Advanced HVAC Design for Better Performance

Understanding HVAC Design Software Programs
to Optimize Comfort and Efficiency
(And Catch Mistakes Before It's Too Late)

HVAC Design Goals
Ductwork that Delivers

The goal of HVAC designers & contractors:
Is to...

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

With...

- Less restrictive filters and A/C coils,
- Smooth transitions and better air-flow,

To...

- Deliver the right amount of heating and cooling to each unique room on all levels of the home, for year-round comfort and optimized efficiency.

Better HVAC Design
Reduce Static-Pressure & Effective Length

Advantages of Computer Designed HVAC Systems:

- Enables HVAC system to maintain even temperatures throughout the whole building with just one blower/fan and one thermostat,
- Solves the problems of: over-heated upper floors, rooms out of sync with the rest of the house, and cold basements, just to name a few,
- Increases the useful life of the HVAC equipment, with fewer repairs and system failures.

A low static-pressure system delivers: ample air-flow w/less noise, to the entire home, and improves efficiency too!

Building Code Requirements
Tools for Best Performance

Manual J: Block Loads and Losses

- Calculates the total heating or cooling capacity needed to maintain desired interior temperatures on the hottest or coldest days,

Manual D: Ductwork Design

- Calculates the exact “room-by-room” heating and cooling needed to offset summer heat gains & winter heat losses, and sizes ducts accordingly,

Manual S: HVAC Equipment Sizing

- Calculates best size of air-conditioner and furnace for whole house comfort & efficiency.

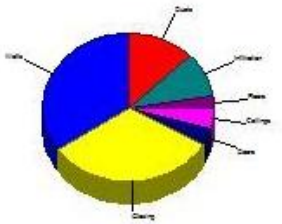
HVAC Design Basics
Tools for Best Performance

Manual J: Total Loads and Losses

- Calculates the total heating and cooling capacity needed to maintain desired indoor temperature on the hottest or coldest days,
- Does not calculate heating/cooling needed for individual rooms or floors in the building,
- Shows energy losses/gains by each building component: ceiling, walls, windows, foundation, infiltration, duct work, humidification, and ventilation.

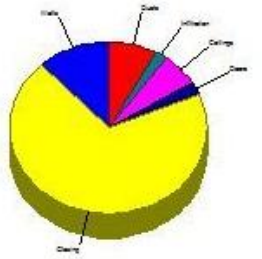
Heating

Component	Btuh/ft²	Btuh	% of load
Walls	6.2	16552	34.5
Glazing	38.8	15504	32.3
Doors	26.5	1671	3.5
Ceilings	2.2	2176	4.5
Floors	1.4	1360	2.8
Infiltration	2.2	4647	9.7
Ducts		6103	12.7
Piping		0	0
Humidification		0	0
Ventilation		0	0
Adjustments		0	
Total		**48012**	**100.0**



Cooling

Component	Btuh/ft²	Btuh	% of load
Walls	1.1	2929	11.8
Glazing	43.3	17308	69.6
Doors	9.4	593	2.4
Ceilings	1.5	1525	6.1
Floors	0	0	0
Infiltration	0.3	542	2.2
Ducts		1955	7.9
Ventilation		0	0
Internal gains		0	0
Blower		0	0
Adjustments		0	
Total		**24852**	**100.0**



Latent Cooling Load = 0 Btuh
Overall U-value = 0.112 Btuh/ft²-°F

This home needs 48k BTU of heating when it's 4° outside, and 25k BTU of Cooling when it's 91° outside.

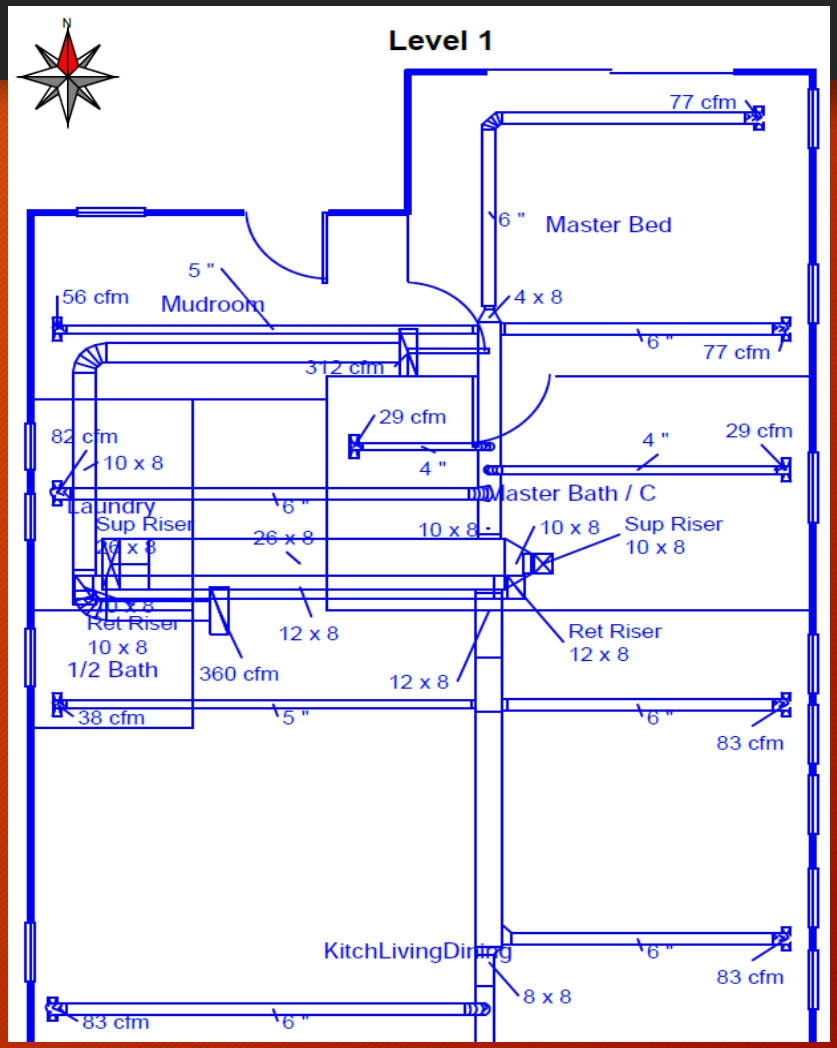
HVAC Design Basics
Manual D for Ductwork

