



Airflow Fundamentals

MODULE C12

CORE SYSTEMS

PREREQ C10

In C10 you walked the whole split system: condenser outside, evaporator coil and blower inside, ducts carrying air to and from the rooms. Here is the uncomfortable truth about that machine: the refrigerant circuit everyone obsesses over only works if the air side delivers the right amount of air across the indoor coil. Air is the cargo. Refrigerant is just the truck that hauls heat out of it. A huge share of "refrigerant problems," "weak cooling" complaints, and outright frozen coils are airflow problems wearing a refrigerant costume. This module gives you the numbers, the measurements, and the habit that separates techs who diagnose from techs who guess: check the air before you touch the gauges.

Short Version

Airflow is measured in CFM, cubic feet of air per minute moving through the system. Residential cooling targets about 400 CFM per ton of capacity, bending down toward 350 in humid conditions (more moisture removal) and up toward 450 in dry climates like Phoenix (more sensible cooling). The blower's enemy is resistance, measured as static pressure in inches of water column. Total external static pressure (TESP) is the sum of the supply side pushing and the return side pulling, and most residential equipment is designed to deliver its rated airflow at 0.5 in WC; real houses routinely measure far above that. You measure TESP by drilling two small test ports, one in the return just before the blower and one in the supply just after the equipment, reading both with a manometer, and adding the magnitudes. With TESP and the blower speed setting, the manufacturer fan table tells you the actual CFM. Filters are a pressure drop you choose: a restrictive 1 inch high-MERV pleat can spend most of your static budget, while a 4 inch media filter cleans better air for less resistance. Blowers respond to static three different ways: PSC motors droop badly, constant torque ECMs droop less, and constant airflow ECMs hold CFM by burning more watts, which hides duct problems. Airflow gets verified before any refrigerant diagnosis, every time, because every superheat and subcooling number assumes the coil is seeing the right amount of air.

Key Values

VALUE	NUMBER	WHAT IT MEANS
CFM	Cubic feet per minute	The volume flow rate of air. The single most important air-side number.
Nominal cooling airflow	400 CFM per ton	The design baseline for residential cooling. A 3 ton system wants about 1,200 CFM.

VALUE	NUMBER	WHAT IT MEANS
High latent (humid) target	About 350 CFM per ton	Slower air spends more time on the coil, condensing more moisture. Used in humid climates and during monsoon-heavy latent loads.
Dry climate target	Up to 450 CFM per ton	Almost no moisture to remove, so faster air maximizes sensible capacity. Common setup choice in Phoenix.
Static pressure unit	Inches of water column (in WC)	Same unit as gas manifold pressure from the furnace world. 1 psi is about 27.7 in WC, so these are tiny pressures.
Design TESP	0.5 in WC	The total external static most residential PSC-rated equipment is designed to breathe against at rated airflow.
Field trouble threshold	Above about 0.8 in WC	A system this high is being strangled. Find the restriction.
Sensible heat formula	$BTU/h = 1.08 \times CFM \times \text{temperature difference}$	From F3. Connects airflow to capacity in both directions.
Temperature rise method	$CFM = \text{furnace output BTU/h} \div (1.08 \times \text{measured rise})$	The classic gas furnace airflow check. Output = input x efficiency.
Typical cooling temperature split	18 to 22 F across the coil	Bigger split suggests low airflow. Smaller split suggests high airflow or low capacity.
Filter face velocity target	About 300 FPM or less for filter grilles	Feet per minute of air at the filter face. Lower velocity means lower pressure drop and better filtration.
Wet coil penalty	Roughly 0.05 to 0.10 in WC extra	A coil condensing water resists air more than a dry coil. Measure cooling static with the coil wet.

Field Checklist

Static pressure and airflow basics on every visit:

- Locate or drill test ports: return side between the filter and the blower, supply side at the equipment outlet (between furnace and coil on a furnace with an external coil). Use a drill stop. Know what is behind the metal before drilling.
- Zero the manometer, insert the static tip pointing into the oncoming airflow, and read with the system at full blower speed.
- Record both readings: return is negative, supply is positive. TESP = the two magnitudes added together.
- Compare TESP to the equipment rating on the nameplate or in the installer manual (most say 0.5 in WC).
- Pull the fan table from the installer manual (or the manufacturer app), find the active speed tap or dip switch setting, and read actual CFM at your measured static.

- Divide CFM by tonnage. Inside 350 to 450 per ton is workable. Below 350, find the restriction before doing anything else.
- Check the filter: type, MERV, condition, and fit. A collapsed or bypassing filter is an airflow lie.
- Eyeball the duct story: crushed or kinked flex, closed dampers, blocked returns, furniture over registers.
- Cap every test port with a plug, never tape.

IB STANDARD

A static pressure reading is taken on every maintenance visit and every diagnostic visit, no exceptions, and the readings go in ServiceTitan with the job photos. Static is the blood pressure of the system. A one-minute reading on every visit builds a history for that equipment, and history is what turns "it seems weaker" into "TESP climbed 0.2 since spring, the new filter is wrong."

