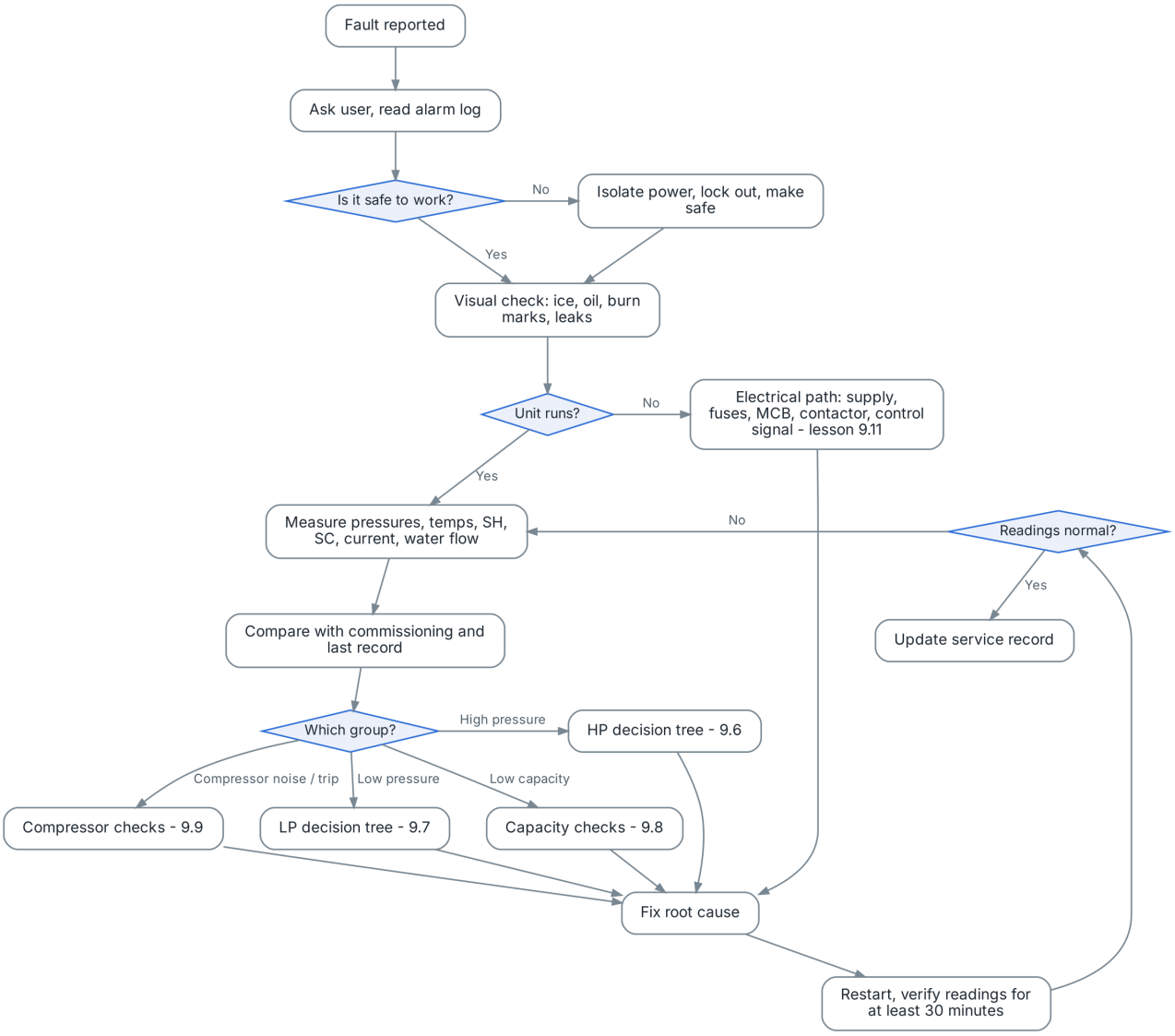
A good doctor asks questions, takes temperature and pulse, then decides. A good technician does the same. Replacing parts until it works is expensive, and the real cause often returns.

Six steps

1. **Listen and gather.** Ask the user what happened, when, and what changed. Read the alarm log.
2. **Observe safely.** Look, listen, smell. Check for ice, oil stains, burnt smells, water leaks.
3. **Measure.** Pressures, temperatures, superheat, subcooling, currents, voltages, water flow.
4. **Compare.** Against commissioning values, the manual, and the previous service record.
5. **Isolate the cause.** Use the decision trees in lessons 9.6 and 9.7. Test one idea at a time.
6. **Fix, verify, record.** Repair the root cause, run the unit, confirm readings, write it down.

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A systematic fault-finding method



A systematic fault-finding method

Normal reading guide (typical, air-to-water heat pump with R32 or R410A)

Reading	Typical normal range	Note
Superheat at compressor suction	4–8 K	Depends on expansion valve setting
Subcooling at condenser outlet	3–8 K	Depends on charge and design
Water ΔT across condenser	3–7 K	Lower means high flow; higher means low flow
Discharge temperature	Typically below about 100–110 °C	Very high means overheating compressor
Phase current imbalance	Within about 2–3 %	Higher points to supply or motor problem

Refrigerant pressures depend on the refrigerant and temperatures, so always convert pressure to saturation temperature with a P-T chart or gauge scale.

Worked example — Is this superheat normal?

Superheat is the suction line temperature minus the evaporating saturation temperature.

$$SH = T_{suction} - T_{sat}(P_{suction})$$

Suction pressure reads 7.5 bar(g). From the P-T chart for the refrigerant, saturation is 2 °C (example). Suction line temperature is 14 °C. SH = 14 − 2 = 12 K.

This is higher than the typical 4–8 K. The evaporator is starved: suspect low charge, a blocked filter-drier, or a faulty expansion valve.

Remember

- Symptom is not cause; keep asking "why".
- Measure before you touch anything.
- Change one thing at a time and re-measure.
- Always verify and record after the fix.

Common mistake: Adding refrigerant just because suction pressure is low, without checking superheat, subcooling and air or water flow first.

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9.5 Reading fault codes and controller logs

Key idea: A fault code tells you which protection acted, not why it acted.

A controller is the electronic board that runs the heat pump. It reads sensors and switches, and stops the unit when a value goes out of range. It then shows a fault code (a short code on the display) and usually stores it in a log with date, time and readings.

Each manufacturer uses its own codes. Always look up codes in that unit's service manual. This lesson explains the general categories, which are similar across makes.

A fault code is like the warning light on a car dashboard. The oil light says oil pressure is low. It does not say whether the oil is leaking or the pump is worn. You still need to investigate.

