The “5 Pillars” of Residential A/C Refrigerant Circuit Diagnosis

Suction pressure, head pressure, subcooling, superheat, Delta T

Taking all five of these calculations into account on every service call is critical. Even if further diagnostic tests must be done to pinpoint the problem, these five factors are the groundwork before more effective diagnosis can be done. I would also add static pressure as an important reading that should be checked regularly (Keep TESP between .3″wc and .7″ wc on most systems) but I would still place it slightly below these five as far as fundamental HVAC technician measurements.

Some of these are "rules of thumb" and obviously are for reference only. Refer to manufacturer recommendations when setting a charge.

Suction Pressure / Low Side
Suction pressure tells us several things. The first thing it tells us is what the boiling temperature of the refrigerant in the evaporator is. If the suction pressure is below 32° saturation temperature, the evaporator coil will eventually freeze.

As a general rule, the higher the temperature of the air passing over the evaporator, the higher your suction pressure will be. A good rule of thumb for suction pressure is 35° saturation below indoor ambient +/- 5° (Return temperature measured at the evaporator coil). This temperature differential is often called an evaporator split or design temperature difference (DTD). When calculating DTD a "Higher" DTD means lower suction pressure in comparison to the return temperature, a lower DTD means higher suction pressure.

This means that when the temperature of the air passing over the evaporator is 80°, the low side saturation temperature should be 45° when the system is set for 400 CFM per ton output. Remember the temperature scale next to the pressure scale on the gauge represents saturation or if you don't have the correct sale on (or in your gauge if you have a Digital manifold) you would need to use a PT chart.

This 35° rule only works at 400 CFM per ton, when a system is designed for 350 CFM per ton the DTD will be closer to 38° – 40° +/- 5°

Make sure you know the actual CFM output of the system before you calculate DTD. It can vary significantly based on the setup of the particular blower. Also keep in mind that oversized evaporator coils that some manufacturers specify for efficiency can also result in slightly lower DTD (higher suction). If you don't know all the details it is my experience that using 35° is the best bet.

Head Pressure / High Side

When used in conjunction with liquid line temperature, we can know what state the refrigerant in the liquid line and that the compressor is pumping / operating in the required compression ratio. We can also know something about the state of the metering device as to whether or not refrigerant is "backing up" against the metering device. A good rule of thumb for head pressure is a 15° – 20° saturation above outdoor ambient +/- 3° for most modern systems. These saturation / ambient calculations are only indicators; they are not set in stone. Keep in mind, when I say ambient; I am talking about the air entering the evaporator for suction pressure and the condenser for head pressure.

Jim Bergmann points out that different equipment efficiencies will have different target Condensing Temperature Over Ambient (CTOA) readings. Keep in mind that these date ranges don't guarantee the SEER but rather give the date ranges that these efficiencies will be most likely. The larger the condenser coil in relationship to the volume of refrigerant being moved the lower the CTOA will be.

6 – 10 SEER Equipment (Older than 1991) = 30° CTOA

10 -12 SEER Equipment (1992 – 2005) = 25° CTOA

13 – 15 SEER Equipment (2006 – Present) = 20° CTOA

16 SEER+ Equipment (2006 – Present) = 15° CTOA

Superheat
Superheat is important for two reasons. It tells us whether or not we could be damaging the compressor and whether we are fully feeding the evaporator with boiling, flashing refrigerant. If the system has a 0° superheat, a mixture of liquid and vapor is entering the compressor. This is called liquid slugging and it can damage a compressor. A superheat that is higher than the manufacturer’s specification can both starve the evaporator, causing capacity loss, as well as cause the compressor to overheat. So how do we know what superheat we should have? First, we must find out what type of metering device the system is using. If it is using a piston or other fixed metering device, you must refer to the manufacturers superheat requirements or a superheat chart like the one below.

