HVAC Design: Part 1 Ductwork that Delivers

Better Climate Control and Efficiency

Ductwork that Delivers
Table of Contents

Carbon Neutral Group
Consulting

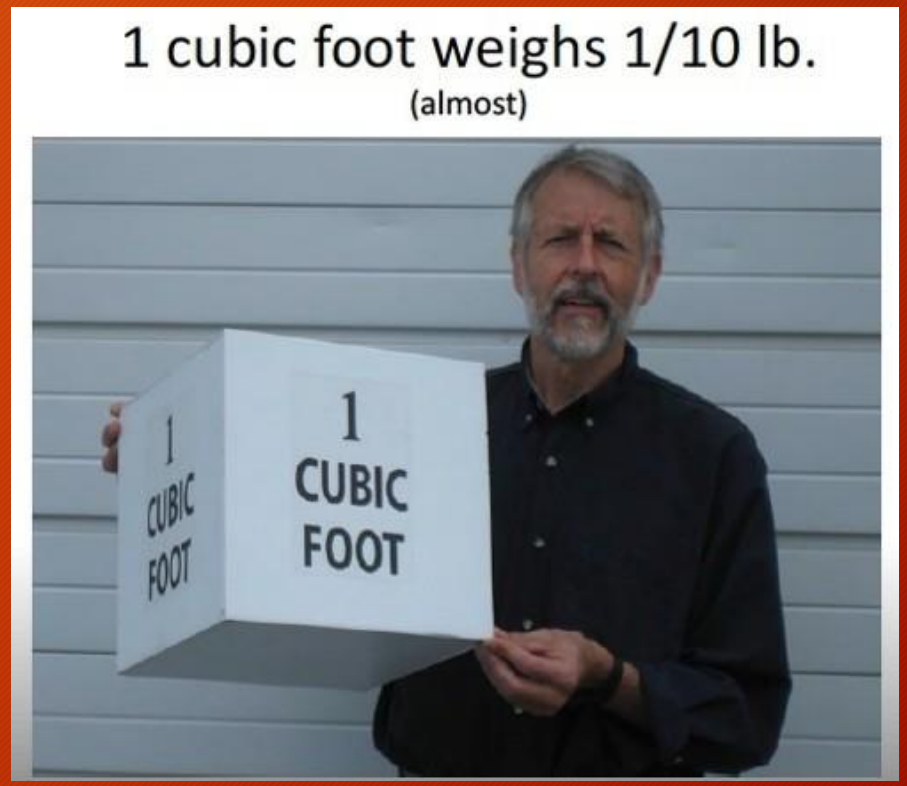
Ductwork that Delivers HVAC Design Concepts

Two Air-Flow Concepts:

- Air under pressure acts like a liquid, and the rules of fluid dynamics apply,
- Air Conditioning requires 450 CFMs* per “ton” of cooling capacity,

Example:

- A 3-Ton air conditioner needs to move 1,350 CFMs of air to be most effective,
- **1,350 CFMs weighs 135 lbs**, and has to flow to every room on every floor.



*CFM’s = Cubic Feet Per Minute

Ductwork that Delivers HVAC Design Concepts

Moving air is hard work and takes energy:

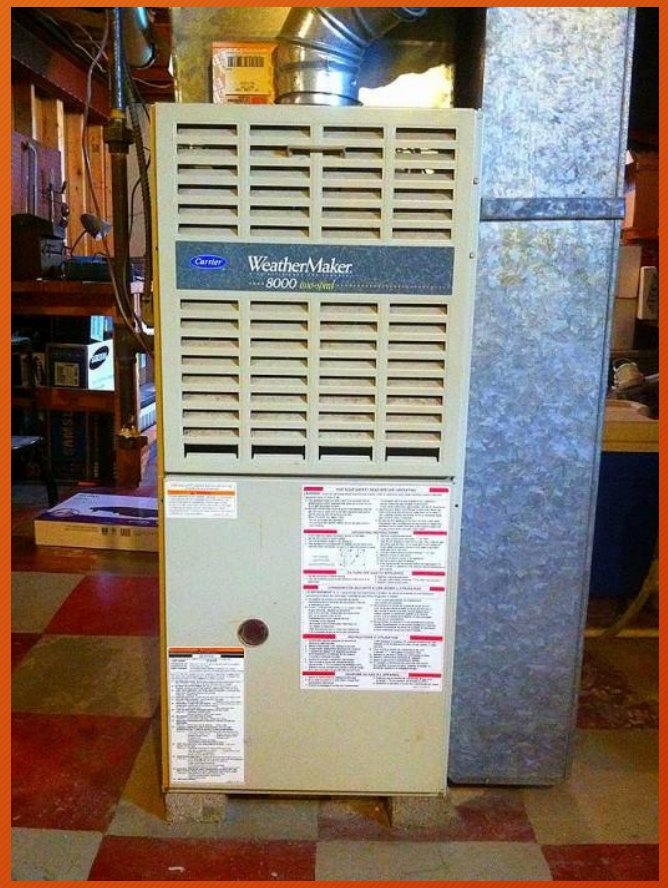
The blower motor and fan is doing the equivalent work that it would take to carry 135 pounds from the basement to the top floor, *every minute!*

Per Minute

Per Hour

That's 8,100 pounds an hour, or the weight of an H1 Hummer!