Generic fault categories

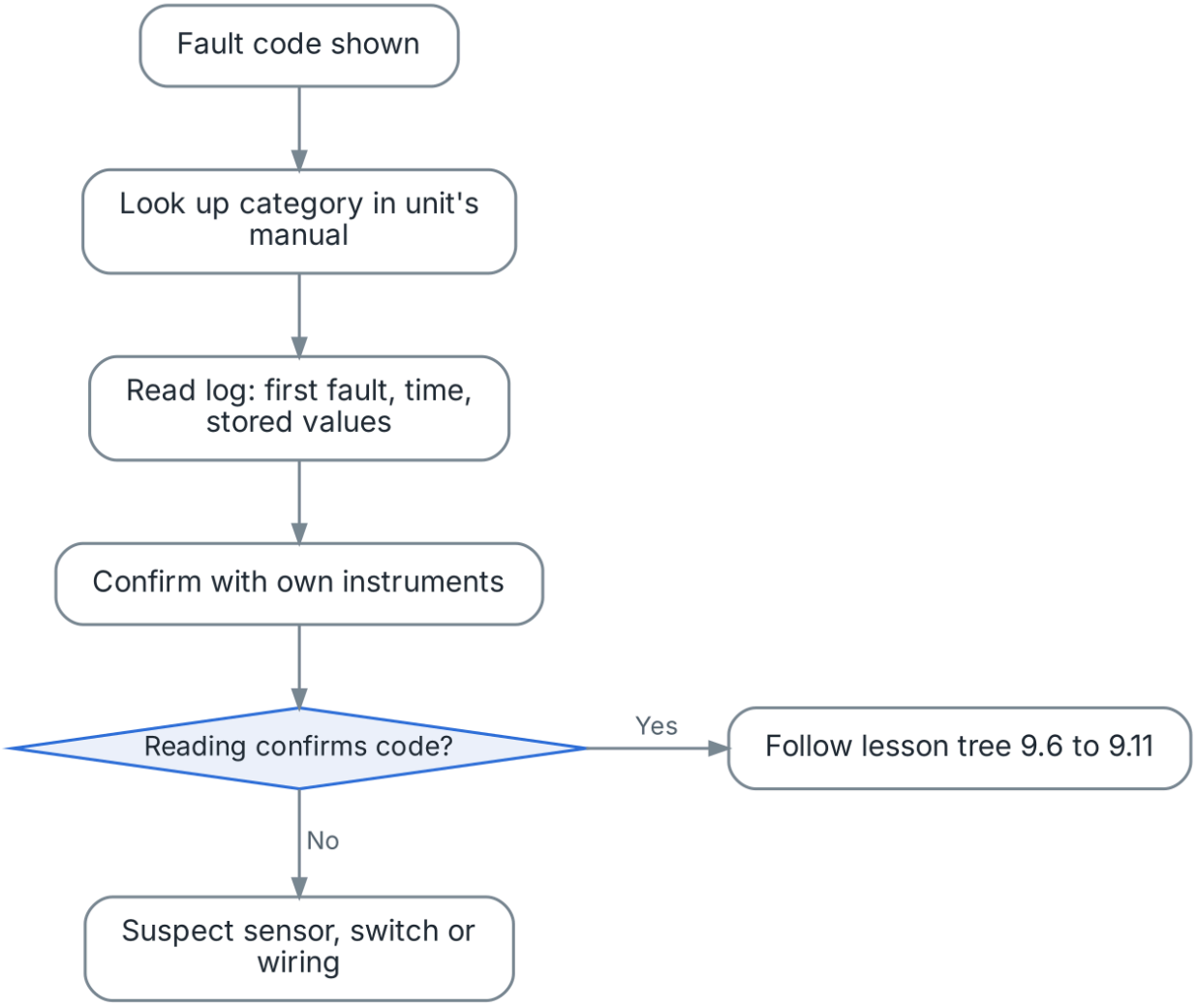
Category	What it means	Typical first checks
High-pressure protection	HP switch or sensor saw too high discharge pressure	Water/air flow at condenser, scale, overcharge, non-condensables (9.6)
Low-pressure protection	LP switch or sensor saw too low suction pressure	Evaporator air/water flow, ice, low charge, expansion valve (9.7)
High discharge temperature	Compressor outlet too hot	Low charge, high superheat, high compression ratio
Water flow fault	Flow switch open or flow too low	Pump, strainer, air lock, closed valve
Freeze protection	Water or refrigerant near 0 °C in evaporator	Low flow, low set point, low charge
Sensor fault	Sensor open or short circuit	Wiring, connector, sensor resistance vs table
Communication fault	Boards or display not talking	Cable, connector, earthing, interference
Compressor overcurrent / overload	Current too high or motor too hot	Voltage, phase loss, locked rotor, high pressure
Phase / voltage fault	Missing phase, wrong sequence, voltage out of range	Supply, phase sequence relay, cables
Inverter / drive fault	Drive detected internal or motor problem	Supply, heat sink, motor windings, drive cooling fan
Defrost fault	Defrost took too long or did not end	Defrost sensor, reversing valve, ice build-up

How to use the log

1. Note the first fault in a sequence. Later faults are often knock-on effects.
2. Note the time pattern: same time each day points to a load, a supply dip or a timer.
3. Read stored values at trip time if available: pressures, temperatures, current.
4. Check how often the fault repeats. Some controllers lock the unit after a set number of trips.

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From fault code to root cause



From fault code to root cause

Remember

- Codes differ by make; always use the unit's own manual.
- A code names the protection, not the cause.
- The first fault in the log is usually the most useful.
- Confirm with your own gauges and meters.

Field tip: Never reset a fault repeatedly to "see if it clears"; each reset can stress the compressor.

9.6 High-pressure trips

Key idea: A high-pressure trip almost always means heat is not being removed from the condenser fast enough.

The high-pressure (HP) switch is a safety switch on the discharge line. It opens when discharge pressure crosses a set limit and stops the compressor. Its job is to protect the compressor, pipes and people from over-pressure.

Think of a pressure cooker on a high flame with a blocked vent. Pressure keeps rising because heat goes in but cannot leave. In a heat pump the condenser is the vent. If it cannot reject heat, pressure rises.

