



# Superheat and Subcooling

MODULE F6

FOUNDATIONS

PREREQ F5

A homeowner in Surprise says her system "just is not keeping up." The outdoor unit is running. The air coming out of the vents feels sort of cool. The breaker has not tripped. Nothing is obviously broken. Two technicians pull up to this exact call. The first one connects gauges, sees a suction pressure that looks "a little low," and adds refrigerant. The second one measures two numbers, superheat and subcooling, does thirty seconds of math, and knows the charge is fine and the real problem is a dirty blower wheel choking airflow. The first tech just overcharged a healthy system. The second tech fixed the actual problem. This module makes you the second tech.

## Short Version

Superheat tells you the evaporator finished its job: every drop of liquid refrigerant boiled off before the suction line, so the compressor is safe and you can see how well the coil is being fed. Subcooling tells you the condenser finished its job: a solid column of pure liquid is leaving the coil, and on a TXV system it is your best read on charge level. You measure each one with a pressure, a temperature, and one subtraction. Superheat is measured suction line temperature minus suction saturation temperature. Subcooling is liquid saturation temperature minus measured liquid line temperature. TXV systems should run about 10 degrees of superheat plus or minus 5, and about 8 to 12 degrees of subcooling unless the nameplate says otherwise. Together, these two numbers are the language every refrigerant-side diagnosis is spoken in.

## Key Values

VALUE	TARGET OR THRESHOLD	NOTES
Superheat, TXV system	10 F plus or minus 5 (6 to 14 F typical)	Measured at the evaporator outlet; up to about 20 F can be acceptable when measured at the condenser end of a long line set
Superheat, fixed orifice system	Varies with conditions	No single target. Use the manufacturer charging chart with outdoor temperature and indoor wet bulb
Subcooling, TXV system	8 to 12 F typical	The nameplate or install data overrides this range. Always check the data plate first
Superheat danger threshold	Near 0 F	Liquid may be reaching the compressor. Floodback risk. Stop and investigate
Subcooling danger threshold	Very high (20 F and up on a 10 F nameplate)	Suggests overcharge or a liquid line restriction. Liquid is stacking in the condenser

VALUE	TARGET OR THRESHOLD	NOTES
Superheat measurement point	Suction line at the condenser, 6 inches from the service valve	Clamp probe on clean, bare copper. Insulate over the probe
Subcooling measurement point	Liquid line at the service valve	Clamp probe on clean, bare copper. Shield from direct sun
Useful R-410A PT anchors	118.4 psig is 40 F, 130 psig is 45 F, 317 psig is about 100 F, 390 psig is about 115 F	From F5. Saturation temperature is what the pressure tells you

## Field Checklist

This is the full measurement procedure, start to finish. Do it the same way every time.

1. Confirm the system has been running in cooling for at least 10 to 15 minutes with doors and panels in their normal positions. A system that just started has not stabilized and its numbers mean nothing yet.
2. Verify basic airflow first: filter in place and reasonably clean, registers open, blower running. Bad airflow will poison your refrigerant numbers before you ever touch a gauge.
3. Connect your pressure probes or gauges to the suction and liquid service ports. Purge or use low-loss fittings as you were taught in F2 so you are not venting charge.
4. Clamp a temperature probe on the suction line about 6 inches from the suction service valve. The copper must be clean and bare at the clamp point. Scuff off oxidation or paint if needed. The probe jaw must sit flat on the pipe, not cocked on a fitting or a bend.
5. Insulate over the suction probe. Wrap the clamp and the pipe around it with pipe insulation or a rag. In Phoenix, outdoor air is often hotter than the pipe, and an uninsulated probe reads the air, not the refrigerant.
6. Clamp a second temperature probe on the liquid line at the liquid service valve, on clean bare copper, shielded from direct sun.
7. Wait for stability. Watch the readings until pressures and temperatures hold steady, drifting less than about 1 degree and a couple of psi over a full minute. On most systems this takes several minutes after probes go on. Do not record a number that is still moving.
8. Convert suction pressure to saturation temperature using your PT app or chart for the refrigerant in the system. That saturation temperature is your evaporator coil boiling temperature, exactly as you learned in F5.
9. Calculate superheat: measured suction line temperature minus suction saturation temperature.
10. Convert liquid pressure to saturation temperature.
11. Calculate subcooling: liquid saturation temperature minus measured liquid line temperature.
12. Compare both numbers to targets: nameplate subcooling if listed, otherwise 8 to 12 F; superheat 10 plus or minus 5 on a TXV, or the charging chart value on a fixed orifice.
13. Record both numbers, the pressures, the line temperatures, the outdoor temperature, and the indoor return conditions. If a reading is impossible, negative superheat or negative subcooling, your measurement is

