
HEAT PUMP TRAINING PROGRAM

Course 5 – Selection and System Design

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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5 Selection and System Design

Level 2 · Application and Design

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Course 5 — Selection and System Design

Powered by Sunniva. This Level 2 course is for consultants, MEP designers and senior technicians who select heat pumps and design the systems around them. After it you will be able to: (1) read a datasheet and correct its ratings to your site conditions; (2) size a heat pump and storage tank together for a real hot water load; (3) choose between direct, indirect, buffered, hybrid and cascaded layouts and draw them as P&IDs; (4) specify water treatment, materials and the electrical supply.

5.1 Reading a datasheet: rating conditions and what they hide

Key idea: A datasheet capacity is true only at the exact air and water temperatures it was tested at.

A datasheet is like a car's mileage figure. It is measured under fixed, gentle conditions, and real roads give less. A heat pump's heating capacity (kW of heat delivered) and COP (coefficient of performance: heat out divided by electricity in) change with outdoor air temperature and the water temperature you ask for.

Every rating should state its rating condition: the ambient dry-bulb (DB) temperature, the wet-bulb (WB) temperature (which tells humidity), and the water inlet and outlet temperatures. If a sheet gives a capacity without these, you cannot compare it with anything.

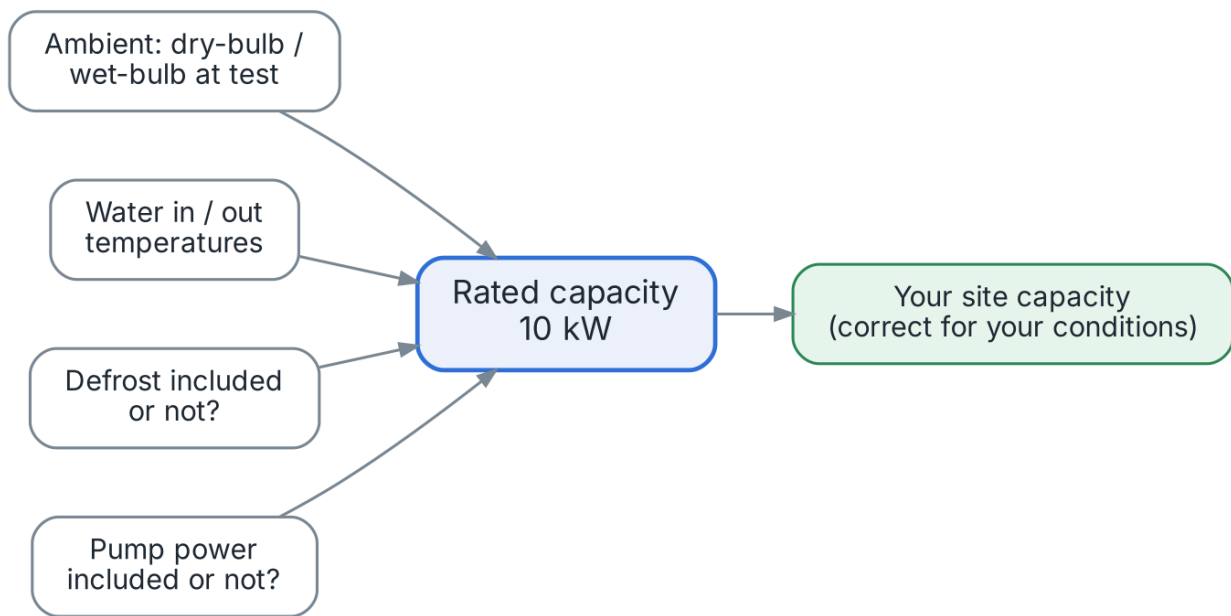
Common rating points used by manufacturers (typical, they vary by standard and product type):

Rating style	Ambient DB / WB	Water	Typical use
Mild "domestic hot water" point	20 °C / 15 °C	15 °C in → 55 °C	Hot water heat pumps
Space-heating low temperature	7 °C / 6 °C	30 °C in → 35 °C out	Underfloor heating
Space-heating medium temperature	7 °C / 6 °C	40 °C in → 45 °C out	Radiators, fan coils
Cold climate check	-7 °C / -8 °C	30 → 35 °C	Winter capacity

What datasheets often hide:

- **Defrost losses.** Ratings at 20 °C have no frost. Below about 7 °C with high humidity, the evaporator frosts and defrost cycles cut average output (typical 5–15 %).
- **Heat-up vs. steady state.** A "15 → 55 °C" rating is an average over a heat-up. Reheating a tank already at 45 °C gives a lower COP.
- **Pump and fan power.** Check whether COP includes the water pump power. Some sheets exclude it.
- **Maximum vs. nominal.** Inverter units list a nominal and a maximum capacity. Size on the capacity at your condition, not the maximum.
- **Sound level.** Sound pressure (dB(A) at a distance) and sound power are different numbers. Sound power is always the larger.

What sits behind one capacity number



What sits behind one capacity number

Worked example — correcting a datasheet COP for site water temperature

A unit is rated 10 kW, COP 4.2 at 20 °C ambient, water 15 → 55 °C. Your site in Shimla needs 60 °C water at 5 °C ambient. Use the manufacturer's correction table. If none exists, a Carnot-ratio estimate gives a rough direction.

$$COP_{Carnot} = \frac{T_{hot}}{T_{hot} - T_{cold}} \quad (K), \quad COP_{site} \approx COP_{rated} \times \frac{COP_{Carnot,site}}{COP_{Carnot,rated}}$$

Rated: $T_{hot} \approx 55$ °C average-to-final. Use average water 35 °C = 308 K; $T_{cold} = 293$ K → Carnot = 308/15 = 20.5. Site: average water 37.5 °C = 310.5 K; $T_{cold} = 278$ K → Carnot = 310.5/32.5 = 9.6. $COP_{site} \approx 4.2 \times 9.6/20.5 \approx 2.0$. This is a rough, conservative estimate. Always prefer the manufacturer's own performance table.

Remember

- No rating condition, no comparison.
- Capacity and COP fall when ambient falls or water temperature rises.
- Ask whether defrost and pump power are included.
- Size on capacity at the design condition, not the maximum.

Common mistake: Comparing one brand's 20 °C rating with another brand's 7 °C rating.

5.2 Capacity vs ambient: derating

Key idea: As outdoor air gets colder, an air-source heat pump delivers less heat, so you size at the coldest design ambient.

An air-source heat pump picks up heat from the air. Colder air holds less heat for the evaporator to collect, and the compressor pumps less refrigerant mass because suction gas is less dense. Cold air simply has less heat to give, so the machine picks up less.

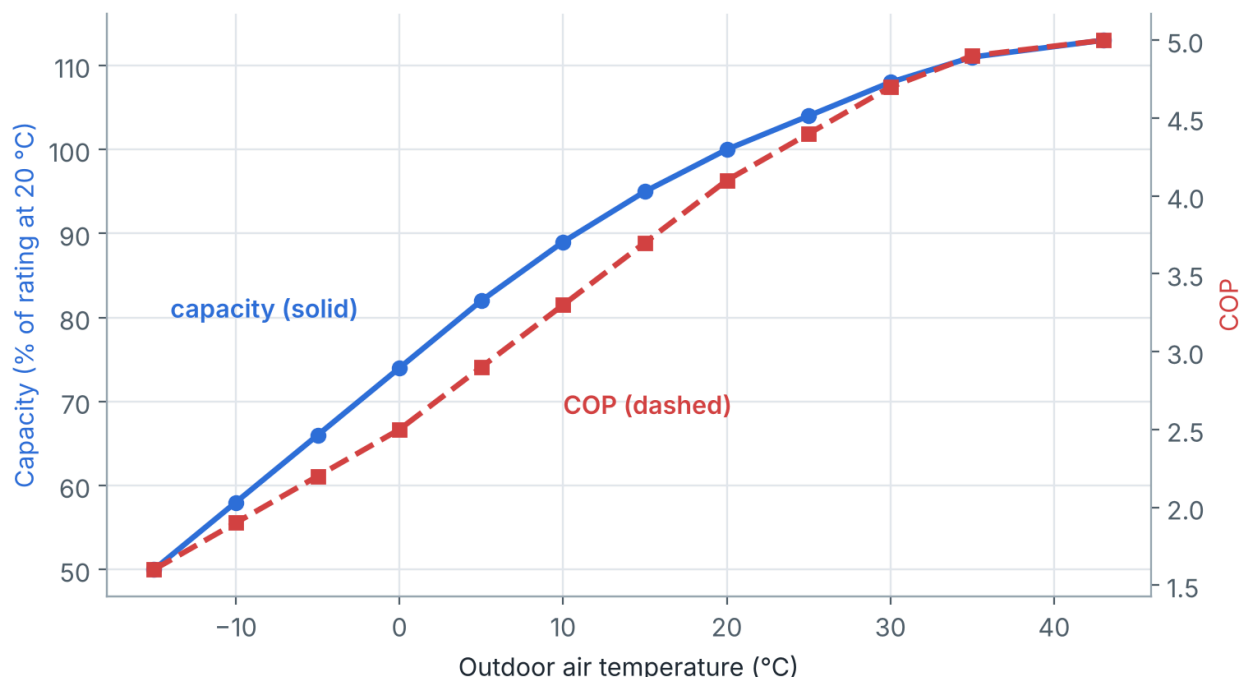
Derating means reducing the rated capacity to the real capacity at your design ambient. The design ambient is the low outdoor temperature you design for, for example the typical winter morning low at your site.