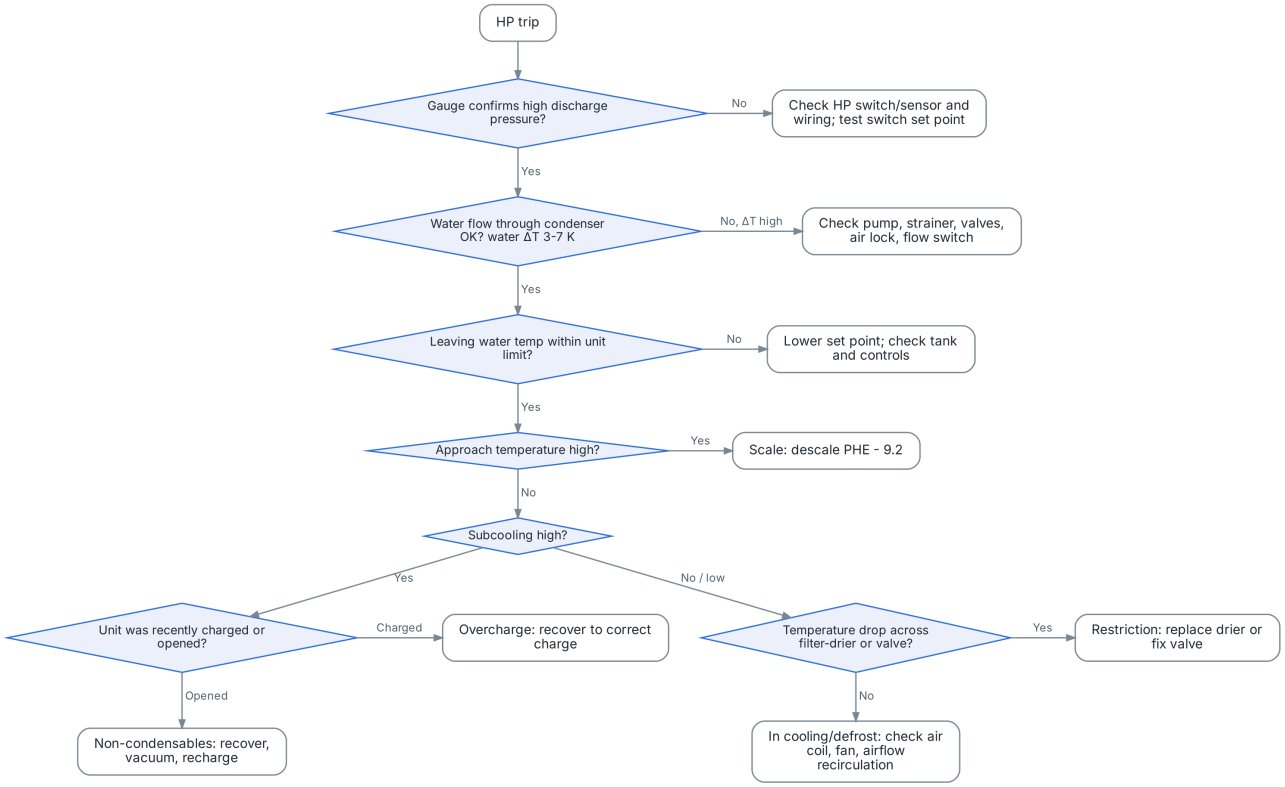
In heating mode, the condenser is the water-side PHE. In cooling or defrost mode, the air coil acts as the condenser. So always ask which heat exchanger is the condenser at the moment of the trip.

Main causes

- Low water flow through the condenser (pump fault, blocked strainer, closed valve, air lock).
- Scale on the PHE water side.
- Water set point too high for the unit, or return water too hot.
- Overcharge of refrigerant.
- Non-condensable gases (air or nitrogen) in the circuit.
- Restriction after the condenser, which backs up liquid.
- In cooling/defrost: dirty air coil, failed fan, hot air recirculation.
- Faulty HP switch or pressure sensor.

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High-pressure trip: decision tree



High-pressure trip: decision tree

Symptom → cause → check → fix (high pressure)

Symptom	Likely cause	Check	Fix
HP trip, water ΔT high (over about 8 K)	Low water flow	Strainer, pump, valves, air vents	Clean strainer, vent air, repair pump
HP trip after months of good running, ΔT normal	Scale on PHE	Approach temperature vs commissioning	Descale PHE
HP trip, high subcooling, after a recharge	Overcharge	Weigh charge vs nameplate	Recover excess
HP high, pressure does not match temperature when off	Non-condensables	Standing pressure vs ambient saturation	Recover, vacuum, weigh in fresh charge
HP trip in cooling, fan running slow or off	Fan motor or capacitor failure	Fan current, capacitor value	Replace capacitor or motor
Trip but gauge shows normal pressure	Faulty switch or sensor	Compare sensor with gauge	Replace switch or sensor

Worked example — Is the water flow too low?

A 20 kW heat pump in Indore heats water. Supply 55 °C, return 45 °C. Find the actual flow.

$$Q = \dot{m} \times c_p \times \Delta T \quad \Rightarrow \quad \dot{m} = \frac{Q}{c_p \times \Delta T}$$

Q = 20 kW, c_p = 4.19 kJ/kg·K, ΔT = 55 − 45 = 10 K ṁ = 20 ÷ (4.19 × 10) = 0.477 kg/s 0.477 kg/s × 3,600 = 1,718 kg/h ≈ 1,720 LPH.

For a 5 K design ΔT the flow should be about 3,440 LPH. The flow is half of design. Clean the strainer and check the pump before blaming refrigerant.

Remember

- First ask: which coil is the condenser right now?
- Check water flow and ΔT before touching refrigerant.
- Rising approach temperature means scale.
- Overcharge and air in the system both raise subcooling and head pressure.

Common mistake: Raising the HP switch set point to stop the trips. This removes the safety and can burst components.

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9.7 Low-pressure trips

Key idea: A low-pressure trip means the evaporator is not getting enough heat or enough refrigerant.

The low-pressure (LP) switch sits on the suction line. It opens when suction pressure falls too low. This protects the compressor from running without enough refrigerant and the evaporator from freezing.

Imagine drinking through a straw from an almost empty glass. You suck harder and harder, but little comes. A starved evaporator is the same: the compressor pulls suction pressure down because too little vapour is coming in.