Historical HVAC Systems
Standard Practices 1960s – 1980s



Historical HVAC Systems
Standard Practices 1980s – 2010s

Comfort complaints are the number one reason people request energy-audits and HVAC service calls and diagnostics:

- Rooms & floors that are harder to heat or cool vs. rest of the home,
- Overheating upper floors in summer, cold basements in winter,
- Bonus rooms, tuck-under garages, and additions that don't keep pace with the thermostat, that are seasonally too hot or cold.

Typical *"broken-zone"* with up to 10-degree variance in temperature from thermostat!

Historical HVAC Systems
Standard Practices 1980s – 2010s

Challenges:

- Single zone of just one thermostat and one blower fan for whole house,
- Heat loads (summer) & heat losses (winter) vary widely by room, floor and/or zone.
- Often three floors w/two floors above grade, and a basement, with a total of 15 (or more) rooms.

Typical *"broken-zone"* with up to 10-degree variance in temperature from thermostat!

Practices 1980s – 2010s "It's Too Hot Upstairs"

Worse-Case Scenario *(almost)*:

- No supply or return trunk-line transitions,
- Squared-off 90-degree return plenum,
- Under-sized one-inch wide filter, smallest length x width, w/high "**static-pressure**",
- Restrictive low air-flow A/C evap coil with high static pressure,
- **"Effective length" of just the junctions pictured = over 500 feet!**

Better HVAC Design
Residential Air-flow Bottlenecks

The restrictive junction pictured exceeds the "***static-pressure***" limit of the entire home's HVAC system:

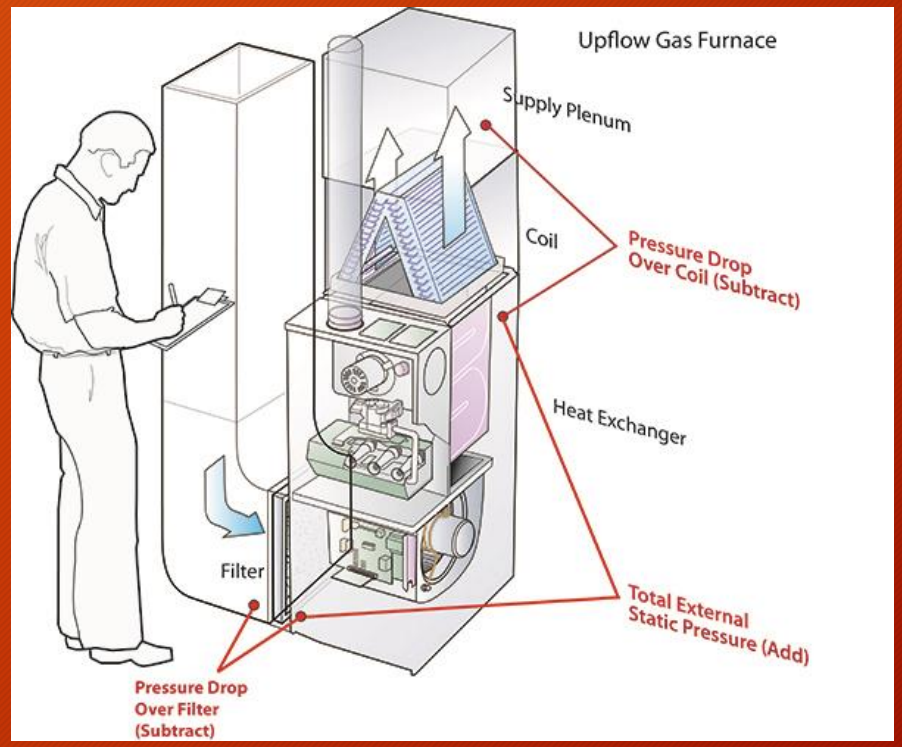
- Return-air duct (plenum) *deadheads* into concrete floor,
- Makes a 90-degree turn and passes through a one-inch pleated filter,
- Then into tight furnace cabinet with blower motor and fan housing obstructing air-flow further.

The measured "***effective length***" of this junction (w/filter) is about 500 feet vs. actual length of *3 feet*.

Ductwork Design Basics
Common Air-flow Bottlenecks

High static-pressure restricts air-flow at these common bottlenecks:

- Square return-air duct at furnace
- Undersized restrictive 1” filters,
- Tight furnace blower fan/motor cabinet,
- Condensate drain in A/C coil,
- Restrictive evaporative coil for A/C,
- Supply plenum to trunk-line junction.



Checking air-flow and static-pressure to ensure the best performance.

Ductwork that Delivers Better HVAC Design

The goal of HVAC designers *is to*...

- Choose proper equipment size/capacity
- Reduce ***"total static-pressure"***,

By...

- Reducing ***"total effective length"*** of the entire ductwork system,

With...

- Less restrictive filters and A/C coils,
- Better **air-flow** and **smooth transitions,**

To...

- Deliver the right amount of heating and cooling to each unique room on all levels of the entire home...

