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COURSE 8 OF 10
FIRST EDITION 2026

HEAT PUMP TRAINING PROGRAM

Course 8 — Commissioning and Performance Testing

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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Level 3 · Field Practice

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LEVEL 3 · FIELD PRACTICE

Course 8 — Commissioning and Performance Testing

Powered by Sunniva. This Level 3 course is for installers and service engineers who start up air-to-water heat pumps and prove they work. It assumes you already know the refrigeration cycle and basic hydronic piping. After this course you will be able to:

- Run a full pre-commissioning check and a safe first start-up.
- Place test instruments correctly and take reliable site readings.
- Calculate actual heating capacity and COP from temperature, flow and power readings.
- Measure superheat and subcooling, read a factory test report, and hand the system over properly.

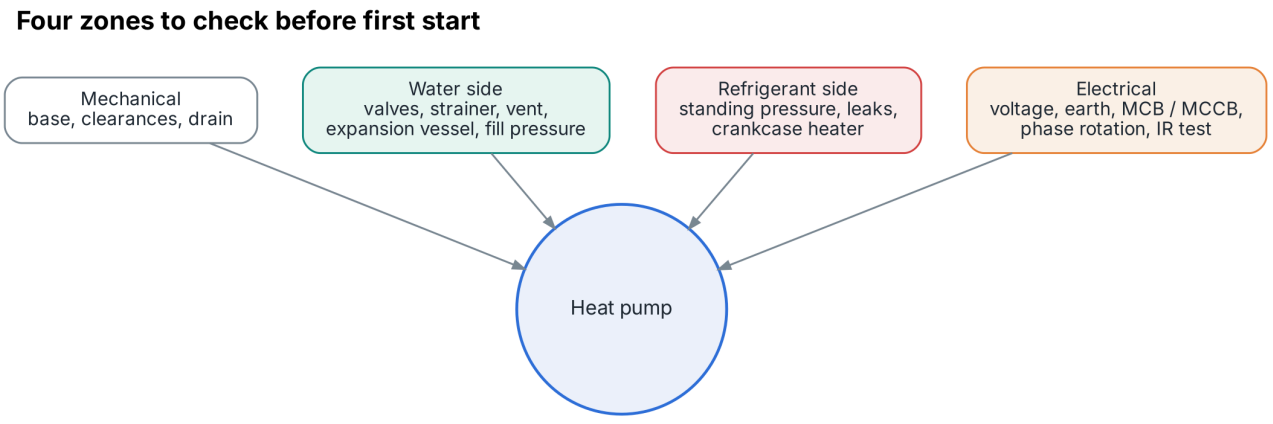
8.1 Pre-commissioning checks

Key idea: Most start-up failures are caused by things that could have been found with the power still off.

Commissioning means proving that an installed system works as designed. Pre-commissioning is everything you check before the compressor runs for the first time. Think of it like checking oil, water and tyres before a long drive on the highway.

Problems found now cost a few minutes. The same problems found after start-up can cost a compressor. A dry pump, a closed valve or a reversed phase can cause damage within minutes.

Work in four groups: mechanical, water side, refrigerant side and electrical. Tick each item only after you have seen it yourself, not because someone told you.



Four zones to check before first start

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Commissioning checklist

Mechanical

- ☐ Unit sits level on a firm base or frame, with anti-vibration pads fitted.
- ☐ Air clearances around the coil and fan match the installation manual.
- ☐ No air short-circuit: discharge air cannot return to the coil inlet.
- ☐ Condensate and defrost drain is free and slopes away from the unit.
- ☐ All transport brackets and packing inside the unit are removed.

Water side

- ☐ Piping is flushed clean before connecting to the heat pump.
- ☐ Strainer is fitted on the inlet to the heat pump and its mesh is clean.
- ☐ All isolation valves on the heat pump circuit are open.
- ☐ Air vents are fitted at high points and the system is fully vented.
- ☐ Closed system: cold fill pressure is set (typical 1.5–2.0 bar) and the expansion vessel pre-charge is checked.
- ☐ Water side pressure test passed (typical 1.5 × working pressure, held with no drop).
- ☐ Water quality is checked: hardness and TDS recorded; softener or treatment fitted where water is hard.

- [ ] Circulating pump turns freely and rotates in the correct direction.
- [ ] Flow switch is fitted in the correct direction and wired.
- [ ] Pipes and fittings outdoors are insulated and UV protected.

Refrigerant side

- [ ] Monoblock: standing pressure on the gauges is present (unit not empty).
- [ ] Split: nitrogen pressure test passed, vacuum below 500 micron (typical), charge as per manual.
- [ ] No oil stains at brazed joints, valves or flare nuts.
- [ ] Service valves are fully open (split units) and caps refitted.

Electrical

- [ ] Supply voltage at the unit terminals is within ±10% of nameplate (typical).
- [ ] Three-phase: voltage imbalance between phases is below 2% (typical).
- [ ] Phase sequence is correct (phase rotation meter or controller check).
- [ ] Cable size, MCB/MCCB rating and RCCB match the manual.
- [ ] Earth is connected and earth continuity is checked.
- [ ] Insulation resistance of compressor windings to earth is above 1 MΩ (500 V tester, typical minimum).
- [ ] All terminal screws are tightened, including inside the control panel.
- [ ] Crankcase heater has been energised for the time stated in the manual (typical 12–24 hours).

Check	Typical value	Why it matters
Closed-loop fill pressure (cold)	1.5–2.0 bar	Prevents air entry and pump cavitation
Insulation resistance	> 1 MΩ	Detects wet or damaged motor windings
Supply voltage	±10% of nameplate	Low voltage overheats the compressor motor
Voltage imbalance (3-phase)	< 2%	Imbalance causes high current in one winding
Crankcase heater on before start	12–24 h	Drives liquid refrigerant out of the oil

Remember

- Never start a heat pump with closed water valves or an unvented circuit.
- Wrong phase sequence can damage a scroll compressor within minutes.
- Measure insulation resistance before first power-up, not after a fault.
- Record every reading; the checklist becomes part of the handover file.

Common mistake: Skipping the crankcase heater wait on a cold morning. Liquid refrigerant in the oil can wash out the bearings at first start.