Manual D Duct Design:

Delivers required heating and cooling (temps and air-flow) room by room with precise duct layout and dimensions.

Detailed Inputs include:

- Glass: orientation, type/specs, square feet, overhangs (eaves),
- Details for: ceilings, wall type, floors over garage, w/materials and R-values,
- Foundation details for: crawlspace, below grade walls, slabs, w/R-values.



HVAC Design Basics
Manual S for Right-Sizing

Manual S: Equipment Sizing

- Calculates best size of air-conditioner and furnace for whole house comfort & efficiency,

- Use total building loads/losses, *AND* required *air-flow and temps* to pick the right sized equip.

Technical Specs:

- Air-flow target for **air-conditioning = 450 CFM's** per Ton (12,000 BTU's) in dry, hot climates,

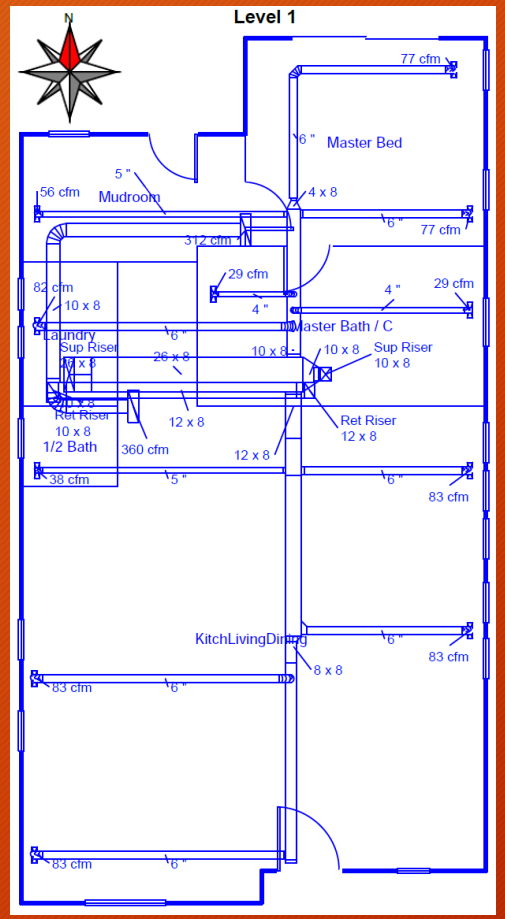
- Air-flow target **forced-air heating = 150 CFM's** per 10,000 BTU's of rated heating capacity.

Many AC systems are still over-sized.

Better HVAC Design
Manual D Ductwork Challenges

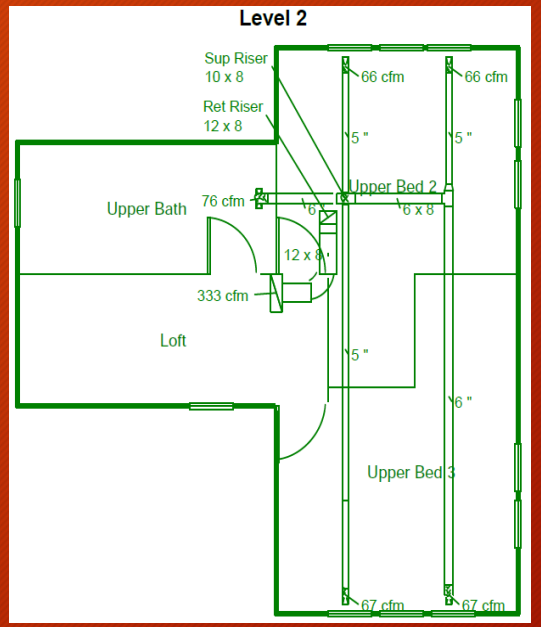
Example: Three-level home with 12 separate spaces/rooms, and only one fan and thermostat:

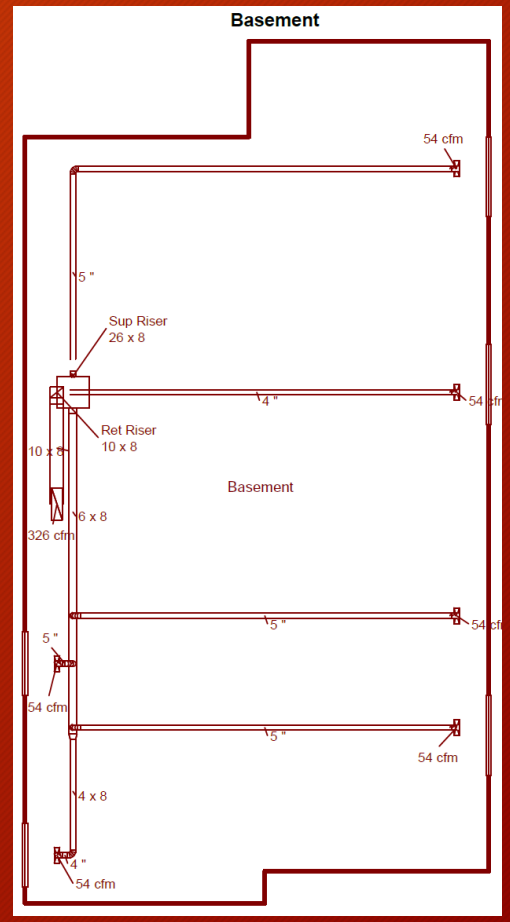
How do we ensure ample heating and cooling air-flow throughout the building?



Design Challenges:

- Static Pressure,
- Total Effective Length,
- Friction Rate,
- Need Chases for Risers,

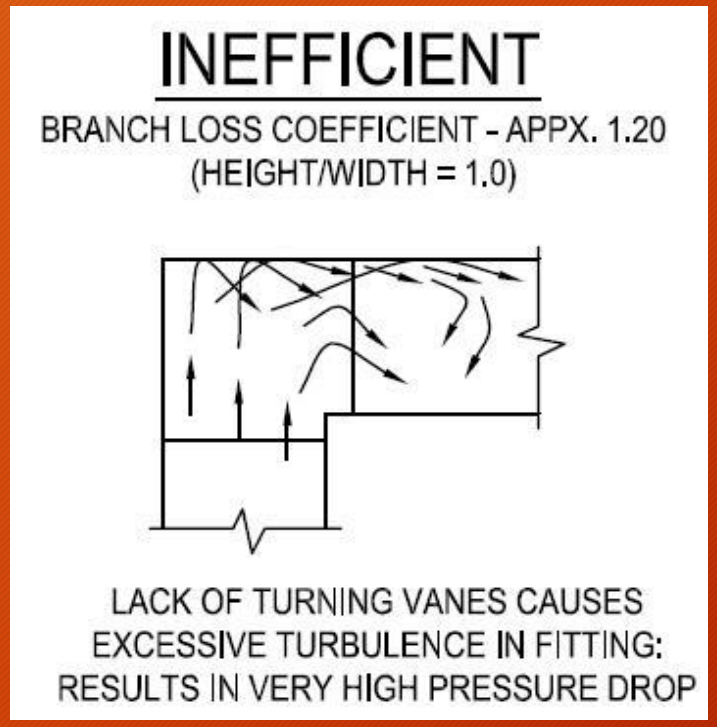




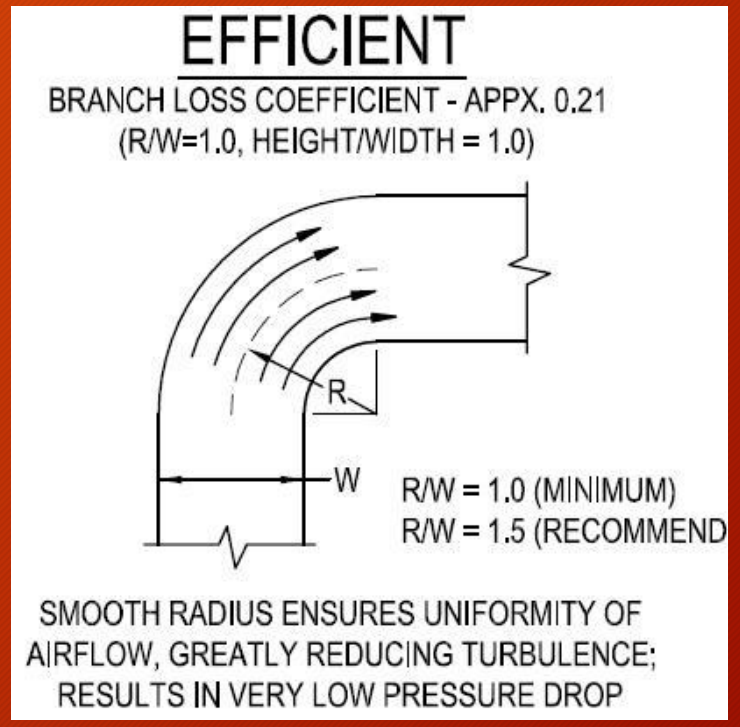
Better HVAC Design
Reduce Static Pressure and Effective Length

The **actual length** these two sections of ductwork is the same, but the difference in **"effective-length"** is huge.

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, especially the longest ducts.



Effective Length of this 90° bend = <u>60 - 120 feet</u>!



