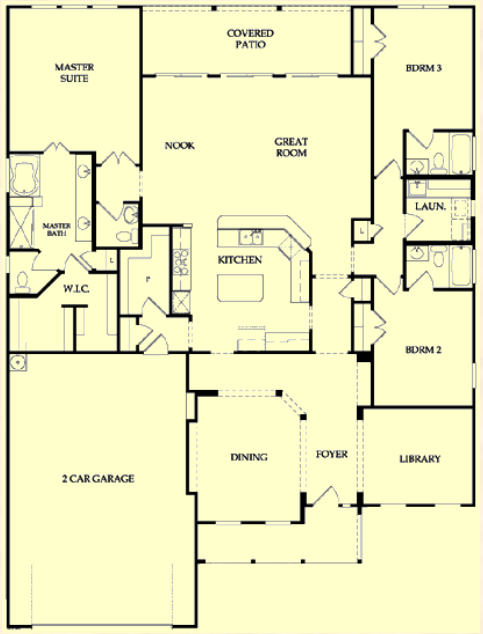
Great Plains Energy Codes Conference
October 16-18, 2012
Omaha, Nebraska

Compliance & Advocacy | Commercial Building Design | Residential Building Design | Value & Practical Applications

Residential HVAC Design Summary

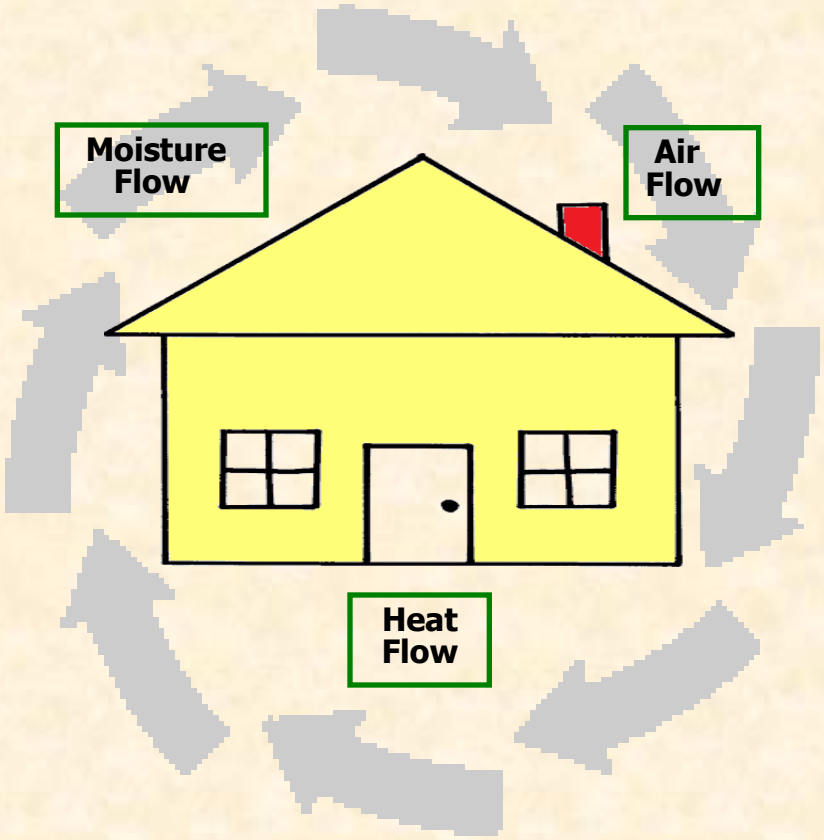
Overview of Industry Standards



REAL WORLD HVAC

System Interdependencies

- The systems within every home are interdependent
  - Structural systems
  - Mechanical systems
- They must <u>all</u> function properly to deliver home safety, durability, indoor air quality and comfort



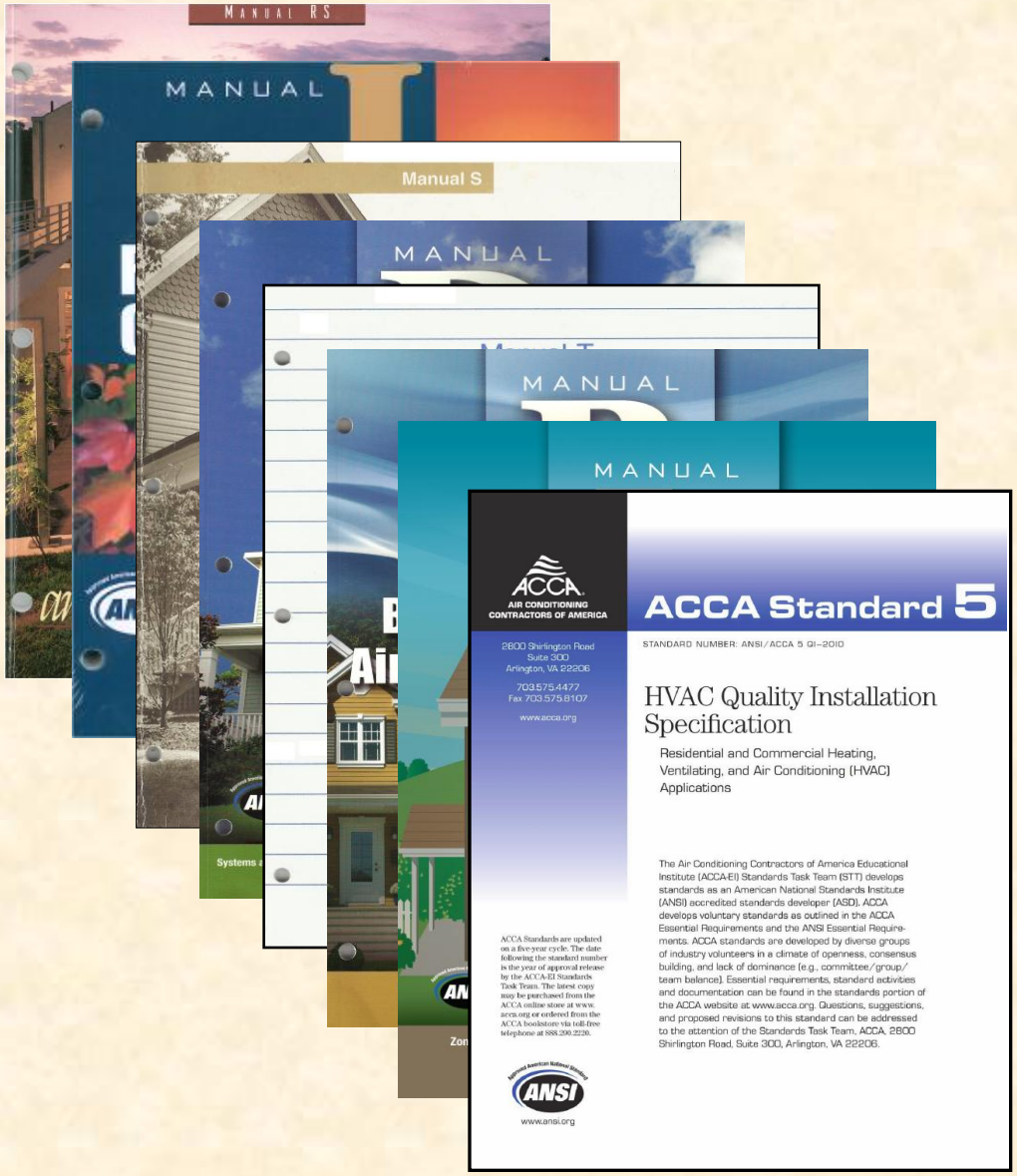
Residential HVAC Code Reference & Beyond

- International code reference includes
  - Manuals J, S and D
  - Version is not addressed
- Additional standards and guidelines are part of the design process
- Successful equipment commissioning is dependent on the HVAC design process.

Residential HVAC System Design Resources

HVAC standards and guidelines are also interdependent

- Manual RS: System Concept
- Manual J:* Load Calculation
- Manual S: Equipment Selection
- Manual D:* Duct Design
- Manual T: Air Distribution
- Manual B: Testing, Adjusting & Balancing
- Manual Zr:* Residential Zoning
- ANSI/ACCA 5 QI:* Quality Installation Specification
  - Installation best practices
  - Capacity and performance testing
- HVAC design is a process of discovery.



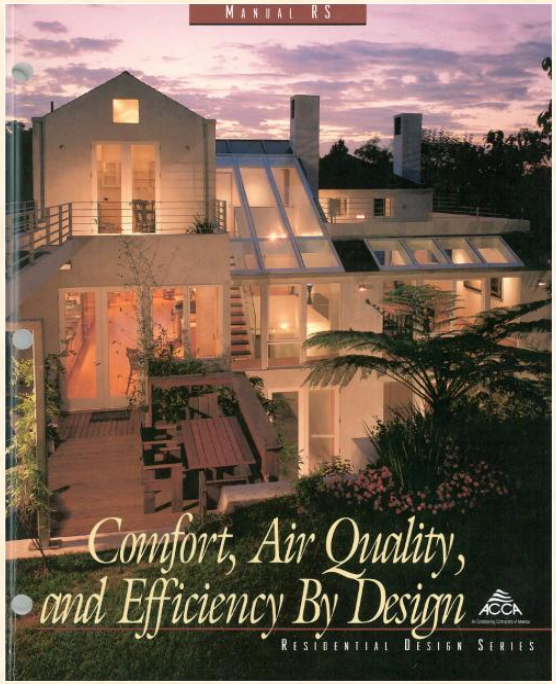
* ANSI Approved Industry Standard

Courtesy Of ACCA

Comfort, Air Quality and Efficiency By Design

Manual RS - provides conceptual guidance

- Indoor air quality considerations
- Zoning considerations
- Equipment options
- Humidification / Air filtration
- Control system options
- Air system design considerations.