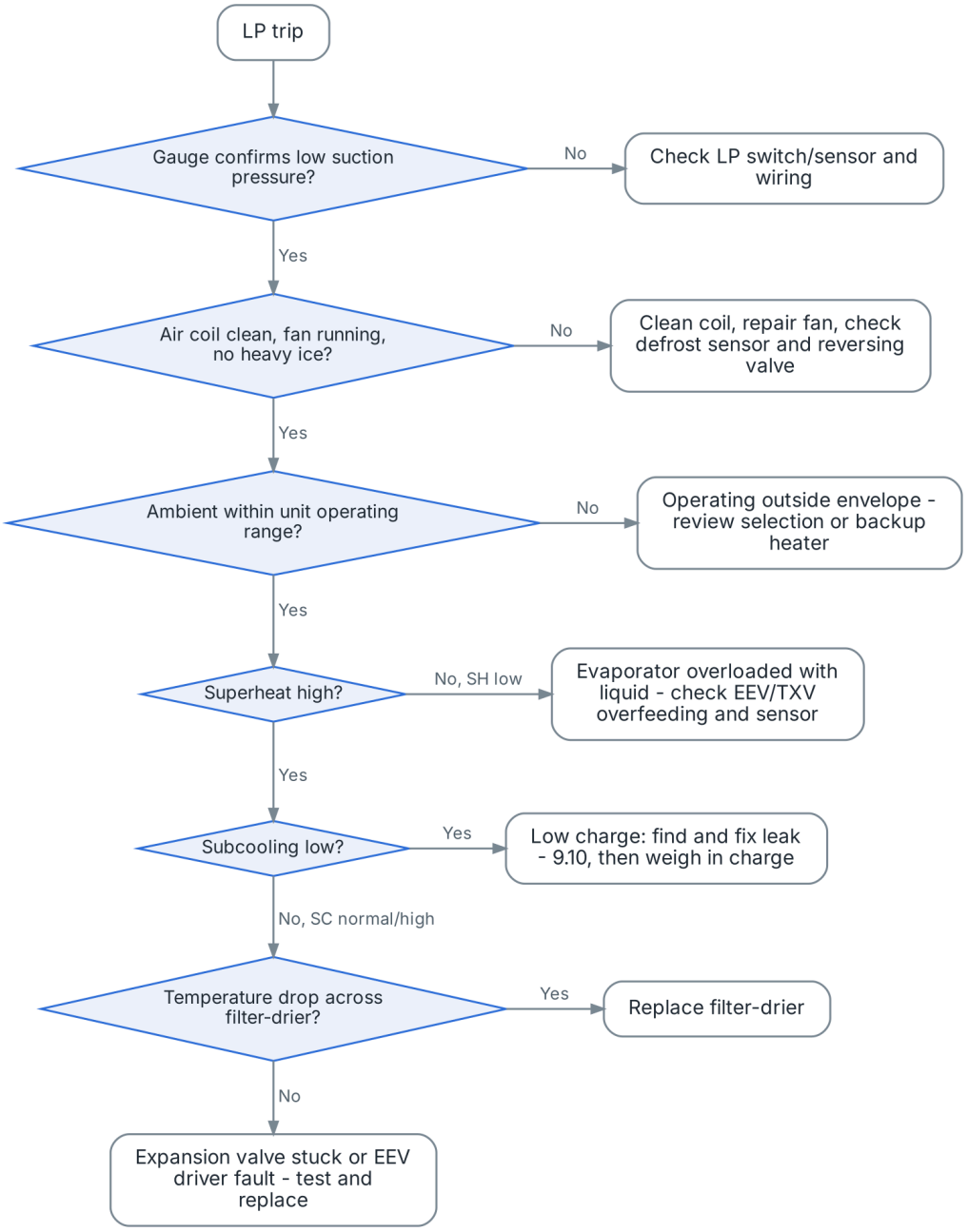
In heating mode the evaporator is the air coil. In cooling mode on a reversible unit, it is the water-side PHE.

Main causes

- Low air flow over the air coil: dirt, ice, failed fan.
- Heavy frosting without proper defrost.
- Very low ambient temperature beyond the unit's operating range.
- Low refrigerant charge (leak).
- Blocked filter-drier or strainer in the liquid line.
- Expansion valve stuck closed or faulty (or EEV driver fault).
- In cooling: low chilled water flow, low set point, frozen PHE.
- Faulty LP switch or sensor.

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Low-pressure trip: decision tree



Low-pressure trip: decision tree

Symptom → cause → check → fix (low pressure)

Symptom	Likely cause	Check	Fix
LP trip, high SH, low SC, oil stains	Refrigerant leak	Leak test (9.10)	Repair leak, vacuum, weigh in charge
LP trip, high SH, normal SC, cold or frosty drier	Blocked filter-drier	Temperature drop across drier over about 2 K	Replace drier
LP trip, high SH, normal SC, drier warm	Expansion valve stuck closed	Valve response, EEV coil and driver	Replace valve or coil/driver
LP trip in heating, coil fully iced	Defrost failure	Defrost sensor, reversing valve, defrost logic	Replace sensor or valve
LP trip, coil dirty, fan slow	Low air flow	Fan current, coil condition	Clean coil, repair fan
LP trip in cooling, chilled water ΔT high	Low water flow at evaporator	Strainer, pump, valves	Restore flow

Worked example — Check the drier

Liquid line temperature before the filter-drier: 38 °C. After it: 33 °C.

$$\Delta T_{drier} = T_{in} - T_{out}$$

ΔT = 38 − 33 = 5 K. A healthy drier shows almost no drop (typically below about 1–2 K). A 5 K drop means it is blocked and the liquid is flashing. Replace the drier.

Remember

- First ask: which coil is the evaporator right now?
- High superheat plus low subcooling usually means low charge.
- High superheat with normal subcooling points to a restriction.
- Check air flow and ice before refrigerant.

Field tip: Feel along the liquid line; a sudden cold spot shows exactly where the restriction is.

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9.8 Low capacity and falling COP

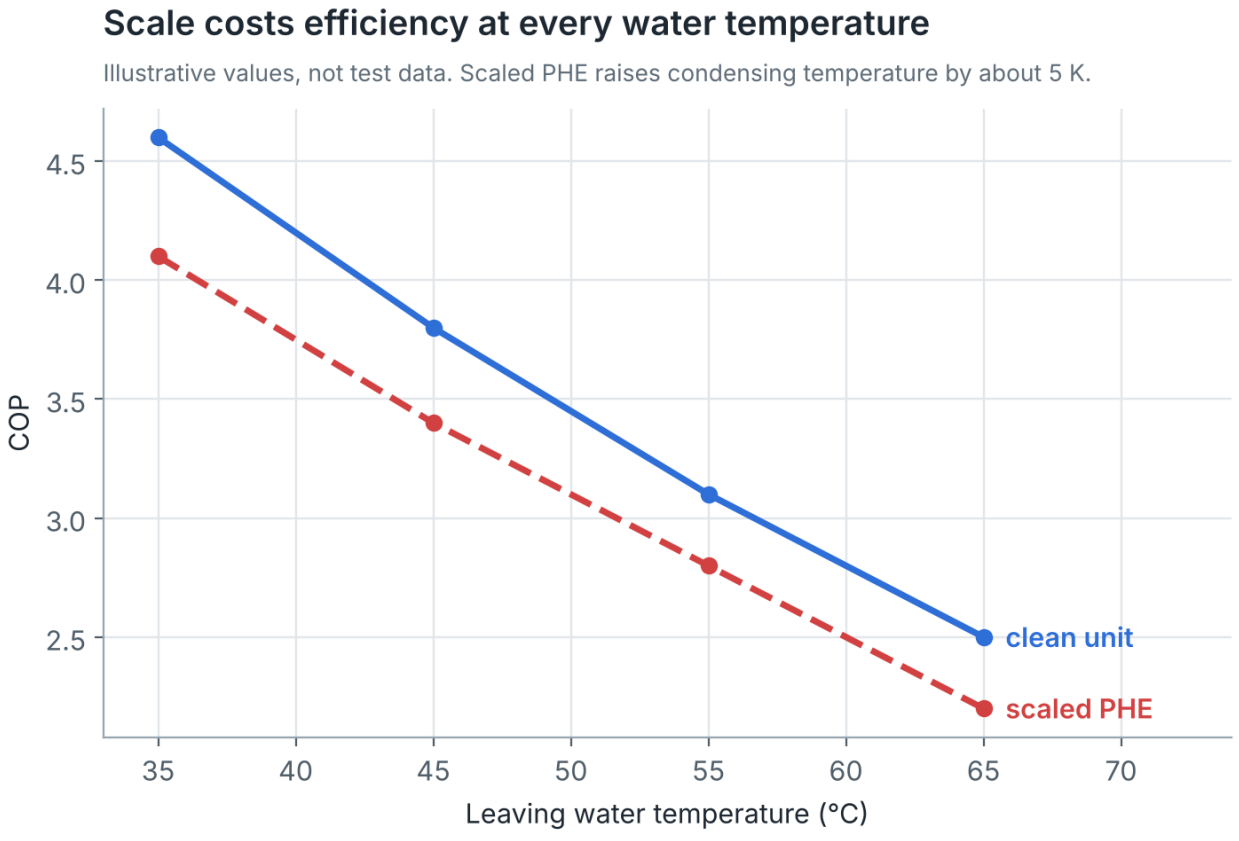
Key idea: When capacity or COP falls, the cause is usually one of three: poor heat transfer, wrong charge, or a tired compressor.