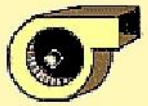
Effective Length of this 90° bend = <u>only 10 feet!</u>

Better HVAC Design
Manual D Ductwork Concepts

Key Elements of Duct Design:

- Set maximum external static pressure at factory spec >
- Enter accurate pressure losses for components >
- Subtract static-pressure losses for HVAC components = available static-pressure >
- Total effective length of entire system/longest run >
- Friction-rate must stay above 0.06, or weak air-flow

Static Pressure for Entire House



	Heating (in H2O)	Cooling (in H2O)
External static pressure	<0.50>	<0.50>
Pressure losses		
Coil	0.25	0.25
Heat exchanger	0	0
Supply diffusers	0.03	0.03
Return grilles	0.03	0.03
Filter	0.15	0.15
Humidifier	0	0
Balancing damper	0	0
Other device	0	0
Available static pressure	0.04	0.04

	Supply (ft)	Return (ft)
Measured length of run-out	33	9
Measured length of trunk	12	1
Equivalent length of fittings	335	150
Total length	379	159
Total effective length		538

Friction Rate	Heating (in/100ft)	Cooling (in/100ft)
Supply	[0.007] < 0.06	[0.007] < 0.06
Return	[0.007] < 0.06	[0.007] < 0.06

FR = Friction Rate
ASP = Available Static Pressure
TEL = Total Effective Length

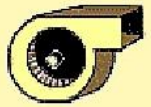
$$FR = \frac{ASP}{TEL} \times 100$$

Better HVAC Design
Manual D Ductwork Challenges

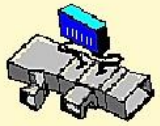
Accuracy is Essential:

- Don't set the static pressure above equipment's rated max,
- Use accurate static-pressure drop across AC evap coil,
- Use accurate static-pressure drop across filter,
- Using inaccurate data (at *right*) will result in systems that don't perform in the real world.

Static Pressure for Entire House



	Heating (in H2O)	Cooling (in H2O)
External static pressure	<0.60>	<0.60>
Pressure losses		
Coil	0.10	0.10
Heat exchanger	0	0
Supply diffusers	0.03	0.03
Return grilles	0.03	0.03
Filter	0.10	0.10
Humidifier	0	0
Balancing damper	0	0
Other device	0	0
Available static pressure	0.34	0.34

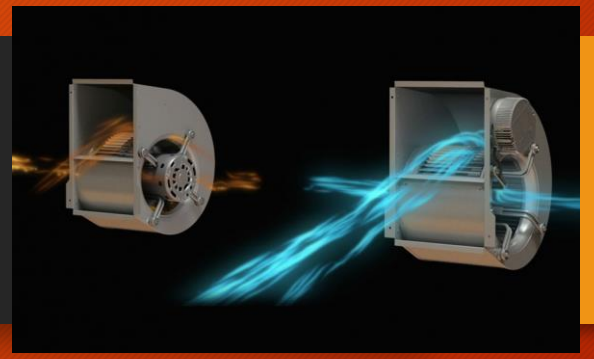


	Supply (ft)	Return (ft)
Measured length of run-out	33	9
Measured length of trunk	12	1
Equivalent length of fittings	335 •••	150 •••
Total length	379	159
Total effective length		538

Friction Rate	Heating (in/100ft)		Cooling (in/100ft)	
Supply	[0.063]	OK	[0.063]	OK
Return	[0.063]	OK	[0.063]	OK

If available static-pressure, total effective-length, and friction-rate are acceptable, the software says **"OK"**, and if not, it says **"<0.06"** (*which is the minimum*). In this case, the inputs are not accurate, and the system only works on paper.

Better HVAC Design
New Energy Efficient Fan Motors



"These motors need to breathe"

Standard PSC* Motor = 45% efficient

DC-brushless ECM* = 85% efficient

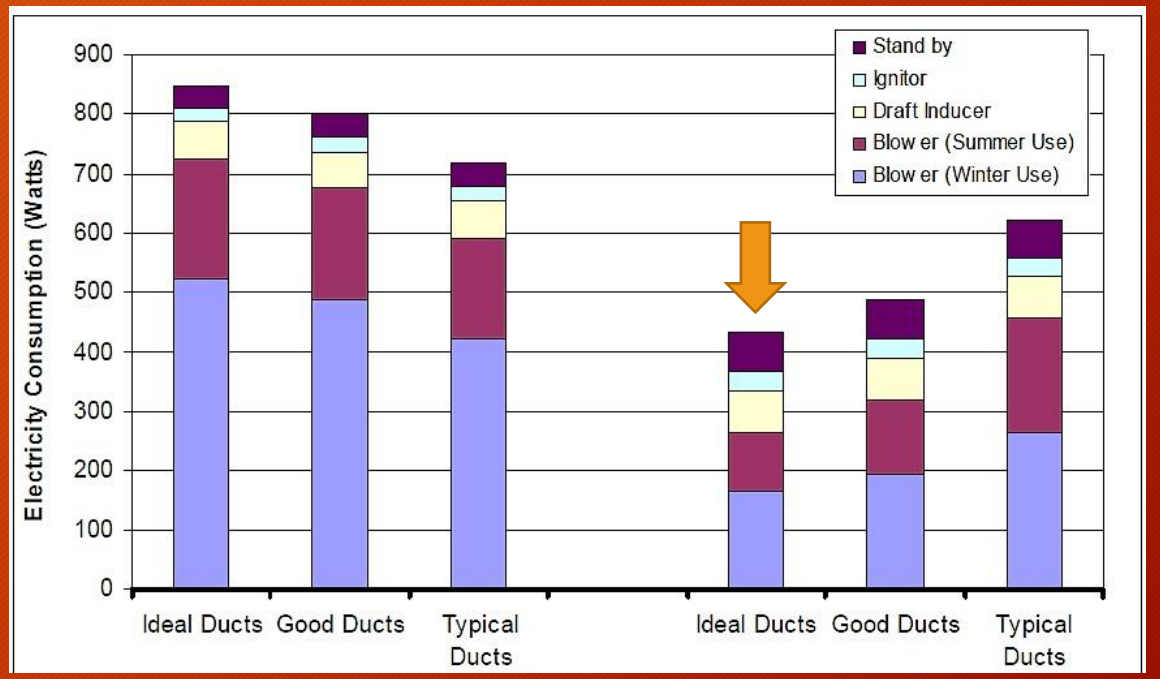
But restrictive ductwork with high-static pressure negates the advantage:

Ideal = 0.25 i.w.c.

Max = 0.50 i.w.c.

Typical = 0.80 i.w.c.

*PSC = permanent split capacitor,
*ECM = electronically commutated motor
i.w.c. = inches water column of pressure



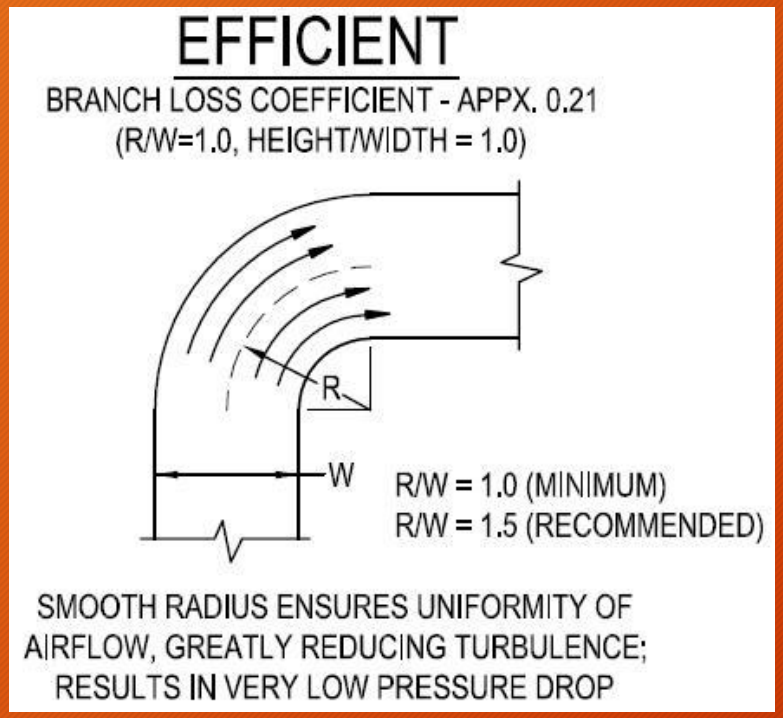
Old PSC Motors

New ECM Motors

Evaluation of Retrofit Variable-Speed Furnace Fan Motors - Consortium for Advanced Residential Buildings January 2014
https://www.nrel.gov/docs/fy14osti/60760.pdf

Better HVAC Design
Manual D Ductwork that Delivers

Apply better design for low static-pressure to improve air-flow to the farthest ends of the HVAC system:



Dramatic improvement in performance for an additional cost of only $200 - $500 on $10,000 to $20,000 systems:

Better HVAC Design
Manual D Ductwork that Delivers

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

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

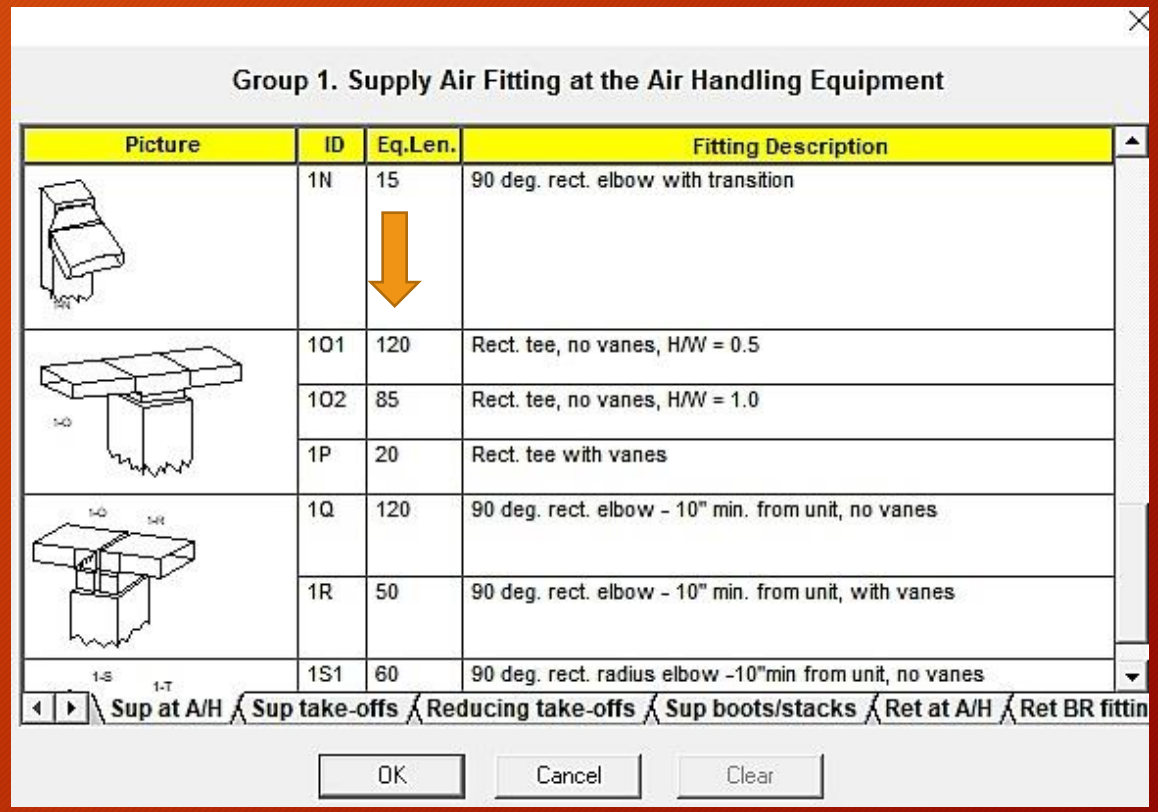
Filter Area = 2.0 square feet for each 400 cfm of air flow!
(wide-pleated filters have lots of surface area)