PHOENIX FIELD NOTE

Between monsoon storms, Phoenix air carries dust loads most markets never see. A filter that lasts 90 days in April can load up in 3 weeks of August haboob season. When a system "suddenly stopped keeping up" in late summer, the filter is suspect number one, and your static reading will convict it before you ever open the gauges.

Full Breakdown

What CFM is and why it runs the system

CFM stands for cubic feet per minute, the volume of air the blower moves through the system every minute. Picture a box one foot on each side: that is a cubic foot, roughly the size of a basketball in a milk crate. A 3 ton system moving 1,200 CFM is pushing 1,200 of those boxes across the evaporator coil every 60 seconds, which is the entire air volume of an average bedroom about once a minute.

Why does the number matter so much? Go back to the F3 sensible heat formula: $BTU/h = 1.08 \times CFM \times \text{temperature difference}$. Capacity is airflow times temperature change. The refrigerant circuit sets how cold the coil can get, but the airflow decides how much heat actually gets delivered to that coil. Cut the CFM in half and you have cut the delivery system in half, no matter how perfect the charge is. The coil gets colder and colder with less and less heat arriving, the refrigerant stops boiling off completely, and you slide toward a frozen coil and liquid headed for the compressor. Every air conditioner is an airflow machine first and a refrigerant machine second.

The 400 CFM per ton rule and when it bends

The residential baseline is 400 CFM per ton of cooling. One ton is 12,000 BTU/h (F3), so:

- 2 tons: about 800 CFM
- 3 tons: about 1,200 CFM
- 4 tons: about 1,600 CFM

- 5 tons: about 2,000 CFM

That 400 number is not arbitrary. It is the airflow at which a standard evaporator coil splits its work between sensible cooling (dropping temperature) and latent cooling (wringing out moisture) the way the equipment ratings assume. Move the airflow and you move that split, which is exactly why the rule bends in two directions:

Bend it down to about 350 CFM per ton when latent load is high. Slower air spends more time in contact with the cold coil, so the coil runs colder and below the dew point longer, condensing more moisture. Humid climates set up near 350 as a matter of course. The cost is a little sensible capacity and a colder coil, so you never go far below 350: too slow and you are flirting with coil freeze.

Bend it up toward 450 CFM per ton in dry climates. When there is almost no moisture to remove, latent capacity is wasted capacity. Faster air keeps the coil warmer and converts nearly all the work into sensible cooling, which is what a dry market actually needs. The cost is moisture removal you were not using anyway, plus a bit more blower noise and energy.

PHOENIX FIELD NOTE

Phoenix is the textbook 450 market for most of the year, and many variable speed systems here are configured for high airflow per ton on purpose. Then monsoon season arrives, dew points jump, and a house set up for maximum sensible can turn clammy. Premium thermostats and ECM systems often have a dehumidify mode that drops airflow toward 350 per ton when humidity climbs. Knowing the rule bends both ways, and why, is how you set that up correctly instead of treating it as a mystery menu option.

Static pressure, the system's blood pressure

A blower does not just move air, it moves air against resistance. Every filter, coil, fitting, damper, grille, and foot of duct pushes back. That resistance shows up as pressure, and because the pressures are tiny we measure them in inches of water column (in WC): the pressure needed to push a column of water up that many inches. You met this unit on the gas side of the trade, where natural gas manifolds run at 3.5 in WC. For scale, 1 psi is about 27.7 in WC. The blower lives its whole life in fractions of one inch.

Total external static pressure (TESP) is the total resistance the blower sees from everything outside the equipment it was rated with: ductwork, registers, grilles, the filter, and on most furnace installations the cooling coil too. The word external is doing real work in that sentence. The blower housing and anything the manufacturer included inside the rated cabinet are already accounted for in the fan table. Your job is to measure everything else.

The medical analogy is worth keeping: static pressure is blood pressure for ductwork. A doctor does not skip blood pressure because the patient looks healthy, and a tech should not skip static because the air at the register feels cold. High static means the blower is straining against a restriction. It tells you the system is sick before it tells you exactly where, and like blood pressure, the reading only has full meaning when you also know the flow that goes with it. That is why static plus the fan table beats static alone.

One design number anchors everything: most residential equipment is designed to deliver rated airflow at 0.5 in WC TESP. That is the assumption baked into the spec sheet. Field reality is uglier: restrictive filters, undersized returns, and crushed flex routinely push real homes to 0.8 in WC and beyond, which means a huge share of the

systems you touch are running strangled out of the box. Above about 0.8 you should assume airflow is compromised until the fan table proves otherwise.

Measuring TESP in the field

TESP is two readings and an addition. The skill is in where the holes go and how you read them.

The tool. A digital manometer (a pressure meter for these tiny pressures) with a static pressure tip: a small metal probe, often with an angled tip, that reads the still-air pressure in the duct rather than the ram effect of moving air. Zero the manometer to room air before every use.