Capacity is the heat output in kW. COP (coefficient of performance) is heat output divided by electrical input. A unit with COP 4 gives 4 kWh of heat for 1 kWh of electricity.

Falling COP often shows up first in the electricity bill, not as a fault code. The unit keeps running but heats slower and costs more. Like a fridge with a dirty back grill, it still cools but runs much longer.

Main causes

- Dirty air coil or scaled PHE.
- Low or high refrigerant charge.
- Wrong water flow (too low or too high).
- Expansion valve badly set or faulty.
- Compressor wear: leaking valves or scroll tips cause low compression.
- Reversing valve leaking hot gas internally into suction.
- Wrong set point or poor controls (short cycling).
- Unit running outside its design conditions (very cold or very hot water).



COP vs leaving water temperature, clean vs scaled

Symptom → cause → check → fix (capacity and COP)

Symptom	Likely cause	Check	Fix
Slow heat-up, high discharge pressure, rising approach	Scaled PHE	Approach temperature	Descale
Slow heat-up, low suction, high SH	Low charge	SH, SC, leak test	Fix leak, recharge by weight
Low current, small pressure difference, normal charge	Compressor wear / internal leak	Compression ratio, current vs data	Replace compressor (find root cause first)
Suction line warm in heating, both reversing valve outlets similar temperature	Reversing valve leaking	Temperatures at valve ports	Replace reversing valve
Frequent start-stop	Short cycling: small buffer, tight differential	Controller log of starts per hour	Adjust differential, add buffer volume
COP low only on very cold mornings	Normal effect of low ambient	Compare with manufacturer data	Expected; check defrost and backup

Worked example — Measure field COP

A heat pump at a hostel in Bhopal. Water flow 2,000 LPH, in 45 °C, out 52 °C. Input power measured 4.2 kW.

$$Q = \dot{m} \times c_p \times \Delta T, \qquad COP = \frac{Q}{P_{in}}$$

ṁ = 2,000 ÷ 3,600 = 0.556 kg/s Q = 0.556 × 4.19 × (52 − 45) = 0.556 × 4.19 × 7 = 16.3 kW COP = 16.3 ÷ 4.2 = 3.9

If commissioning COP at the same conditions was 4.3, the drop is about 9 %. Daily cost impact for 10 hours at the example rate of ₹9/kWh: Input at COP 4.3 = 16.3 ÷ 4.3 = 3.79 kW; at COP 3.9 = 4.2 kW. Extra = 0.41 kW × 10 h × ₹9 = ₹37 per day, about ₹13,500 per year.

Remember

- COP = heat out ÷ power in; measure both.
- Compare at the same water and ambient conditions.
- Small COP losses add up to large yearly costs.
- Clean heat exchangers first; condemn the compressor last.

Common mistake: Measuring COP during a defrost cycle or right after start-up; wait for steady running.

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9.9 Compressor failures and their root causes

Key idea: Compressors rarely fail on their own; they are usually killed by something else in the system.

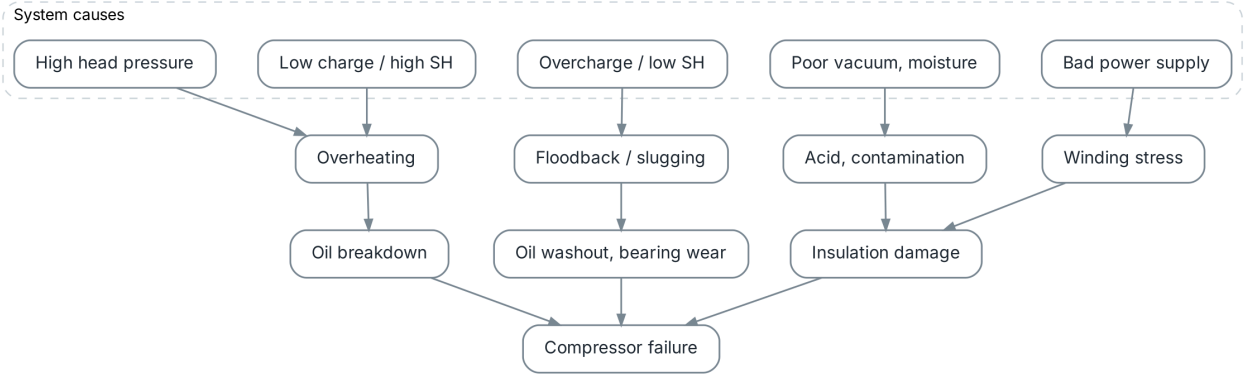
The compressor is the heart of the heat pump. When it fails, replacing it without finding the root cause often leads to a second failure within weeks. Always ask what made it fail.

Like a motorbike engine seized because the oil ran out, the engine is the victim, not the cause. The same is true for compressors.

Main failure types

Failure	What happens	Common root causes
Liquid floodback	Liquid refrigerant enters the compressor and washes oil away	Low superheat, overcharge, faulty expansion valve, low evaporator air or water flow
Liquid slugging	A slug of liquid enters the compression chamber; mechanical damage	Refrigerant migration during off cycle, no crankcase heater, poor piping
Overheating	Motor and oil get too hot; oil breaks down	Low charge, high superheat, high discharge pressure, high compression ratio
Oil loss	Bearings run dry	Oil trapped in system, long pipes without oil return, leaks, floodback
Electrical burnout	Motor windings short to each other or to earth	Voltage imbalance, single phasing, overheating, moisture and acid in system
Contamination	Moisture, air or debris cause acid and wear	Poor evacuation, open system left too long, no drier, brazing without nitrogen

How system faults kill compressors



How system faults kill compressors

Checks before condemning a compressor

Check	How	Typical result for healthy compressor
Winding resistance (single-phase: C-S, C-R, S-R; three-phase: between each pair)	Multimeter, power isolated	Three-phase windings equal within a few percent; single-phase S-R = C-S + C-R
Insulation resistance to earth	Insulation tester at 500 V DC	Above 1 MΩ minimum at 500 V DC (healthy compressors usually read well above 2 MΩ; follow the manufacturer's manual)
Running current	Clamp meter on each phase	Within nameplate RLA, balanced
Compression	Pressure difference when running	Normal discharge-suction difference for conditions
Oil condition	Sample or acid test kit	Clear, no burnt smell, acid test negative

After a burnout

1. Recover refrigerant; do not vent.
2. Test oil for acid.
3. Replace compressor and filter-drier; fit a suction line filter-drier if acid is present.
4. Pressure test with dry nitrogen; evacuate deeply (lesson 9.10).
5. Weigh in correct charge.
6. Check acid again after running; change drier again if needed.