Superheat for A/C with fixed Orifice R-22

	Evaporator Inlet Air Temperature Fahrenheit Wet Bulb (enthalpy)																
	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82
Outside Air Temperature Dry bulb																	
60	7	11	13	17	18	20	24	26	28	30							
65		8	11	13	15	17	18	22	25	28	30						
70			8	11	12	14	16	18	22	25	28	30					
75				7	10	12	14	16	18	23	26	28	30				
80					6	8	12	14	16	18	23	27	28	30			
85						6	8	12	14	17	20	25	27	28	30		
90							6	9	12	15	18	22	25	27	28	30	
95								7	11	13	16	20	23	24	26	28	30
100								5	8	11	14	18	20	22	24	26	28
105									6	8	12	15	19	21	23	25	26
110									5	7	11	12	17	19	21	23	25
115										5	8	13	15	17	20	22	23

If it is a TXV type metering device, the TXV will generally attempt to maintain between a 5° to 15° superheat on the suction line exiting the evaporator coil (10° +/- 5°)

TXV target superheat setting may vary slightly based on equipment type.

Subcooling
Subcooling tells us whether or not the liquid line is full of liquid. A 0° subcool reading tells us that the refrigerant in the liquid line is part liquid and part vapor. An abnormally high subcool reading tells us that the refrigerant is moving through the condenser too slowly, causing it to give up a large amount of sensible heat past saturation temperature. A high subcool is often accompanied by high head pressure and, conversely, a low subcool by low head pressure. Subcool is always a very important calculation to take because it lets you know whether or not the metering device is receiving a full line of liquid. Typical ranges for subcooling are between 8 and 14 degrees on a TXV system, but always check the manufacturer’s information to confirm. in general on a TXV system using 10° +/- 3° at the condenser outlet is the best “rule of thumb” in the absence of manufacturer’s data.

On a fixed orifice / piston system the subcooling will vary even more based on load conditions and you will see a range of 5° to 23° making subcooling less valuable on a fixed orifice system. In my experience during normal operating conditions the subcooling on a fixed orifice system will still usually be in the 10° +/- 3° range.

Evaporator Air Temperature Split (Delta T)
The evaporator air temperature split (Delta T) is a nice calculation because it gives you a good look at system performance and airflow. A typical air temperature split will be between 16 and 22 degrees difference from return to supply. Keep in mind, when you are doing a new system start up, high humidity will cause your air temperature split to be on the low side. Refer to the air temperature split and comfort considerations sheets for further information.

For systems that are set to 400 CFM per ton, you can use a target Delta T sheet like the one shown below