Typical Indian design ambients (illustrative, check local climate data):

City	Typical winter design ambient	Note
Chennai	18–20 °C	Little derating
Mumbai	15–17 °C	Little derating
Bengaluru	12–14 °C	Mild
Delhi	4–6 °C	Moderate, fog/frost mornings
Shimla	–2 to 2 °C	Strong derating, defrost
Leh	–20 to –15 °C	Needs cold-climate (EVI) unit

Capacity and COP vs ambient at 55 °C water

Generic, illustrative. Defrost dip around 0–5 °C not shown. Use the maker's tables.



Capacity and COP vs ambient at 55 °C water

Worked example — derating for Delhi winter

A unit is rated 20 kW at 20 °C. Its table shows 82 % capacity at 5 °C with 55 °C water. Defrost loss is taken as 8 % (typical).

$$Q_{site} = Q_{rated} \times f_{ambient} \times (1 - f_{defrost})$$

$Q_{site} = 20 \times 0.82 \times (1 - 0.08) = 20 \times 0.82 \times 0.92 = 15.1 \text{ kW}$. The "20 kW" machine is a 15 kW machine on a Delhi January morning.

Remember

- Size at design ambient, not at rating ambient.
- Capacity and COP both fall with ambient.
- Add defrost loss below about 7 °C in humid air.
- In hot climates the unit has spare capacity in summer.

Field tip: Ask for the full capacity table, not the brochure single point.



5.3 The operating envelope

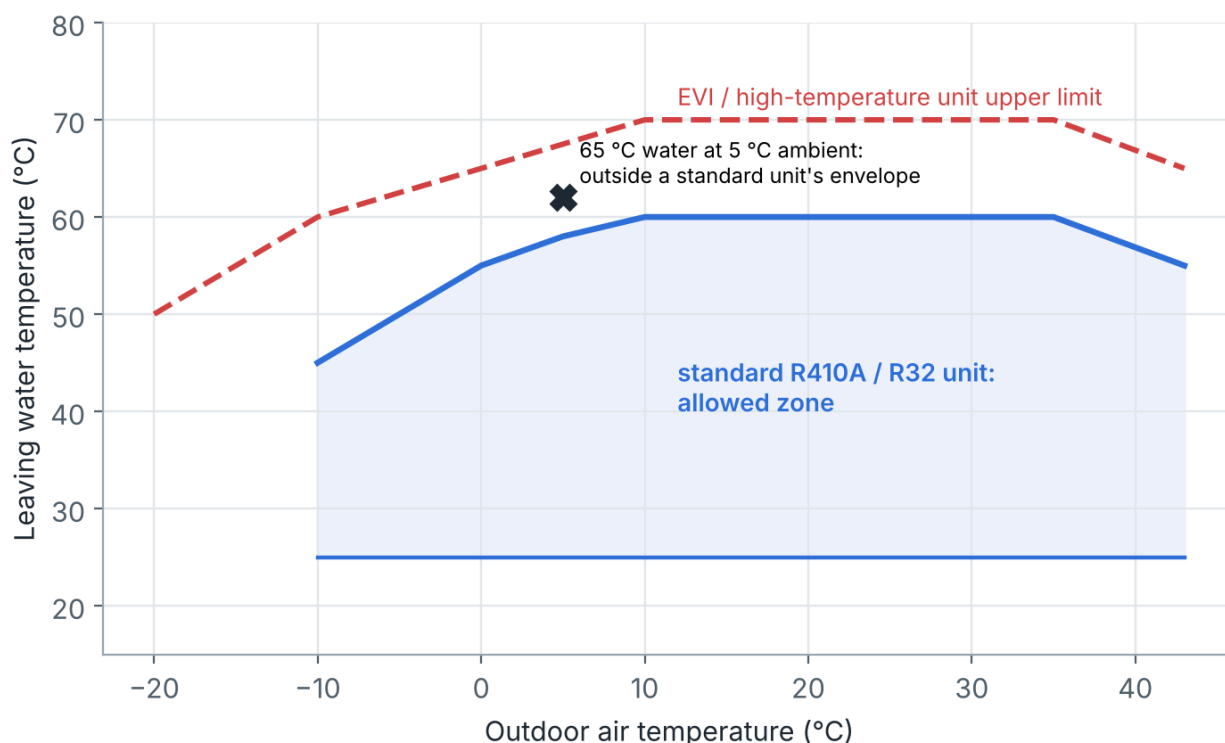
Key idea: The operating envelope is the map of ambient and water temperatures in which the compressor can run safely.

Every compressor has limits. If the water is too hot or the air too cold, the discharge temperature and pressure climb too high. The unit then trips on high pressure (HP) or high discharge temperature. The envelope shows the allowed area.

Read it like a road map. X-axis is ambient air temperature. Y-axis is leaving water temperature (LWT), the hot water temperature leaving the heat pump. Inside the shaded area the unit runs. Outside it, it stops or limits itself.

Operating envelope: where the machine is allowed to run

Generic and illustrative. Real limits come from the manufacturer.



Operating envelope (generic, illustrative)

Envelope edge	What happens if you cross it
Top (water too hot)	High-pressure trip, high discharge temperature
Left (air too cold)	Low suction pressure, low-pressure trip, poor oil return
Right (air too hot)	High condensing pressure; unit may limit capacity
Bottom (water too cold at start)	Low head pressure; some units need a minimum water temperature

Worked example — will it run?

Project in Shimla: design ambient -2°C , required 60°C water. On the generic envelope, the upper boundary at -2°C is about 53°C . $60^{\circ}\text{C} > 53^{\circ}\text{C}$, so the standard unit is outside the envelope. Options:

choose an EVI (enhanced vapour injection) or high-temperature unit, or heat to 50 °C and top up with an electric or boiler stage.

Remember

- Plot your design point (ambient, LWT) on the envelope before selecting.
- Check both winter and summer corners.
- The envelope tightens at low ambient.
- EVI and CO₂ machines widen the envelope.

Common mistake: Setting the controller to 60 °C on a unit whose envelope ends at 55 °C, then blaming HP trips on the gas charge.



5.4 Sizing: capacity, running hours and storage trade-off

Key idea: Hot water sizing is a trade-off — a bigger tank lets a smaller heat pump run longer hours.

Hot water demand is peaky. A hotel uses most of its water 6–9 am and 7–10 pm. A geyser meets a peak with high power. A heat pump meets it with stored hot water, filled slowly over many hours. The tank is a battery of heat.

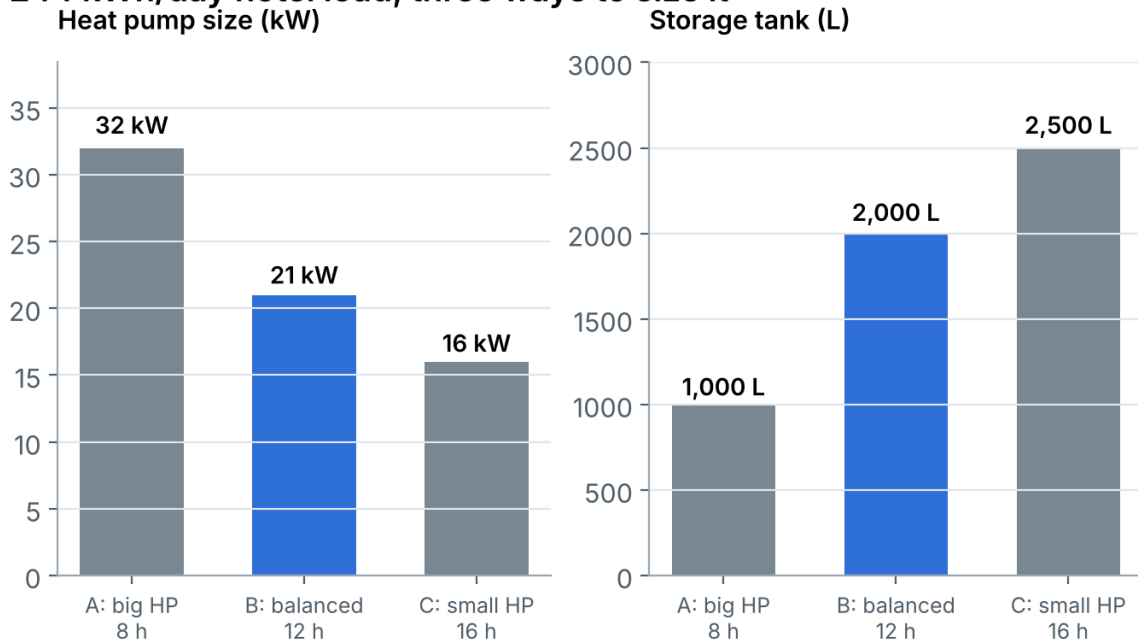
Three steps:

1. Find daily hot water energy.
2. Choose running hours (typically 8–16 h per day for hot water; more hours means a smaller unit).
3. Size storage to cover the peak that the heat pump cannot meet in real time.

$$E_{day} = \frac{V \times c_p \times \Delta T}{3600} \text{ [kWh]}, \quad c_p = 4.186 \text{ kJ/kg} \cdot \text{K}, \quad 1 \text{ L} \approx 1 \text{ kg}$$

$$Q_{HP} = \frac{E_{day}}{h_{run}}, \quad V_{tank} \approx \frac{(E_{peak} - Q_{HP} t_{peak}) \times 3600}{c_p \Delta T \eta_{usable}}$$

Same 244 kWh/day hotel load, three ways to size it



Running cost is the same if COP is equal; option B (highlighted) usually balances cost, space and recovery.

Three ways to size the same hotel load

Worked example — 40-room hotel in Pune

Load: 40 rooms × 2 guests × 60 L at 60 °C = 4,800 L/day plus kitchen 1,200 L = 6,000 L/day. Cold water 25 °C (typical Pune winter). $\Delta T = 35 \text{ K}$. $E_{day} = 6,000 \times 4.186 \times 35 / 3600 = 244 \text{ kWh/day}$. Morning peak: 50 % of daily use in 3 hours = 122 kWh. Usable fraction of tank (stratification and mixing) $\eta = 0.8$ (typical 0.75–0.9).

Option	Running hours	HP size	HP output in 3 h peak	Energy tank must hold	Tank volume
A — big HP	8 h	$244/8 = 30.5$ kW $\rightarrow$ 32 kW	96 kWh	$122 - 96 = 26$ kWh	$26 \times 3600 / (4.186 \times 35 \times 0.8) \approx 800$ L $\rightarrow$ 1,000 L
B — balanced	12 h	$244/12 = 20.3$ kW $\rightarrow$ 21 kW	63 kWh	59 kWh	$\approx 1,800$ L $\rightarrow$ 2,000 L
C — small HP	16 h	$244/16 = 15.3$ kW $\rightarrow$ 16 kW	48 kWh	74 kWh	$\approx 2,260$ L $\rightarrow$ 2,500 L

Running cost is the same for all three if COP is equal: $244 \text{ kWh} \div \text{COP } 3.8 = 64 \text{ kWh electricity/day} \times ₹9 = ₹578/\text{day}$ (example rate). Option B is usually best: moderate tank, room to recover if a second peak comes early, and some spare hours for derating. Check: the evening peak must be recovered in the hours between peaks. Option C needs $74 \text{ kWh} \div 16 \text{ kW} \approx 4.6$ h refill time — fine if peaks are 10 h apart.

Remember

- Energy per day sets total work; running hours set machine size.
- Storage covers what the machine cannot deliver during the peak.
- Leave 20–30 % spare hours for derating and defrost.
- Check recovery time between peaks.

Field tip: Ask the client for water meter readings, not guesses; hotels often use 40–80 L per guest at 60 °C.



5.5 Storage tank sizing and stratification

Key idea: A stratified tank keeps hot water on top and cold at the bottom, so you can draw more usable hot water from the same volume.

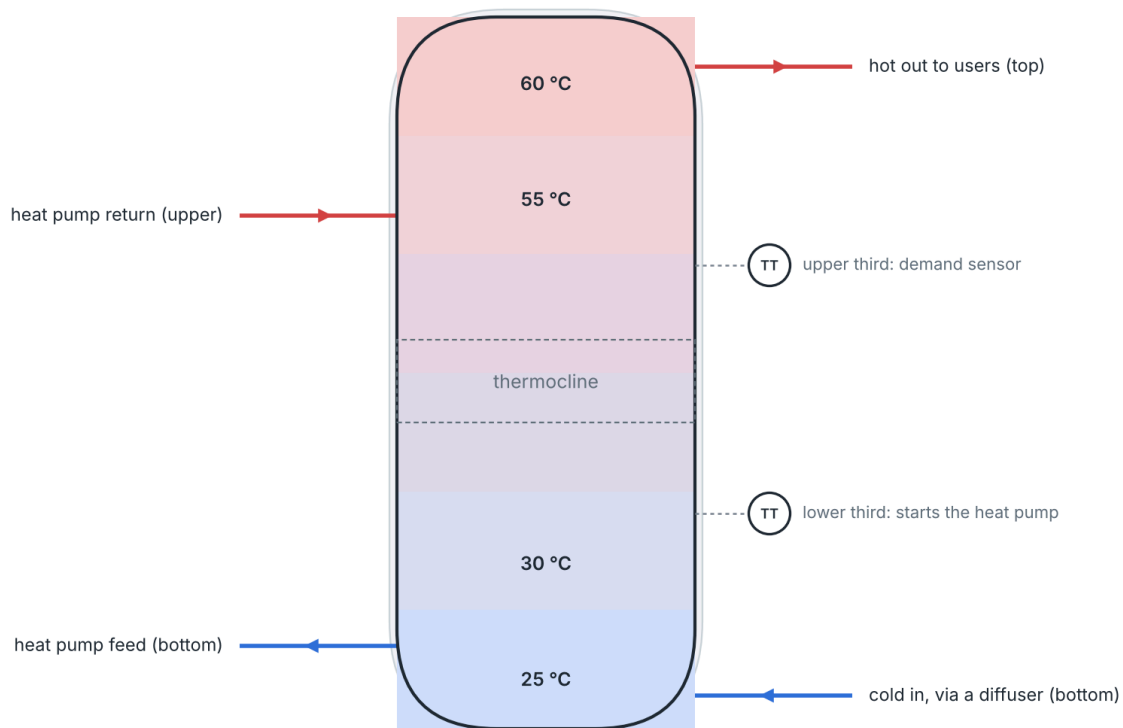
Hot water is lighter than cold. Left still, it forms layers: hot at the top, cold at the bottom, with a thin mixing zone between called the thermocline. This is stratification. Stir the tank and the layers mix, and the effect is lost.

Good stratification means the heat pump gets cold water from the bottom, which raises its COP. The user gets hot water from the top at full temperature until the tank is almost empty.

How to keep stratification:

- Bring cold make-up in at the bottom through a diffuser, at low velocity (typical under 0.3 m/s at inlet).
- Take hot draw-off from the top.
- Return heat pump hot water to the top; take heat pump feed from the bottom.
- Prefer tall vertical tanks (height:diameter around 2:1 to 3:1).
- Avoid recirculation return lines dumping into the middle at high flow.

Stratified storage tank: keep hot on top, cold at the bottom



Stratified storage tank

Item	Typical value
Usable fraction, well stratified	0.8–0.9
Usable fraction, mixed tank	0.6–0.7
Storage temperature	55–60 °C
Legionella control	Store ≥ 60 °C, periodic pasteurisation cycle above 60 °C
Tank insulation	50–100 mm PUF, typical loss target < 1 °C per 12 h

Worked example — standing loss check

A 2,000 L tank at 60 °C in a 20 °C plant room loses heat at 2.0 W/K (UA, typical for well-insulated tank).

$$Q_{loss} = UA \times (T_{tank} - T_{room})$$

$Q_{loss} = 2.0 \times (60 - 20) = 80 \text{ W} = 1.92 \text{ kWh/day}$. Cost = $1.92 \div \text{COP } 3.8 \times ₹9 \approx ₹4.5/\text{day}$. Good insulation makes standing losses minor.

Remember

- Hot in at top, cold in at bottom, slowly.
- Tall tanks stratify better.
- Place the HP start sensor in the lower third.
- Store at 60 °C or run pasteurisation for Legionella safety.

Common mistake: A high-flow recirculation pump that mixes the whole tank and kills stratification.