Worked example — Voltage imbalance

Measured line voltages: 410 V, 400 V, 385 V.

$$\text{Imbalance (\%)} = \frac{\text{max deviation from average}}{\text{average}} \times 100$$

Average = (410 + 400 + 385) ÷ 3 = 398.3 V Maximum deviation = 398.3 − 385 = 13.3 V Imbalance = 13.3 ÷ 398.3 × 100 = 3.3 %

Voltage imbalance above about 2 % is generally considered harmful to motors; the current imbalance it causes is several times larger. Get the supply checked before fitting a new compressor.

Remember

- The compressor is usually the victim, not the culprit.
- Floodback and overheating are the two biggest killers.
- Check windings, insulation, current and oil before condemning.
- After a burnout, clean the system or the new compressor will fail too.

Common mistake: Replacing a burnt compressor without changing the filter-drier and testing for acid.

9.10 Leak detection and repair

Key idea: Find the leak, fix it properly, then prove the system is tight and dry before charging.

A refrigerant leak lowers charge, cuts capacity and can let air and moisture in. Many refrigerants are greenhouse gases, and some, like R32 and R290, are flammable to different degrees. So leaks matter for performance, safety and environment.

Common leak points are brazed joints, flare nuts, Schrader valve cores, service valve stems, capillary tubes rubbing on the frame, and vibration cracks. Brazing leaks are often caused by poor joint clearance, overheating or not using nitrogen purge.

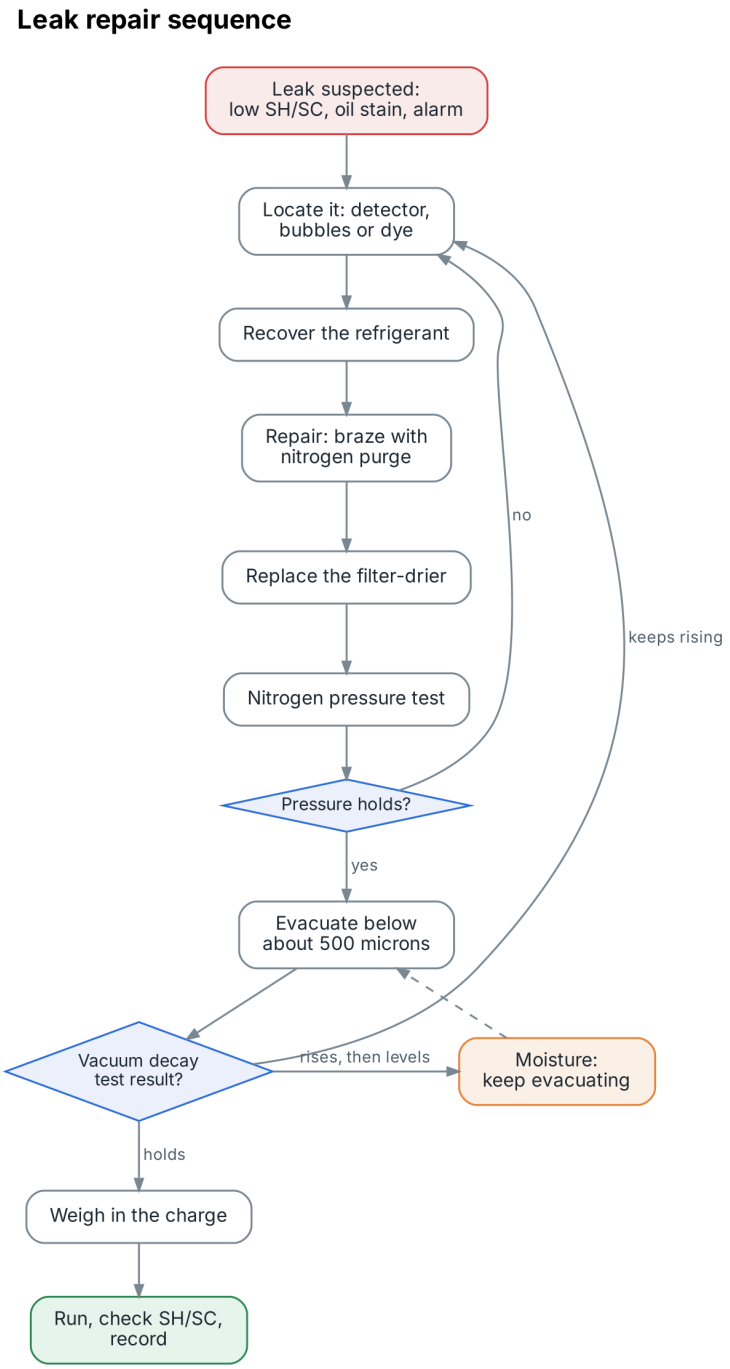
Leak detection methods

Method	How it works	Good for	Limit
Visual / oil stain	Refrigerant carries oil out; joint looks wet or dusty	First quick check	Small leaks may not show
Soap bubbles	Bubbles form at leak	Pinpointing on accessible joints	Slow; needs pressure in system
Electronic detector	Sensor senses refrigerant	Searching wide areas	Wind and other gases confuse it
UV dye	Dye glows under UV light	Intermittent leaks	Dye must be compatible with oil
Nitrogen pressure test	Fill with dry nitrogen, watch pressure	Proving tightness after repair	Allow for temperature change
Nitrogen + tracer (95/5 nitrogen-hydrogen)	Detector finds hydrogen	Very small leaks	Needs suitable detector
Vacuum hold (decay) test	Pressure rise while under vacuum	Proves tight and dry	Moisture also causes rise

Repair procedure

1. Recover refrigerant into a recovery cylinder. Never vent it.
2. Make the repair. Braze with dry nitrogen flowing through the pipe to stop oxide scale forming inside.
3. Replace the filter-drier whenever the system is opened.
4. Pressure test with dry nitrogen to the test pressure in the manual. Hold and watch for drop (correct for temperature).
5. Release nitrogen and evacuate to a deep vacuum. A common target is below 500 microns (about 0.67 mbar absolute).
6. Isolate the pump and do a decay test. If pressure keeps rising, there is a leak; if it rises then levels off, there is still moisture.
7. Weigh in the charge by weight from the nameplate, as liquid where the refrigerant is a blend.
8. Run, check SH and SC, leak test again, record.

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Leak repair sequence

Worked example — Correcting a nitrogen test for temperature

Nitrogen test pressure set at 30 bar(g) at 25 °C in the morning in Kolkata. In the afternoon the reading is 30.8 bar(g) at 32 °C. Is it holding?