Better HVAC Design
Reduce “Static-Pressure”

***“Static-pressure”* for ductwork air-flow is similar to *blood pressure* for people:**

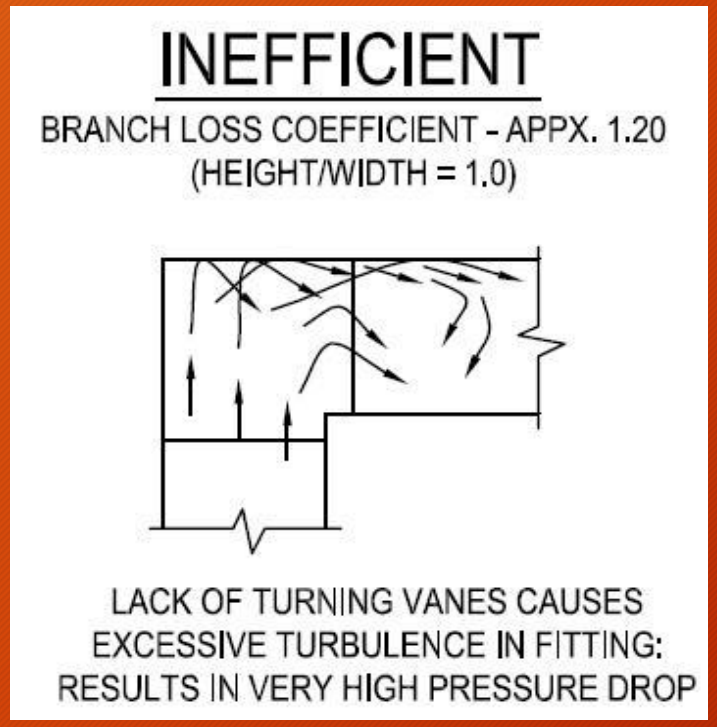
Restrictive ductwork leads to:

- uneven heating & cooling,
- weak air-flow to long runs & top floor,
- increased electricity consumption due to higher amp-draw for blower motors,
- more frequent repairs and shortened equipment life; fan motors, compressor motors, heat-exchangers, etc.

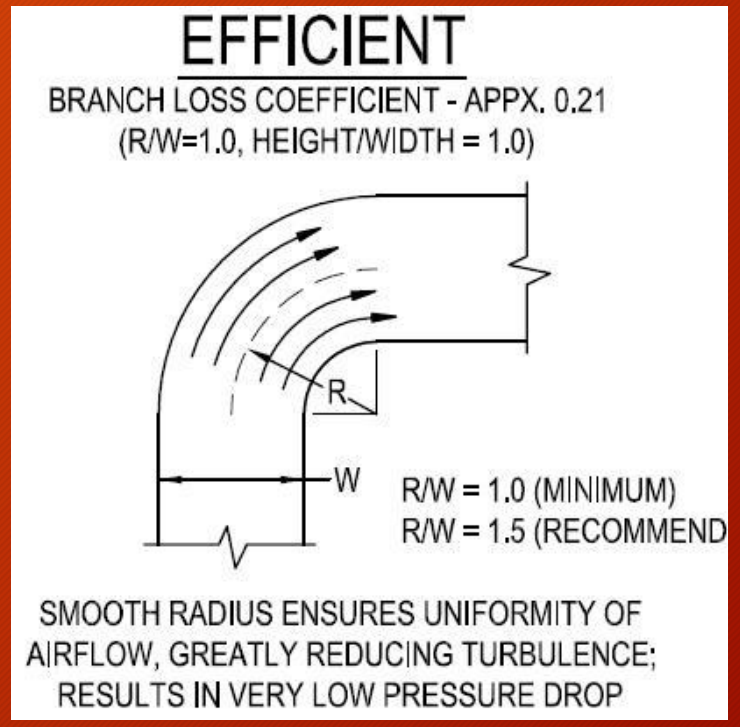
Better HVAC Design
Reduce “Total Effective Length”

There is a huge difference in the **“effective-length” (versus actual length) of** these two sections of ductwork.

The longer the total effective-length of a ductwork system, the less likely it will be able to deliver the needed air-flow throughout the building.



Effective Length of this 90° bend = 60 - 120 feet!



Effective Length of this 90° bend = only 10 feet

Ductwork that Delivers
Choosing the Right Filter

Bigger is Always Better!

- "High-Efficiency" filters trap smaller particles but reduce air-flow significantly,
- Smaller filters, with higher "MERV" ratings, are very restrictive to air-flow,
- Increasing surface area of the filter is the easiest ways to improve air-flow, efficiency and climate control,
- Filtration has a much bigger impact on air-flow, climate control, and efficiency than is generally recognized.

https://www.pvhvac.com/blog/this-is-why-people-love-media-filters

Better HVAC Design
Excellent Return-Air Ductwork

Restrictive Return-Air Side Problems are Still Very Common in New Construction:

- Filter Surface Area should be 2.0 square feet for each 400 cfm of air flow!
- Use smooth “radius elbows” and air-boxes under furnaces for better flow and less resistance,
- Provide 120% return-air to supply-air ratio for vent and duct dimensions,

