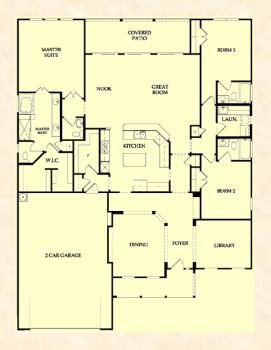


# **Residential HVAC Design Summary** Overview of Industry Standards

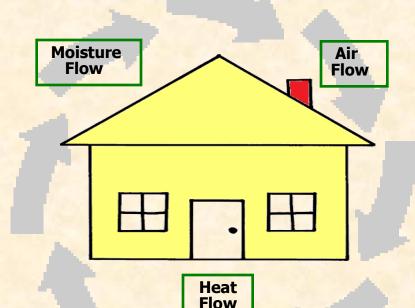






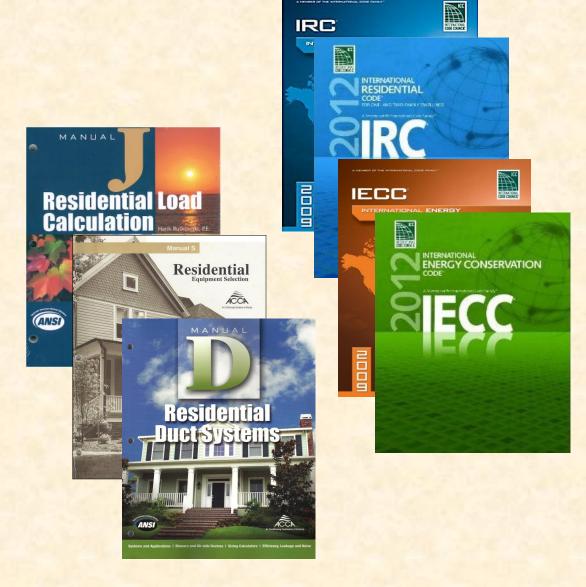
### **System Interdependencies**

- 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**

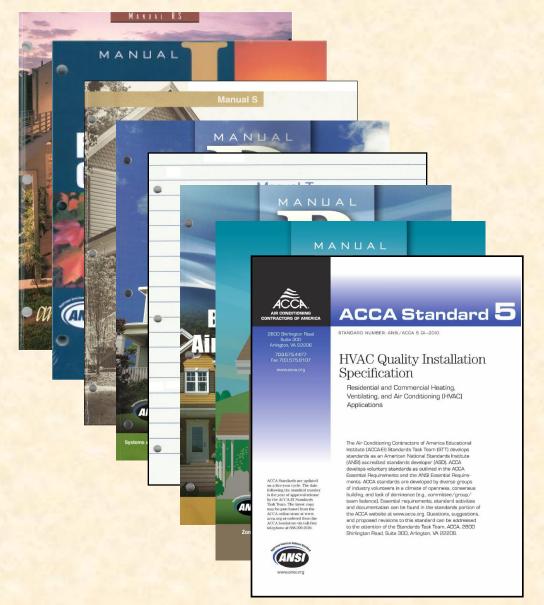
- International code reference includes
  - Manuals J, S and D
  - Version is not addressed
- Additional standards and guidelines are part of the design process
- Successful equipment commissioning is dependent on the HVAC design process.