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8.2 First start-up sequence

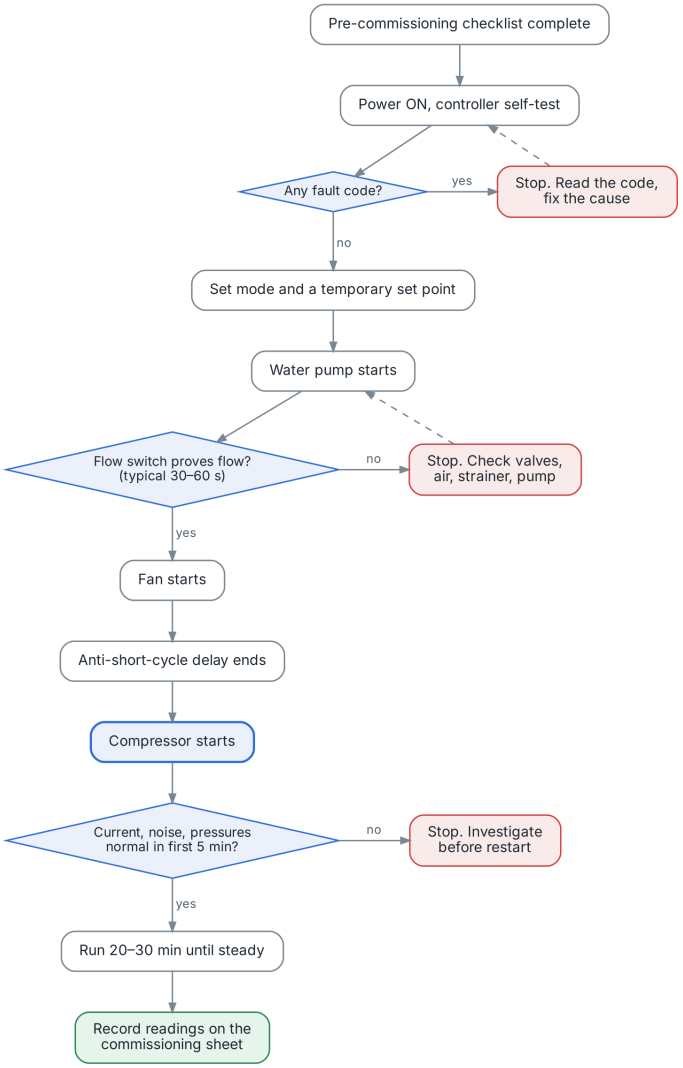
Key idea: A heat pump starts in a fixed order — water first, then air, then the compressor — and each step must prove itself before the next.

The controller follows a sequence of interlocks. An interlock is a condition that must be true before the next step is allowed. It is like a pressure cooker: the lid must lock before pressure can build.

Your job at first start is to watch each step happen. If a step does not happen, stop and find out why. Do not bypass a safety to "just see it run".

Typical order: the water pump starts, the flow switch proves flow, the fan starts, then the compressor starts after its anti-short-cycle delay. An anti-short-cycle timer is a minimum off time (typical 3 minutes) that protects the compressor from rapid restarts.

First start-up, step by step



First start-up, step by step

Step	What to watch	Normal sign
Pump start	Pump sound, pressure gauge	Steady hum, small rise in pressure
Flow proven	Flow switch, controller display	No flow alarm
Fan start	Rotation, vibration	Smooth, correct direction
Compressor start	Clamp meter on compressor lead	Inrush then settles near rated current
First 5 minutes	Suction and discharge pressure	Suction falls, discharge rises steadily
20–30 minutes	Water ΔT, superheat	Readings stable within ±0.5 K

Remember

- Water flow must be proven before the compressor is allowed to run.
- Never jumper the flow switch or high-pressure switch to get a start.
- Measure starting and running current on every phase.
- Take performance readings only after the system is steady.

Field tip: Keep your hand near the isolator for the first compressor start. Any metallic knocking or a loud hum without rotation means switch off at once.

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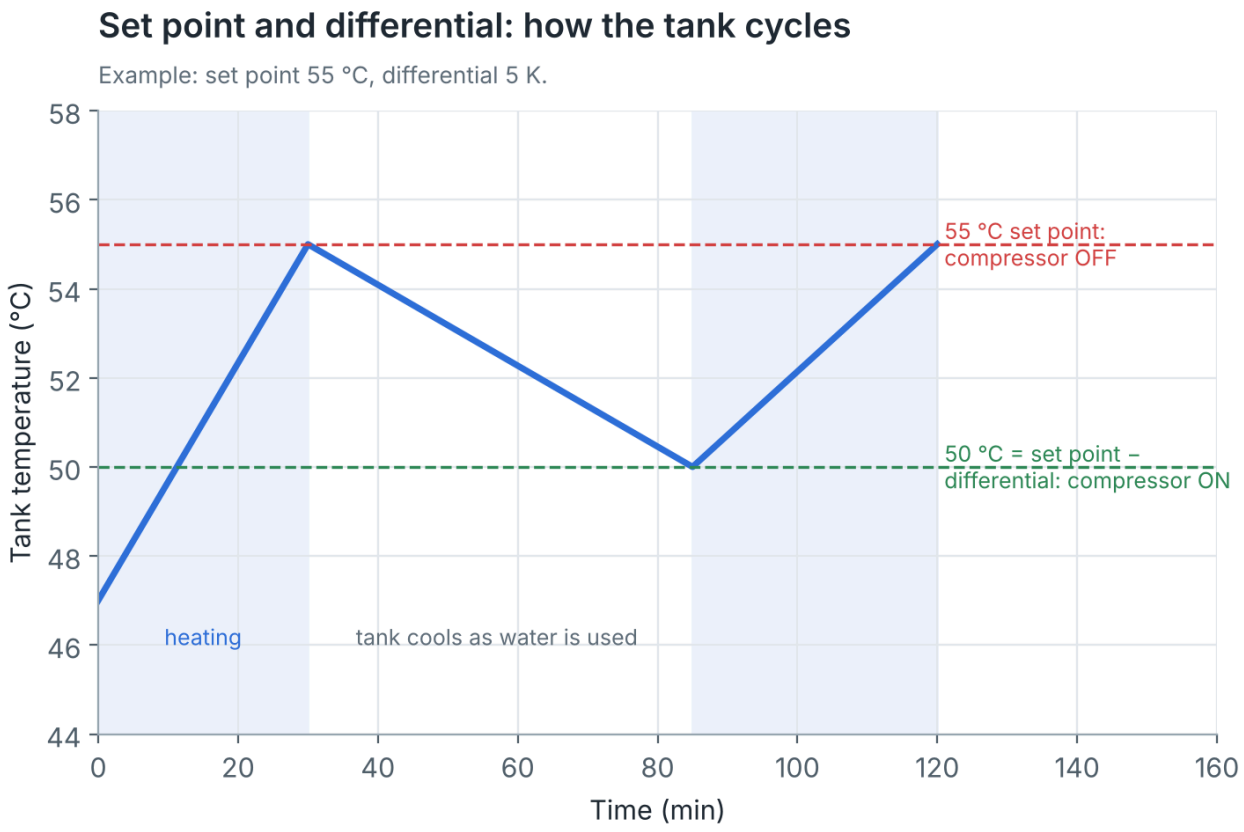
8.3 Controller setup and set points

Key idea: The controller decides how the heat pump behaves; wrong set points can make a good machine look bad.