Better HVAC Design
Manual D Ductwork that Delivers

Outdated Design = Poor Performance:

- The typical “T” plenum-to-supply trunk-line junction has an effective length of **120 ft!**
- Resulting in elevated static-pressure, weak air-flow to longest effective runs, and uneven temps throughout the building.

At right: Duct fittings chart with effective-length, from Manual D duct-design software >



Group 1. Supply Air Fitting at the Air Handling Equipment

Picture	ID	Eq.Len.	Fitting Description
	1N	15	90 deg. rect. elbow with transition
	1O1	120	Rect. tee, no vanes, H/W = 0.5
	1O2	85	Rect. tee, no vanes, H/W = 1.0
	1P	20	Rect. tee with vanes
	1Q	120	90 deg. rect. elbow – 10" min. from unit, no vanes
	1R	50	90 deg. rect. elbow – 10" min. from unit, with vanes
	1S1	60	90 deg. rect. radius elbow –10"min from unit, no vanes

Sup at A/H | Sup take-offs | Reducing take-offs | Sup boots/stacks | Ret at A/H | Ret BR fittin

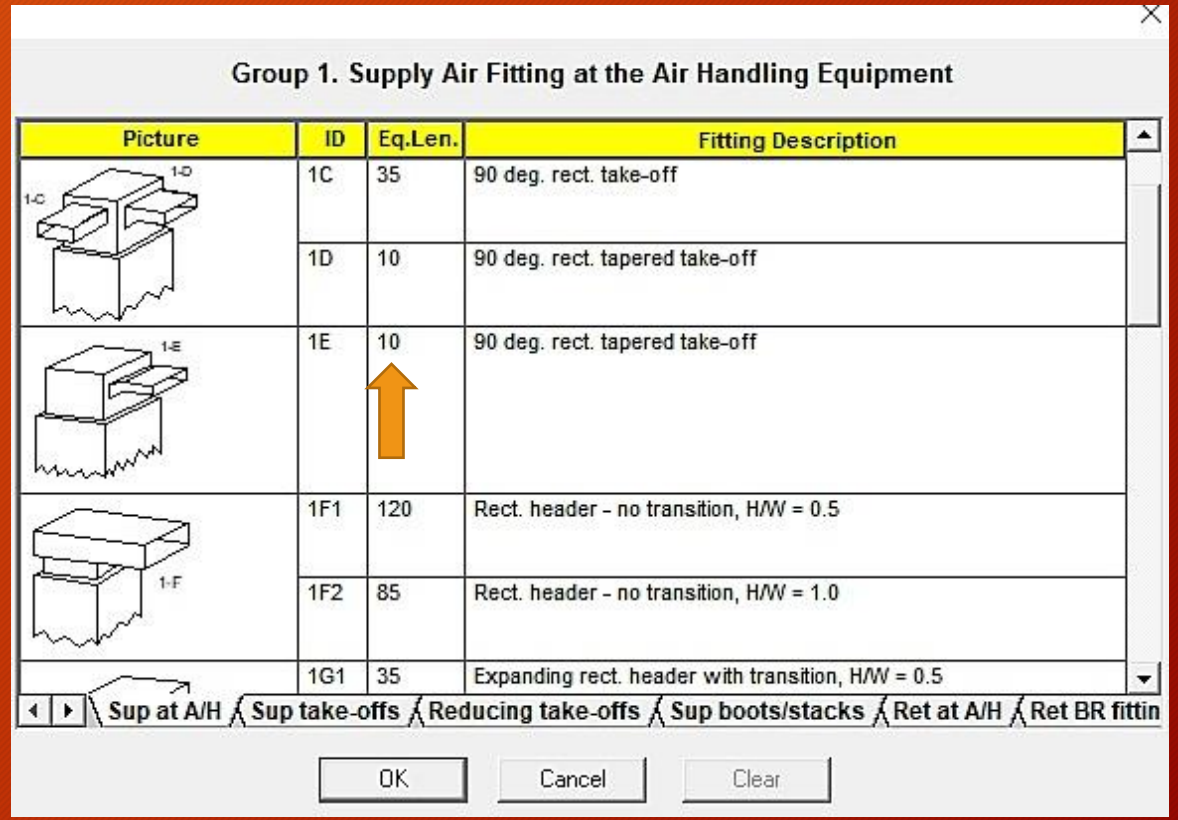
OK Cancel Clear

Better HVAC Design
Manual D Ductwork that Delivers

Better Design = Better Performance:

- "Tapered" transitions reduce effective length of furnace plenum to supply trunk line junction to only **10 feet!**
- Resulting in moving more air with less effort, and more uniform temps throughout the building.