Where to drill. Two test ports, 3/8 inch holes, each as close to the equipment as you can get while staying away from turns, takeoffs, and anything inside the cabinet:

1. **Return side: between the filter and the blower.** This reading captures everything upstream pulling against the blower: return grille, return duct, and the filter. On systems where the filter sits in a rack at the equipment, drill downstream of the filter, just before the blower cabinet. If the only filter is at a return grille across the house, drill the return plenum or drop just before the cabinet; the filter is still upstream of your hole, so it is still counted.
2. **Supply side: at the equipment outlet.** On a gas furnace with the evaporator coil sitting on top in its own casing, the coil was not inside the furnace when the manufacturer built the fan table, so the coil counts as external resistance: drill between the furnace outlet and the coil inlet. On a fan coil or air handler where the coil lives inside the rated cabinet, the coil is already internal: drill the supply plenum just above the cabinet outlet.

Before the drill spins, know what is behind the metal. The two classic drilling disasters are putting a bit through the evaporator coil and putting it through the condensate pan, and either one turns a 10 minute measurement into a very bad day. Look inside through existing panels, know where the coil and pan sit, drill where you can see or confidently map clear space, and use a drill stop or a short bit so the bit cannot lunge. Watch for wiring and gas lines run along the outside of plenums too.

Probe orientation and signs. Insert the static tip so it points into the oncoming airflow: toward the duct opening the air is arriving from. In the return that means pointing away from the blower; in the supply it means pointing back toward the equipment. The return reading will be negative because the blower is sucking on that side; the supply reading will be positive because the blower is pushing. Run the blower at the speed you care about (cooling speed for a cooling diagnosis), let the reading settle, and record both.

The math. TESP is the two magnitudes added, signs dropped:

Return reads minus 0.31 in WC. Supply reads plus 0.51 in WC. $TESP = 0.31 + 0.51 = 0.82$ in WC.

The split between the two numbers is itself diagnostic. The 0.5 budget is shared by both sides, and a healthy split runs somewhere near 40 percent return, 60 percent supply on a furnace where the supply reading includes the coil. A return reading dominating the total points at the filter or a starving return. A supply reading dominating points at the coil, supply duct, or registers. The same total can have two completely different causes, and the split tells you which side of the blower to go hunting on.

Measure cooling static with a wet coil. A coil actively condensing water resists air more than a dry one, typically by 0.05 to 0.10 in WC. Fifteen minutes of cooling runtime before you read makes the number honest.

When you are done, cap the ports with plastic test port plugs. Tape falls off in an attic by August.

IB STANDARD

Test ports get drilled once, capped, and reused for the life of the equipment. If you drill new ports, photograph their locations for ServiceTitan so the next tech is not drilling new holes next to yours.

Filters and the pressure they cost

Every filter is a deal: capture more particles, pay more pressure. Your job is to know the price of each option, because the filter is the one piece of TESP the homeowner changes without telling anyone.

MERV (Minimum Efficiency Reporting Value) rates how well a filter captures particles, on a scale from 1 to 16 for residential equipment. Higher MERV catches smaller particles. MERV says nothing about pressure drop directly, and that is where techs get burned: two MERV 11 filters can have wildly different resistance depending on how much surface area they spread the work across.

The ladder, from loosest to tightest (typical clean pressure drops at normal residential face velocity):

1. **1 inch fiberglass (MERV 2 to 4), roughly 0.05 to 0.08 in WC.** Barely restricts and barely filters. It is a rock catcher protecting the blower, not the lungs of the household.
2. **1 inch pleated MERV 8 (roughly 0.15 to 0.20 in WC).** The workhorse. Reasonable capture, reasonable cost in static.
3. **1 inch pleated MERV 11 (roughly 0.20 to 0.28 in WC).** Better capture, and now you are spending close to half the 0.5 in WC design budget on the filter alone, clean.
4. **1 inch pleated MERV 13 (roughly 0.25 to 0.35 in WC clean).** The restriction trap. Marketed as premium, and in a 1 inch rack it can spend most of the static budget the day it is installed, then get worse as it loads.
5. **4 to 5 inch media filter, MERV 11 to 13 (roughly 0.10 to 0.20 in WC).** The honest answer to the tradeoff. Deep pleats multiply the surface area, so air spreads out, face velocity through the media drops, and you get MERV 13 capture at a fraction of the 1 inch penalty, with months more dust-holding capacity.

The pattern to internalize: surface area is how you buy filtration without paying in static. A bigger filter, a deeper filter, or more filter locations all lower face velocity, which is the speed of air through the filter face in feet per minute (FPM). Keep filter grilles around 300 FPM or less and both pressure drop and capture improve.

And remember the dirt: every number above is a clean filter. A loaded filter can double or triple its own pressure drop. The airflow arrow on the frame points toward the equipment.