Use absolute pressure and absolute temperature (gas law, constant volume).

$$\frac{P_2}{P_1} = \frac{T_2}{T_1}$$

P_1 = 30 + 1.013 = 31.0 bar abs; T_1 = 25 + 273 = 298 K; T_2 = 32 + 273 = 305 K. P_2 expected = 31.0 × 305 ÷ 298 = 31.7 bar abs = 30.7 bar(g).

Reading 30.8 bar(g) ≈ expected 30.7 bar(g). The rise is only from heat; the system is holding.

Remember

- Recover, never vent.
- Braze with nitrogen flowing; change the drier.
- Prove tightness with nitrogen, then dryness with vacuum.
- Charge by weight.

Common mistake: "Topping up" a leaking unit every season instead of finding and fixing the leak.

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9.11 Electrical and control faults

Key idea: Many "refrigeration" faults are really electrical or control faults, so check power, signals and sensors early.

The electrical side has two parts. The power circuit carries high current to the compressor, fans and pump through MCBs (miniature circuit breakers), contactors and drives. The control circuit carries small signals from sensors, switches and the controller.

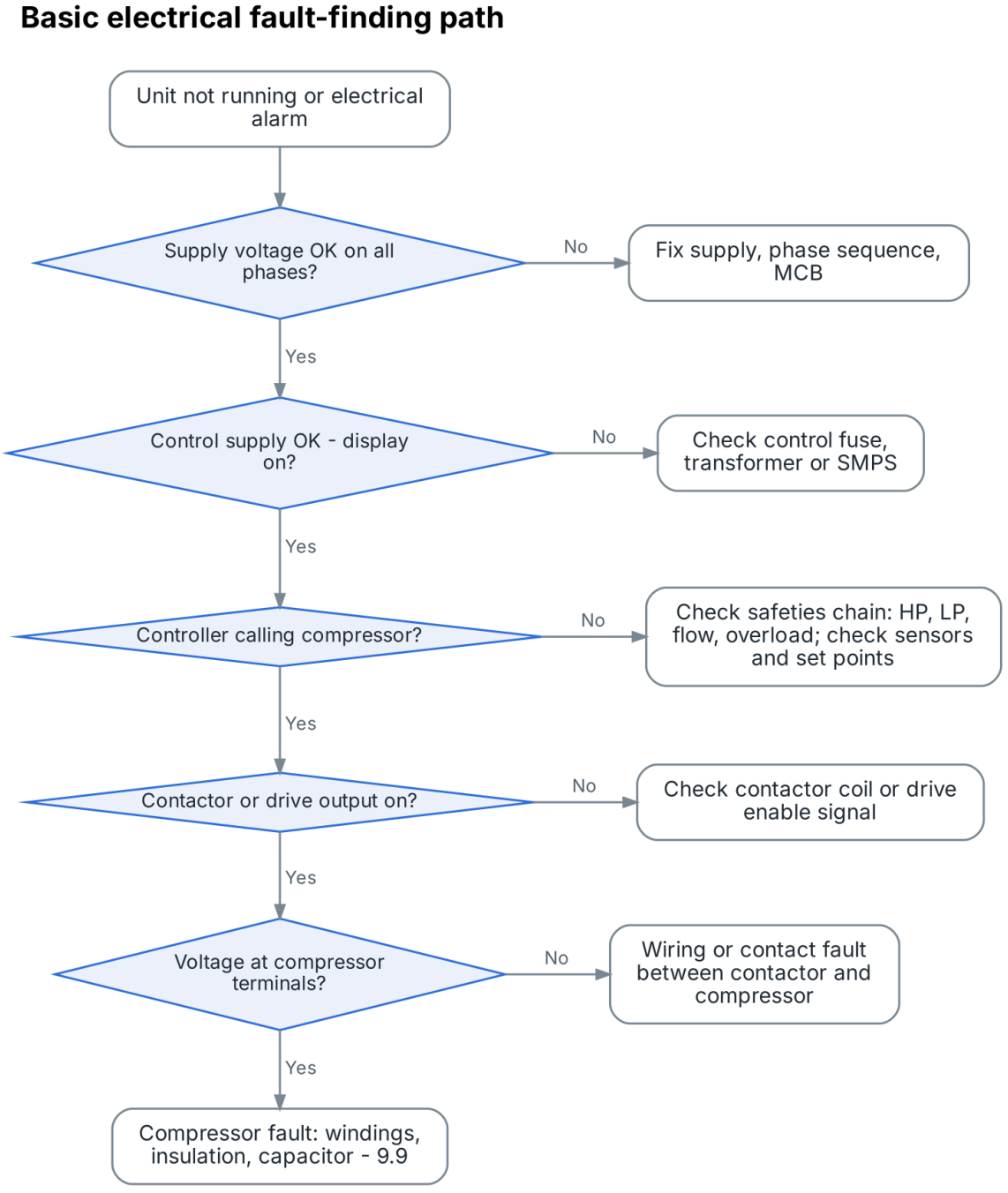
Indian sites often face voltage swings, missing phases and loose terminals from heat and vibration. A loose terminal heats up like a bad plug on an iron, until it burns.

Safety first: Isolate, lock out and prove dead with a tested voltage tester before touching terminals. Capacitors and inverter drives can hold dangerous charge after power is off; wait the time stated on the drive and measure.

Common electrical and control faults

Symptom	Likely cause	Check	Fix
Unit dead, no display	No supply, tripped MCB, blown control fuse, failed transformer/SMPS	Voltage at incoming terminals and control supply	Restore supply, find why it tripped, replace fuse/PSU
Phase fault alarm	Missing phase or wrong phase sequence	Voltage each phase, phase sequence meter	Fix supply; swap two phases if sequence wrong (fixed-speed scroll)
Compressor hums, will not start (single-phase)	Failed run/start capacitor, low voltage, seized rotor	Capacitor µF vs rating, voltage at start	Replace capacitor; check voltage; condemn if seized
Contactor chatters	Low coil voltage, loose control wire	Coil voltage, terminals	Tighten, fix supply to coil
Burnt contactor contacts	Normal wear, frequent starts, low voltage	Inspect contacts, starts per hour	Replace contactor; reduce short cycling
Sensor fault code	Open or short sensor, damp connector	Sensor resistance vs temperature table	Dry, re-terminate or replace sensor
Wrong temperature shown	Sensor out of pocket, poor contact	Compare with reference thermometer	Refit with paste and insulation; replace
Communication fault	Loose cable, poor earth, interference from power cables	Cable continuity, routing, shield earthing	Re-route away from power cables, earth shield at one end
Inverter drive trip	Supply problem, overheated drive, motor fault	Heat sink fan, ambient, motor winding test	Clean and cool drive; fix supply; follow drive manual
Flow switch fault but water flowing	Paddle stuck, switch misadjusted	Switch contact operation	Clean, adjust or replace
Earth leakage (RCCB) trips	Insulation failure, water in junction box	Insulation test on each motor and heater	Dry out or replace faulty part

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Basic electrical fault-finding path

Worked example — Check an NTC sensor

An NTC (negative temperature coefficient) thermistor's resistance falls as temperature rises. Many heat pump sensors are 10 kΩ at 25 °C (typical), but the table depends on the sensor.