Courtesy Of ACCA

Next – Residential Load Calculations

Manual J – Load Calculation

- Cornerstone of the design process

There have been a number of updates:

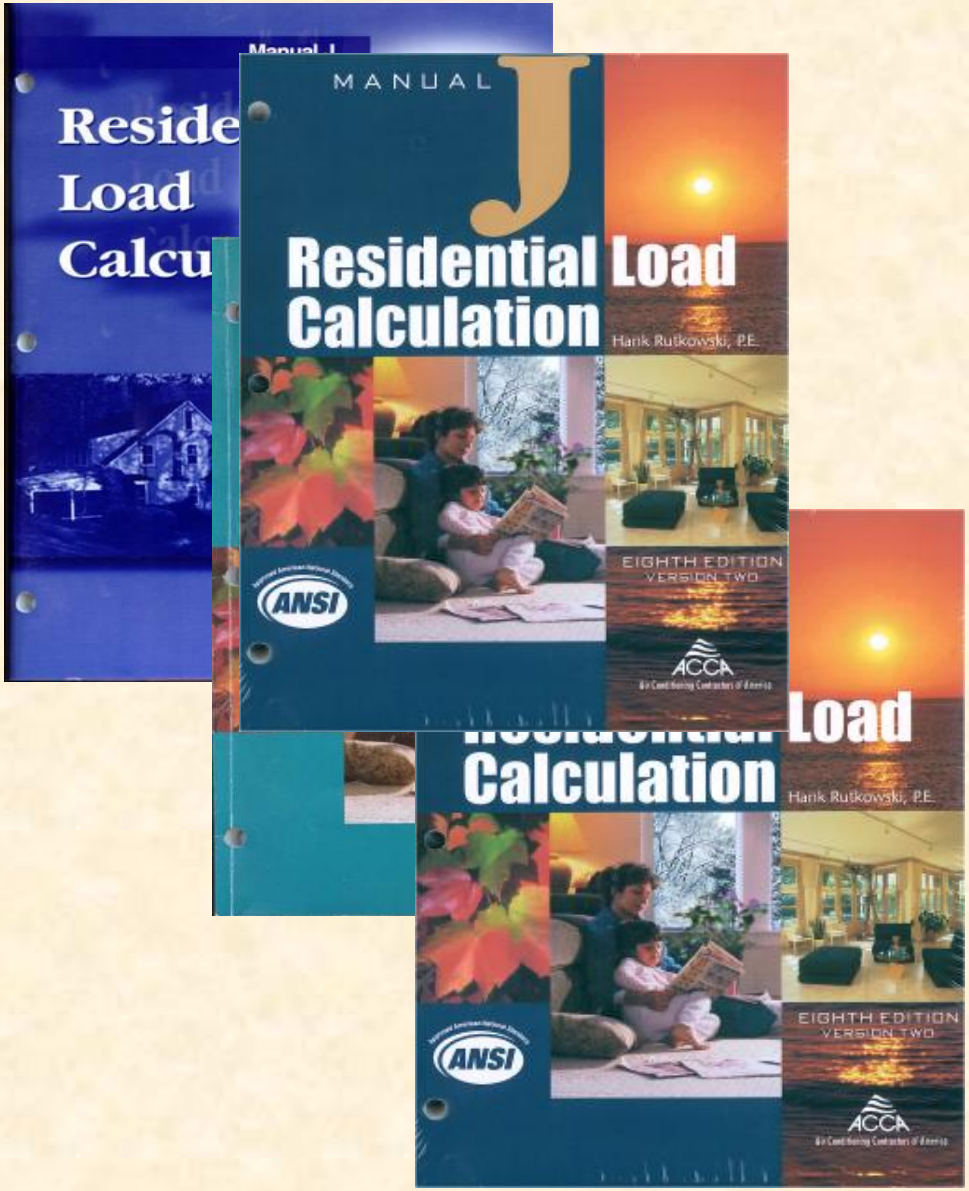
- Manual J Version 7
- Manual J Version Abridged Edition
- Manual J Version 8

Each has delivered:

- increased sensitivities
- enhanced load accuracy
- improved modeling

Each has boundaries within which accurate loads can be produced

- It's important that the current version be used
- Poor assumptions and self-imposed safety factors remain an issue
- Proficiency is tied to frequency of use.

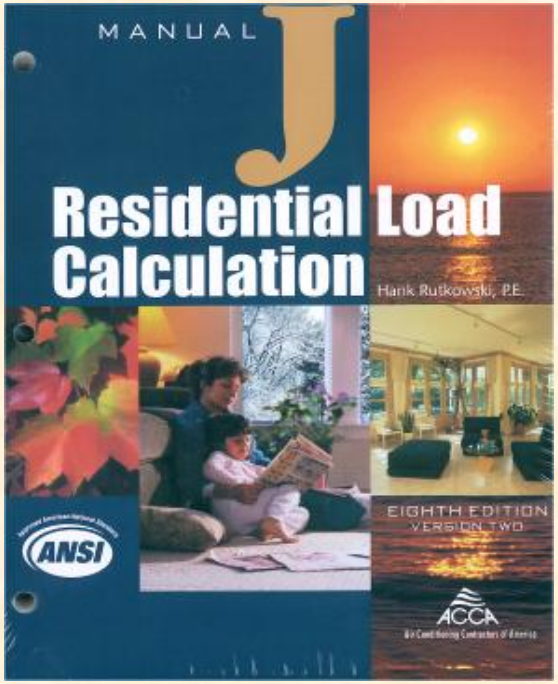


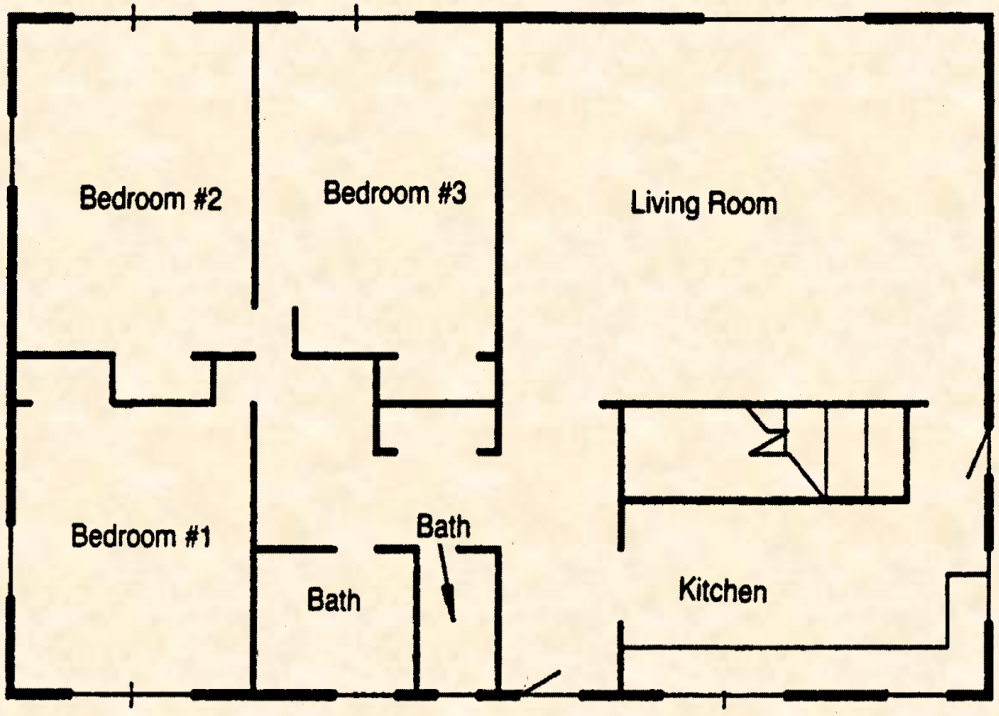
Courtesy Of ACCA

Residential Load Calculation

Manual J *(8th edition)* process provides:

- Total heating and cooling loads
- Room by room heating and cooling loads
- Peak room loads for cooling in zoning applications.



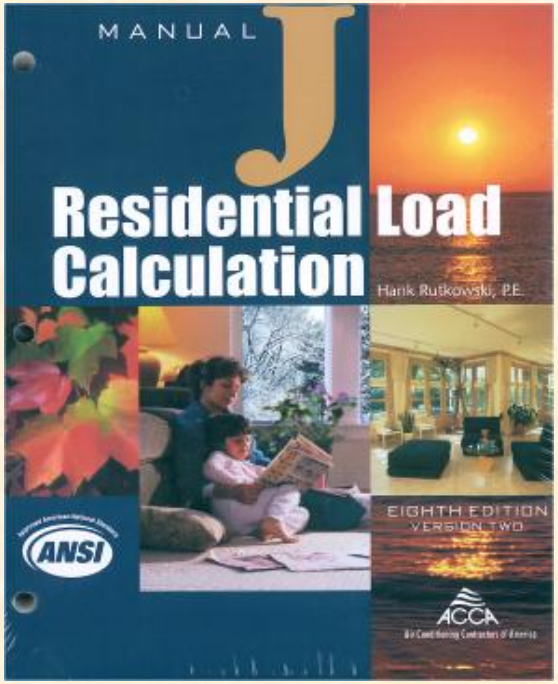


Load Calculation Determines SHR

Manual J process provides:

- Sensible and latent cooling load
  - Sensible Heat Ratio (SHR)
  - SHR target for the cooling coil selection.

$$\text{SHR} = \frac{\text{Sensible Cooling Load}}{\text{Total Cooling Load}}$$



Load Calculations Use Local Climate Data

Manual J process provides equipment selection data

- Based on local climate data and operating conditions:
  - Outdoor dry bulb
  - Indoor dry bulb
  - Indoor wet bulb
- OEM data correlates equipment performance with operating conditions
- Inflated load calculations come at a price
  - Lack of confidence regarding weather extremes is a catalyst for over-sizing.