PHOENIX FIELD NOTE

Phoenix dust loads filters faster than the packaging promises, especially in haboob season. The combination that generates "stopped cooling" calls every August is a 1 inch MERV 13 pleat plus a single small return plus a month of dust storms. The filter starts at 0.30, loads to 0.6 by itself, the coil starves, and the coil freezes. The homeowner thinks they bought the best filter on the shelf. Your static reading and a media filter recommendation are the real fix.

Blower types and how each fights static

Three blower motor families dominate residential equipment, and they respond to rising static three different ways. You met motor construction in F8; this is about behavior.

PSC (permanent split capacitor). The old standard: a fixed-speed induction motor with speed taps. A PSC motor has no idea what the airflow is. As static climbs, airflow droops, and droops hard: a PSC blower rated for 1,200 CFM at 0.5 in WC might move barely 60 percent of that at 0.9. High static on a PSC system means low airflow, period, and the system suffers the full consequences: frozen coils, long runtimes, poor delivery to far rooms.

ECM constant torque (often called X13 style). An ECM (electronically commutated motor) is a brushless DC motor with onboard electronics. The constant torque version is programmed to hold a set torque for each tap. It is far more efficient than PSC and droops noticeably less as static rises, but it still droops. Think of it as a fitter athlete running the same uphill: better performance, same hill.

ECM constant airflow (true variable speed). This motor is programmed to deliver a target CFM and will change its RPM and power draw to hit it. Static goes up, the motor spins faster and pulls more watts, and the airflow stays at target, up to the limit of the motor's capability (commonly somewhere around 0.8 to 1.0 in WC, model dependent). Two consequences matter in the field. First, the good one: airflow stays right as the filter loads. Second, the trap: a constant airflow motor hides duct disease. The house feels fine, the airflow checks out, and meanwhile the motor is screaming against 1.0 in WC, running hot, eating watts, making noise, and aging fast. On these systems, static pressure and watt draw are how you find the problem, because airflow will not tell on the ducts. A constant airflow ECM does not fix a bad duct system. It pays the duct system's debts monthly, with interest, until it dies young.

One more field implication: the static-plus-fan-table method of finding CFM (next section) works on PSC and constant torque motors because their airflow is a function of static. On a constant airflow ECM, the fan table logic inverts: the airflow is whatever was programmed, and your static reading tells you how hard the motor is working to deliver it.

Duct basics

You do not have to be a duct designer to diagnose airflow, but you need the vocabulary and the failure patterns.

The two halves. The supply side is everything downstream of the blower: it pressurizes and delivers. The return side is everything upstream: it is under suction and feeds the blower. A system needs both sized right; air delivered must equal air returned, every second the blower runs.

Plenum. The sheet metal box bolted directly to the equipment where air collects before splitting off (supply plenum) or after merging together (return plenum). Your supply test port usually lives in or near the supply plenum.

Trunk and branch, takeoffs. Many systems run a large trunk duct with smaller branch runs peeling off to individual rooms. The fitting where a branch leaves the trunk or plenum is a takeoff. Takeoffs crowded together, or a takeoff immediately beside your test port location, create turbulence; keep test holes a couple of inches clear of them.

Flex versus metal. Sheet metal duct is smooth, holds its shape, and has low friction, but every joint needs sealing (mastic, not cloth duct tape, which dies in heat). Flexible duct is a wire helix with a plastic liner and insulation jacket: cheap and fast, and genuinely fine when it is pulled tight, supported every few feet, and run in gentle curves. Flex fails when it is compressed, sagging between supports, kinked at a sharp turn, or pinched by something stacked on it. The inner liner accords, the effective diameter shrinks, and friction multiplies; a badly compressed flex run can lose a huge fraction of its airflow while looking fine from six feet away. When you find high supply-side static, walk the flex.

Returns are where systems are starved. Supply problems make one room uncomfortable. Return problems strangle the entire system, because the blower can only push what the return lets it pull. Quick sanity math: a 4 ton system wants about 1,600 CFM. Through a single 20 by 20 inch return grille (about 2.8 square feet) that is nearly 580 FPM of face velocity, roughly double the comfortable target for a filter grille, which means noise, high pressure drop, and a filter that loads into a wall. Fixes are simple in principle: more return area, added return paths from closed-off rooms, or a deeper filter with more surface area.

PHOENIX FIELD NOTE

The single most common airflow sin in Phoenix housing stock is the undersized return: one small return grille feeding a 4 or 5 ton system through a 1 inch filter. Builders saved sheet metal, the dry climate hid the symptoms, and twenty years later you are the one reading 0.9 in WC. And remember where the rest of the duct system lives here: a 140 to 160 F attic (F3). Phoenix attic ducts are flex, baking in that oven, with crush points wherever someone crawled to the unit. When you are in the attic for any reason, look at the duct runs. Thirty seconds of looking finds problems gauges never will.

Three ways to measure airflow

"The air feels strong" is not a measurement. Here are the three field methods, in the order you will actually use them.