5.6 Direct vs indirect heating

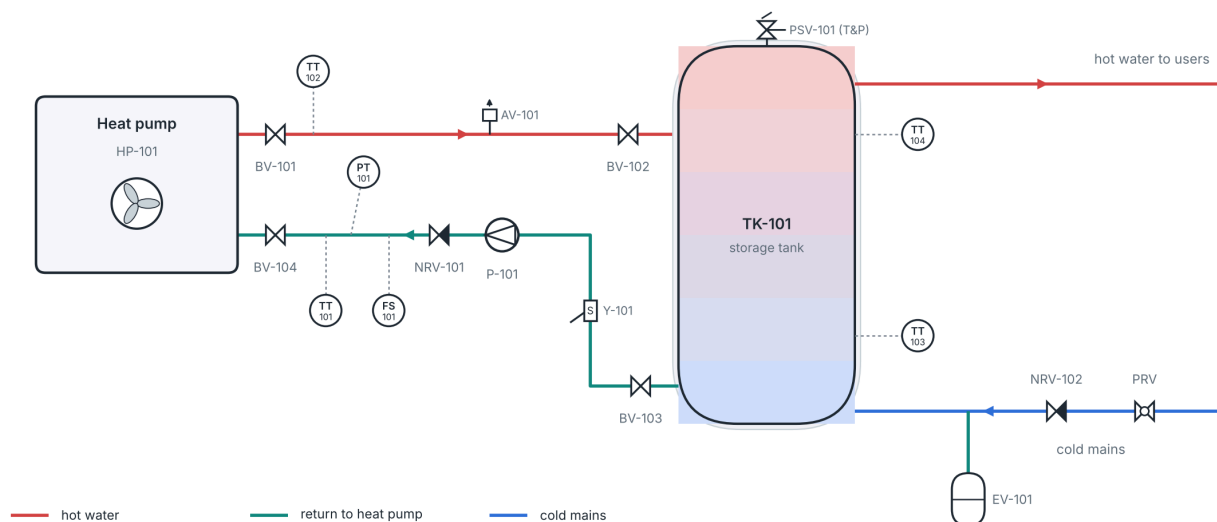
Key idea: Direct heating passes the user's water through the heat pump condenser; indirect heating keeps it in a separate loop through a heat exchanger.

In a direct system, the potable (drinking-quality) or process water flows straight through the heat pump's condenser. It is simple and has no exchanger losses. But hard or dirty water scales the condenser.

In an indirect system, the heat pump heats a closed loop of clean, treated water. A plate heat exchanger (PHE) or tank coil transfers heat to the user water. This protects the heat pump, at the cost of a 3–5 K approach (temperature lost across the exchanger) and an extra pump.

P&ID 1: direct heating

Tank water passes straight through the heat pump's condenser

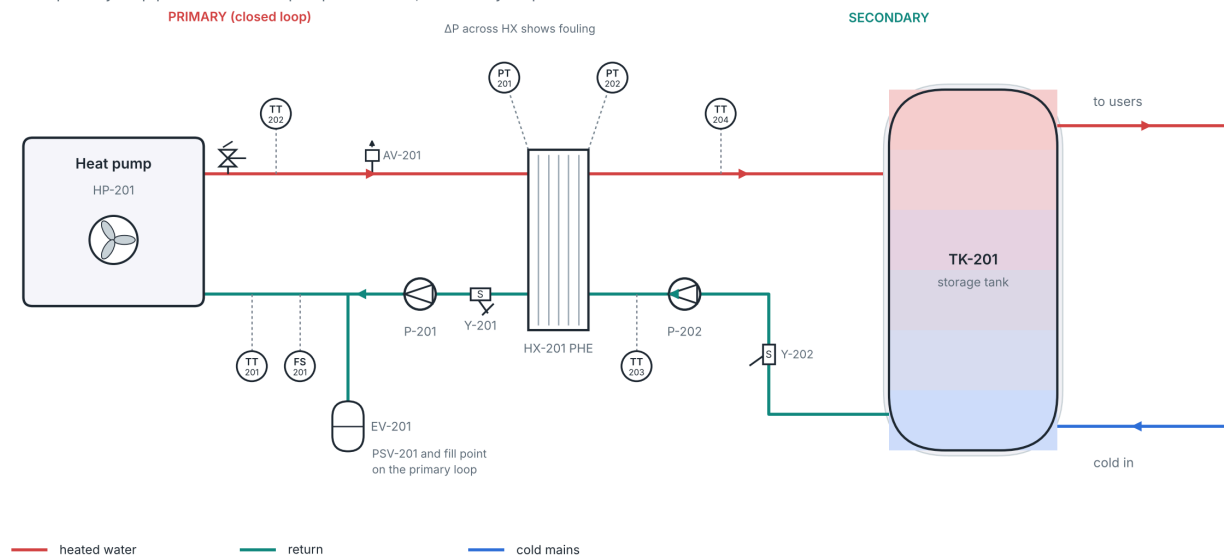


P&ID 1: direct heating

Create • Conserve • Sustain

P&ID 2: indirect heating through a plate heat exchanger

Closed primary loop protects the heat pump from scale; secondary loop heats the tank



P&ID 2: indirect heating through a plate heat exchanger

Factor	Direct	Indirect (PHE)
Efficiency	Best — no approach loss	COP lower by typical 5–10 %
Cost	Lower	Extra PHE, pump, controls
Scaling risk to HP	High with hard water	Low — closed treated loop
Maintenance	Descale HP condenser	Descale PHE (easy to open/CIP)
Best for	Soft water, RO water, small domestic	Hard water, process fluids, pools, hygiene

Worked example — approach penalty

Need 58 °C user water. PHE approach 4 K → primary must make 62 °C. If the envelope limit is 60 °C at design ambient, indirect fails while direct (58 °C) works. Either pick a higher-temperature unit or a closer-approach PHE (2 K, more plates).

Remember

- Direct is simpler and more efficient; indirect protects the machine.
- Use indirect when TDS/hardness is high or the fluid is not clean water.
- Add the PHE approach to the HP leaving water temperature.
- Fit isolation valves on both PHE sides for cleaning.

Field tip: Above about 150–200 mg/L hardness (as CaCO_3), plan indirect or softening from day one.

5.7 Hydraulics: piping, pumps, buffer tanks, flow rates

Key idea: The heat pump needs a steady, correct water flow — get the flow wrong and nothing else matters.

Flow rate links capacity and temperature rise:

$$\dot{V} [\text{m}^3/\text{h}] = \frac{Q [\text{kW}] \times 3600}{\rho c_p \Delta T} \approx \frac{0.86 Q}{\Delta T}$$

Most heat pumps want a ΔT of about 5 K across the condenser (typical 3–7 K). Too low a flow raises condensing temperature and trips on HP. Too high a flow wastes pump power and erodes pipes.

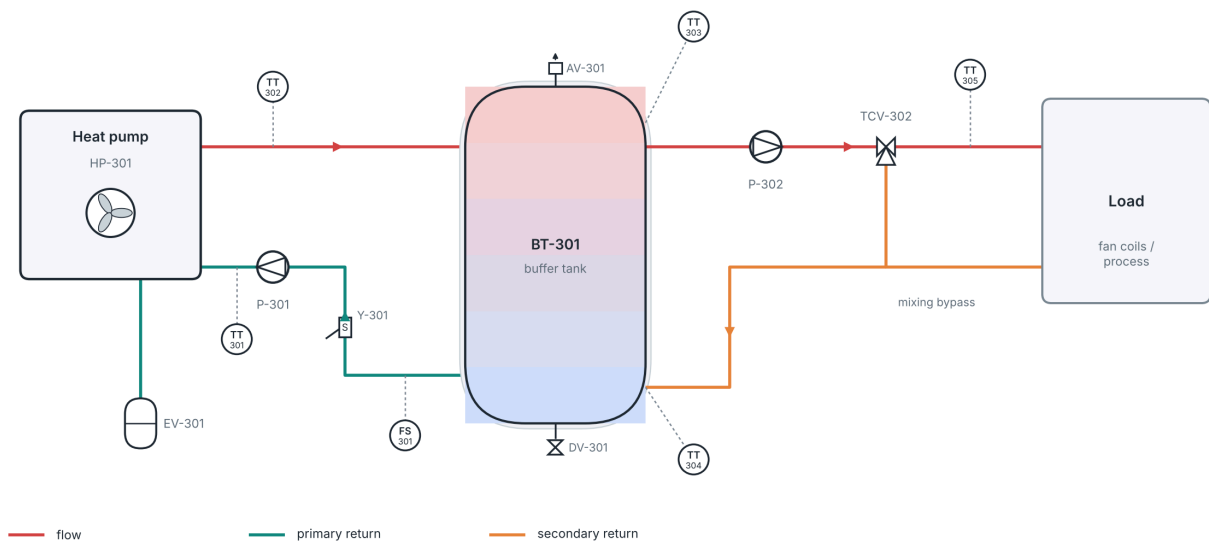
Pipe velocity guide (typical): 0.6–1.2 m/s for small pipes, up to 1.5–2.0 m/s for larger mains. Keep below about 2.5 m/s to limit noise and erosion.