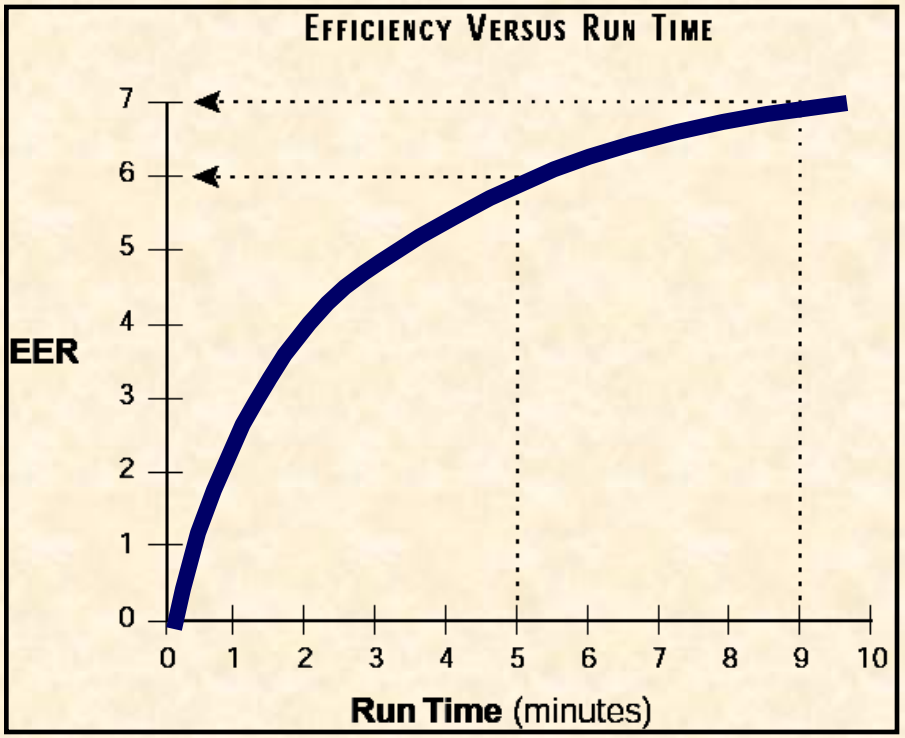
Table 1A

Outdoor Design Conditions For the United States and Canada

Location	Elevation	Latitude	Winter	Summer					
	Feet	Degrees North	Heating 99% Dry Bulb	Cooling 1% Dry Bulb	Coincident Wet Bulb	Design Grains 55% RH	Design Grains 50% RH	Design Grains 45% RH	Daily Range (DR)
Livingston AP	4656	45	-14	87	60	-36	-29	-23	H
Miles City AP	2634	46	-13	93	65	-23	-16	-10	H
Missoula AP	3190	46	-1	88	61	-33	-26	-20	H
Nebraska									
Beatrice	1323	40	-2	95	74	28	35	41	M
Bellevue, Offutt AFB	1047	41	1	91	75	36	43	49	M
Chadron AP	3296	42	-3	94	65	-22	-15	-9	H
Columbus	1443	41	-2	95	73	17	24	30	M
Fremont	1203	41	-2	95	74	23	30	36	M
Grand Island AP	1841	41	-2	93	72	15	22	28	H
Hastings	1954	40	-3	94	71	7	14	20	H
Kearney	2131	40	-4	93	70	3	10	16	H
Lincoln CO	1180	40	-2	94	74	25	32	38	M
McCook	2579	40	-2	95	69	-11	-4	2	H
Norfolk	1552	42	-5	92	72	16	23	29	H
North Platte AP	2775	41	-4	92	69	-1	6	12	H
Omaha AP	977	41	-2	92	75	34	41	47	M
Omaha WSO	1332	41	-2	90	75	38	45	51	M
Scottsbluff AP	3958	41	-3	92	64	-25	-18	-12	H
Sidney AP	4304	41	-1	92	63	-29	-22	-16	H
Valentine	2598	42	-8	94	67	-15	-8	-2	H
Nevada									
Carson City	4675	39	9	91	59	-47	-40	-34	H
Elko AP	5050	40	1	92	59	-48	-41	-35	H
Ely AP	6263	39	0	87	56	-55	-48	-42	H
Las Vegas AP	2162	36	30	106	66	-39	-32	-26	H
Lovelock AP	3904	40	12	96	63	-35	-28	-22	H
Mercury	3310	36	28	100	64	-38	-31	-25	H
North Las Vegas, Nellis AFB	1868	36	31	106	67	-34	-27	-21	H
Reno AP	4412	39	13	92	60	-44	-37	-31	H
Reno CO	5046	39	11	93	60	-45	-38	-32	H
Tonapah AP	5426	38	13	92	57	-58	-51	-45	H
Winnemucca AP	4301	40	7	94	60	-48	-41	-35	H
New Hampshire									
Berlin	1161	44	-9	84	69	12	19	25	M
Claremont	545	43	-4	86	70	14	21	27	M
Concord AP	342	43	-2	87	70	13	20	26	H
Keene	488	43	-7	87	70	13	20	26	M
Laconia	545	43	-5	86	70	14	21	27	M
Lebanon	597	43	-3	86	69	9	16	22	M
Manchester, Grenier AFB	234	43	-3	88	71	17	24	30	M
Mount Washington	6266	44	-19	58	54	-18	-11	-5	L
Portsmouth, Pease AFB	101	43	9	85	70	16	23	29	M
New Jersey									
Atlantic City CO	64	39	13	88	73	29	36	42	M
Long Branch	36	40	13	90	73	24	30	37	M
Millville	82	39	15	89	74	33	40	46	M
Newark AP	7	40	14	90	73	25	32	38	M
New Brunswick	100	40	10	89	73	25	32	38	M
Patterson	186	40	10	91	73	22	29	35	M

Oversizing Equipment Comes At A Price

- Increased first costs
- Reduced operating efficiency due to equipment short-cycling
  - Excessive wear / increased maintenance
  - Humidity control / IAQ
  - Temperature swings
  - Poor air circulation / hot/cold spots
  - Noise
  - Increased operating costs
- Slightly undersized equipment may actually provide greater comfort at a lower cost
  - In some cases, two-stage equipment can provide a good fit.



Next - Residential Equipment Selection

Manual S: Heating and Cooling Equipment Selection

- Select for cooling
- Ensure adequate blower CFM range for heating

For cooling:

- "Total cooling" data is used in conjunction with the OEM "performance data" for equipment selection
- Manual J data provides the initial cooling CFM estimate.

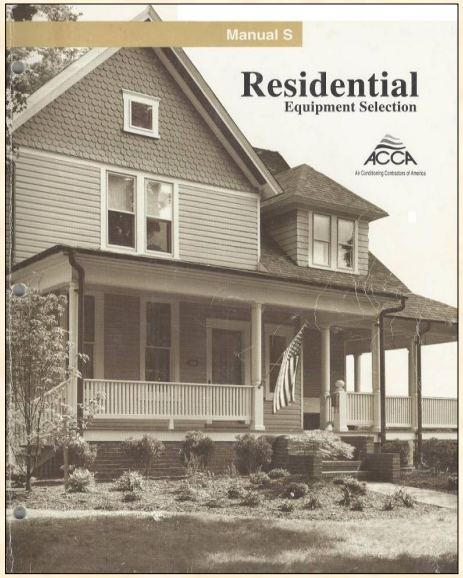
Sensible Heat Ratio Versus TD Value	
Home's SHR	ΔT
Below 0.80	21°F
0.80 – 0.85	19°F
Above 0.85	17°F
ΔT = Entering dry bulb – Leaving dry bulb	

$$\text{CFM estimate} = \frac{\text{BTUH } \textit{(Sensible)}}{1.08 \times \Delta T \textit{ (SHR table)}}$$

Residential Equipment Selection - Cooling

Manual S: Equipment Selection

- Expanded performance data
  - CFM
  - Outdoor dry bulb
  - Indoor dry bulb
  - Indoor wet bulb
  - Total capacity
  - Sensible / latent capacity
- Stay within sizing limitations
  - Iterative process.



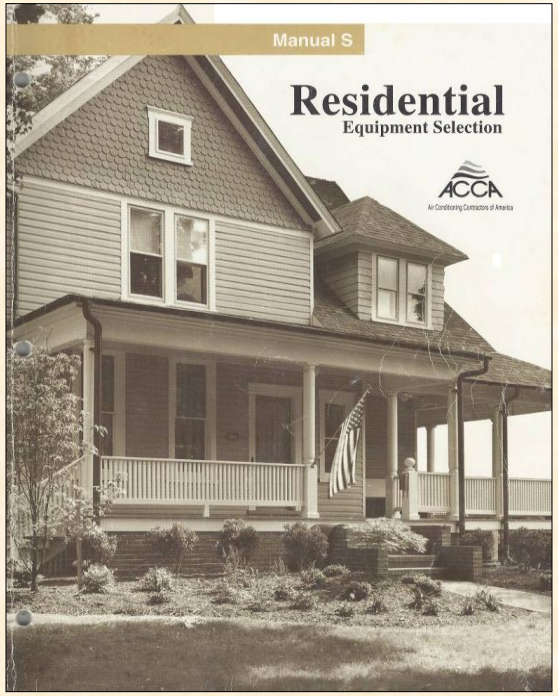
			Outdoor Ambient Temperature							
			85°F				95°F			
			Entering Indoor Wet Bulb Temperature							
IDB	Airflow		59	63	67	71	59	63	67	71
75	875	MBh	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	24.6	26.7	28.6
		S/T	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.76	0.58	0.37
		ΔT	21	20	16	11	21	20	16	11
		kW	2.18	2.23	2.29	2.36	2.28	2.33	2.40	2.47
		Amps	8.0	8.2	8.4	8.7	8.5	8.7	9.0	9.3
		Hi PR	280	301	318	332	319	343	363	378
		Lo PR	117	124	135	144	123	130	142	152
	1000	MBh	26.6	27.4	29.6	31.8	25.9	26.7	28.9	31.0
		S/T	0.86	0.77	0.58	0.37	0.89	0.79	0.60	0.39
		ΔT	21	19	16	11	21	19	16	11
		kW	2.23	2.28	2.34	2.41	2.34	2.38	2.45	2.53
		Amps	8.2	8.4	8.6	9.0	8.7	8.9	9.2	9.6
		Hi PR	289	311	328	342	329	354	374	390
		Lo PR	120	128	140	149	126	134	147	156
	1125	MBh	27.4	28.2	30.5	32.7	26.7	27.5	29.8	31.9
		S/T	0.90	0.80	0.61	0.39	0.93	0.83	0.63	0.40
		ΔT	20	19	15	10	20	19	15	11
		kW	2.25	2.29	2.36	2.43	2.35	2.40	2.47	2.55
		Amps	8.3	8.4	8.7	9.0	8.8	9.0	9.3	9.6
		Hi PR	292	314	331	346	332	358	378	394
		Lo PR	121	129	141	150	128	136	148	158

Residential Equipment Selection - Heating

Manual S: Equipment Selection

For heating:

- Ensure blower compatibility for heating equipment based on cooling selection
  - Sizing limitations (output capacity)
  - Exchanger ΔT range:
    - Complete a ΔT calculation:



$$\Delta T = \frac{\text{Output Capacity}}{1.08 \times \text{Heating CFM}}$$

Ensure Matched Systems Equipment Selection

- Indoor and outdoor units must be matched to deliver rated cooling performance
  - Ensures the system will:
    - deliver rated efficiency
    - balance out at the desired operating point.

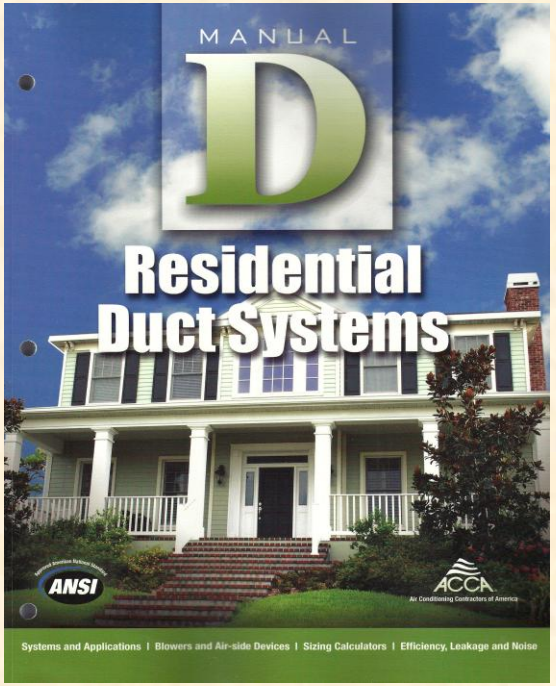
Manual S: Under Technical Review & Update

- Objectives:
- Improve / update guidance for staged and variable speed equipment
- Explore sizing / selection rules for
  - heat pumps
  - varied weather climates.

Next - Residential Duct Design

Manual D: Duct Design

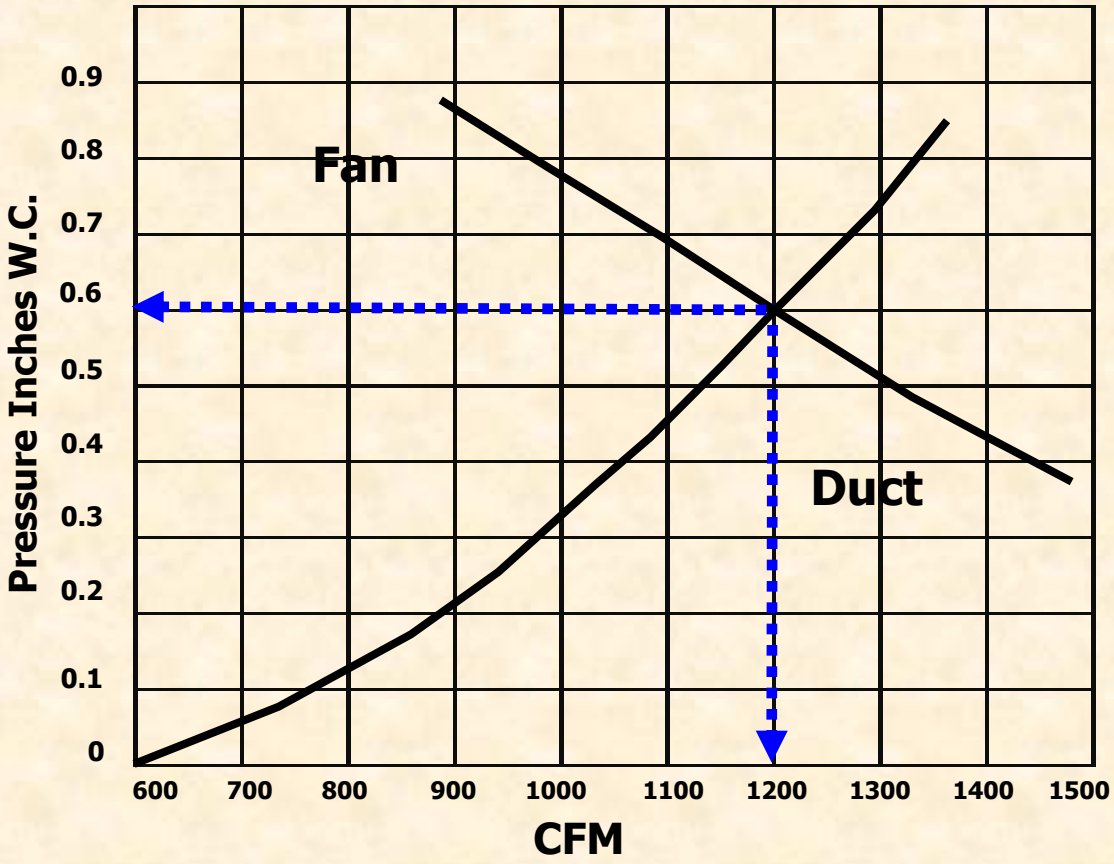
- Equipment selection required prior to duct design
- Furnace blower data must be referenced for duct calculations
  - Design the duct system to match equipment and blower fan capabilities.