Method 1: Static pressure plus the fan table (the everyday method). Measure TESP as described above, then open the installer manual for the exact equipment model and find the blower performance table: rows for each speed tap or dip switch setting, columns for external static, cells showing CFM. Confirm which speed the system is actually wired or configured to use, run your finger to your measured static, and read the CFM. Interpolate between columns when your reading lands between them.

Worked example, the one Darrel runs in the demo video: 3 ton cooling, furnace blower on the high tap. Fan table says 1,240 CFM at 0.5 in WC, 1,175 at 0.6, 1,090 at 0.7, 985 at 0.8, 860 at 0.9. Measured TESP is 0.82, so actual airflow is a bit under 985, call it about 975 CFM. Divide by 3 tons: about 325 CFM per ton. That system is below the 350 floor, and nothing about its refrigerant charge can be judged until the restriction is found. In the demo, a loaded 1 inch MERV 13 filter was costing 0.17 in WC; swapping it dropped TESP to 0.65, the table read about 1,130 CFM, and 377 per ton put the system back inside the window.

The honest limits: fan tables assume a clean blower wheel and honest motor performance, and they apply to PSC and constant torque motors. They are an estimate, good to roughly 10 percent, which is exactly good enough for go or no-go field decisions.

Method 2: Temperature rise (the gas furnace cross-check). In heating, the furnace adds a known amount of heat to the air, so the F3 sensible formula can be flipped to solve for CFM:

CFM = furnace output BTU/h divided by (1.08 x temperature rise)

Output is input times efficiency: an 80,000 BTU/h input furnace at 80 percent efficiency delivers 64,000 BTU/h to the air. Measure return air temperature and supply air temperature, with the supply probe placed out of line of sight of the heat exchanger so radiant heat does not inflate the reading. Say return is 70 F and supply is 120 F: rise is 50 F.

CFM = 64,000 / (1.08 x 50) = 64,000 / 54 = about 1,185 CFM.

Every furnace nameplate lists an acceptable rise range (for example 35 to 65 F). Rise above the range means low airflow; below the range means high airflow or an input problem. The method's limits: heating only, it trusts the nameplate input (a furnace can be over- or under-fired), and it needs honest temperature probes. But it requires no fan table and no drilling, and when it disagrees badly with Method 1, believe that something is wrong and find out what.

Method 3: Anemometers (know what they cannot do). A vane anemometer is a small windmill that reads air velocity in FPM at a register or grille. Multiply velocity by area and you get CFM, in theory. In practice, register face readings are coarse: the grille blades redirect and concentrate air, the free area of the register is not its face area, and readings swing with probe position. Treat register anemometer numbers as plus or minus 20 percent or worse for totals. What anemometers are genuinely good for is comparison: room A versus room B, before versus after a repair, this register versus last visit. Balancing work and total-CFM verification at a higher standard use a flow hood (a fabric capture hood with a built-in grid) or an in-duct traverse, which you will meet if you move into commercial or performance work. For residential diagnosis, Method 1 is the daily driver, Method 2 is the heating season cross-check, and Method 3 is for comparisons, not verdicts.

Airflow first, refrigerant second

Here is the rule this whole module exists to install in your head: airflow is verified before any refrigerant diagnosis begins. Not sometimes. Every time.

The reason is brutally simple: every refrigerant number you learned in F6 assumes correct airflow. Superheat and subcooling targets, pressure expectations, temperature splits, all of them are defined at rated airflow across the coil. Starve the coil of air and the refrigerant readings go haywire while the charge is perfectly fine:

- Low airflow means less heat reaching the evaporator. The coil runs colder, suction pressure falls, and on gauges alone the system looks undercharged.
- A tech who trusts the gauges adds refrigerant to a healthy system. Now it is overcharged AND starved for air, two problems where there was one, and the original complaint is still there.
- Keep starving the coil and it ices over. Ice blocks more air, which makes more ice. The customer reports warm air and a frozen copper line, and the actual root cause was a collapsed filter or a crushed flex run.
- The temperature split tells the same story from the air side: a split well above 22 F usually means the air is moving too slowly across the coil.

This is why the diagnostic sequence in this course is built the way it is: filter, blower, static, fan table, and only then gauges. When you reach D24 and D25, the refrigerant diagnosis modules, the very first step in those

procedures will be "confirm airflow," and it will reference this module. The two minutes a static reading takes is the cheapest insurance in the trade: it is the difference between diagnosing the system in front of you and diagnosing a system that does not exist.

IB STANDARD

Island Breeze techs do not connect gauges until airflow has been verified or deliberately ruled in as part of the diagnosis. If a refrigerant-side repair is recommended, the work order shows the static reading and airflow evidence that ruled the air side out. Refrigerant added to a system with unverified airflow is a callback waiting to happen, and callbacks are tracked.