wrong. Fix the probe, not the system.

#### IB STANDARD

Island Breeze requires superheat AND subcooling recorded on every refrigerant-side call in ServiceTitan. Not one or the other. Both numbers, with the pressures and line temperatures behind them, go in the job record every time gauges or probes touch a system. A refrigerant diagnosis without both numbers documented is an incomplete call.

## Full Breakdown

### Building superheat from saturation

In F5 you learned the most important idea in refrigeration: at any given pressure, a refrigerant has one saturation temperature, the temperature where it boils and condenses. As long as liquid and vapor exist together, the refrigerant sits exactly at that saturation temperature. It cannot get hotter while there is still liquid present, the same way a pot of boiling water on the stove stays at 212 F no matter how hard the burner roars, because all the extra heat goes into changing liquid to vapor instead of raising the temperature.

Now walk into the evaporator with that idea. Refrigerant leaves the metering device as a cold mixture, roughly 70 percent liquid and 30 percent vapor, all of it at saturation temperature. Say the suction pressure is 118.4 psig on an R-410A system. From the PT relationship, that is a 40 F saturation temperature, so the refrigerant boiling through that coil is at 40 F. Warm indoor air blows across the coil, heat pours into the refrigerant, and the liquid boils, staying pinned at 40 F the entire time, just like the pot of water.

Then, somewhere inside the coil, the last droplet of liquid boils away. From that point on there is nothing left to boil. Now the heat from the indoor air starts raising the temperature of the vapor itself. The vapor climbs above saturation: 42, 45, 48 F. Any temperature above saturation, in vapor, is called superheat.

**Superheat is the number of degrees the vapor has climbed above its saturation temperature.** If the suction line measures 52 F and saturation is 40 F, the superheat is 12 F.

The math, every time:

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`` Superheat = measured suction line temperature - suction saturation temperature Superheat = 52 F  
- 40 F = 12 F ``
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You never measure superheat directly with one instrument. It is always two readings and a subtraction: a pressure (converted to saturation temperature) and a line temperature.

### What superheat signifies

Superheat is proof of two things at once.

First, it is proof that no liquid is reaching the compressor. Vapor can only be hotter than saturation if every drop of liquid is gone. A compressor is a vapor pump. Liquid does not compress, and liquid slugging into a compressor washes out its oil and beats up its valves and internals. A healthy superheat reading is a signed certificate that the compressor is receiving dry vapor only. This is the safety meaning of superheat.

Second, superheat is a measure of how well the evaporator is being fed. Picture the point inside the coil where the last droplet boils off. If the metering device feeds generously, that point moves toward the end of the coil: more of the coil is full of boiling liquid, the coil absorbs more heat, and the vapor has only a short distance to warm up, so superheat is low. If the metering device starves the coil, the last droplet boils off early, a long stretch of coil is doing nothing but warming vapor, and superheat is high. Low superheat means a full coil. High superheat means a starved coil.

These two meanings pull against each other. A fuller coil moves more heat, but the closer superheat gets to zero, the thinner the safety margin against liquid escaping the coil. That is why the TXV target is about 10 F plus or minus 5: full enough to perform, with margin against floodback. There is also a floor below which a TXV cannot control smoothly and starts oscillating open and closed, called hunting; you will go deep on that in C11.