Courtesy Of ACCA

Fan Capacity and Pressure Limits

- The fan will always operate where the fan and duct curves cross
- The objective is to ensure delivered CFM equals design CFM.



Fan Capacity and Pressure Limits

Total available pressure:

- Fan Blower: **0.6 inches W.C.**

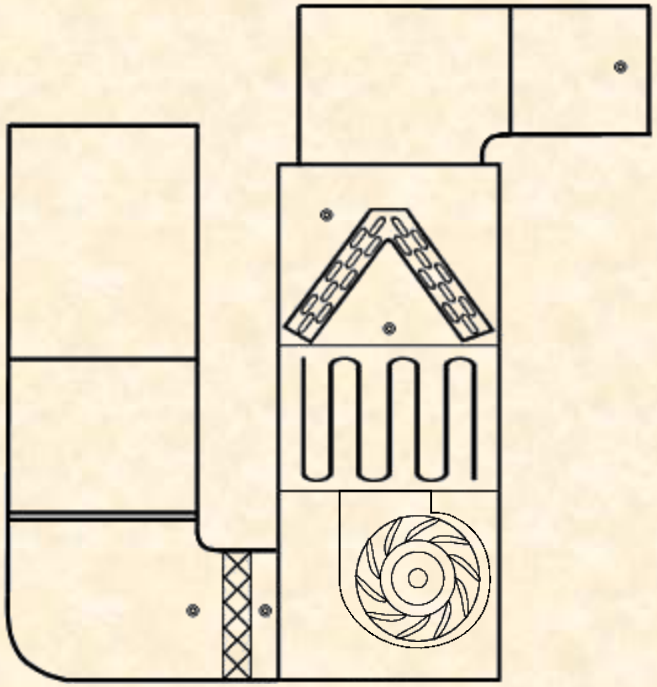
Equipment pressure drop:

- Filter . . . . . : **0.14 ″**
- Coil . . . . . : **0.20 ″**

Air-side device pressure drop:

- Supply air terminals . . . . . : **0.03 ″**
- Return air terminals . . . . . : **0.03 ″**
- Dampers. . . . . : **0.03 ″**

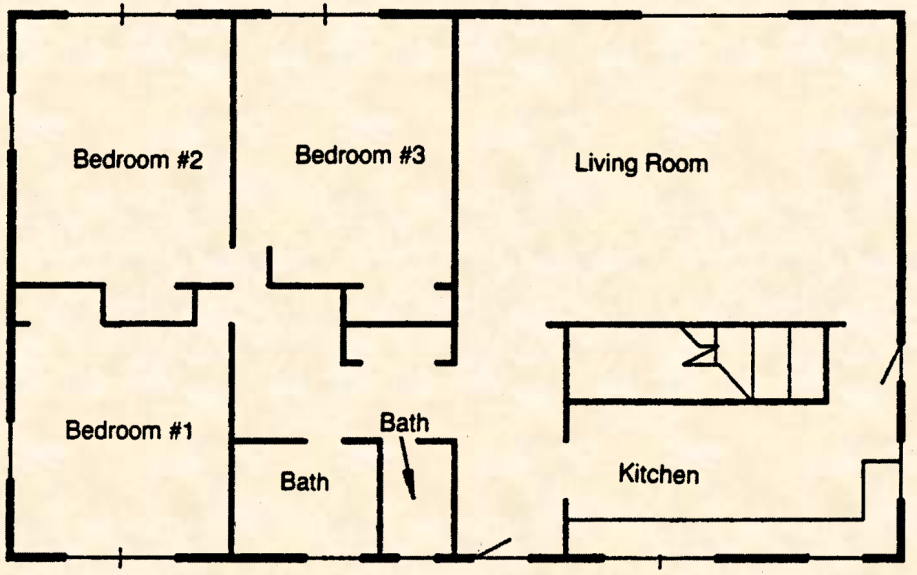
Net blower pressure remaining . : **0.17 IWC**



Room / Space CFM Requirements

Manual D Procedures:

- The design CFM requirements for each room or space must be defined
  - Use HF and CF factors.



Room	H-BTUH	C-BTUH	H-CFM	C-CFM
Bed #2	5867	2059	82	82
Bed #3	4220	1296	59	52
Liv Rm	6236	3152	87	125
Kitchen	9086	5249	127	209
Bath (1)	1276	462	18	18
Bath (M)	1439	539	20	21
Bed #M	4600	1920	65	76
Hallway	239	156	4	6
Bsmt	7711	4568	388	261
Total	-------	-------	850	850
-------	-------	-------		
Total	60672	21399	Sensible	
		3761	Latent	
		25160	Total	

Calculate CFM per BTU of Load

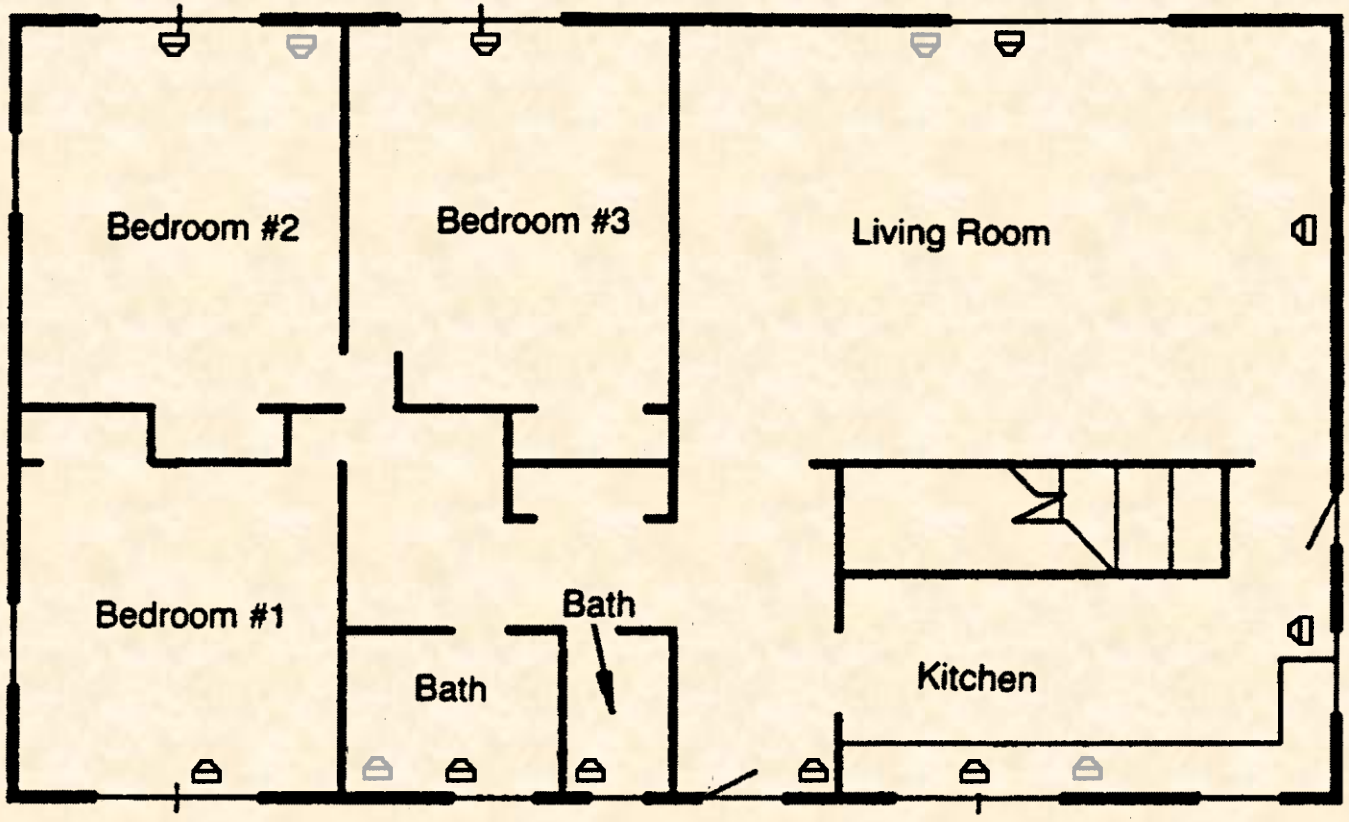
Heating Factor =
Blower CFM ÷ Manual J Heat Loss

Cooling Factor =
Blower CFM ÷ Manual J Sensible Heat Gain

Initial Duct Routing

Manual D Procedures:

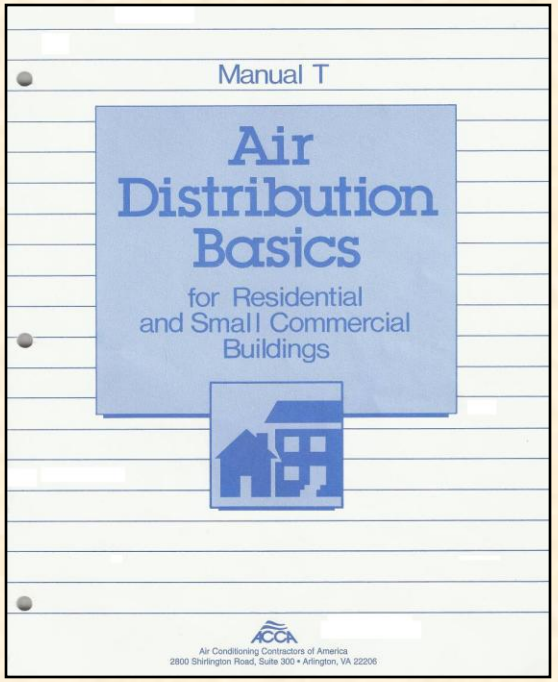
- A reference drawing to define duct pathways must be identified
  - Register, diffuser & grille selection and location must be defined.