The controller is the brain of the unit. It reads sensors and switches the pump, fan, compressor and valves. Setting it up means telling it what the site needs.

A set point is the target temperature, for example 55 °C hot water. A differential (also called hysteresis) is the band around the set point. The unit stops at the set point and restarts when the water falls by the differential. A fridge works the same way: the compressor stops when cold, and restarts after it warms a little.

A very small differential causes short cycling, which means frequent stops and starts. Short cycling wears the compressor and wastes energy. A very large differential lets the water get too cold before restart.



Set point and differential

Parameter	What it does	Typical setting
Hot water set point	Target water temperature	50–55 °C for domestic and commercial hot water
Space heating set point	Target flow temperature	35–45 °C (floor heating lower, radiators higher)
Differential	Restart band below set point	3–5 K
Anti-short-cycle timer	Minimum compressor off time	3 minutes
Pump overrun	Pump runs after compressor stops	1–3 minutes
Defrost start	Coil temperature that triggers defrost	As per manual; depends on refrigerant and coil
Anti-legionella cycle	Periodic high-temperature cycle	60 °C or above, weekly (where required)
Max outlet water limit	Protects against over-temperature	Below the unit's operating envelope limit
Clock and schedules	Sets cheap-tariff or working hours	Match site timings

Indian practice: many commercial sites (hotels, hostels, hospitals) need hot water mainly at 5–9 am and 6–10 pm. Use schedules so the tank is hot before these peaks. In Bengaluru or Pune winters, the morning ambient can drop to 10–15 °C, so allow extra heating time.

Remember

- Set the set point to what the user needs, not the maximum the unit can reach.
- A differential of 3–5 K is typical; smaller values cause short cycling.
- Higher water temperature means lower COP — every few degrees matter.
- Record all final controller settings on the commissioning sheet.

Common mistake: Leaving factory test settings in place. Always check set points, schedules and the clock before handover.

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8.4 Measuring temperature, pressure, flow and power

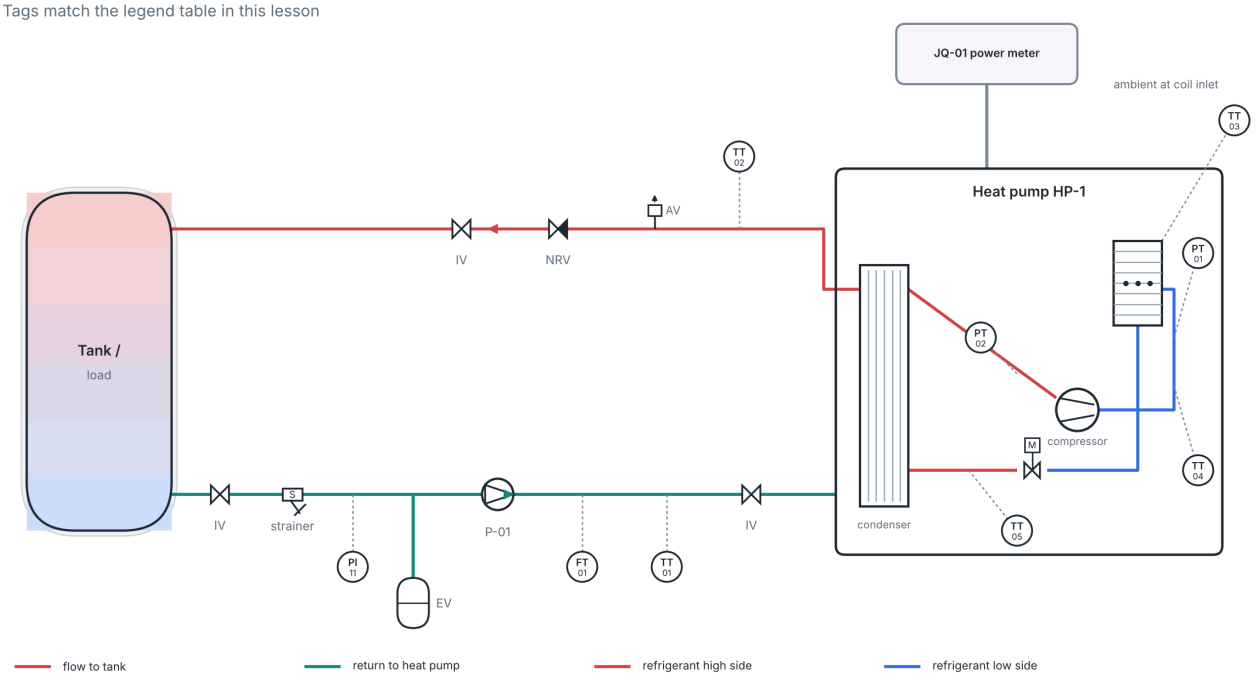
Key idea: A capacity or COP figure is only as good as the four measurements behind it — temperature, flow, pressure and power.

To prove performance on site you need a measured heat output and a measured electrical input. Heat output comes from water flow and temperature rise. Electrical input comes from a power meter.

Each instrument must sit in the right place. A temperature sensor placed after a mixing tee, or a flow meter right after a bend, gives a wrong reading. The P&ID below shows where every test instrument goes. A P&ID (piping and instrumentation diagram) is a drawing that shows pipes, valves and instruments with standard symbols and tags.