Dramatic performance improvement for additional cost of only $200 - $400

Better HVAC Design
Excellent Return-Air Ductwork

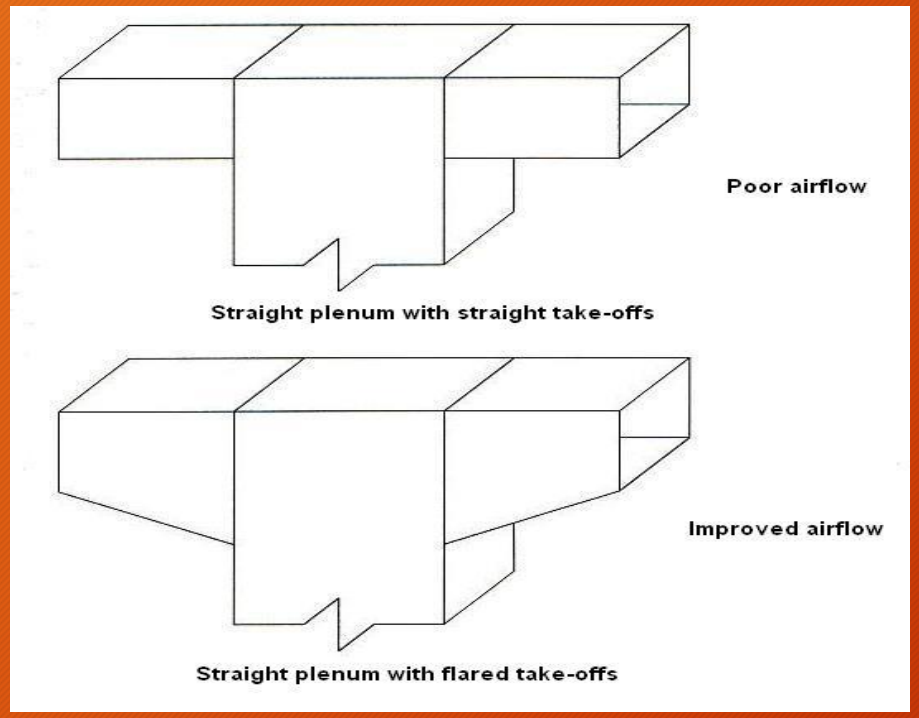
The Advantages of the *"Sled-pack"*:

- Over-sized jumbo 4" media filter with low static-pressure drop,
- Radius elbow in return plenum,
- Air-box directly under blower fan/motor assembly allows more air-flow through unit.

Filter Area = 2.0 square feet for each 400 cfm of air flow!

Ductwork that Delivers Riser to Trunk Line Transitions

Effective length w/o transitions = 120 ft vs. with transitions = only 20 ft:



Negligible additional cost for much better climate control and efficiency:

Ductwork that Delivers
Riser to Trunk Line Transitions

Tapered transition reduces static-pressure and effective length:

Effective length of supply riser to trunk junction = only 10 ft.

Better HVAC Design
Yesterday's Fan Motors

Annual Operating Cost of 3/4HP Fan Motor:

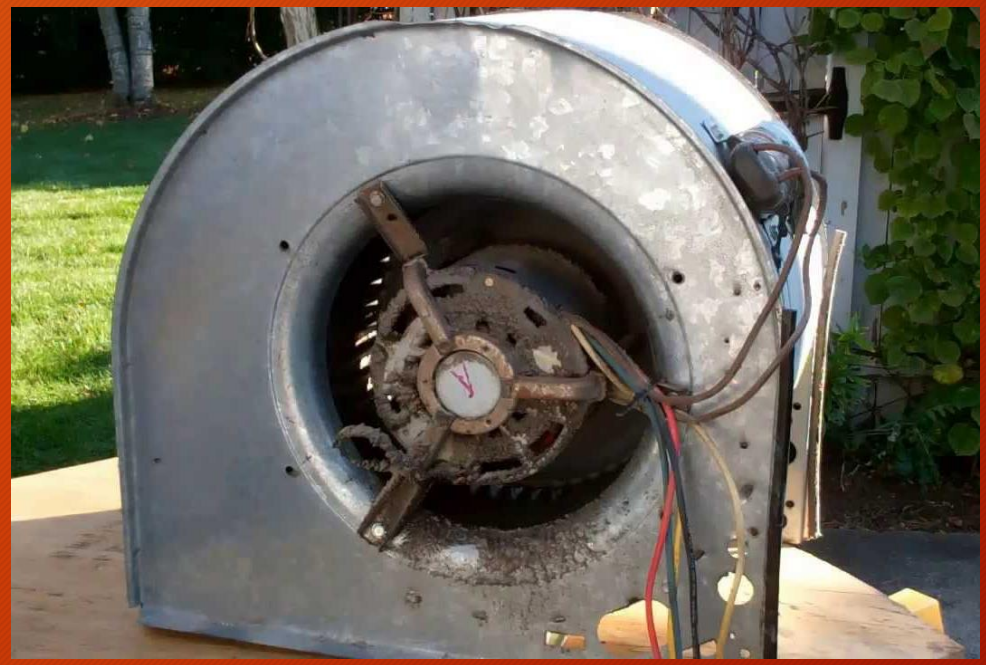
Heating: 750 watts x 1,000 hrs

@ $0.15 per kwh = $113

Cooling: 870 watts x 500 hrs

@ 0.15 per kwh = $65

Annual Runtime Cost: $178



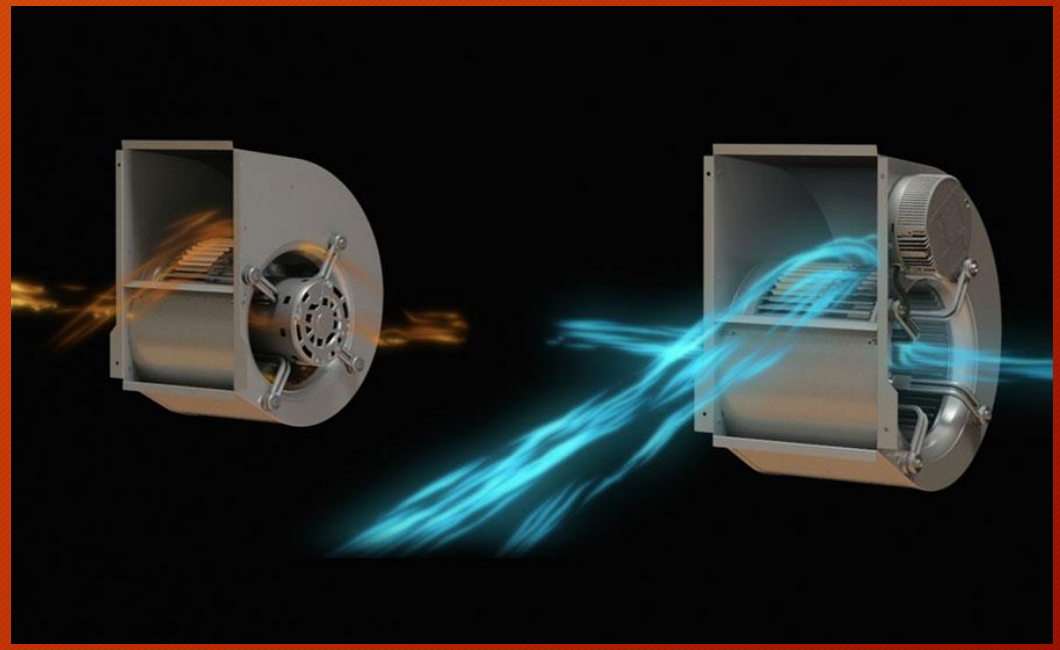
Full-time "fan-on" mode in larger homes results in much higher costs = $350 per yr (3500 kilowatt hours).

Better HVAC Design
Energy Efficient Fan Motors

The **Dept. of Energy** has updated their Furnace **Efficiency** Rating (FER) standard, mandating that these **energy** conserving motors be used in all **new** furnaces, with…

"the expectation that this will result in significant energy conservation and reduction of carbon pollution."

New fan motor standards go in as of July 3rd, 2019

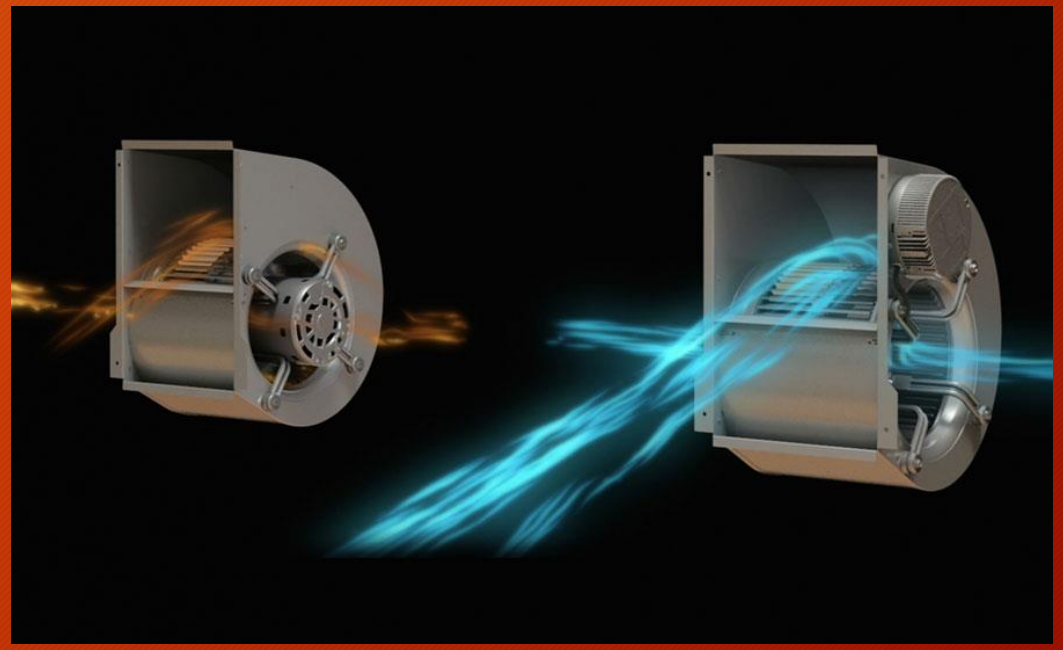


New fan-motors are called:
Variable-speed, DC-Brushless, or
Electronically Commutated Motors (ECM's)

Better HVAC Design
Energy Efficient Fan Motors

Return on Investment:

- These more efficient motors add $400 to upfront costs, with…
- 4-year payback period in small/medium sized homes,
- 2.5-year payback period in larger homes,
- ***ECM fan-motors save energy when installed in well-designed HVAC systems with better air-flow and lower static-pressures…***



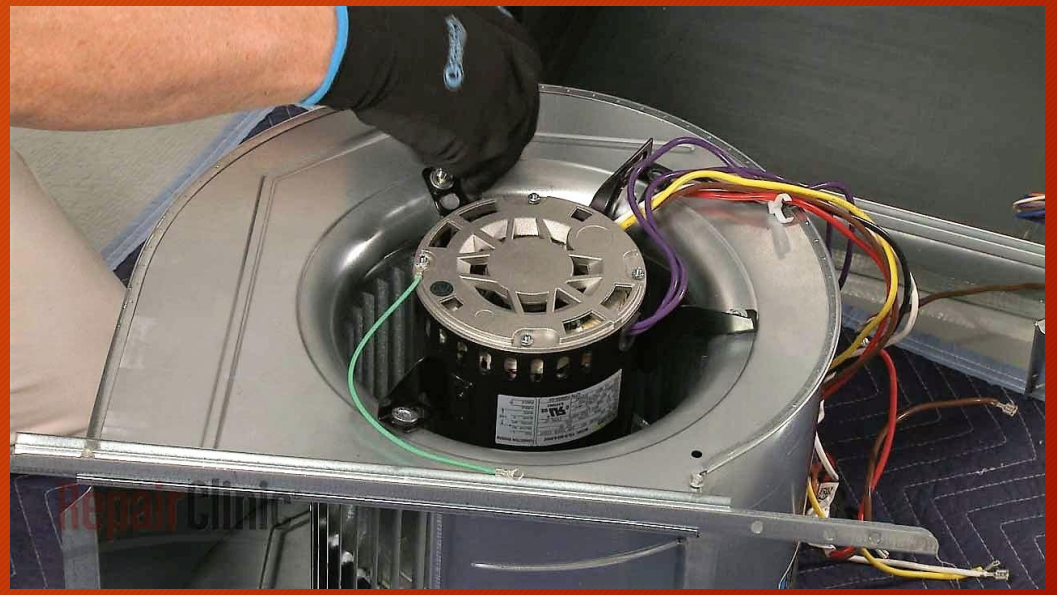
…but ECM's Use MORE ENERGY in restrictive ductwork with high static-pressures.

Better HVAC Design
ECM/DC-Brushless Motor Efficiency

High Static-Pressure *Increases* Energy-Use at Constant Air-flow, with No Benefits:

1200 CFM of air-flow at five different total external static-pressures (TESP):

1) at 0.1 TESP = 170 watts,
2) at 0.3 TESP = 230 watts,
3) at 0.5 TESP = 285 watts,
4) at 0.7 TESP = 345 watts,
5) at 0.9 TESP = 405 watts,



	Ideal Ducts	Good Ducts	Typical Ducts
Energy Savings: low to high TESP	% Electricity Savings	% Electricity Savings	% Electricity Savings
Blower Only - Heating	65 to 71%	56 to 62%	26 to 39%
Blower Only - Cooling	45 to 51%	29 to 33%	-11.2% to -10.7%

Ductwork that Delivers Better Air-flow Evaporator Coils

Indoor AC Evaporator Coil Issues:

Static Pressure Affects Air-flow

Typical Static-Pressure = 0.25 to 0.35 i.w.c.*

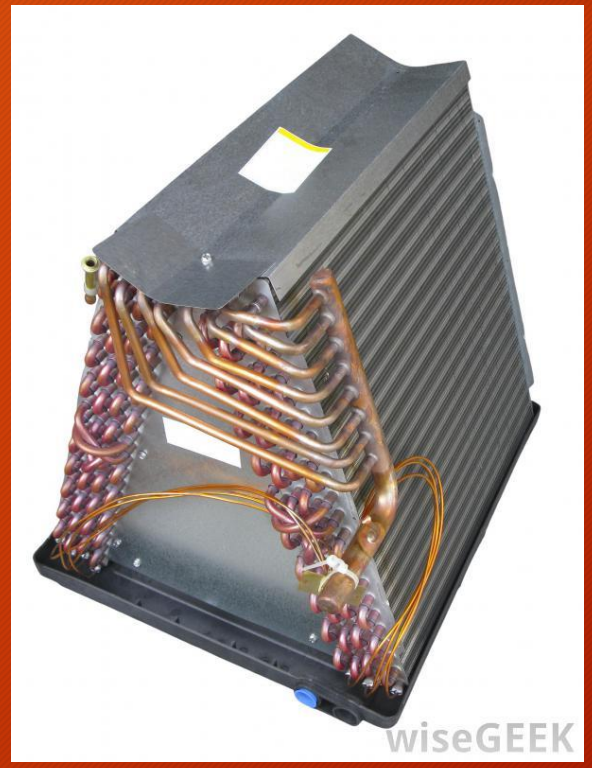
Upgrade Air-flow Coil = 0.09 to 0.15 i.w.c.*

Additional Tips:

Upsize coil by ½ ton = higher SEER rating,

TXV* is critical for efficiency, costs $100.