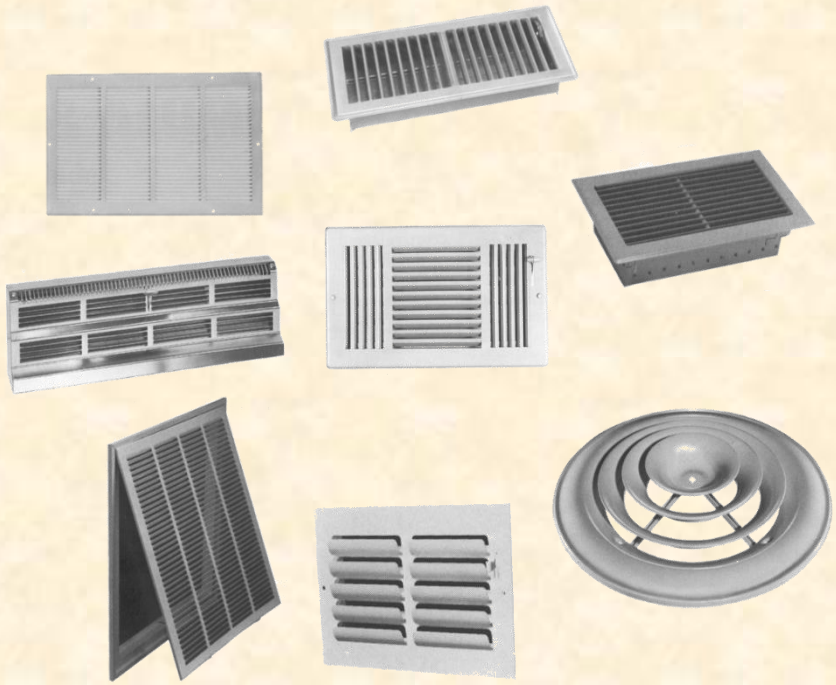


Next – Air Terminal Device Selection

Manual T: Air Distribution Basics

- Room by room load data is used to select air terminal devices.



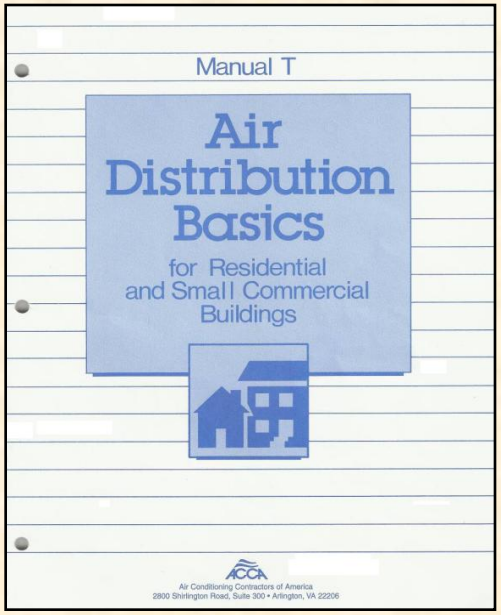


Courtesy Of ACCA

Air Terminal Device Selection

Manual T: Air Terminal Devices

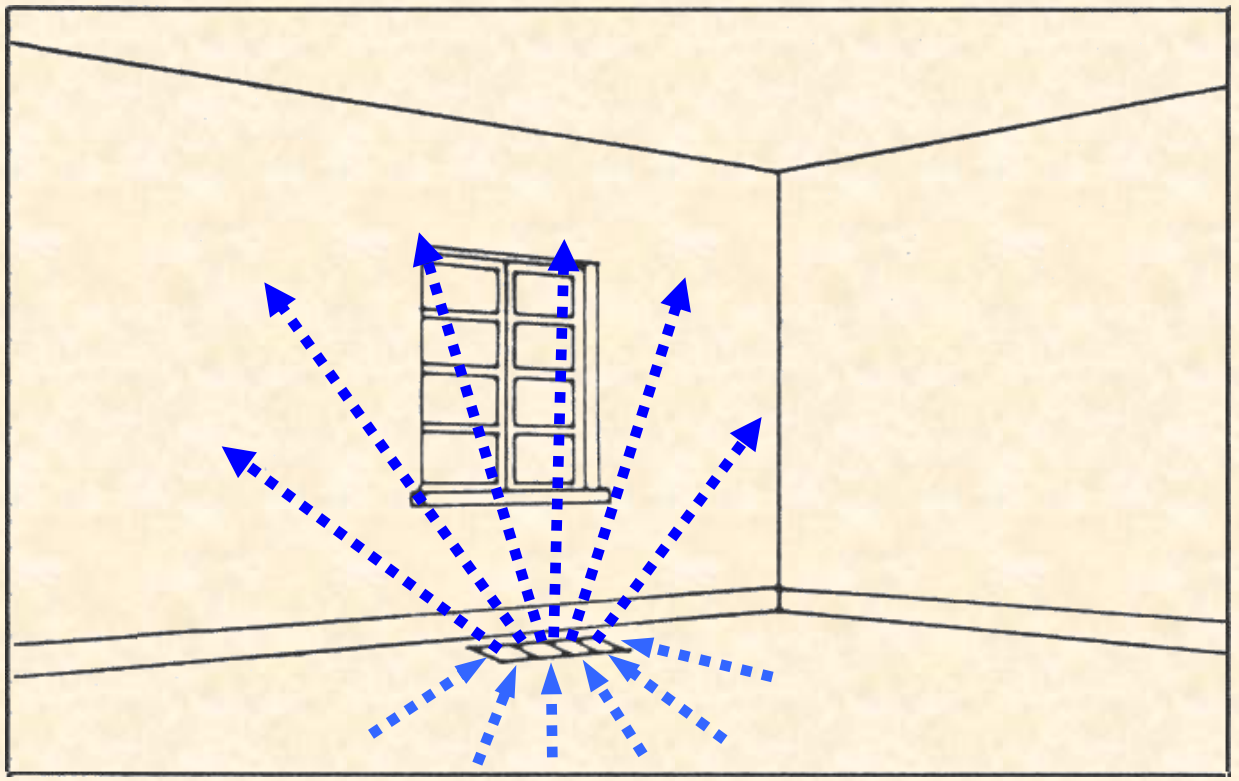
- Use manufacture data to select based on:
  - Size
  - Btuh capacity
  - CFM
  - Pressure drop
  - Velocity
  - Throw
  - Spread.



NOMINAL SIZE	FREE AREA SQ. IN.						
		Heating BTU/h	3045	4565	6090	7610	9515
		Cooling BTU/h	855	1280	1710	2135	2670
		C.F.M.	40	60	80	100	125
2¼" x 12"	21	T.P. Loss	.009	.015	.027	.037	.050
		Vert. Throw (ft.)	3	4	5	6	8
		Vert. Spread (ft.)	6	8	10	11	14
		Face Velocity	280	420	565	705	880
2¼" x 14"	24	T.P. Loss	.006	.010	.021	.031	.042
		Vert. Throw (ft.)	3	4	4.5	5.5	8
		Vert. Spread (ft.)	6	8	9	11	14
		Face Velocity	245	365	490	610	760
4" x 10"	32	T.P. Loss		.008	.021	.026	.032
		Vert. Throw (ft.)		3	4	5	7
		Vert. Spread (ft.)		6	8	9	12
		Face Velocity		265	355	445	555

Air Terminal Device Selection

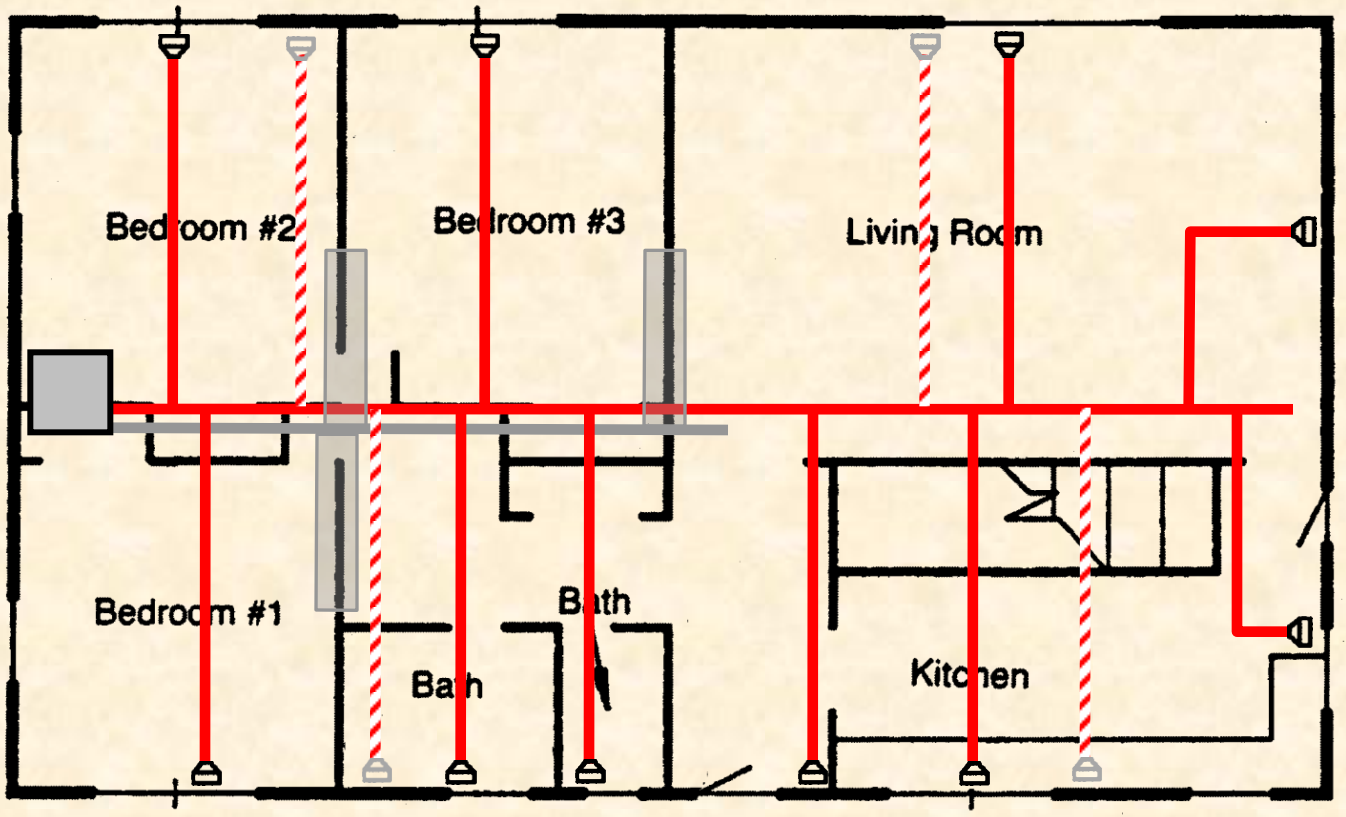
- Air terminal device selection impacts air flow patterns and coverage
  - Primary air stream
  - Secondary air stream.



Initial Duct Routing

Back to Manual D Procedures:

- Following register, diffuser & grille selection, continue with location of:
  - Equipment
  - Main Trunk
  - Branch Runs
  - Returns.