Where the test instruments go (P&ID)

Tags match the legend table in this lesson



P&ID: where the test instruments go

Legend (table under the diagram):

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Tag / symbol	Meaning	Where it goes
TT-01	Temperature transmitter, inlet water	Pipe into heat pump, after pump and flow meter, close to unit
TT-02	Temperature transmitter, outlet water	Pipe out of heat pump, before any tee or mixing
TT-03	Ambient air temperature	Shaded, at the air inlet of the coil, not in exhaust air
TT-04	Suction line temperature	Suction pipe near compressor, insulated over sensor
TT-05	Liquid line temperature	Liquid pipe after condenser, insulated over sensor
FT-01	Flow transmitter / flow meter	Straight pipe run on inlet side
PT-01	Suction pressure	Suction service port
PT-02	Discharge pressure	Discharge / high-side service port
PI-11	Water pressure gauge	Return line, near pump suction
JQ-01	Power and energy meter	Electrical supply feeding the whole unit
P-01	Circulating pump	Return line to heat pump
IV	Isolation valve	Both sides of heat pump
NRV	Non-return valve	Flow line, prevents back-flow
AV	Automatic air vent	High point of circuit
EV	Expansion vessel	Return line, pump suction side
Strainer	Y-strainer	Before pump and heat pump inlet

Measurement	Instrument	Typical accuracy needed	Placement rule
Water temperature	PT100 Class A or calibrated thermistor in a thermowell	±0.2 °C or better	Immersed in flow, thermowell filled with paste
Air temperature	Shaded probe	±0.5 °C	At coil inlet, out of sun
Water flow	Electromagnetic or ultrasonic flow meter	±1–2%	Straight run, typical 10 D upstream and 5 D downstream
Refrigerant pressure	Digital manifold	±0.5% of full scale	Service ports, hoses purged
Refrigerant pipe temperature	Clamp probe	±0.5 °C	Clean pipe, insulated over probe
Electrical power	True-RMS power meter (kW, kWh)	±1%	On the unit supply, all phases

Why ±0.2 °C matters: with a 5 K water ΔT, an error of 0.2 °C on each sensor can shift ΔT by 0.4 K. That is an 8% error in capacity before you even start.

Remember

- Measure the water ΔT with matched, calibrated sensors, not the unit's own display alone.
- Ultrasonic clamp-on meters need a straight pipe and correct pipe data.
- Measure power with a true-RMS meter on all phases; amps alone are not watts.
- Place the ambient probe where the coil actually breathes, in shade.

Field tip: Swap the two water probes into the same bucket of water before testing. If they differ, note the offset and correct for it.

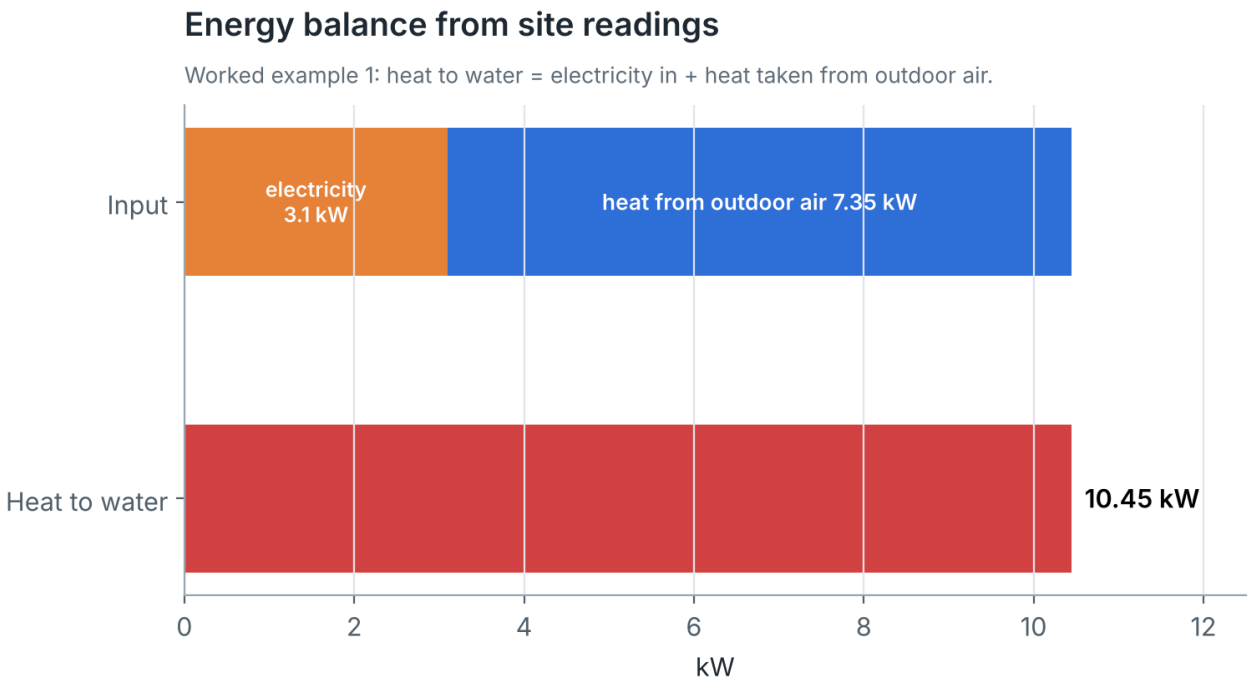
8.5 Calculating actual capacity and COP on site

Key idea: Capacity is water flow × specific heat × temperature rise; COP is that capacity divided by electrical input.

Heating capacity is the heat the unit puts into the water, in kW. Specific heat (cp) is the energy needed to warm 1 kg of a substance by 1 K. For water it is about 4.18 kJ/kg·K.

COP (coefficient of performance) is heat out divided by electricity in. A COP of 3.5 means 3.5 kW of heat for every 1 kW of electricity. The extra heat comes free from the outdoor air.

An electric geyser has a COP of about 1. That is why a heat pump can cut water heating electricity by two-thirds or more.



Energy balance from site readings

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

$$\text{COP} = \frac{Q}{P_{\text{electrical}}}$$

Shortcut for water (flow in LPH):

$$Q\,(\text{kW}) = \frac{\text{Flow}\,(\text{LPH}) \times \Delta T\,(\text{K})}{860}$$

Worked example 1 — Circulating heat pump at a hotel in Pune

Site readings after 30 minutes of steady running. Ambient (TT-03) 28 °C. Inlet water (TT-01) 50.0 °C. Outlet water (TT-02) 55.0 °C. Flow (FT-01) 1.8 m³/h. Power meter (JQ-01) 3.10 kW.