A buffer tank adds water volume. It is used when (a) the system water volume is too small, causing short cycling (frequent stop-starts), (b) defrost needs heat stored, or (c) primary and secondary flows differ. The buffer then acts as a hydraulic separator: primary pump (HP side) and secondary pump (load side) work independently.

Minimum water volume rule of thumb: typical 5–10 L per kW for inverter units, 10–20 L per kW for on/off units. Check the manufacturer's figure.

P&ID 3: buffer tank, primary and secondary circuits

Heat pump flow and load flow are separated, so each pump can run at its own rate



P&ID 3: buffer tank, primary and secondary circuits

Capacity	Flow at ΔT 5 K	Typical pipe (copper/PPR/steel)
5 kW	0.86 m ³ /h (860 LPH)	22 mm Cu / 25 mm PPR / DN20
10 kW	1.72 m ³ /h	28 mm Cu / 32 mm PPR / DN25
20 kW	3.44 m ³ /h	35 mm Cu / 40 mm PPR / DN32
40 kW	6.9 m ³ /h	50 mm PPR / DN40
80 kW	13.8 m ³ /h	DN50–DN65

Worked example — pump for a 30 kW unit

Flow = $0.86 \times 30 / 5 = 5.16$ m³/h. Pipe DN40 (ID $\approx$ 41 mm): area = 0.00132 m²; velocity = $5.16/3600/0.00132 = 1.09$ m/s — fine. Head: condenser 3.5 m (from datasheet), pipe 30 m equivalent $\times$ 0.03 m/m = 0.9 m, strainer + valves 1.5 m $\rightarrow$ 5.9 m; add 15 % margin $\rightarrow$ about 6.8 m. Select a pump for 5.2 m³/h at about 7 m head: shaft power $\approx$ 212 W (hydraulic power $\approx$ 96 W) at 45 % pump efficiency.

$$P_{shaft} = \frac{\rho g H \dot{V}}{\eta} = \frac{1000 \times 9.81 \times 6.8 \times 5.16/3600}{0.45} \approx 212 \text{ W}$$

Remember

- Set flow for $\Delta T \approx 5$ K across the heat pump.
- Fit a strainer before the heat pump and a flow switch at its inlet.
- Use a buffer when water volume is small or flows differ.
- Air vents at high points, drains at low points.
- Where load-side demand swings widely (hotel recirculation, fan-coil loops), fit the secondary pump with a variable frequency drive (VFD): pump power falls roughly with the cube of speed, so running at part load saves far more energy than throttling a valve.

Common mistake: Undersized pipe from the client's old geyser line — the flow switch never makes.



5.8 Hybrid systems with solar thermal and boilers

Key idea: In a hybrid system, the cheapest heat source runs first and the heat pump or boiler tops up.

Solar thermal collectors (flat plate or evacuated tube) give free heat on sunny days. A heat pump gives heat at low running cost any time. A boiler (LPG, PNG or diesel) gives high temperature quickly and acts as backup.

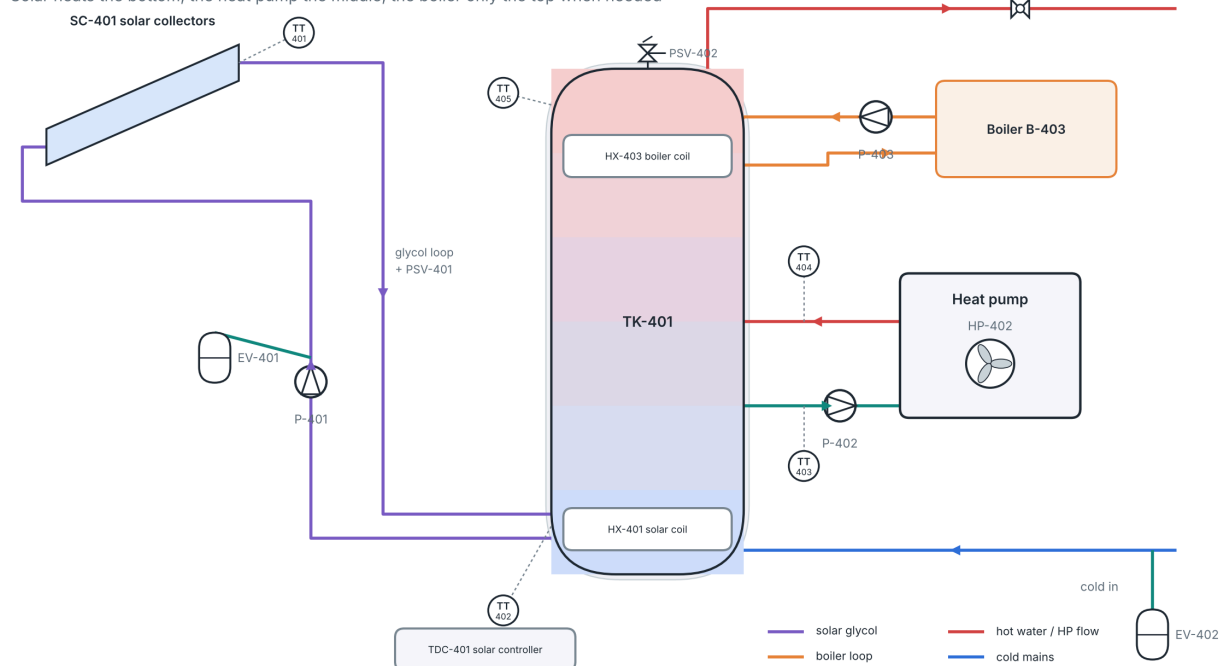
The usual order: solar preheats the bottom of the tank, the heat pump lifts water to 50–55 °C, and the boiler or electric heater tops up only for peaks, pasteurisation, or a heat pump failure.

Running cost per kWh of heat delivered (example rates):

Source	Example price	Efficiency	Cost per kWh heat
Solar thermal	free	—	≈ ₹0 (plus pump power)
Heat pump COP 3.5	₹9/kWh	350 %	₹2.6
PNG boiler	₹75/scm, ~10.5 kWh/scm (typical)	88 %	₹8.1
LPG boiler	₹100/kg, ~12.8 kWh/kg (typical)	88 %	₹8.9
Diesel boiler	₹100/L, ~10 kWh/L (typical)	85 %	₹11.8
Electric heater	₹9/kWh	~100 %	₹9.0

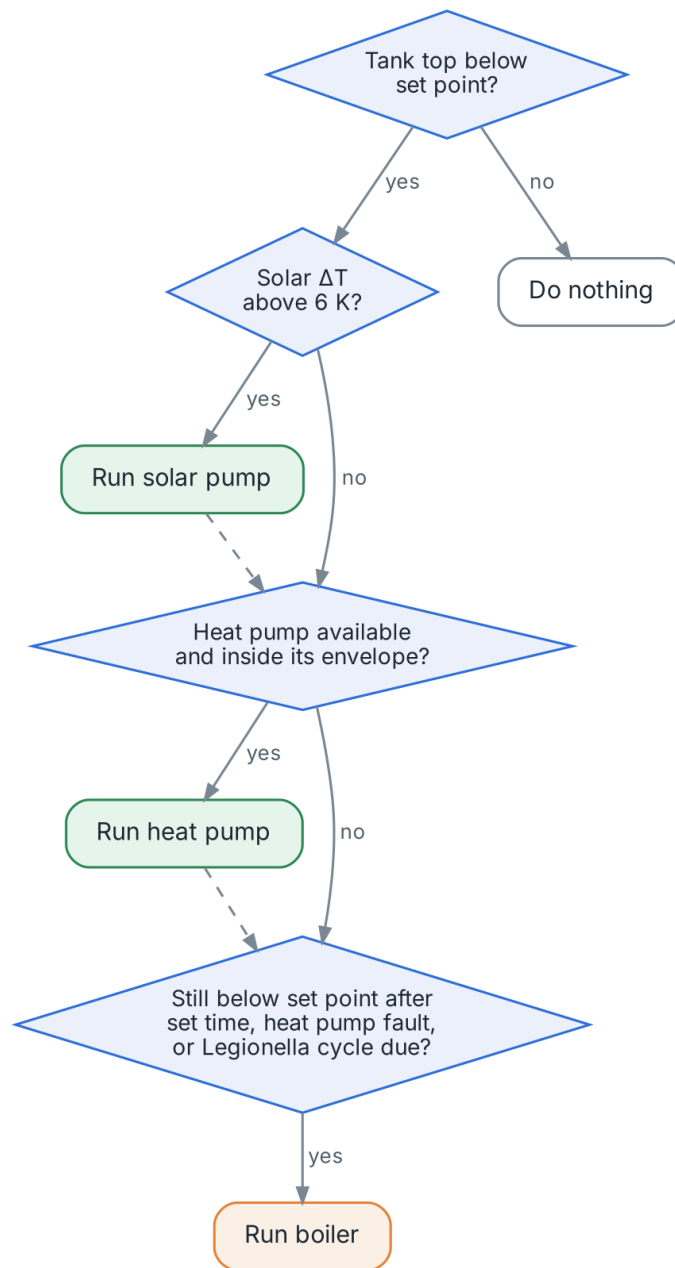
P&ID 4: hybrid system with solar thermal and boiler back-up