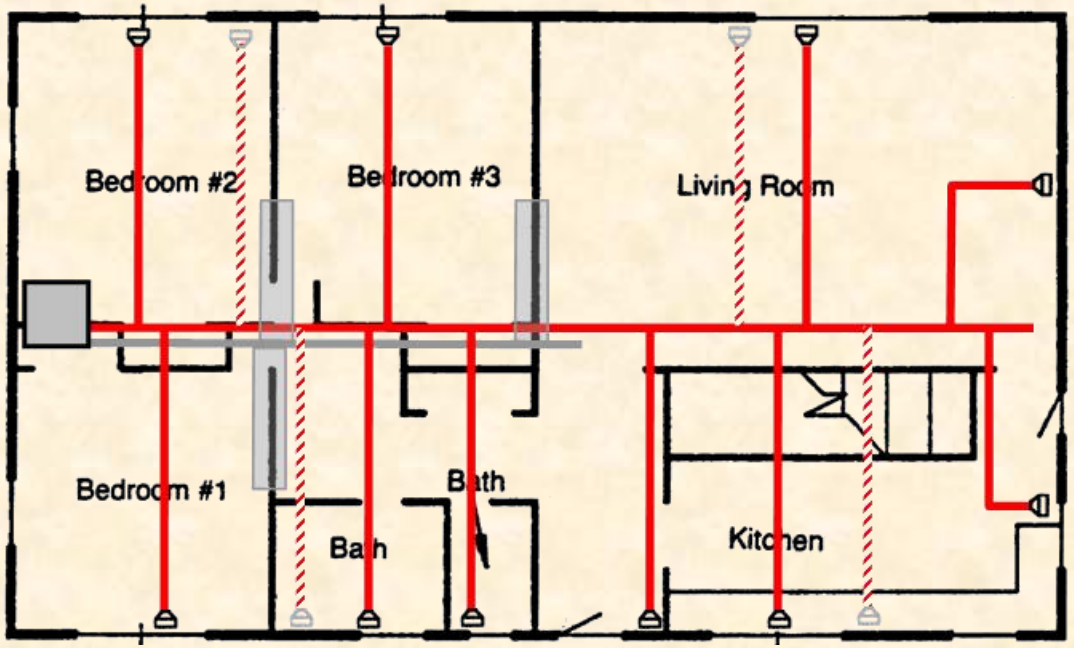


Determining Duct Size

Manual D Procedures:

- Duct is designed based on total effective length (TEL):
  - Length of straight duct
  - Equivalent length of each fitting

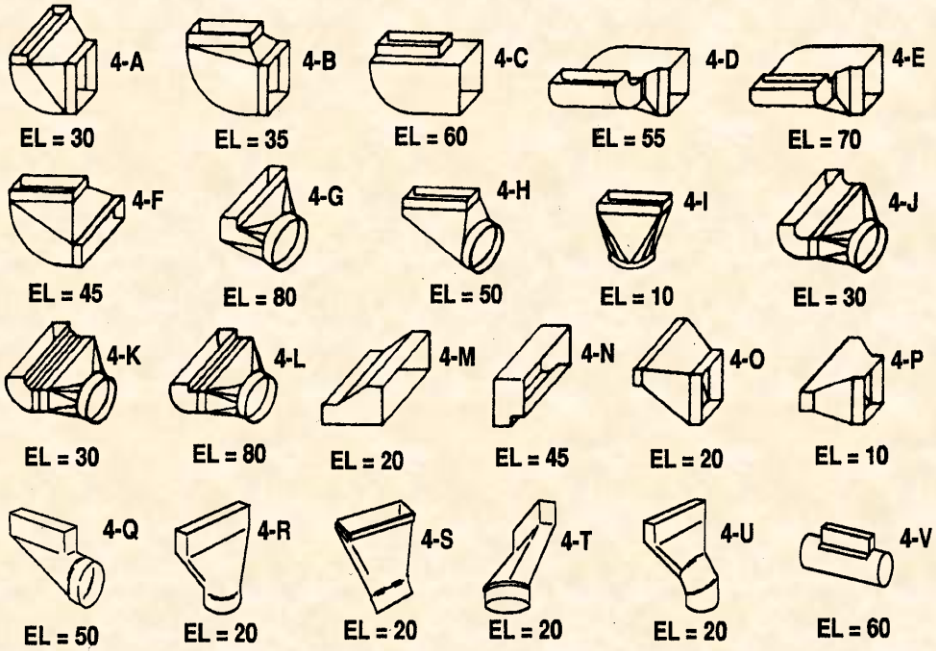
Equivalent Length = 10 ft



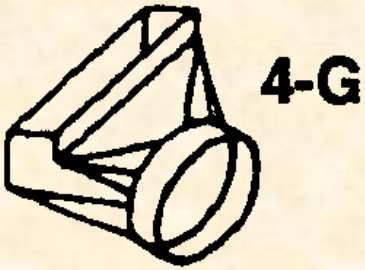
Fitting Geometry Affects Performance

Fitting Geometry Affects Performance

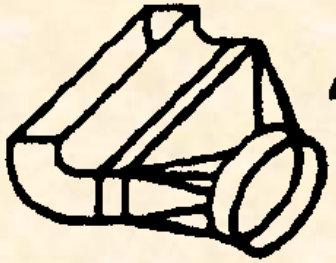
- Equivalent lengths for various branch fittings can be very different.



EL: Equivalent Length



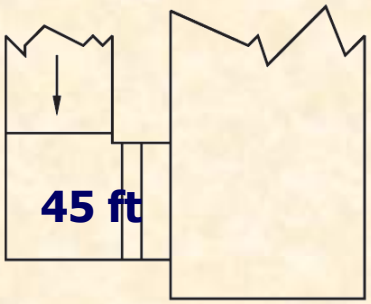
EL = 80

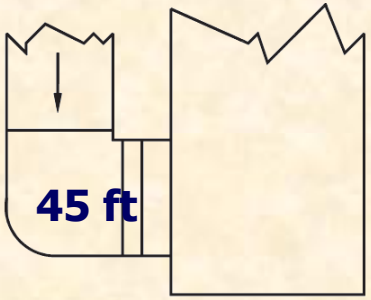


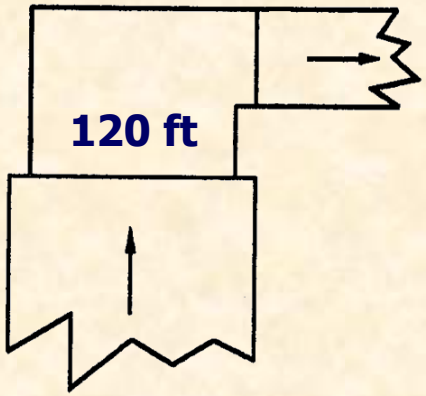
EL = 30

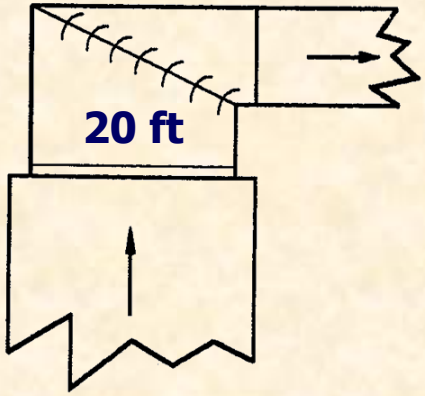
Fitting Impact on Equivalent Length

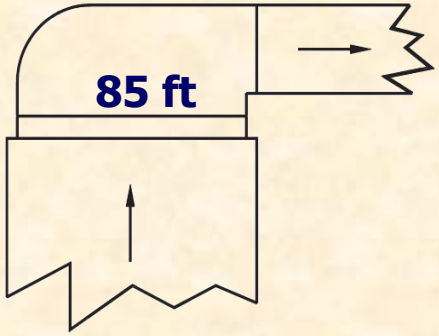
Comparison of furnace plenum geometry:

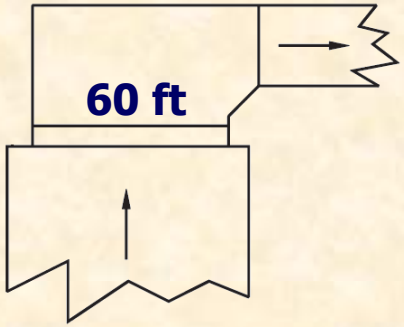


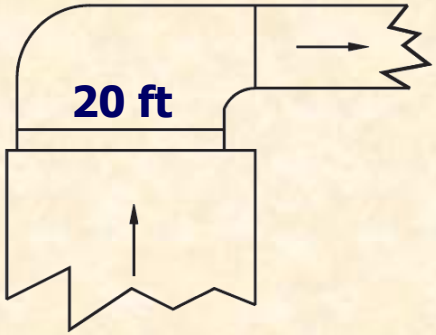






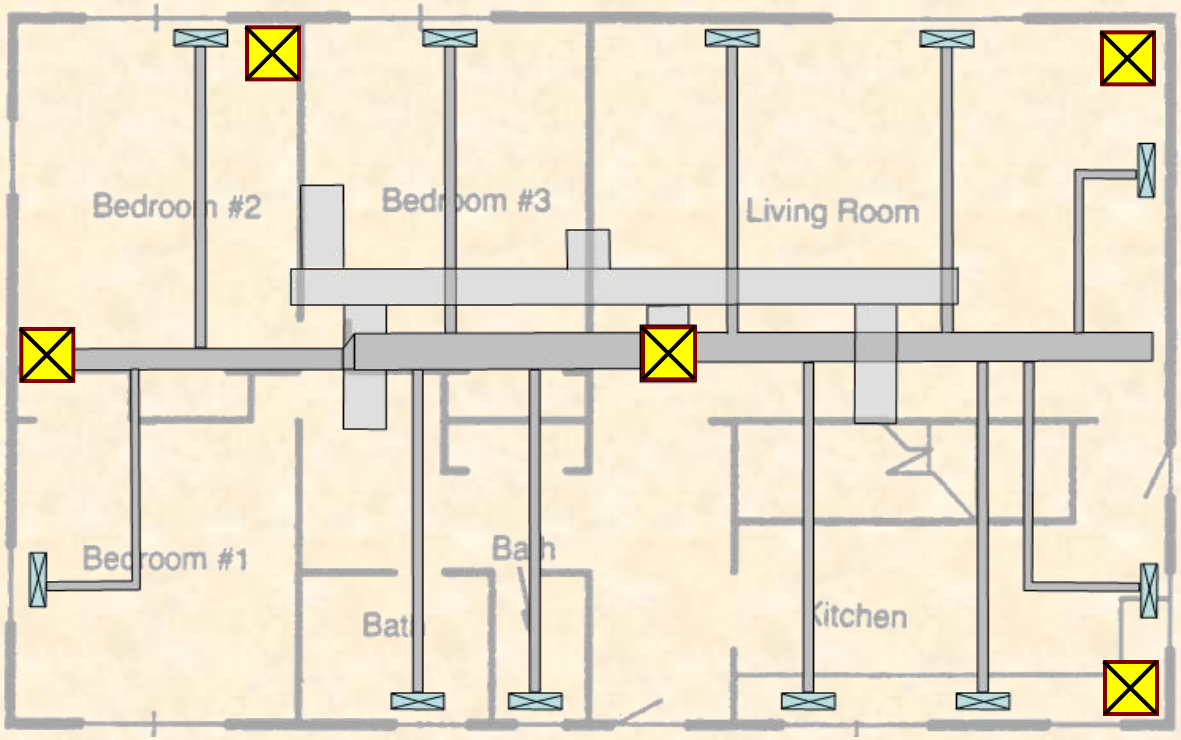






Equipment Location Impacts Design

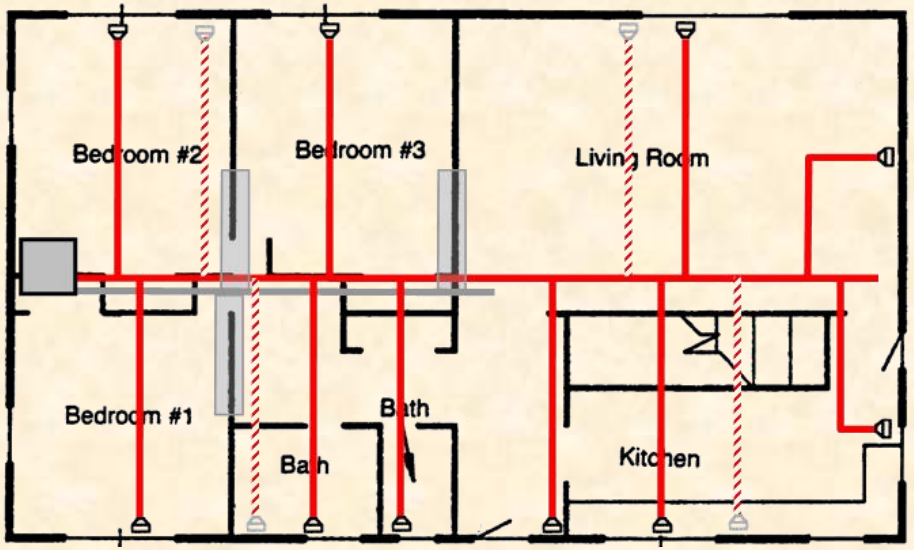
- Duct size and performance is affected by:
  - floor plan
  - equipment location