Step 1 — mass flow. 1.8 m³/h = 1800 L/h. Water at this temperature is close to 1 kg/L.

$$\dot{m} = \frac{1800\ \text{kg/h}}{3600\ \text{s/h}} = 0.50\ \text{kg/s}$$

Step 2 — temperature rise.

$$\Delta T = 55.0 - 50.0 = 5.0\ \text{K}$$

Step 3 — capacity.

$$Q = 0.50 \times 4.18 \times 5.0 = 10.45\ \text{kW}$$

Check with the shortcut: 1800 × 5 / 860 = 10.47 kW. Same answer.

Step 4 — COP.

$$\text{COP} = \frac{10.45}{3.10} = 3.37$$

Step 5 — compare. Look up the manufacturer's data at 28 °C ambient and 55 °C outlet, not the headline rating. If the data shows about 10.5 kW and COP 3.4 at these conditions, the unit is performing as expected.

Step 6 — what it saves (example rate ₹9/kWh). Over 8 running hours the unit delivers 10.45 × 8 = 83.6 kWh of heat for 3.10 × 8 = 24.8 kWh of electricity. That costs 24.8 × 9 = ₹223. An electric geyser would use about 83.6 kWh, costing about ₹752.

Worked example 2 — Tank heat-up method at a home in Bengaluru

When no flow meter is available, time a tank heat-up. A 500 L tank is heated from 25 °C to 55 °C in 1.5 hours. The energy meter shows 4.2 kWh used.

$$Q_{\text{energy}} = m \times c_p \times \Delta T = 500 \times 4.18 \times 30 = 62\,700\ \text{kJ}$$

$$62\,700\ \text{kJ} \div 3600 = 17.4\ \text{kWh}$$

$$\text{Average capacity} = \frac{17.4\ \text{kWh}}{1.5\ \text{h}} = 11.6\ \text{kW}$$

$$\text{Average COP} = \frac{17.4}{4.2} = 4.1$$

This method ignores tank heat loss and assumes the tank is well mixed. It gives a fair average, not an exact figure. Make sure no water is drawn off during the test.

Error source	Effect on result	How to avoid
Probes not matched	ΔT wrong, capacity off by 5–10%	Bucket test, note offset
Reading during defrost or start-up	Capacity too low	Wait for steady state
Flow meter in turbulent spot	Flow wrong	Use straight pipe run
Measuring amps, not kW	Power wrong (power factor ignored)	Use a true-RMS power meter
Comparing to rating at different conditions	False "underperforming" claim	Compare at the same ambient and water temperature

Remember

- Q = ṁ · cp · ΔT; for water, kW = LPH × ΔT / 860.
- Always compare site results with data at the same ambient and water temperatures.
- Take readings only in steady state, never during defrost.
- Small ΔT errors make big capacity errors; calibrate probes.

Common mistake: Using the nameplate input power instead of the measured power. Nameplate values are at rating conditions, not today's site conditions.

8.6 Superheat and subcooling

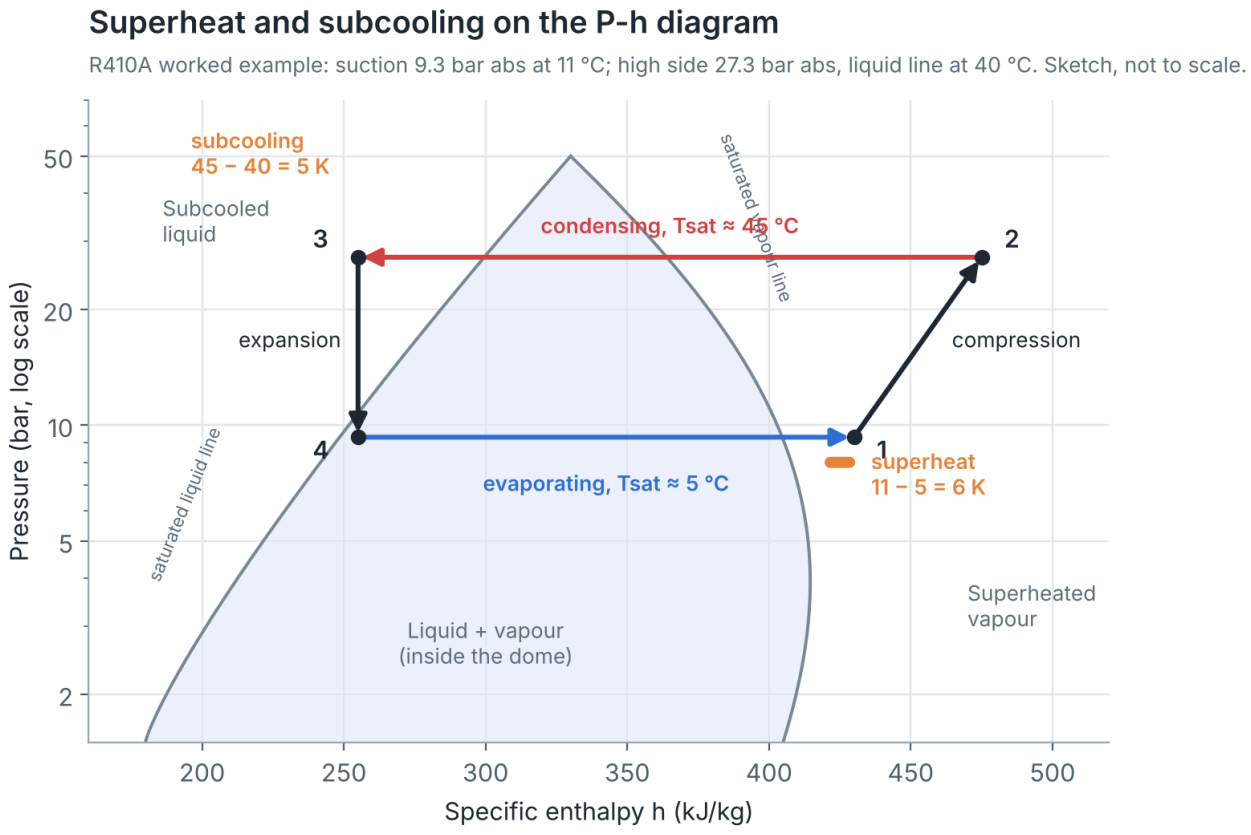
Key idea: Superheat tells you if the evaporator is fed correctly; subcooling tells you if the condenser side has the right charge.