## Building subcooling from saturation

Now go to the other coil. Hot, high-pressure vapor leaves the compressor and enters the condenser well above its saturation temperature. The condenser does three jobs in sequence. First it cools the hot vapor down to saturation temperature, called desuperheating. Then the vapor condenses to liquid, sitting at saturation temperature the whole time, the boiling pot running in reverse. Finally, once the last bubble of vapor has condensed, the pure liquid keeps giving up heat to the outdoor air and drops below saturation temperature.

Liquid that is colder than its saturation temperature is subcooled. **Subcooling is the number of degrees the liquid has dropped below its saturation temperature.**

Say the liquid pressure on an R-410A system is 390 psig, which converts to a saturation temperature of about 115 F. If the liquid line at the service valve measures 105 F, the subcooling is 10 F.

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`` Subcooling = liquid saturation temperature - measured liquid line temperature Subcooling = 115 F - 105 F = 10 F ``
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Notice the subtraction flips compared to superheat. For superheat, the measured temperature is the bigger number because the vapor climbed above saturation. For subcooling, the saturation temperature is the bigger number because the liquid dropped below it. If you ever calculate a negative superheat or negative subcooling, the system is not breaking physics; your measurement is wrong.

## What subcooling signifies

Subcooling is proof of a full liquid seal at the condenser exit. Liquid can only be colder than saturation if it is 100 percent liquid with no vapor bubbles mixed in. That matters because the metering device downstream is designed to feed solid liquid. Bubbles in the liquid line starve the evaporator and make every reading downstream lie to you.

On a TXV system, subcooling is also your best read on charge level. Here is why. The TXV holds superheat at its setpoint by opening and closing automatically, so on a TXV system superheat mostly tells you about the valve and the evaporator, not about how much refrigerant is in the system. The extra refrigerant has to show up somewhere, and it shows up as liquid stacked in the bottom of the condenser. More charge means a taller stack of liquid, which spends more time cooling below saturation, which means more subcooling. Less charge means a shorter stack and less subcooling. Subcooling is, in effect, a dipstick reading of how much liquid is stored in

the condenser. That is why TXV systems are charged to a subcooling target, usually printed on the nameplate, typically in the 8 to 12 F range.

## Reading high and low

**High superheat means a starved evaporator.** The last droplet boiled off early and a long stretch of coil is wasted on warming vapor. Causes: low charge (not enough refrigerant to feed the coil), a restriction in the liquid line or metering device (refrigerant cannot get through), or a TXV that is underfeeding (stuck nearly closed, lost bulb charge, or misadjusted). Chronic high superheat also means the compressor breathes hot, thin vapor. Cool suction vapor is what carries heat away from compressor motor windings, so a compressor that runs years of high superheat runs hot and dies early. The damage is delayed, like sun damage to skin: nothing fails today, but the lifespan quietly shrinks.

**Low superheat means a flooded or overfed evaporator.** The liquid is boiling off at the very end of the coil or not finishing at all. Causes: overcharge on a fixed orifice system (a fixed hole passes more refrigerant as you add charge), an overfeeding TXV (stuck open, bulb lost contact with the line so it senses warm air and drives the valve open), or low airflow on a fixed orifice system (the coil absorbs less heat, so liquid does not finish boiling). Superheat near zero is the danger threshold: liquid may already be leaving the coil and heading for the compressor.

**High subcooling means liquid is stacking in the condenser.** Causes: overcharge (too much refrigerant, all of it parked as liquid), or a downstream restriction such as a plugged filter drier or a TXV stuck nearly closed, which dams refrigerant up into the condenser. A very high subcooling reading also raises head pressure, because stacked liquid eats condensing surface area.

**Low subcooling means the liquid seal is thin or broken.** Causes: low charge most commonly, or a TXV stuck wide open draining the condenser faster than it can build a liquid column. At very low subcooling, vapor bubbles can ride out into the liquid line.