Solar heats the bottom, the heat pump the middle, the boiler only the top when needed



P&ID 4: hybrid with solar thermal and boiler back-up

Hybrid control: cheapest heat first



Hybrid control: cheapest heat first

Worked example — annual saving of adding a heat pump to an LPG boiler (Bengaluru hostel)

Load 150 kWh/day heat, 365 days = 54,750 kWh/year. Solar covers 40 % (typical in Bengaluru with good array) = 21,900 kWh. Remaining 32,850 kWh. LPG only: $32,850 \times ₹8.9 = ₹2.92$ lakh/year. HP covers 90 % of remainder, LPG 10 %: HP $29,565 \times ₹2.6 = ₹76,900$; LPG $3,285 \times ₹8.9 = ₹29,200$. Total ₹1.06 lakh. Saving $\approx ₹1.86$ lakh/year (example rates).

Remember

- Solar first, heat pump second, boiler last.
- Keep each source in its own tank zone to protect stratification.
- Solar heats the bottom, which lowers HP COP — size HP return accordingly.
- Use a TMV on outlet when sources can overheat the tank.



Field tip: Interlock so the boiler cannot run while the HP is meeting setpoint; check controller priorities at commissioning.



5.9 Multiple units: cascading and redundancy

Key idea: Several smaller heat pumps in cascade give better part-load efficiency and keep hot water flowing if one unit fails.

Cascading means connecting several heat pumps to one header and switching them on in stages as demand rises. A master controller rotates the lead unit to share running hours equally.

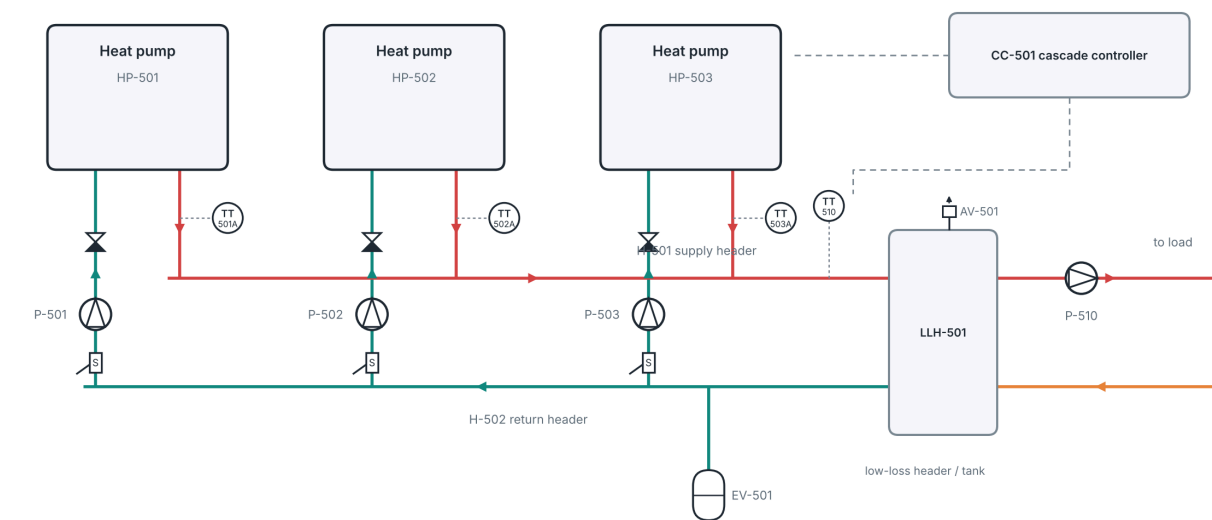
Redundancy is the spare capacity you keep for failure. N+1 means one more unit than needed. For a hospital or hotel, losing hot water is not acceptable, so N+1 is common.

Header design:

- Use a common supply and return header with reverse-return piping, or a low-loss header, so each unit gets equal flow.
- Each unit has its own pump (or motorised valve), NRV, isolation valves, strainer and flow switch.
- Size header velocity low (typical ≤ 0.6 m/s) so it acts as a hydraulic separator.

P&ID 5: three heat pumps in cascade on a common header

Each unit has its own pump and non-return valve; one controller stages them



Isolation valve pairs on every unit allow one heat pump to be serviced while the others run (redundancy).

P&ID 5: three heat pumps in cascade

Arrangement	Pros	Cons
One large unit	Low capital, simple	No backup, poor part-load
2 × 50 %	Some backup (50 %)	Half output on failure
3 × 50 % (N+1)	Full output with one down	Higher capital
4 × 33 % (N+1)	Fine staging, full backup	More pipework, controls

Worked example — redundancy choice for a 120 kW hospital load

Design load 120 kW at design ambient. Option 1: 3 × 40 kW (N). One failure → 80 kW = 67 % output.
Option 2: 4 × 40 kW (N+1). One failure → 120 kW = 100 %. Extra capital is one unit; for a hospital, choose N+1.

Remember

- Cascade for part-load efficiency and resilience.
- Equal flow to each unit: reverse return or individual pumps with balancing.
- NRV on every unit to stop back-flow through idle units.
- Rotate lead unit to equalise hours.

Common mistake: No NRV on idle units — hot water bypasses back through them and the header never reaches setpoint.



5.10 Water quality and material selection

Key idea: Bad water kills heat exchangers faster than anything else, so match materials and treatment to the site water.

Indian water ranges from soft rainwater to borewell water with TDS above 1,500 mg/L. Hardness (calcium and magnesium) forms scale on hot surfaces. Scale is a thermal blanket: a 1 mm layer can cut heat transfer noticeably and raise condensing pressure.

Key terms:

- TDS (total dissolved solids): all dissolved salts, mg/L (ppm).
- Hardness: calcium + magnesium, expressed as mg/L CaCO_3 .
- Chlorides: attack stainless steel (pitting), especially when hot.
- pH: acidity; below about 6.5 corrodes copper, above about 9 encourages scale.