Saturation temperature is the temperature at which refrigerant boils or condenses at a given pressure. You read it from the pressure-temperature (P-T) chart or the digital manifold. A pressure cooker shows the same idea: higher pressure, higher boiling point.

Superheat is the suction line temperature minus the evaporating saturation temperature. It proves that only vapour reaches the compressor. Too little superheat risks liquid entering the compressor. Too much means the evaporator is starved, often from low charge or a faulty expansion valve.

Subcooling is the condensing saturation temperature minus the liquid line temperature. It proves the expansion valve receives solid liquid. Low subcooling often means undercharge. High subcooling often means overcharge or a restriction.

A P-h diagram plots pressure (vertical) against enthalpy (horizontal). Enthalpy is the heat content per kg of refrigerant. The dome shape is the saturation curve. Superheat sits just right of the dome on the low-pressure line. Subcooling sits just left of the dome on the high-pressure line.



Superheat and subcooling on the P-h diagram

Worked example — R410A unit in Chennai, steady running

Readings: suction gauge 8.3 bar(g); suction line temperature (TT-04) 11 °C. Discharge-side gauge 26.3 bar(g); liquid line temperature (TT-05) 40 °C.

Step 1 — convert gauge to absolute pressure (add about 1 bar).

$$P_{abs} = P_{gauge} + 1.0$$

Suction: 8.3 + 1.0 = 9.3 bar abs. High side: 26.3 + 1.0 = 27.3 bar abs.

Step 2 — read saturation temperatures from the R410A P-T chart. At 9.3 bar abs, Tsat ≈ 5 °C. At 27.3 bar abs, Tsat ≈ 45 °C. (Most digital manifolds do this for you once the refrigerant is selected.)

Step 3 — superheat.

$$SH = T_{suction\ line} - T_{sat,\ evap} = 11 - 5 = 6\ \mathrm{K}$$

Step 4 — subcooling.

$$SC = T_{sat,\ cond} - T_{liquid\ line} = 45 - 40 = 5\ \mathrm{K}$$

Step 5 — judge. Both values fall in the typical range below. The charge and expansion valve are working normally.

Reading	Typical range	Too low means	Too high means
Superheat (EXV/TXV systems)	4–8 K	Flooding risk, liquid to compressor	Starved evaporator, low charge, valve fault
Subcooling	3–8 K	Undercharge, flash gas at valve	Overcharge, restriction, condenser flooded

Always use the target values in the installation manual where given. Fixed-orifice and capillary systems behave differently from electronic expansion valves.

Remember

- Superheat = suction line temp − evaporating saturation temp.
- Subcooling = condensing saturation temp − liquid line temp.
- Convert gauge to absolute pressure if your chart is in absolute.
- Measure on clean pipe with the probe insulated, in steady state.

Common mistake: Adding refrigerant because suction pressure "looks low" on a cold morning. Check superheat and subcooling first; low ambient alone lowers suction pressure.

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8.7 Reading a factory performance test report

Key idea: A factory test report proves each unit met its design performance under controlled conditions; learn to read every column.

Before dispatch, good factories run each unit, or a sample, on a test bench. The bench controls the air and water conditions and records performance. The record is called a performance test report.

On site, this report is your baseline. If site readings differ a lot from the report at similar conditions, something has changed — installation, water flow, charge or supply voltage.

Sample performance test record (generic)

Refrigerant: R410A. Unit type: air-to-water heat pump, rated 20 kW heating at 20 °C ambient, 40 → 45 °C water. Tolerance: ±5% on capacity and COP (typical; the real figure is set in the test specification).

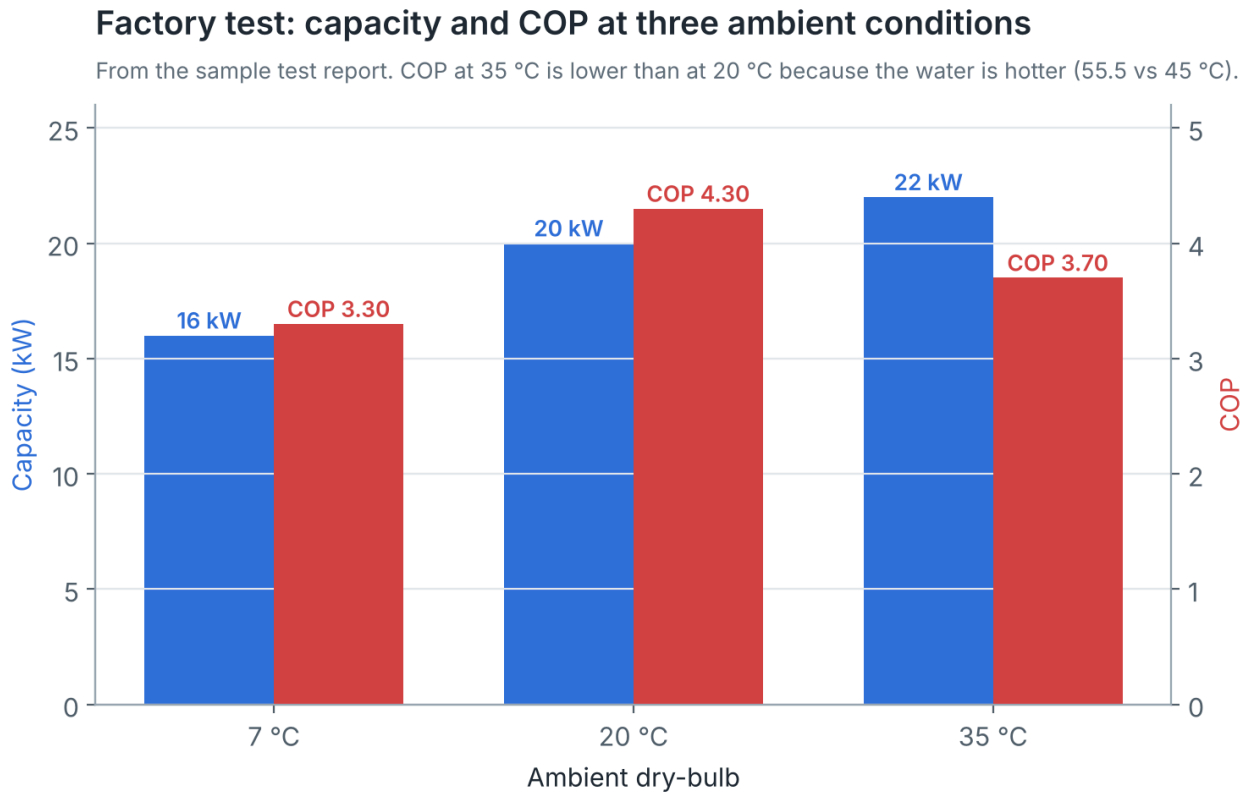
Test no.	Ambient DB (°C)	Ambient RH (%)	Water in (°C)	Water out (°C)	Flow (m^3/h)	Capacity (kW)	Voltage (V)	Current (A)	Input power (kW)	COP	Suction P (bar g)	Discharge P (bar g)	SH (K)	SC (K)	Result
T1	20	65	40.0	45.0	3.44	20.0	415	7.4	4.65	4.30	9.8	29.5	6	5	Pass
T2	7	85	41.0	45.0	3.44	16.0	415	7.7	4.85	3.30	6.0	29.5	5	4	Pass
T3	35	45	50.0	55.5	3.44	22.0	412	9.5	5.95	3.70	12.5	37.0	7	5	Pass