*i.w.c. = inches water column, a unit of pressure

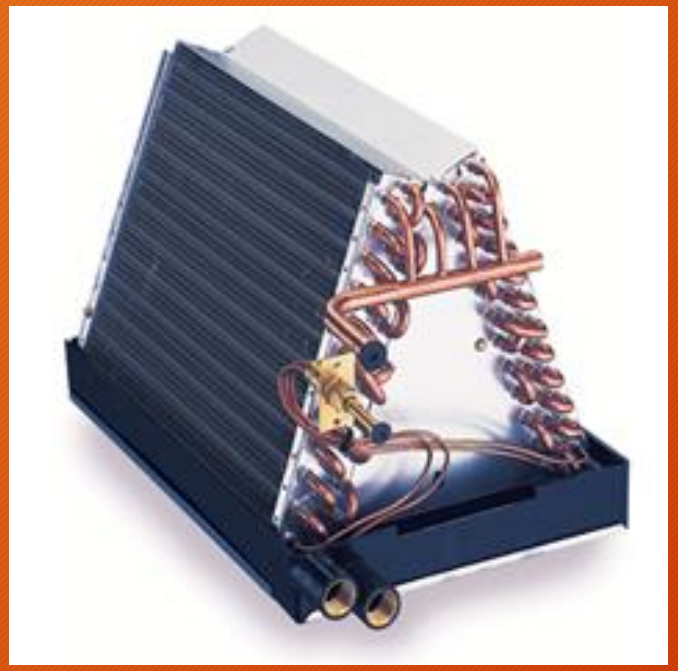


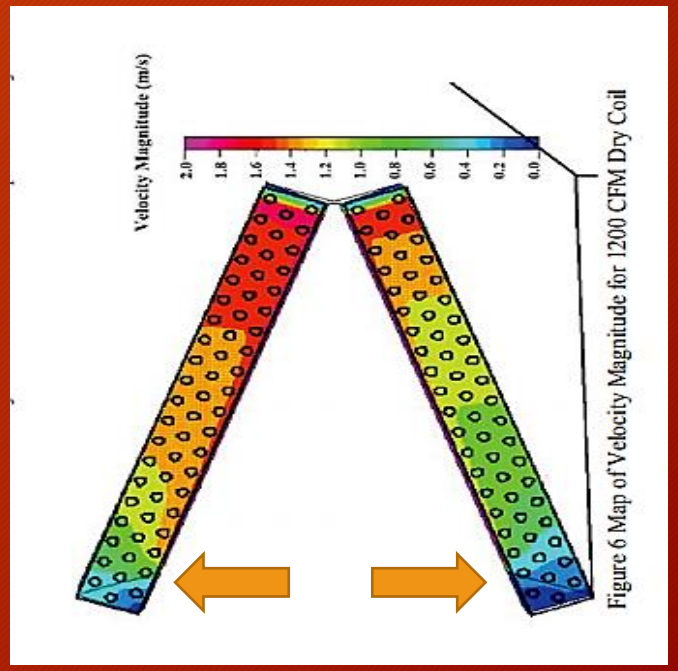
*TXV = Thermal Expansion Valve

Higher Air-flow Coil = only $100 extra!

Ductwork that Delivers Air-flow Issues with Evaporator Coils

Condensate pans partially block critical cooling airflow, reducing airflow and cooling near the condensate pan:





Less airflow near drain pan:

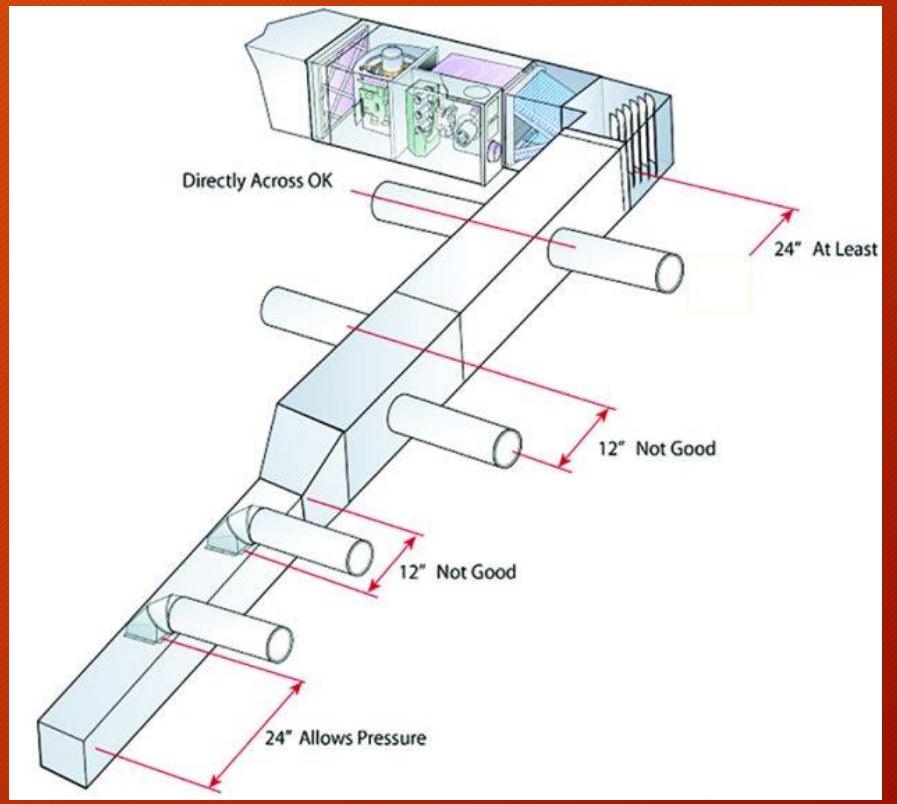
Ductwork that Delivers Better Air-flow Evaporator Coils