Return Air Dry-Bulb (°F) ($T_{return, db}$)	Return Air Wet-Bulb (°F) ($T_{return, wb}$)																										
	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
70	20.9	20.7	20.6	20.4	20.1	19.9	19.5	19.1	18.7	18.2	17.7	17.2	16.5	15.9	15.2	14.4	13.7	12.8	11.9	11.0	10.0	9.0	7.9	6.8	5.7	4.5	3.2
71	21.4	21.3	21.1	20.9	20.7	20.4	20.1	19.7	19.3	18.8	18.3	17.7	17.1	16.4	15.7	15.0	14.2	13.4	12.5	11.5	10.6	9.5	8.5	7.4	6.2	5.0	3.8
72	21.9	21.8	21.7	21.5	21.2	20.9	20.6	20.2	19.8	19.3	18.8	18.2	17.6	17.0	16.3	15.5	14.7	13.9	13.0	12.1	11.1	10.1	9.0	7.9	6.8	5.6	4.3
73	22.5	22.4	22.2	22.0	21.8	21.5	21.2	20.8	20.3	19.9	19.4	18.8	18.2	17.5	16.8	16.1	15.3	14.4	13.6	12.6	11.7	10.6	9.6	8.5	7.3	6.1	4.8
74	23.0	22.9	22.8	22.6	22.3	22.0	21.7	21.3	20.9	20.4	19.9	19.3	18.7	18.1	17.4	16.6	15.8	15.0	14.1	13.2	12.2	11.2	10.1	9.0	7.8	6.6	5.4
75	23.6	23.5	23.3	23.1	22.9	22.6	22.2	21.9	21.4	21.0	20.4	19.9	19.3	18.6	17.9	17.2	16.4	15.5	14.7	13.7	12.7	11.7	10.7	9.5	8.4	7.2	5.9
76	24.1	24.0	23.9	23.7	23.4	23.1	22.8	22.4	22.0	21.5	21.0	20.4	19.8	19.2	18.5	17.7	16.9	16.1	15.2	14.3	13.3	12.3	11.2	10.1	8.9	7.7	6.5
77	-	24.6	24.4	24.2	24.0	23.7	23.3	22.9	22.5	22.0	21.5	21.0	20.4	19.7	19.0	18.3	17.5	16.6	15.7	14.8	13.8	12.8	11.7	10.6	9.5	8.3	7.0
78	-	-	-	24.7	24.5	24.2	23.9	23.5	23.1	22.6	22.1	21.5	20.9	20.2	19.5	18.8	18.0	17.2	16.3	15.4	14.4	13.4	12.3	11.2	10.0	8.8	7.6
79	-	-	-	-	-	24.8	24.4	24.0	23.6	23.1	22.6	22.1	21.4	20.8	20.1	19.3	18.5	17.7	16.8	15.9	14.9	13.9	12.8	11.7	10.6	9.4	8.1
80	-	-	-	-	-	-	25.0	24.6	24.2	23.7	23.2	22.6	22.0	21.3	20.6	19.9	19.1	18.3	17.4	16.4	15.5	14.4	13.4	12.3	11.1	9.9	8.7
81	-	-	-	-	-	-	-	25.1	24.7	24.2	23.7	23.1	22.5	21.9	21.2	20.4	19.6	18.8	17.9	17.0	16.0	15.0	13.9	12.8	11.7	10.4	9.2
82	-	-	-	-	-	-	-	-	25.2	24.8	24.2	23.7	23.1	22.4	21.7	21.0	20.2	19.3	18.5	17.5	16.6	15.5	14.5	13.4	12.2	11.0	9.7
83	-	-	-	-	-	-	-	-	-	25.3	24.8	24.2	23.6	23.0	22.3	21.5	20.7	19.9	19.0	18.1	17.1	16.1	15.0	13.9	12.7	11.5	10.3
84	-	-	-	-	-	-	-	-	-	25.9	25.3	24.8	24.2	23.5	22.8	22.1	21.3	20.4	19.5	18.6	17.6	16.6	15.6	14.4	13.3	12.1	10.8

If the leaving temperature/delta T split is high it is an indication of low airflow. If it is low it is an indication of poor system performance / capacity.

Again, this only applies to 400 CFM ton. 350 CFM per ton or less are more common today than ever and in those cases the above chart won't apply.

Diagnosing With The Five Pillars

The way this list must be utilized is by taking all five calculations and matching up the potential problems until you find the most likely ones. A very critical thing to remember is that a TXV system will maintain a constant superheat, and a fairly constant suction pressure. The exceptions to this rule are when the TXV fails, is not receiving a full line of liquid or does not have the required liquid pressure/pressure drop to operate. This situation would show 0° subcooling and in this case, will no longer be able to maintain the correct superheat. Before using this list, you must also know what type of metering device is being utilized, then adjust thinking accordingly. Also remember, in heat mode, the condenser is inside and the evaporator is outside.

Low Suction Pressure

• Low on charge

• Low air flow /load – dirty filter, dirty evaporator, kinked return, return too small, not enough supply ducts, blower wheel dirty, blower not running correct speed, insulation pulling up against the blower, etc.