How the numbers fit: Capacity = Flow (LPH) × ΔT / 860. For T1: 3440 × 5.0 / 860 = 20.0 kW. COP = 20.0 / 4.65 = 4.30.

Column	What it means	What to look for
Test no.	Test point identifier	Each rating condition has its own row
Ambient DB	Dry-bulb air temperature at coil inlet	Defines the test condition
Ambient RH	Relative humidity of inlet air	High RH at low ambient means frost and defrost
Water in / out	Water temperatures at unit inlet and outlet	ΔT should match the design (here about 4–5.5 K)
Flow	Water flow rate through the condenser	Site flow should be close to this
Capacity	Heat delivered, from flow × cp × ΔT	Compare with rated value ± tolerance
Voltage	Supply voltage during test	Results apply at this voltage
Current	Running current per phase	Site current should be similar at similar conditions
Input power	Measured electrical input in kW	Includes compressor, fan and controls (check if pump is included)
COP	Capacity ÷ input power	Falls with lower ambient and higher water temperature
Suction P / Discharge P	Refrigerant pressures (gauge)	Baseline for site gauge readings
SH / SC	Superheat and subcooling	Baseline for charge checks
Result	Pass or fail against tolerance	Any fail must be explained and retested

Other items on a good report: unit serial number, refrigerant type and charge, test date, bench instrument calibration reference, tester name and signature, and electrical safety tests (insulation resistance, earth continuity, high-voltage test).

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Factory test: capacity and COP at three ambients

Remember

- A test result only means something together with its test conditions.
- Check that capacity = flow × ΔT / 860 on the report; the numbers must agree.
- Confirm whether input power includes the water pump.
- Keep a copy of the report in the site file as the performance baseline.

Field tip: When a customer complains of low output, compare the site readings with the factory row closest to today's ambient and water temperature.

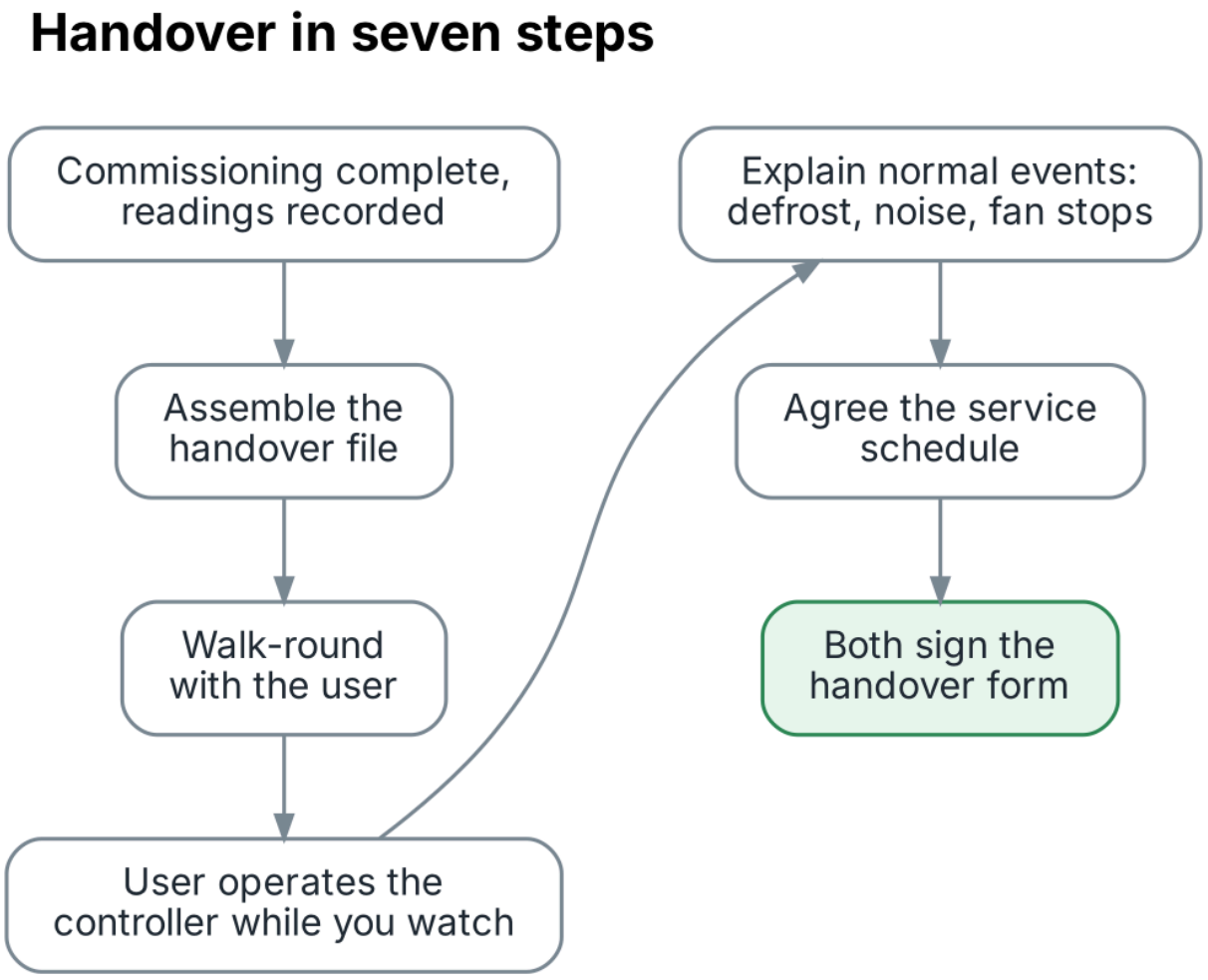
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8.8 Handover: documents and user training

Key idea: The job is not finished until the user knows how to operate the system and has every document they need.