Common Mistakes

1. **Skipping static because the air "feels fine."** Cold air at one register proves nothing about CFM. A strangled system still makes cold air, just not enough of it. The cost: a refrigerant misdiagnosis built on an airflow problem.
2. **Drilling blind.** Through the evaporator coil or the condensate pan. One careless hole turns a measurement into a coil replacement. Map the cabinet, use a drill stop, drill where you know what is behind the metal.
3. **Measuring supply static on the wrong side of the coil.** On a furnace with an external coil, drilling above the coil misses the coil's pressure drop and understates TESP. Know whether the fan table for your equipment treats the coil as internal or external.
4. **Treating the 400 rule as a constant.** Setting 400 per ton in dehumidification conditions ruins latent performance; leaving 350 programmed in a dry Phoenix June gives away sensible capacity. The rule bends with the latent load.
5. **Selling a 1 inch high-MERV filter as an upgrade.** A MERV 13 pleat in a 1 inch rack can spend most of the static budget the day it is installed. Filtration upgrades come with surface area (media cabinets), not just a higher number on a 1 inch frame.
6. **Trusting airflow on a constant airflow ECM as proof of duct health.** The motor holds CFM by working harder. Airflow looks perfect right up until the overworked motor fails. Static and watt draw are the truth tellers on variable speed systems.
7. **Reading register velocity with an anemometer and reporting it as total CFM.** Register readings are comparison tools, not totals. Totals come from static plus the fan table, temperature rise, or a flow hood.
8. **Adding refrigerant to a low-suction system without checking air.** The classic sin this module exists to end. Low airflow imitates low charge. Check the air, then the charge.

What Is Next

C13 onward builds the rest of the core systems picture, and everything you just learned compounds: gas furnaces live and die by temperature rise, heat pumps are even less forgiving of low airflow than straight cooling, and IAQ work in A36 is applied static pressure management. Most importantly, when you reach D24

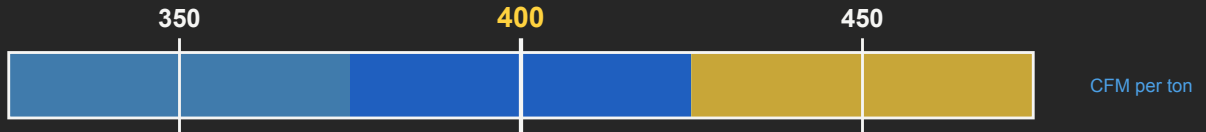
and D25 and start running real refrigerant diagnostics, step one of every procedure will already be a habit: prove the air before you judge the charge.

Module Visuals

400 CFM RULE

C12: The 400 CFM per Ton Rule, and When It Bends

Airflow sets the split between sensible cooling and moisture removal



ABOUT 350 / TON HIGH LATENT LOAD

Slower air, colder coil, more time below dew point: more moisture wrung out of the air.

Humid climates, dehumidify modes, monsoon-season comfort calls.

400 / TON NOMINAL THE DESIGN BASELINE

The airflow equipment ratings assume. Balanced split between temperature drop and moisture.

Start here. Deviate on purpose, never by accident.

UP TO 450 / TON DRY CLIMATES

Almost no moisture to remove, so faster air converts the work into maximum sensible cooling.

The Phoenix setup for most of the year, outside monsoon weeks.

Well below 350 per ton: coil runs too cold, freeze risk. Low airflow imitates low charge on the gauges.

AT THE 400 BASELINE: 1 TON = 12,000 BTU/h = 400 CFM

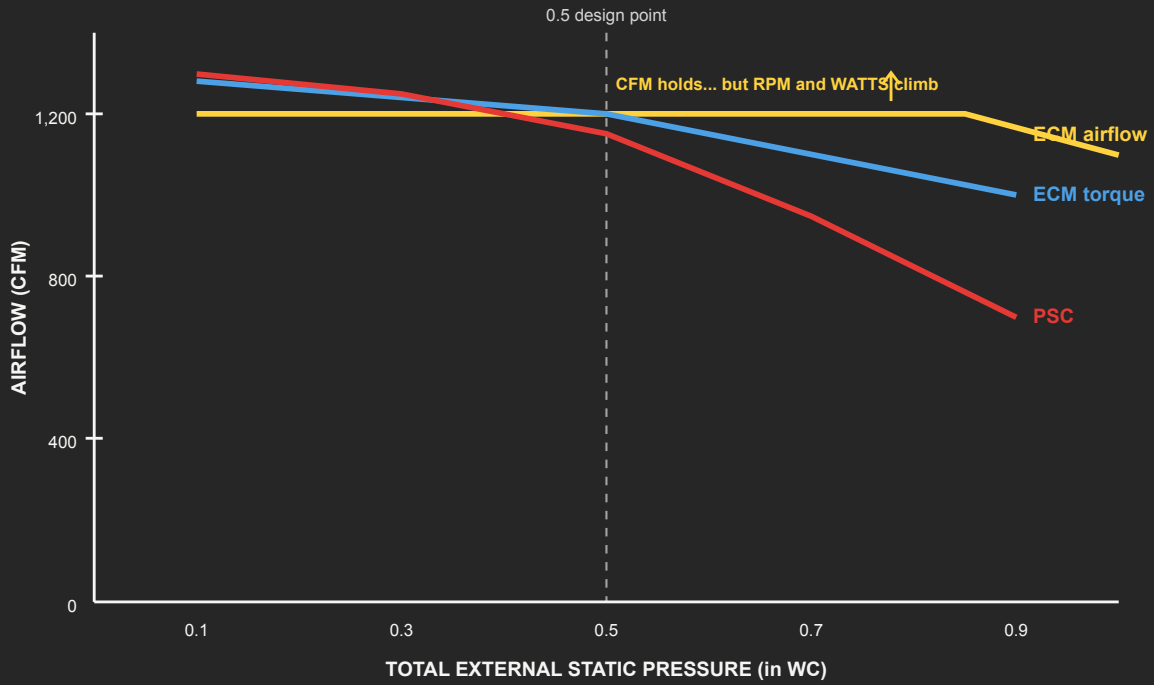
2 TONS	3 TONS	4 TONS	5 TONS
800 CFM	1,200 CFM	1,600 CFM	2,000 CFM