## Why these two numbers together are the language of diagnosis

One number alone is ambiguous. High superheat could be low charge, or a restriction, or an underfeeding valve. You cannot tell which from superheat by itself. But pair it with subcooling and the picture sharpens:

SUPERHEAT	SUBCOOLING	STRONGEST SUSPICION
High	Low	Low charge. The whole system is starved of refrigerant
High	High	Restriction or underfeeding TXV. Refrigerant exists but is dammed up in the condenser and cannot reach the evaporator
Low	High	Overcharge, especially on fixed orifice. Too much refrigerant everywhere
Low	Low or normal	Overfeeding TXV, often a bulb contact or insulation problem. The valve is dumping the condenser into the evaporator

This is why the two numbers are called the language of diagnosis: each one is a letter, and only together do they spell a word. Pressures alone cannot do this. A low suction pressure shows up in low charge, in airflow problems, and in metering problems alike, which is exactly how healthy systems get refrigerant they do not

need. In D24 you will extend this table into the full charge misdiagnosis triangle, low charge versus TXV versus airflow, and add pressures, temperature splits, and amp draws as additional letters in the word. The table above is the foundation it all stands on.

One more rule that will save you from chasing ghosts: when one reading is wildly out of line and everything else looks normal, suspect the measurement before the system. A loose probe, sun on the clamp, or a system still settling produces outlier numbers constantly. One impossible or out-of-family reading is usually a measurement problem, not a system problem.

## Measurement craft

The math is easy. The craft is in the measurement, and the measurement is where most techs go wrong.

**Probe quality.** A clamp probe with a clean, firm, spring-loaded jaw on bare copper reads the pipe. A worn-out clamp, a probe lying loosely against the line, or a bead thermometer taped on with one wrap of tape reads something between the pipe and the air. Your superheat math is only as good as the single line temperature feeding it; a 5 degree probe error is a 5 degree superheat error, which can flip a diagnosis.

**Placement.** Superheat: suction line at the condenser, 6 inches from the service valve, on a straight section of clean bare copper, not on a fitting, a bend, or the valve body itself. Subcooling: liquid line at the service valve, same rules. Be consistent so your numbers are comparable from visit to visit, and remember from the source physics that a long line set running through a hot attic adds heat to the suction line, so superheat measured at the condenser reads higher than superheat at the evaporator outlet. On long line sets, up to about 20 F at the condenser can still be acceptable on a TXV system.

**Ambient interference.** A temperature probe sitting in 115 F air, clamped to a 55 F pipe, is being pulled toward the air temperature the entire time. Insulate over the suction probe, every time, so the probe sees only pipe. The liquid line cuts the other way: a dark copper liquid line soaking in direct sun carries a skin temperature above the refrigerant inside it, which understates your subcooling. Shade it, clamp on the underside, and give it time.

**Stability.** Refrigerant systems breathe. Pressures and temperatures swing for minutes after startup, after a panel goes back on, or after clouds pass. Record numbers only when they have stopped moving. A snapshot of a moving target is not data.

### PHOENIX FIELD NOTE

Phoenix sun is a measurement saboteur. A liquid line in direct afternoon sun can read several degrees above the refrigerant actually inside it, which makes your subcooling calculation come out low and tempts you to add charge a system does not need. Clamp the liquid probe on the underside of the pipe, shade it with your hand, a rag, or your body, and let it settle before you trust it. If the subcooling number jumps the moment your shadow covers the line, the sun was in your reading.

## PHOENIX FIELD NOTE

At 118 F ambient, everything about your gauge reading runs high and tight. Condensing temperature rides 15 to 30 F above ambient, so expect R-410A head pressures in the 475 to 500 psig neighborhood on a brutal afternoon, and remember from F5 that R-410A condensing in the 130s is closing in on its 160 F critical temperature, so small charge errors swing the numbers harder than they would on a 90 F day. Hoses and manifolds baking on a rooftop also pick up heat. None of that means the system is broken. Judge the system against saturation math and nameplate targets at the actual ambient, not against the pressures you remember from a spring tune-up.