Duct fittings chart with effective-length, from Manual D duct-design software >



Group 1. Supply Air Fitting at the Air Handling Equipment

Picture	ID	Eq.Len.	Fitting Description
1-C 1-D	1C	35	90 deg. rect. take-off
	1D	10	90 deg. rect. tapered take-off
1-E	1E	10	90 deg. rect. tapered take-off
1-F	1F1	120	Rect. header - no transition, H/W = 0.5
	1F2	85	Rect. header - no transition, H/W = 1.0
	1G1	35	Expanding rect. header with transition, H/W = 0.5

Sup at A/H | Sup take-offs | Reducing take-offs | Sup boots/stacks | Ret at A/H | Ret BR fittin

OK Cancel Clear

Better HVAC Design
Manual D Ductwork that Delivers

Indoor AC Evaporator Coil Issues:

Static Pressure and Air-flow:

Typical Pressure Drop = 0.25 – 0.35 iwc

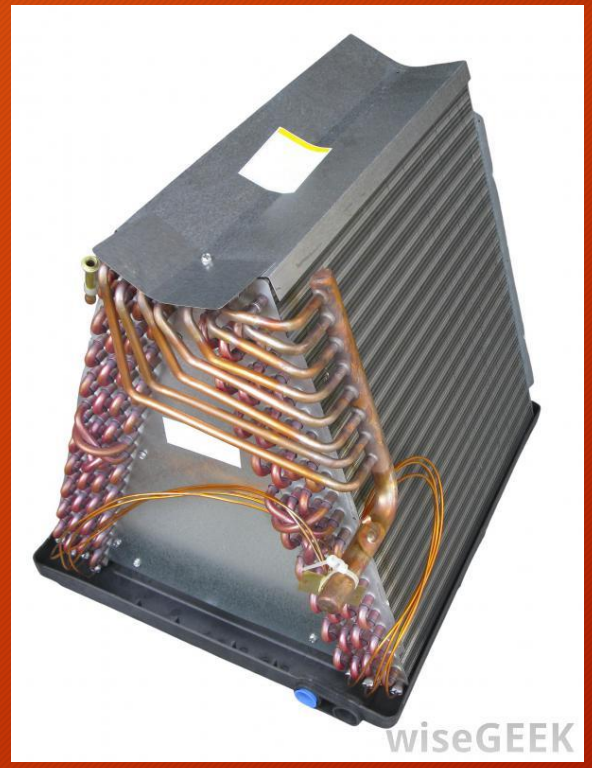
High Air-flow Coil = 0.09 – 0.15 iwc

Higher Air-flow Coil = only $100 extra!

Notes:

Upsize coil by ½ ton = higher SEER rating,

TXV is critical for efficiency, costs $100.



Better HVAC Design
Manual D for Ductwork that Delivers

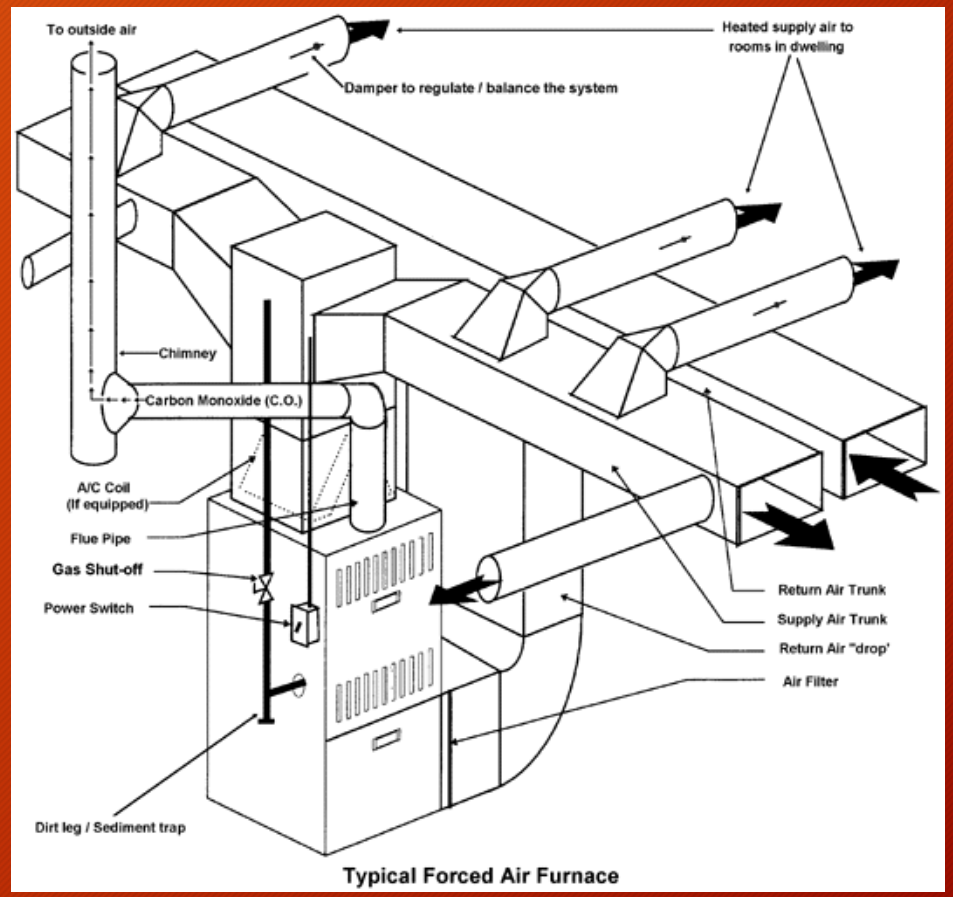
Better Supply-side Airflow for Air-Conditioning:

- Upsize indoor AC-coil to improve SEER-rating and cooling capacity,
- 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) cost $115

Better Duct Design
Ductwork “Tinner” Fundamentals

- Limit trunk-lines to 24 ft in length without reductions, or 48 ft total from centrally located unit,
- Lower width-to-height ratios have lower friction losses so *make trunks as square as possible (8’ standard not always best)*,
- No take-offs within 24” of trunk end cap,
- Never locate a takeoff in the end cap,
- When the trunk is wider than the plenum, a transition fitting must be used,
- Provide 120% return-air to supply-air ratio for vent and duct dimensions, or more.



Typical Forced Air Furnace

HVAC Design
Ductwork Mistakes that Matter

Never locate a takeoff in the end cap, and no take-offs within two feet of trunk-line end cap:

Five supply branches in last 2ft of trunk line, causing comfort issues in the rest of the home.

HVAC Design
Ductwork Mistakes that Matter

Four supply-air branches in the last two feet of supply trunk:

Upstream supply branches receive little air-flow:

Better HVAC Design
Ductwork Mistakes that Matter

Avoid supply vents in trunk-line, use branch take-offs:

Mistakes in branches & trunks causes weak, uneven air-flow:

Better HVAC Design
Ductwork Mistakes that Matter

Sags and bends decrease air-flow, flex duct needs stretch & support:

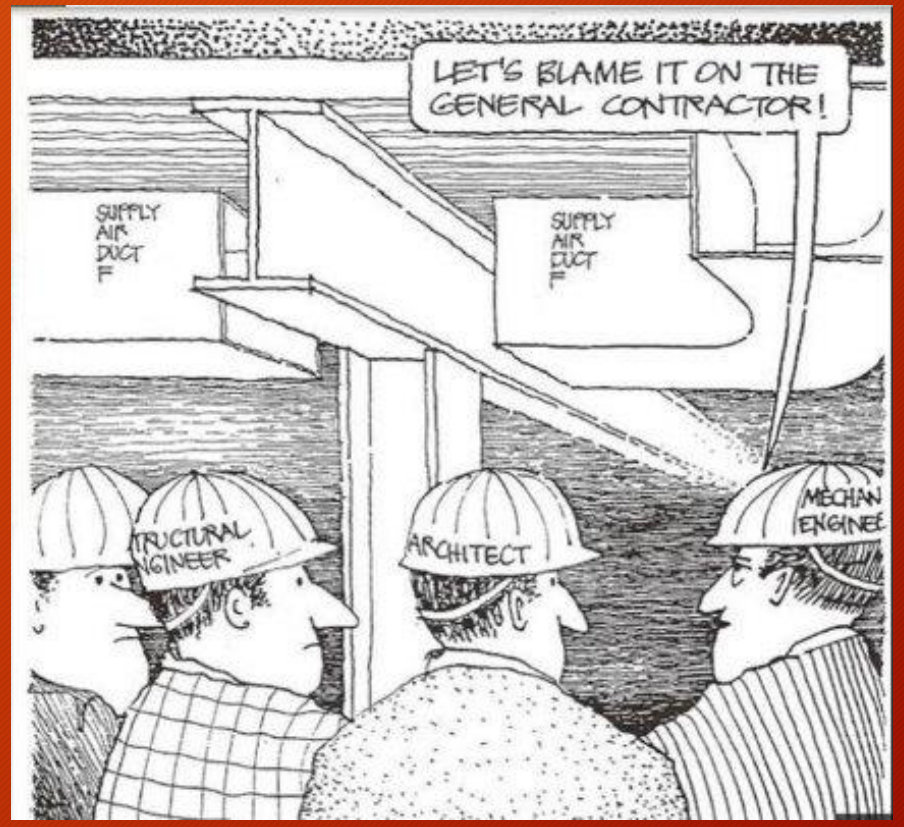
Hard/metal radius elbows should be used for flex-duct as necessary:

A round 14” return-duct compressed to 6” oval:

Better HVAC Design for Ductwork that Delivers

HVAC Design and Commissioning:

- Improvements and “Best Practices” are becoming more standardized,
- Higher operational efficiency delivers lower heating/cooling costs, superior climate-control and customer satisfaction.



Better HVAC Design
Manual D for Ductwork that Delivers

Carbon Neutral Group
Consulting

Recommended Diagnostic Testing for Ductwork Airflow & Comfort:

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

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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