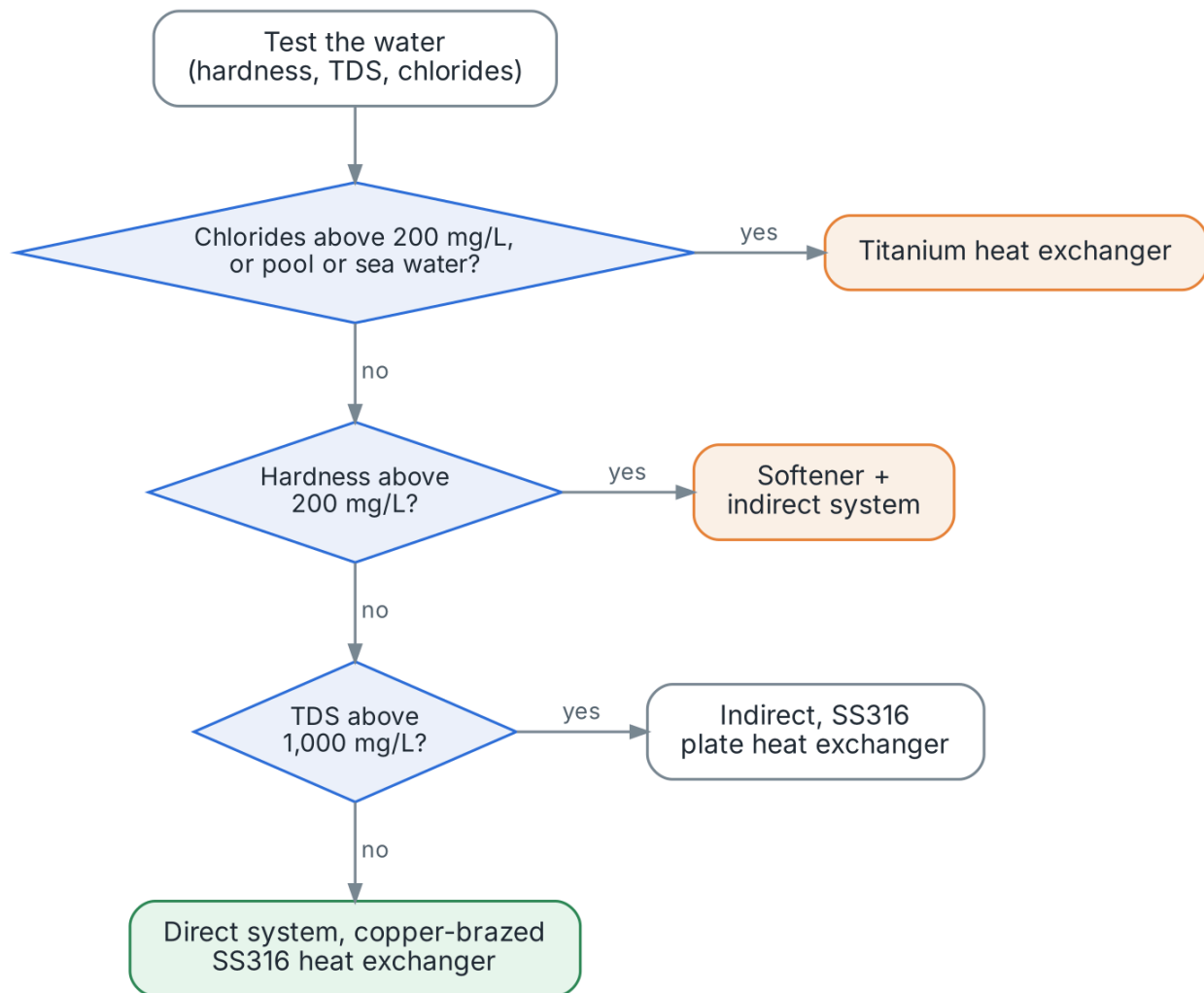
Typical guide values for water passing through a brazed plate or coaxial condenser (check manufacturer):

Parameter	Typical acceptable	Comment
pH	7.0–9.0	
Total hardness	< 150–200 mg/L as CaCO_3	Soften above this
TDS	< 500 mg/L (preferred), up to ~1,000 with care	
Chlorides	< 100–200 mg/L for SS304	SS316 or titanium above
Free chlorine	< 0.5–1 mg/L	Pools need care
Iron	< 0.2 mg/L	Fouling

Material selection:

Water type	Condenser material
Soft / RO municipal	Copper-brazed SS316 plate or copper coaxial
Hard borewell	Indirect loop + softener; SS316 PHE on user side
Swimming pool (chlorinated)	Titanium coil
Sea / brackish water	Titanium
Process with ammonia contact	Nickel-brazed or fully welded SS (no copper)

Choose materials from a water test (typical limits)



Choose materials from a water test

Worked example — scale penalty

A unit in Jaipur on borewell water (hardness 450 mg/L) builds scale. Condensing temperature rises 4 K. Rule of thumb: COP falls roughly 2–3 % per K of extra lift (typical). COP drops from 3.5 to about $3.5 \times (1 - 0.025 \times 4) = 3.15$. On 200 kWh heat/day: electricity rises from 57.1 to 63.5 kWh/day = 6.4 kWh $\times$ ₹9 = ₹58/day $\approx$ ₹21,000/year, before the cost of a failed condenser.

Remember

- Test the water before selecting: pH, hardness, TDS, chlorides, iron.
- Pools and sea water need titanium.
- High hardness $\rightarrow$ softener and/or indirect loop.
- Plan CIP (clean-in-place) connections on PHEs.

Field tip: Carry a TDS pen and a hardness strip kit to every site survey.

5.11 Electrical design: supply, protection, starting current

Key idea: The electrical supply must handle the heat pump's running current, its starting current and the local voltage swings.

Heat pumps up to about 5–7 kW heating output are often single phase (230 V). Larger units are usually three phase (415 V). Check the nameplate for rated input current, maximum running current (at the hottest/most loaded condition), and locked rotor amps (LRA), the current a fixed-speed compressor draws for a moment at start.

Starting current:

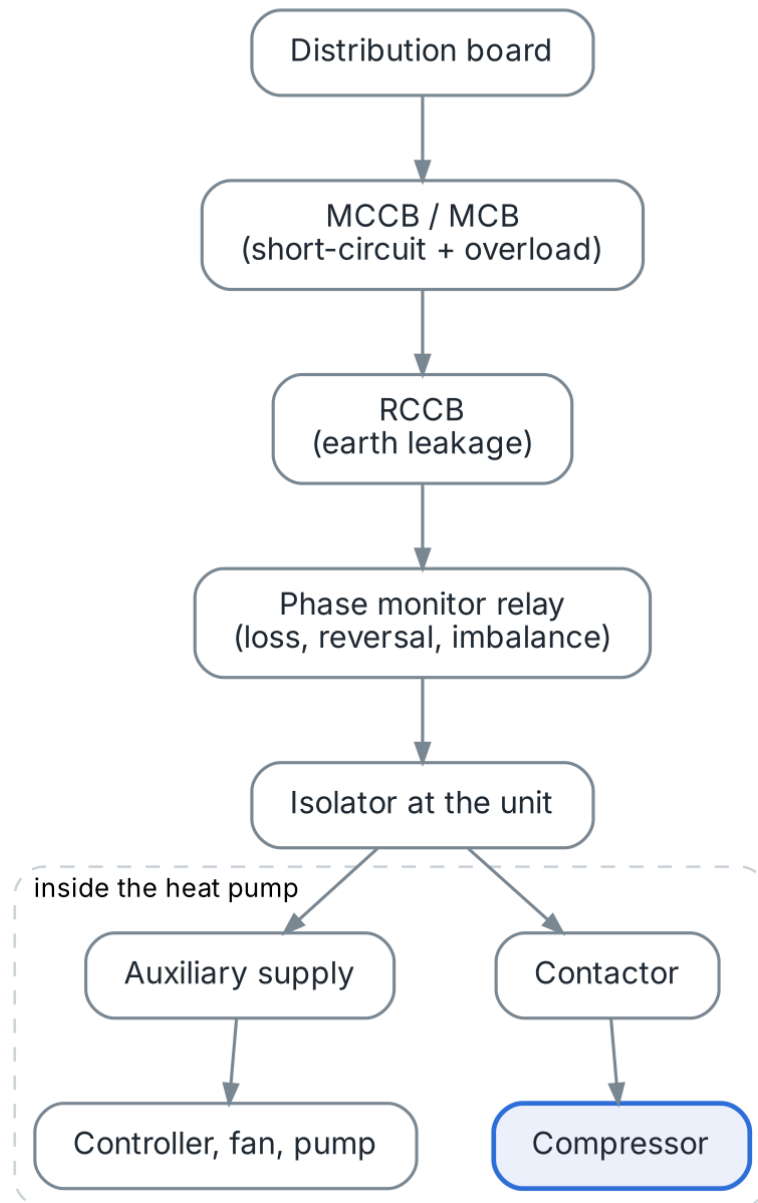
- A fixed-speed scroll compressor on direct-on-line (DOL) start can draw 5–7 times running current for a fraction of a second.
- Soft starters reduce this to typical 2–3 times.
- Inverter compressors ramp up gently; inrush stays near running current.

Indian supply issues: voltage can sag to 180–200 V on single phase in rural areas, and phases can be unbalanced. Use a phase-failure and phase-sequence relay, and a voltage monitor or stabiliser sized for the starting kVA where supply is weak.

Protection chain (typical): incoming MCB/MCCB → RCCB/RCBO (earth leakage, 30 mA for personnel protection or 100–300 mA for equipment per local practice) → contactor → overload relay or compressor motor protector. Fit a local isolator next to the outdoor unit. Earth properly — test earth resistance.



Electrical supply to a heat pump: single-line view



Electrical supply: single-line view

Unit heating output	Typical supply	Typical running current (indicative)
3–5 kW	1-phase 230 V	4–7 A
10 kW	3-phase 415 V	4–6 A per phase
25 kW	3-phase 415 V	10–14 A per phase
50 kW	3-phase 415 V	20–28 A per phase

Worked example — cable and MCB for a 25 kW (heat) unit

COP at design 3.0 → electrical input $25/3.0 = 8.3$ kW. Max running input (hot day, high water) say 10 kW, pf 0.9.

$$I = \frac{P}{\sqrt{3} V \cos \phi}$$

$I = 10,000 / (1.732 \times 415 \times 0.9) = 15.5 \text{ A}$. Choose a 20 A C-curve or D-curve MCB (D-curve if DOL start with high LRA). Cable: 4 mm² copper, 4-core armoured, typical for runs up to about 30 m; check voltage drop (keep under 3–5 %) and derating for grouping and ambient. Starting check (fixed speed, LRA 6 × 15.5 ≈ 93 A): transformer/DG must accept this dip. With a soft starter, about 40 A.