## Common Mistakes

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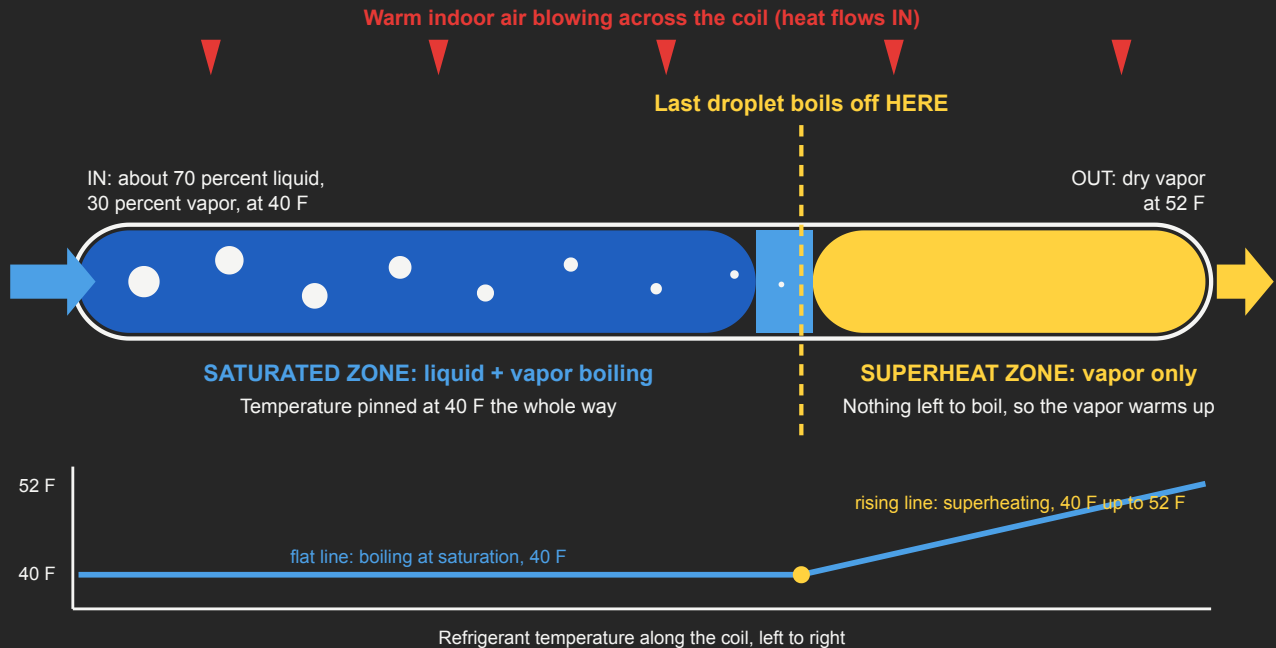
1. **Measuring on an unstable system.** Probes go on, numbers appear, tech writes them down 90 seconds later. The system was still settling and every number was a lie. Give it 10 to 15 minutes of runtime and wait for readings to hold steady before you record anything.
2. **Bad probe contact.** A clamp cocked on a bend, sitting on paint or oxidation, or hanging loose reads air, not refrigerant. Clean copper, flat contact, straight section, insulation over the suction probe. If superheat or subcooling comes out negative, your probe is lying, not the laws of physics.
3. **Using the wrong saturation side for subcooling.** Subcooling uses the liquid line pressure converted to its saturation temperature. Grabbing the suction saturation number, or mixing up which gauge feeds which calculation, produces nonsense like 60 F of subcooling. High side pressure for subcooling, low side pressure for superheat, every time.
4. **Charging to superheat on a TXV system.** The TXV actively holds superheat at its setpoint, so superheat barely moves as you add charge, and a tech chasing a superheat target on a TXV will keep adding refrigerant while the valve keeps absorbing it. TXV systems are charged to the subcooling target. Superheat method belongs to fixed orifice systems, with the manufacturer charging chart.
5. **Condemning charge from pressures alone.** "Suction is low, it needs a pound" is the most expensive sentence in residential HVAC. Low suction pressure happens with low charge, low airflow, and metering problems alike. Without superheat and subcooling, you are guessing, and guessing usually means overcharging a healthy system. Two numbers, thirty seconds of math, then a verdict.