Duct Total Effective Length

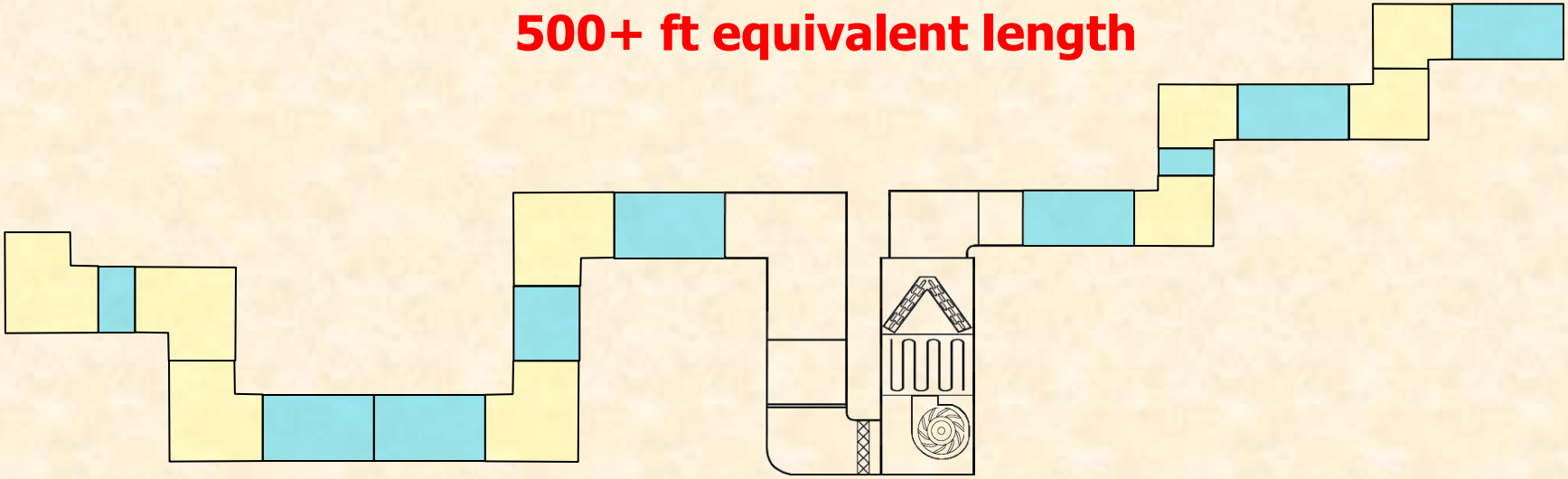
Manual D Procedures:

- Determine the total effective length for the longest supply and return run combination



45 ft actual

500+ ft equivalent length



Equivalent Length & Duct Friction Rate

- Adjust net blower pressure based on design total effective length.

Total available pressure:

- Fan Blower: **0.6 inches W.C.**

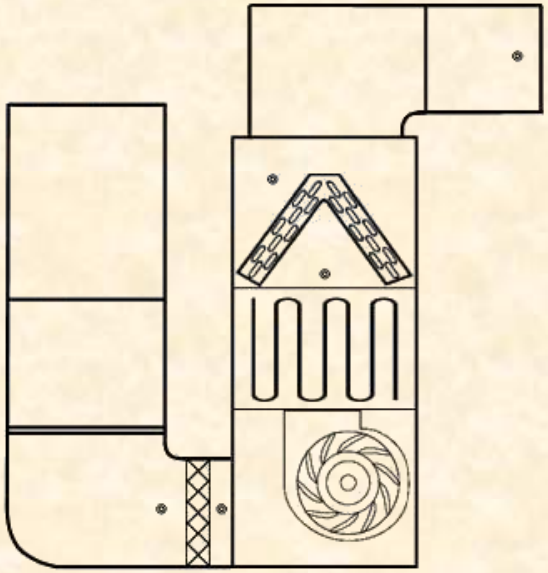
Equipment pressure drop:

- Filter . . . . . : **0.14 "**
- Coil . . . . . : **0.20 "**

Air-side device pressure drop:

- Supply air terminals . . . . . : **0.03 "**
- Return air terminals . . . . . : **0.03 "**
- Dampers. . . . . : **0.03 "**

Net blower pressure remaining . : **0.17 IWC**



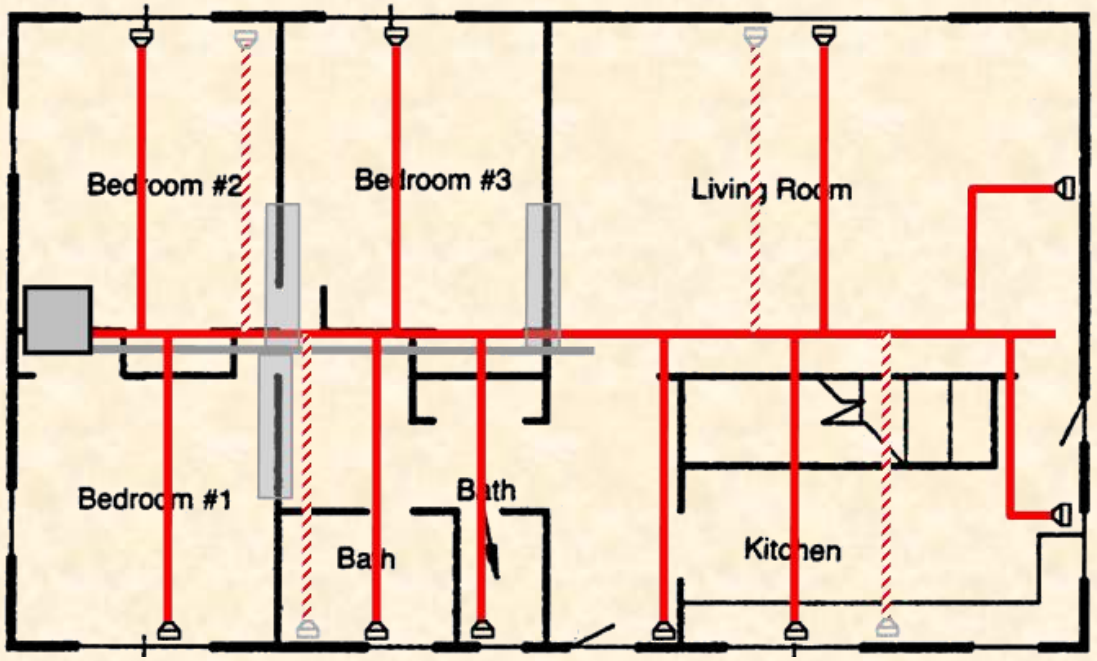
Friction Rate: Defined as friction per 100 ' of duct

$$\text{Friction Rate} = \frac{.17 \times 100}{500} = 0.034$$

Residential Duct Design

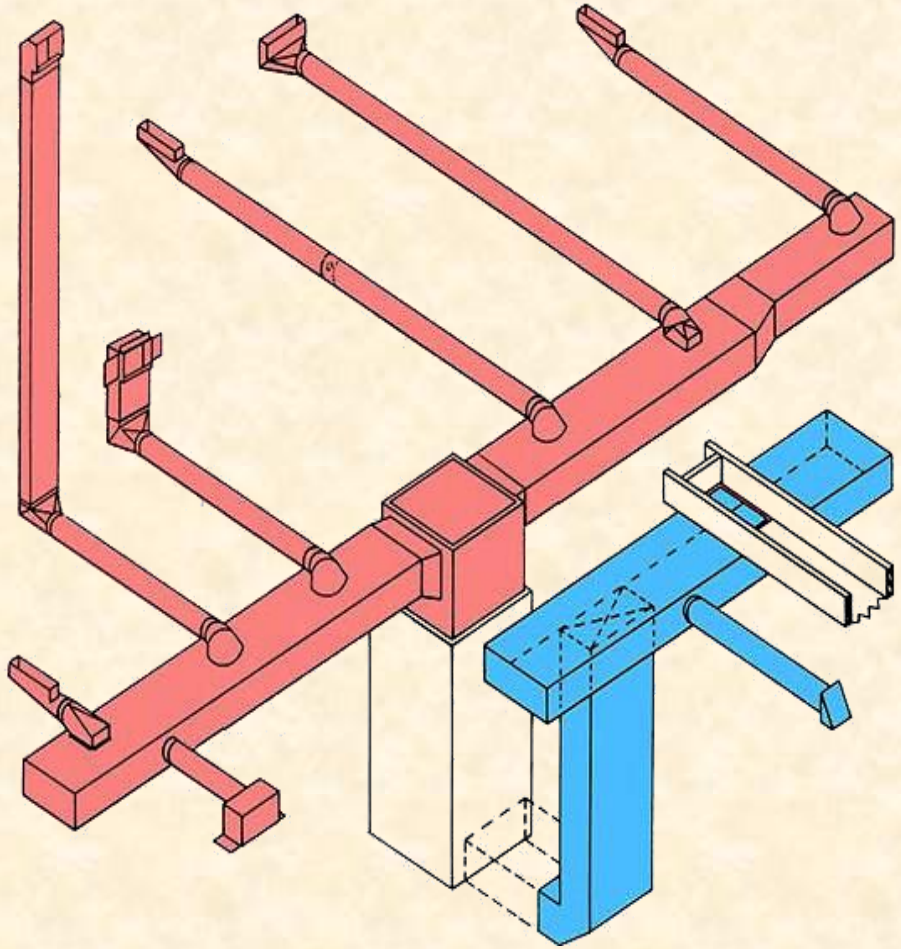
Manual D Procedures:

- Size the trunk and branch ducts for:
  - CFM
  - Friction Rate
  - Velocity



Next – Fabrication, Installation & Start-up

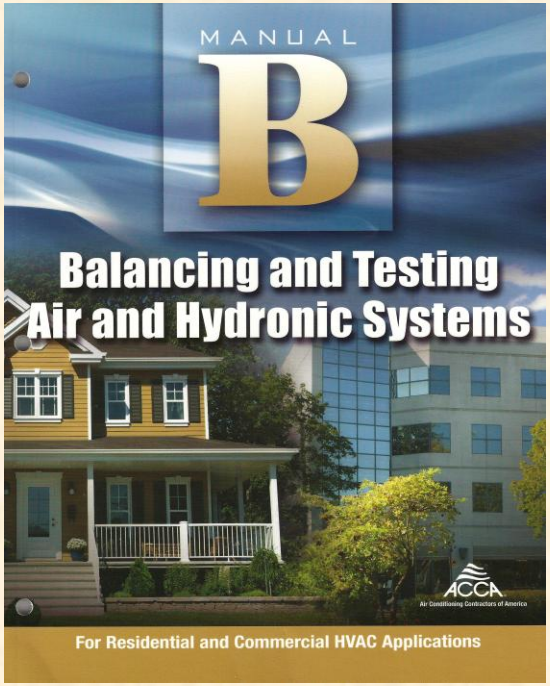
- Installation
- Seal the duct system
- Start-up.