Better Supply-side Airflow, with Air Conditioning:

- Upsize indoor AC-coil to improve air-flow past the coil drain pan.
- Wider AC-coils reduces pressure drop across the evaporator coil,
- Access door allows for inspection and cleaning of clogged AC-coils,
- System Service Transition (SST) costs $115 retail.

Ductwork that Delivers Use the “Rule of Two Feet”

- No take-offs within 24” of trunk end-cap,
- Never locate a takeoff in the end-cap,
- Limit trunk-lines to 24 ft in length without reductions, or 48 ft total from a centrally located unit,
- Lower width-to-height ratios have lower friction losses so *make trunks as square as possible (8’ standard not always best)*,
- When the trunk is wider than the plenum, a transition fitting must be used,



https://hvactoday.com/0719-two-foot-rule/

Better HVAC Design
Ductwork Mistakes that Matter

Never install supply branch take-offs within two feet of a trunk-line end-cap, to avoid robbing upstream branches of air-flow:

Never install branch take-offs in a trunk-line end-cap, this also robs upstream branches of air-flow:

Better HVAC Design
Final Commissioning and Testing

Recommended Diagnostic Testing for Airflow, Efficiency and & Comfort:

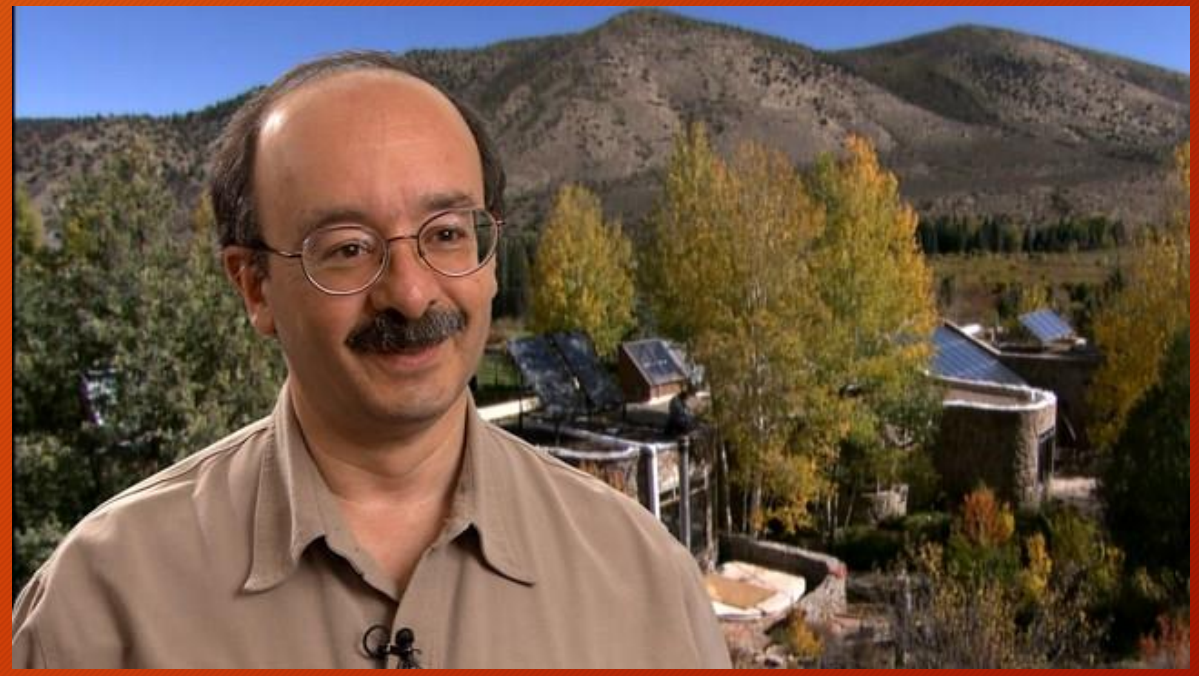
- Total system air-flow,
- Correct static-pressure,
- Amp-draw for fan-motor,
- Duct-sealing is acceptable,
- Room-by-room air flows are correct,
- Attic-based systems are well sealed, and completely insulated.

Better HVAC Design
Ductwork that Delivers

Carbon Neutral Group
Consulting

"Just optimizing friction by making the world's pipes and ducts fat, short, smooth and straight — rather than thin, long, and crooked...

— could save roughly half the world's coal-fired electricity, with typical paybacks under one year in retrofits and less than zero in new-builds."



Amory Lovins, PhD

Chief Scientist of Rocky Mountain Institute (www.rmi.org)

Better HVAC Design
Ductwork that Delivers

To Learn More about Energy Codes or Green Building, please contact:

Community Development

https://www.larimer.org/building

Building: 970-498-7700 or

Planning: 970-498-7683

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