## Module Visuals

### 1 EVAPORATOR SUPERHEAT

#### F6-1: Inside the Evaporator: Where Boiling Ends and Superheat Begins

R-410A example: suction pressure 118.4 psig = 40 F saturation temperature

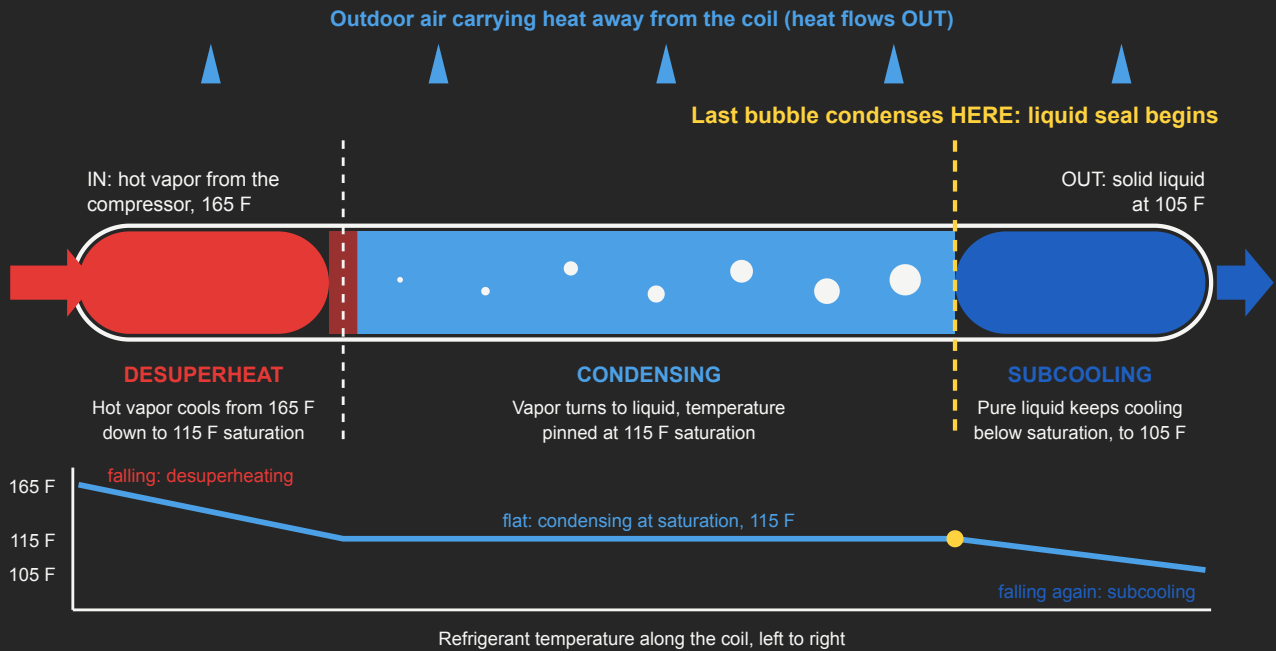


**Superheat = measured suction temp minus saturation temp**  
**52 F minus 40 F = 12 F superheat**

## 2 CONDENSER SUBCOOLING

### F6-2: Inside the Condenser: Desuperheat, Condense, Subcool

R-410A example: liquid pressure 390 psig = about 115 F saturation temperature

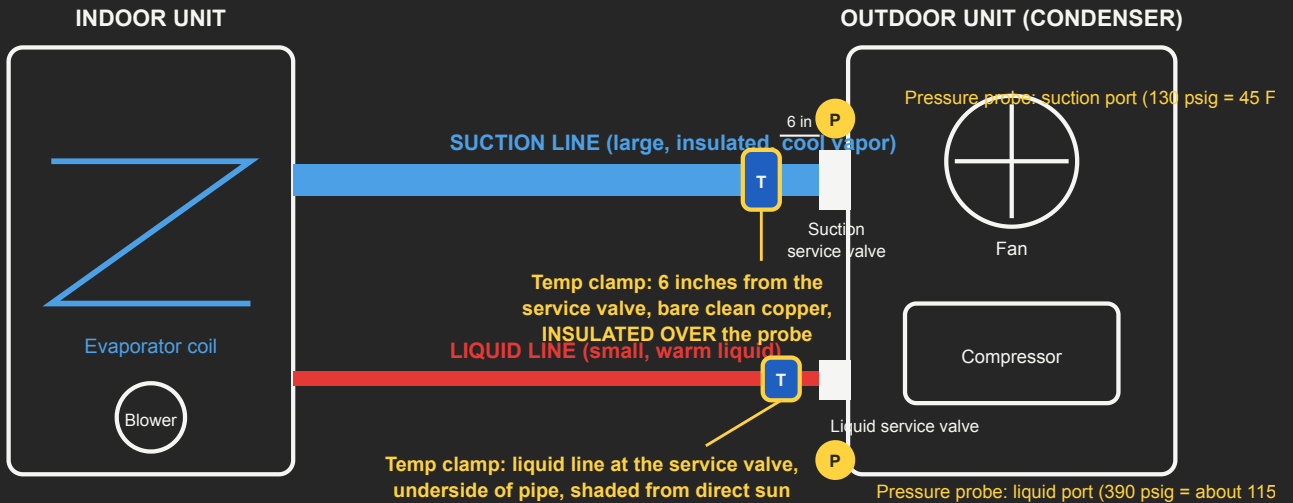


**Subcooling = saturation temp minus measured liquid temp**  
**115 F minus 105 F = 10 F subcooling**

### 3 MEASUREMENT POINTS

## F6-3: Where the Probes Go on a Split System

Four readings: two pressures at the service ports, two temperatures on the lines