Remember

- Size cable on maximum running current, not nominal.
- Check LRA against DG and weak grid supply.
- Phase monitor + RCCB + local isolator on every installation.
- Voltage drop under 3–5 % at full load.

Common mistake: Running a DOL unit on a small DG set sized only for running kW — it stalls at every start.



Quiz 5

1. A datasheet lists 10 kW at 20 °C DB / 15 °C WB, water 15 → 55 °C. At 5 °C ambient you should expect:
A) more than 10 kW B) exactly 10 kW C) less than 10 kW D) the same kW but lower COP only
2. The main purpose of an operating envelope is to show: A) noise levels B) safe ambient and water temperature combinations C) refrigerant charge D) pump head
3. Daily hot water energy for 3,000 L heated by 35 K is about: A) 61 kWh B) 122 kWh C) 244 kWh D) 35 kWh
4. Increasing running hours from 8 to 16 h for the same daily load generally: A) doubles the HP size B) halves the HP size but needs more storage C) needs no storage D) halves running cost
5. In a well stratified tank, the heat pump should take its feed from: A) the top B) the middle C) the bottom D) the hot outlet
6. Indirect heating via a PHE is preferred when: A) water is RO-treated and soft B) water is hard or the fluid is not clean water C) maximum COP is the only goal D) the site has no space
7. Flow for a 20 kW heat pump at ΔT 5 K is about: A) 0.86 m³/h B) 1.7 m³/h C) 3.4 m³/h D) 6.9 m³/h
8. In a hybrid solar + HP + boiler system, the normal operating priority is: A) boiler, HP, solar B) HP, boiler, solar C) solar, HP, boiler D) all together
9. In a cascade of heat pumps on a common header, each unit needs a non-return valve mainly to: A) reduce noise B) stop flow bypassing back through idle units C) raise COP D) meter energy
10. For a swimming pool with chlorinated water, the best condenser material is: A) copper B) SS304 C) titanium D) mild steel

Answer key

1. C — capacity falls as ambient air gets colder.
2. B — it maps where the compressor can run without tripping.
3. B — $3,000 \times 4.186 \times 35 / 3600 \approx 122$ kWh.
4. B — same energy over twice the hours halves kW; storage must cover more of the peak.
5. C — cold bottom water gives the best COP and keeps layers.
6. B — the closed primary loop protects the heat pump.
7. C — $0.86 \times 20 / 5 = 3.44$ m³/h.
8. C — cheapest heat first; boiler only tops up.
9. B — without NRVs, water short-circuits through stopped units.
10. C — titanium resists chloride attack.

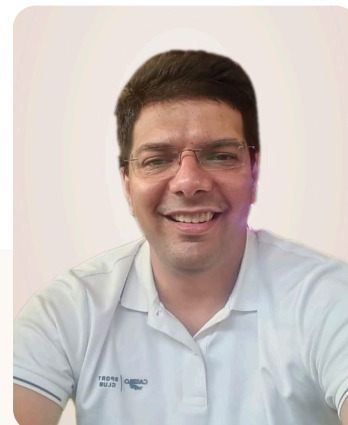
Glossary

Term	Meaning
Rating condition	The ambient and water temperatures at which a datasheet value was measured
Dry-bulb (DB) / Wet-bulb (WB)	Air temperature / temperature that also reflects humidity
COP	Heat delivered divided by electrical input
Derating	Reducing rated capacity to actual capacity at site conditions
Design ambient	The low outdoor temperature the system is designed to work at
Defrost	Melting ice off the outdoor coil, which briefly stops heating
Operating envelope	Map of allowed ambient vs leaving water temperatures
LWT	Leaving water temperature from the heat pump
EVI	Enhanced vapour injection, a compressor feature for cold climates and high water temperatures
Stratification	Hot water layer on top of cold in a still tank
Thermocline	The mixing zone between hot and cold layers
Usable fraction	Share of tank volume delivered at useful temperature
Direct heating	User water flows through the heat pump condenser
Indirect heating	A closed loop heats user water through a heat exchanger
PHE	Plate heat exchanger
Approach	Temperature difference between the two fluids at the exchanger end
Buffer tank	Extra water volume that prevents short cycling and separates circuits
Short cycling	Frequent stops and starts that wear the compressor
Hydraulic separator / low-loss header	Device that lets primary and secondary flows run independently
Cascade	Several units staged on one header
N+1	One more unit than needed, for redundancy
TDS	Total dissolved solids in water, mg/L
Hardness	Calcium and magnesium content, as mg/L CaCO ₃
CIP	Clean-in-place connections for descaling
LRA	Locked rotor amps, the momentary starting current
DOL	Direct-on-line motor starting
RCCB	Residual current circuit breaker for earth leakage protection
P&ID	Piping and instrumentation diagram
TT / PT / FT / FS	Temperature transmitter / pressure transmitter / flow transmitter / flow switch

ABOUT THE AUTHOR

Kashyap Anandpara

Founder Director, Sunniva Encon LLP



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

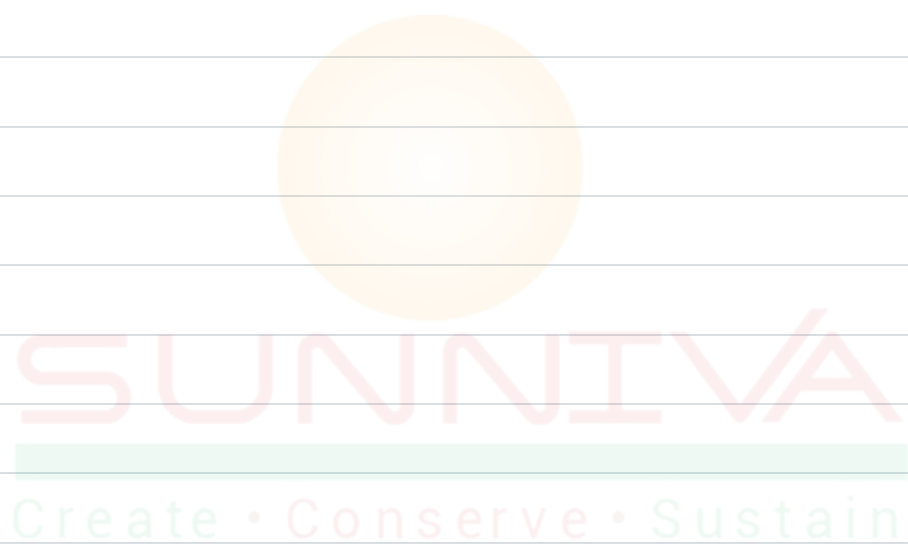
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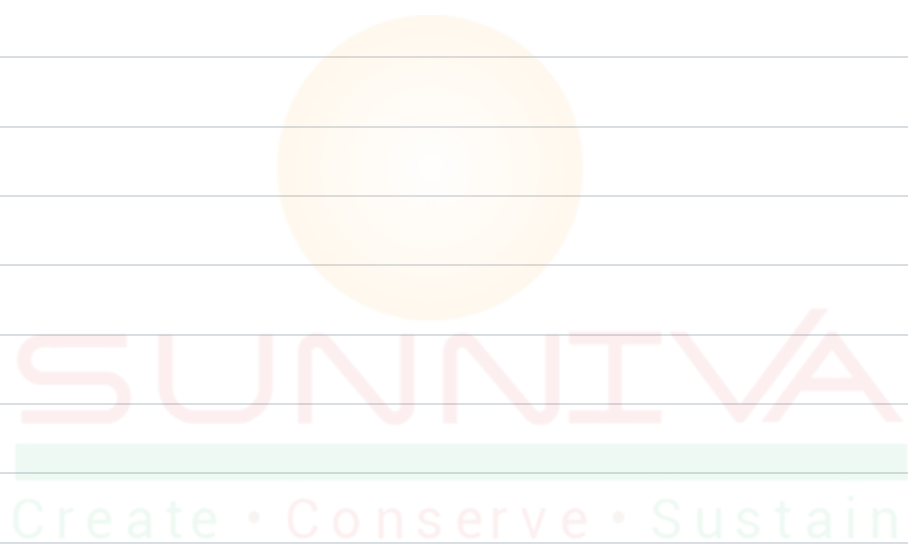
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NOTES



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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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