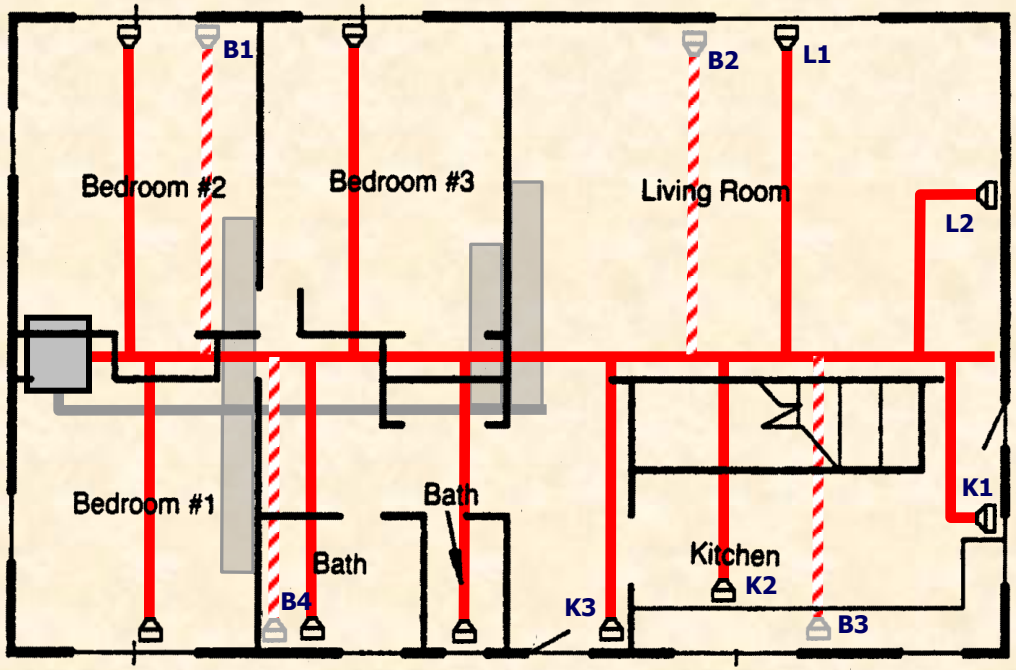


Next – Balance The Duct System

Manual B: Testing, Adjusting and Balancing

- Duct system must be balanced following installation.

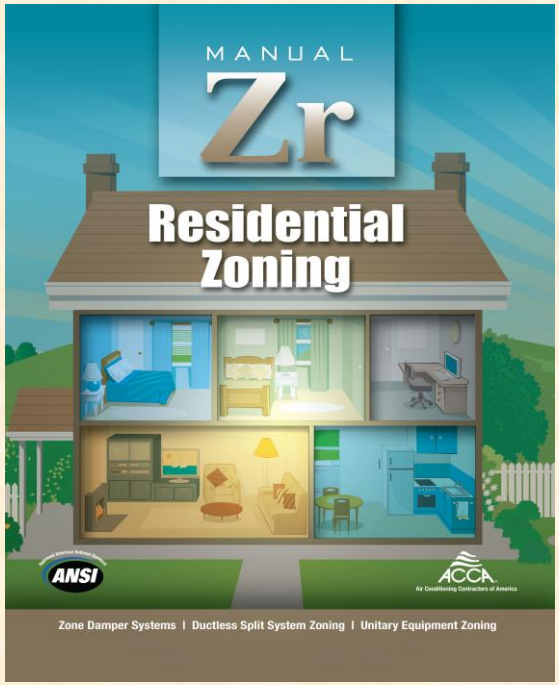




Courtesy Of ACCA

NEW - ACCA Manual Zr Residential Zoning

- Manual Zr: Residential Zoning
  - Released January 2012
  - Generic guidance and solutions for residential zoning
- Goals:
  - Protect the HVAC equipment
  - Improve comfort and temperature control
  - Maximize customer satisfaction
- Zoning Requires:
  - Accurate load calculations
  - Properly size equipment
  - Accurate duct design
  - Air balancing
- Zoning Rules:
  - Don’t zone to resolve design, construction or installation problems.



Courtesy Of ACCA

ANSI/ACCA 5 QI: Quality Installation Specification

- Road map for quality installation
- Consistent with manufacturer's installation instructions
- Opportunity to improve installation processes
  - Design
  - Equipment Installation
  - Air Distribution
  - System Documentation
  - Owner Education


ACCA
AIR CONDITIONING CONTRACTORS OF AMERICA

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Arlington, VA 22206
703.575.4477
Fax 703.575.8107
www.acca.org

ACCA Standard 5

STANDARD NUMBER: ANSI/ACCA 5 QI–2010

HVAC Quality Installation Specification

Residential and Commercial Heating, Ventilating, and Air Conditioning (HVAC) Applications

The Air Conditioning Contractors of America Educational Institute (ACCA-EI) Standards Task Team (STT) develops standards as an American National Standards Institute (ANSI) accredited standards developer (ASD). ACCA develops voluntary standards as outlined in the ACCA Essential Requirements and the ANSI Essential Requirements. ACCA standards are developed by diverse groups of industry volunteers in a climate of openness, consensus building, and lack of dominance (e.g., committee/group/team balance). Essential requirements, standard activities and documentation can be found in the standards portion of the ACCA website at www.acca.org. Questions, suggestions, and proposed revisions to this standard can be addressed to the attention of the Standards Task Team, ACCA, 2800 Shirlington Road, Suite 300, Arlington, VA 22206.

ACCA Standards are updated on a five-year cycle. The date following the standard number is the year of approval release by the ACCA-EI Standards Task Team. The latest copy may be purchased from the ACCA online store at www.acca.org or ordered from the ACCA bookstore via toll-free telephone at 888.290.2220.

ANSI
www.ansi.org

The only way to confirm capacity, efficiency and performance:

- Test !

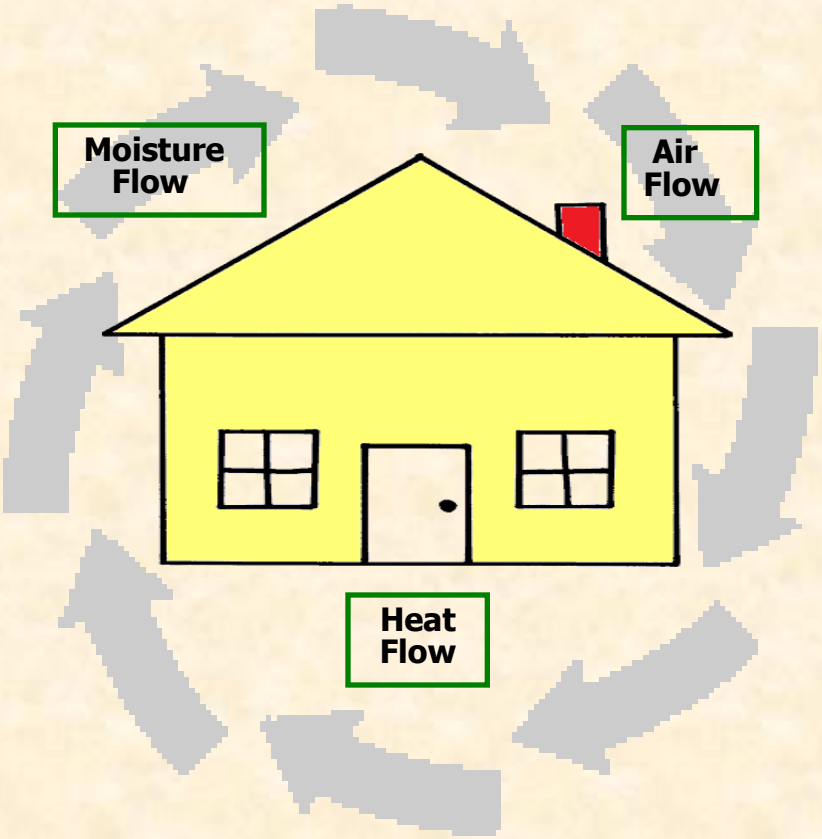
Courtesy Of ACCA

Routine AC System Problems

- Dirty evaporator
- Electrical burn out (compressor)
- Dirty filter
- Dirty condenser
- Dirty blower motor
- Low air flow
- Wrong wire size
- Moisture in the system
- Damaged coil surfaces
- Incorrect refrigerant charge
- Air in the system
- Contaminants/acids in the system
- Low voltage or voltage drop
- Valve damage
- Plugged metering device
- Control wiring problems
- Lose wire/connection
- Refrigerant piping errors
- Refrigerant leaks
- Mismatched system
- Improperly sized unit
- Wrong size installed metering device
- Age
- Lightning / Mother Nature
- Condenser Not Level
- Oil Loss
- Kinked refrigerant Line
- Compressor stuck/not performing
- Wrong refrigerant
- Bypassed control (jumpers)

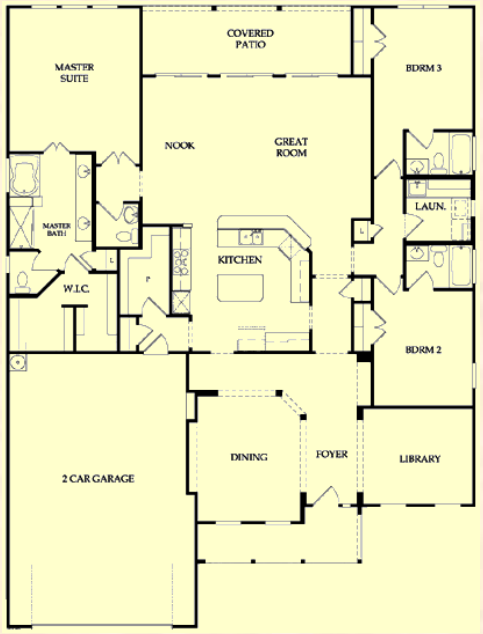
Back to Where We Started
System Interdependencies

- The systems within every home are interdependent
  - Structural systems
  - Mechanical systems
- Interdependencies within the HVAC design process must be addressed
- Industry standards and guidelines provide the roadmap for quality in the design, installation and commissioning process
  - Where these fit within building codes will continue to evolve.



Great Plains Energy Codes Conference
October 16-18, 2012
Omaha, Nebraska

Enjoy the rest of the conference!



REAL WORLD HVAC