#### The four readings become two numbers

##### **SUPERHEAT (suction side)**

measured line temp minus saturation temp

$$55 \text{ F minus } 45 \text{ F} = 10 \text{ F}$$

##### **SUBCOOLING (liquid side)**

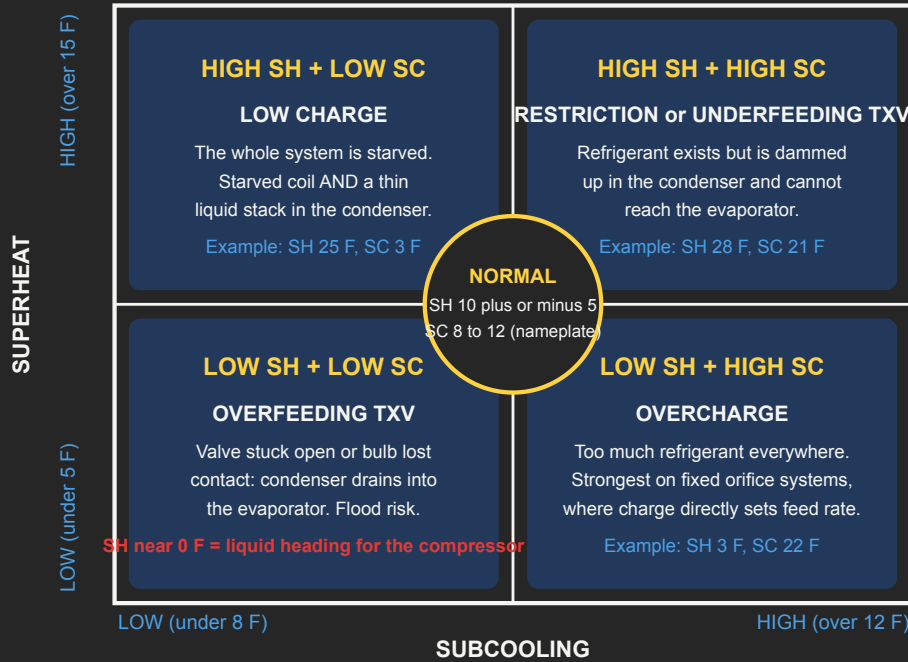
saturation temp minus measured line temp

$$115 \text{ F minus } 105 \text{ F} = 10 \text{ F}$$

## 4 DIAGNOSIS QUADRANTS

### F6-4: Reading Superheat and Subcooling Together

Each number is a letter. Together they spell the word. (Full triangle method in D24)



**Quadrants SUGGEST a suspect. They never convict one.**

Verify airflow, probe contact, and stability before condemning charge or a valve. TXV targets shown.