Water is at 40 °C (measured with a reference thermometer). The sensor's resistance table shows about 5.3 kΩ at 40 °C for a typical 10 kΩ B3950 sensor. The meter reads 5.2 kΩ: the sensor is good.

If the meter reads infinity (open circuit) or near zero (short), the sensor or its wire has failed. Always use the resistance table for the actual sensor fitted.

$$R(T) = R_{25}\,\exp\left[B\left(\frac{1}{T} - \frac{1}{298.15}\right)\right]$$

With R_{25} = 10 kΩ, B = 3950 K, T = 313.15 K: 1/313.15 − 1/298.15 = 0.0031934 − 0.0033540 = −0.0001606 B × (−0.0001606) = −0.6345 R = 10 × e^(−0.6345) = 10 × 0.530 = 5.3 kΩ.

Remember

- Isolate, lock out and prove dead before touching terminals.
- Check supply and phases early in any fault.
- Test sensors against their resistance table.
- Keep signal cables away from power cables.

Field tip: Tighten all power terminals at every quarterly visit; heat and vibration loosen them.

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Quiz 9

1. Which of these is a quarterly task rather than a daily one?
    - A. Checking for active alarms
    - B. Measuring superheat and subcooling
    - C. Listening for unusual noise
    - D. Reading supply and return water temperature
2. During descaling of a PHE, the main isolation valves should be:
    - A. Open, so acid cleans the whole system
    - B. Closed, with the descaling pump connected to the service valves
    - C. Half open
    - D. Removed
3. The approach temperature of a water-side condenser rises from 3 K to 8 K at the same load. The most likely cause is:
    - A. Overcharge
    - B. Scale on the water side
    - C. Faulty LP switch
    - D. Low ambient temperature
4. Which water setup best protects a heat pump PHE on very hard borewell water?
    - A. Open system with no treatment
    - B. Higher hot-water set point
    - C. Indirect closed loop with a coil in the storage tank
    - D. Removing the strainer
5. A fault code shows "high-pressure protection". What does it tell you?
    - A. The exact root cause
    - B. Which protection acted, not why
    - C. That the compressor has failed
    - D. That the refrigerant is low
6. A heat pump in heating mode trips on HP. Water ΔT across the condenser is 11 K (design 5 K). First action?
    - A. Recover some refrigerant
    - B. Raise the HP switch set point
    - C. Check strainer, pump and valves for low water flow
    - D. Replace the compressor
7. LP trip with high superheat and low subcooling most likely means:
    - A. Overcharge
    - B. Low refrigerant charge
    - C. Scaled condenser
    - D. High water flow

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8. Measured flow 2,000 LPH, ΔT 7 K, input 4.2 kW. Field COP is about:
    - A. 2.5
    - B. 3.9
    - C. 5.2
    - D. 16.3
9. Which is the most common root cause of compressor liquid floodback?
    - A. High superheat
    - B. Low superheat from overfeeding or low evaporator air/water flow
    - C. High supply voltage
    - D. Clean coils
10. After a leak repair, the vacuum decay test shows pressure rising and then levelling off. This means:
    - A. A leak is still present
    - B. Moisture is still in the system; keep evacuating
    - C. The system is ready to charge
    - D. The gauge is faulty

Answer key

1. **B** — Superheat and subcooling need gauges and a technician; daily checks are done by operators.
2. **B** — Closing V1/V2 keeps acid in the PHE only, circulated through service valves.
3. **B** — A growing approach at the same load is the classic sign of water-side scale.
4. **C** — Hard water never reaches the heat pump PHE in an indirect closed loop.
5. **B** — Codes name the protection; the cause must be found by measuring.
6. **C** — A high ΔT means low flow, the most common HP trip cause in heating.
7. **B** — A starved evaporator (high SH) with little liquid in the condenser (low SC) points to low charge.
8. **B** — Q = 0.556 × 4.19 × 7 = 16.3 kW; 16.3 ÷ 4.2 ≈ 3.9.
9. **B** — Low superheat means liquid leaves the evaporator and reaches the compressor.
10. **B** — A rise that stops shows moisture boiling off; a continued rise would mean a leak.

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Glossary

Term	Meaning
Approach temperature	Difference between refrigerant saturation temperature and leaving water temperature in a heat exchanger
Back-flush	Flushing a coil or PHE in the direction opposite to normal flow
Breakdown maintenance	Repair done after a failure
COP	Coefficient of performance: heat output divided by electrical input
Contactor	Electrically operated switch that starts motors
Descaling	Removing mineral scale using a mild acid solution
EEV / TXV	Electronic or thermostatic expansion valve; meters refrigerant into the evaporator
Filter-drier	Liquid line component that removes moisture and dirt
Floodback	Liquid refrigerant returning to the compressor
Hardness	Dissolved calcium and magnesium, as mg/L $CaCO_3$
HP / LP switch	High- and low-pressure safety switches
Insulation resistance	Resistance between windings and earth, tested at 500 V DC
Non-condensables	Air or nitrogen trapped in a refrigerant circuit
NTC thermistor	Temperature sensor whose resistance falls as temperature rises
PHE	Plate heat exchanger
Preventive maintenance (PM)	Planned checks done before failure
Root cause	The first fault in a chain that led to the symptom
Scale	Hard mineral layer left by heated hard water
Service record	Written history of readings and work on a unit
Subcooling (SC)	Temperature below saturation of liquid leaving the condenser
Superheat (SH)	Temperature above saturation of vapour leaving the evaporator
TDS	Total dissolved solids in water, mg/L
Vacuum decay test	Holding a vacuum to prove a system is tight and dry
Voltage imbalance	Largest deviation of line voltages from their average, as a percentage

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> *It started as an instinct. In 2012 I wanted to do something in energy conservation. That was the whole of it. There was no plan to build machines, and no plan to build them in India. Both came later.*

Kashyap founded Sunniva Encon in 2012 to work on energy conservation. The company now designs and builds heat pumps at its own factory in Asangaon, Maharashtra, with its office in Mumbai, and supplies hot water, space heating and process heat systems across India, including remote, high-altitude sites.

Over these years he has seen heat pumps chosen, sized, installed and serviced in every kind of Indian condition, and seen how often good machines are let down by poor selection, rushed installation or missing maintenance. Most of those problems come from knowledge that is not widely taught.

This program is his answer: an open, vendor-neutral course that shares that knowledge with students, technicians, installers, consultants and facility teams. It teaches the technology, not a brand. The lessons carry no product names or sales claims; Sunniva's part is only to make the material available.

- Founder Director, Sunniva Encon LLP, since 2012
- More than 5,000 heat pump installations across India
- Own heat pump factory in Asangaon, Maharashtra, built for 2,000 machines a year
- Nationwide service network reaching sites as remote as Leh
- Published research paper on ScienceDirect (Elsevier, 2015): sciencedirect.com/science/article/pii/S1877050915007735

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THANK YOU.

Thank you for learning with us. Questions, corrections and suggestions for the next edition are welcome.

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