• Metering device restricting flow too much – piston too small, piston or TXV restricted, TXV failing closed

• Liquid line restriction – clogged filter/drier, clogged screen, kinked copper

• Low ambient (Low evaporator load)

• Extremely Kinked suction line (after the kink)

• Internal evaporator restriction

High Suction Pressure

• Overcharge

• High return temperature (Evaporator Load)

• Metering device allowing too much refrigerant flow – piston too large, TXV failing open, piston seating improperly

• Too much airflow over the evaporator (Blower tapped or set too high)

• Compressor not pumping properly – bad suction valve, bad discharge valve, bad or broken crank

• Reversing valve bypassing

• Discharge line restriction

Low Head Pressure

• Low on charge

• Low ambient temperature / low load

• Metering device allowing too much refrigerant flow – piston too large, TXV failing open, piston seating improperly

• Wet condenser coil

• Compressor not pumping properly – bad suction valve, bad discharge valve, bad or broken crank

• Reversing valve bypassing (heat pump units)

• Kinked suction line

• Restricted discharge line

• Severe Liquid Line Restriction

High Head Pressure

• Overcharge
• Low condenser airflow – condensing fan not operating, dirty condenser, fins bent on condenser, bushes too close to condenser, wrong blade, wrong motor, blade set wrong
• High outdoor ambient temperature
• Mixed / incorrect refrigerant / retrofit without proper markings
• Non-condensables in the system
• Liquid line restriction + overcharge (someone added charge when they saw low suction) – piston too small, piston or TXV restricted, TXV failing closed, restricted line drier

Low Superheat

• Overcharge
• Low air flow / load – dirty filter, dirty evaporator, kinked return, return too small, not enough supply ducts, blower wheel dirty, blower not running correct speed, insulation pulling up against the blower etc.
• Metering device allowing too much refrigerant flow – piston too large, TXV failing open, piston seating improperly
• Low return air temperature
• Abnormally low humidity
• Internal evaporator restriction
• Very Poor Compression (Compressor, reversing Valve Issues) but will also be combined with VERY HIGH suction

High Superheat

• Low on charge
• Metering device restricting flow / underfeeding / overmetering – piston too small, piston or TXV restricted, TXV failing closed
• High return air temperature
• Liquid line restriction – clogged filter/drier, clogged screen, kinked copper

Low Subcooling

• Low on charge
• Metering device allowing too much refrigerant flow – *piston too large, TXV failing open, piston seating improperly*

• Compressor not pumping properly – *leaking suction valve, leaking discharge valve, bad or broken crank*
• Reversing valve bypassing
• Discharge Line Restriction
• Compressor not pumping

High Subcooling

• Overcharge
• Metering device restricting too much flow – *piston too small, piston or TXV restricted, TXV failing closed*
• Liquid line restriction – *clogged filter/drier, clogged screen, kinked copper*
• Wet condenser coil
• Dirty Condenser Coil on New High Efficiency Condensers (*Increased Condensing Temp Can Actually Result in Higher Subcooling*)
• Having an H.R.U. in the discharge line (*old school I know*)
• Internal evaporator restriction

High Evaporator Air Temperature Split

• Low air flow – *dirty filter, dirty evaporator, kinked return, return too small, not enough supply ducts, blower wheel dirty, blower not running correct speed, insulation pulling up against the blower etc.*
• Abnormally low humidity (WB Temp)
• Blower not running the correct speed or running backward

Low Evaporator Air Temperature Split

• Undercharge
• Severe Overcharge with fixed orifice metering device – *because saturation temperature is increased with overcharge*
• Metering device not functioning properly – restricting too much flow or allowing too much flow
• Too much airflow through the evaporator – blower not running correct speed
• Heat strips running with air
• Abnormally high humidity
• Liquid line restriction
• Compressor not pumping properly – bad suction valve, bad discharge valve, bad or broken crank

- Reversing valve bypassing
- Discharge line restriction

This is an incomplete list designed to help you. Always keep your eyes and ears open for other possibilities. Diagnosis is an art as well as a science.

— Bryan