Capacity rides on airflow: $BTU/h = 1.08 \times CFM \times \text{temperature difference (from F3)}$

BLOWER TYPES

C12: Three Blowers, Three Responses to Rising Static

Airflow delivered as total external static pressure climbs



PSC (speed taps)

Blind to airflow. Droops hard.
High static = low CFM, period.

ECM constant torque (X13)

Efficient, droops less, still droops.
Fan table method works on both of these.

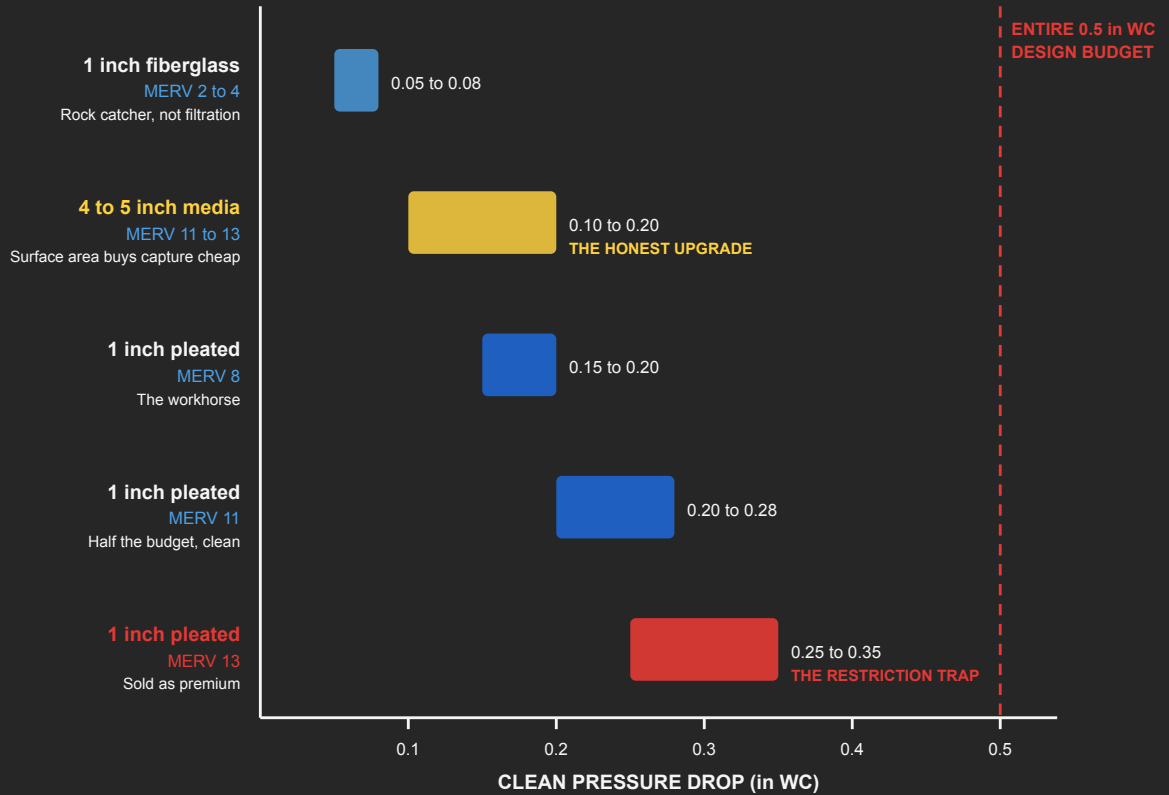
ECM constant airflow (variable speed)

Holds CFM by eating watts. HIDES duct disease: check static and watt draw.

FILTER PRESSURE DROP LADDER

C12: Filter Ladder, What Each Type Costs in Static

Clean pressure drop at typical residential face velocity. Dirt can double or triple every bar.