Handover is the formal transfer of the system to the owner or operator. A good handover prevents most "nuisance" service calls. Many early complaints come from users who do not understand defrost, schedules or set points.

Train the person who will actually operate the system — the hotel maintenance man, the hostel warden, or the homeowner. Show, then ask them to do it while you watch.



Handover in seven steps

Document	Contents	Who keeps it
Commissioning report	Checklist, readings, capacity, COP, SH/SC, settings	Owner and installer
Factory performance test report	Bench test results for this serial number	Owner
Installation and user manual	Operation, safety, fault codes	Owner, near the unit
As-built schematic / P&ID	Actual piping, valves, sensors, electrical feed	Owner and service team
Controller settings sheet	Set points, differential, schedules, limits	Owner and installer
Warranty card and registration	Serial number, start date, conditions	Owner
Service schedule	Filter, strainer, coil, water quality checks	Owner
Contact details	Service phone, email, QR code if any	Posted on or near unit

User training topics:

- Switching on and off, changing set point and schedule.
- What defrost is: the fan stops and steam may rise from the coil — this is normal.
- Normal sounds, and which sounds mean "call service".
- Reading and noting fault codes before calling.
- Simple care: keep the coil clear of leaves, dust and stored items; clean the strainer as advised.
- Water quality: where water is hard, maintain the softener to prevent scale.
- Safety: do not open panels; isolator location; keep children away from the unit.

Remember

- Hand over a complete file: commissioning report, test report, manuals, settings and warranty.
- Train the real operator and have them practise.
- Explain defrost and normal noises to avoid false complaints.
- Get a signed handover form with the date; warranty usually starts here.

Field tip: Take a photo of the final controller settings and the commissioning sheet, and send it to the owner the same day.

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Quiz 8

1. Before the first start of a compressor with a crankcase heater, the heater should typically be energised for:
   - A. 5 minutes B. 30 minutes C. 12–24 hours D. It is not needed
2. In the start-up sequence, the compressor is allowed to start only after:
   - A. The fan reaches full speed only B. Water flow is proven by the flow switch C. The tank reaches set point D. Defrost ends
3. A heat pump runs with 2400 LPH flow and a 5 K water temperature rise. Its capacity is about:
   - A. 4.8 kW B. 9.6 kW C. 14.0 kW D. 20.0 kW
4. The same unit uses 4.0 kW of electrical power. Its COP is:
   - A. 2.5 B. 3.0 C. 3.5 D. 4.0
5. Where should the ambient temperature sensor be placed?
   - A. In the fan exhaust air B. On the roof in direct sun C. Shaded, at the coil air inlet D. Inside the control panel
6. Suction saturation temperature is 4 °C and suction line temperature is 10 °C. Superheat is:
   - A. 4 K B. 6 K C. 10 K D. 14 K
7. Low subcooling with high superheat most often indicates:
   - A. Overcharge B. Undercharge C. Too much water flow D. Correct charge
8. Why is a ±0.2 °C sensor error important in capacity testing?
   - A. It is not important B. With a 5 K ΔT it can cause about 8% capacity error C. It only affects COP, not capacity D. It only matters above 60 °C
9. On a factory test report, the most important thing to check alongside capacity is:
   - A. The colour of the unit B. The test conditions (ambient and water temperatures) C. The tester's handwriting D. The packing list
10. A very small controller differential (for example 1 K) usually causes:
    - A. Higher COP B. Short cycling C. Lower water temperature D. Longer defrost

Answer key

1. C — Liquid refrigerant must be driven out of the oil; typical 12–24 h.
2. B — Running without flow causes high pressure trips and heat exchanger damage.
3. C — 2400 × 5 / 860 = 13.95 ≈ 14.0 kW.
4. C — 14.0 / 4.0 = 3.5.
5. C — It must read the air the coil actually draws in, without sun heating it.
6. B — 10 − 4 = 6 K.
7. B — Not enough refrigerant starves the evaporator and leaves little liquid in the condenser.
8. B — Two 0.2 °C errors can shift ΔT by 0.4 K, which is 8% of 5 K.
9. B — Capacity and COP change with conditions; a number without its conditions is meaningless.
10. B — The unit reaches set point and restarts too often, wearing the compressor.

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Glossary

Term	Meaning
Commissioning	Proving that an installed system works as designed and recording the results
Pre-commissioning	Checks done before the first start-up, with the compressor off
Interlock	A condition that must be met before the next step is allowed
Anti-short-cycle timer	Minimum compressor off time, typically 3 minutes
Set point	Target temperature the controller works towards
Differential (hysteresis)	Temperature band between switch-off and restart
Short cycling	Frequent compressor starts and stops
P&ID	Piping and instrumentation diagram, using standard symbols and tags
TT / PT / FT	Temperature, pressure and flow transmitter (ISA tags)
JQ	Power/energy meter tag (power totaliser)
Heating capacity (Q)	Heat delivered to the water, in kW
Specific heat (cp)	Energy to raise 1 kg by 1 K; water ≈ 4.18 kJ/kg·K
ΔT	Temperature difference, here outlet minus inlet water
COP	Coefficient of performance: heat out ÷ electricity in
Steady state	Running condition where readings no longer change
Saturation temperature	Boiling or condensing temperature at a given pressure
Superheat	Suction line temperature minus evaporating saturation temperature
Subcooling	Condensing saturation temperature minus liquid line temperature
P-h diagram	Chart of refrigerant pressure against enthalpy
Enthalpy	Heat content of refrigerant per kg, kJ/kg
Gauge vs absolute pressure	Absolute = gauge + about 1 bar (atmospheric)
Insulation resistance	Resistance between motor windings and earth; typical minimum 1 MΩ
True-RMS power meter	Meter that measures real power in kW, accounting for power factor
Performance test report	Factory record of a unit's tested capacity, power and COP
Handover	Formal transfer of the system and documents to the owner
Defrost	Cycle that melts frost from the outdoor coil

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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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