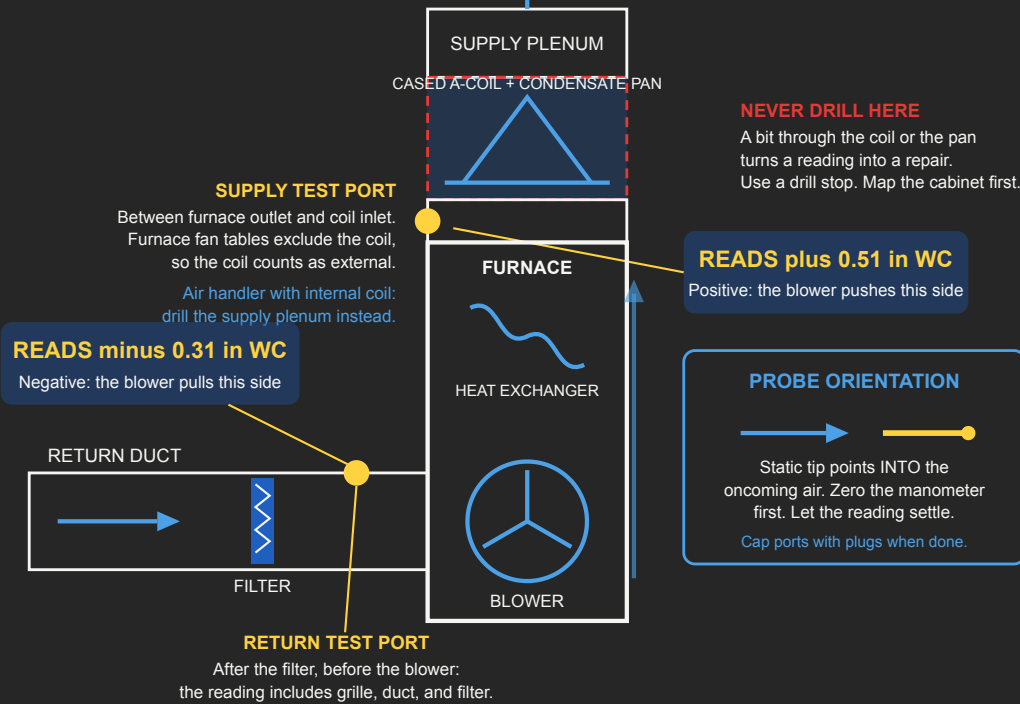


Higher MERV is bought with SURFACE AREA, not a tighter 1 inch frame. Target about 300 FPM at the filter face.

STATIC PRESSURE MAP

C12: Static Pressure Map, Where to Drill and What You Will Read

Upflow furnace with cased coil. Two ports, two signs, one addition.



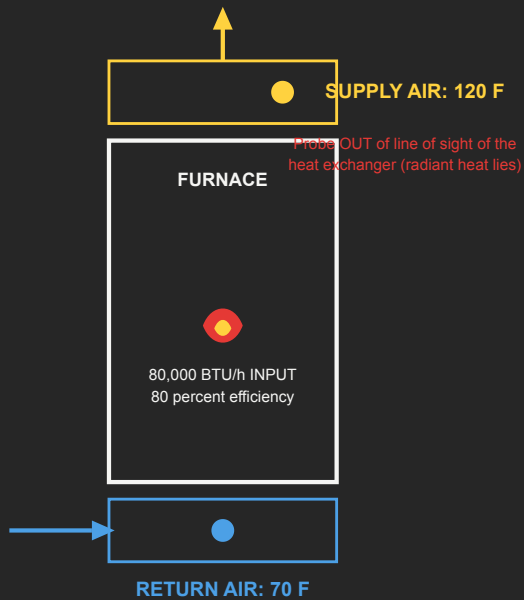
$$\text{TESP} = 0.31 + 0.51 = 0.82 \text{ in WC (magnitudes added, signs dropped)}$$

Most equipment is rated at 0.5 in WC. Above about 0.8: the system is being strangled.

TEMP RISE METHOD

C12: The Temperature Rise Method, Airflow Without a Drill

A gas furnace adds a known amount of heat, so CFM falls out of the math



STEP 1: Heat actually delivered to the air

Output = input x efficiency

$$80,000 \times 0.80 = 64,000 \text{ BTU/h}$$

STEP 2: Measure the rise

Rise = supply temp minus return temp

$$120 - 70 = 50 \text{ F}$$

STEP 3: Solve the F3 formula for CFM

CFM = output / (1.08 x rise)

$$\text{CFM} = 64,000 / (1.08 \times 50) = 64,000 / 54$$

$$\text{CFM} = \text{about } 1,185$$

CHECK THE NAMEPLATE RISE RANGE (example: 35 to 65 F)

Rise ABOVE the range = airflow too LOW. Rise below = airflow high or an input problem. The furnace tells the same story as the manometer.

Limits: heating only, trusts the nameplate input, needs honest probes. Cross-check against static plus fan table.