### **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.

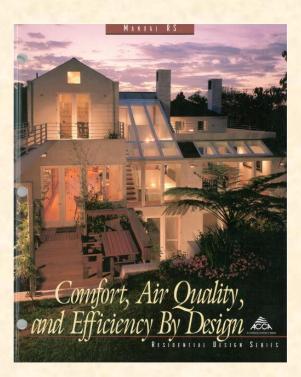




## **Comfort, Air Quality and Efficiency By Design**

#### Manual RS - provides conceptual guidance

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

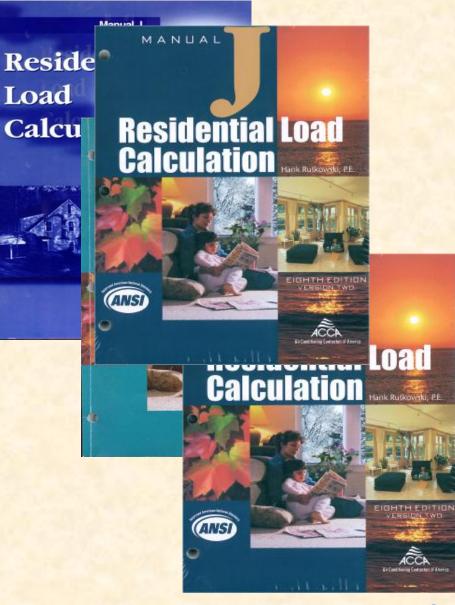




#### **Next – Residential Load Calculations**

#### 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.

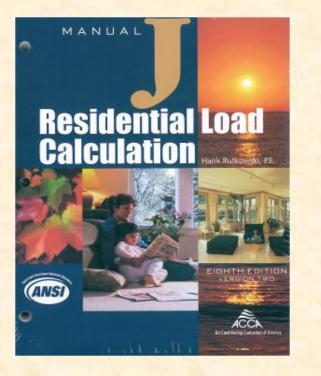


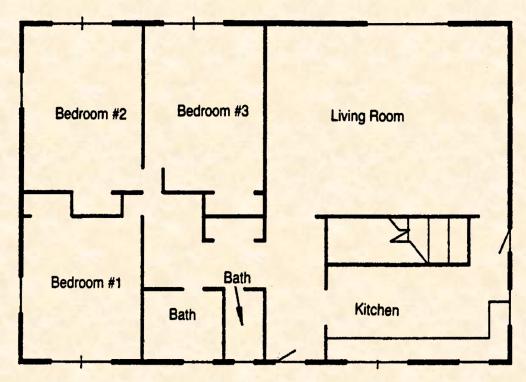


### **Residential Load Calculation**

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.

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SHR = Sensible Cooling Load Total Cooling Load



#### **Load Calculations Use Local Climate Data**

#### Manual J process provides equipment selection data

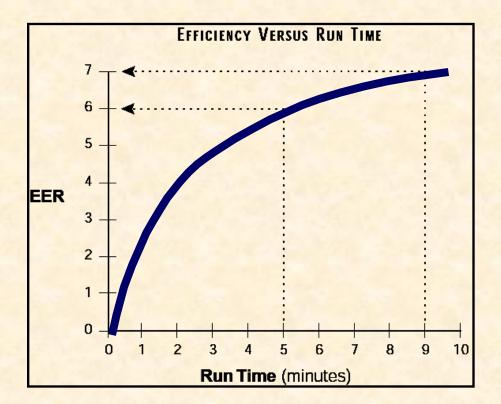
- Based on local climate data and operating conditions:
  - Outdoor dry bulb
  - Indoor dry bulb
  - Indoor wet bulb
- OEM data correlates equipment performance with operating conditions
- Inflated load calculations come at a price
  - Lack of confidence regarding weather extremes is a catalyst for over-sizing.

Location      Elevation      Latitude Degrees      Heating Degrees      Control Degrees      Control Degrees	Outdoor Design Conditions For the United States and Canada											
Image      Image      Top      Top      Sort      Barling      Grains      Grains      Grains      Grains      Grains      Barling      Grains      Barling      Grains      Barling      Sort      Head        Livingsito AP      466      4:5      -1:4      93      95      -29      -19      19      H        Miscolia AP      3190      46      -1      88      61      -33      -28      19      H        Barlos      122      40      -1      91      75      36      43      49      M        Chadon AP      1323      41      -2      95      73      17      14      30      M        Debarlos      1431      41      -2      95      73      121      30      M        Columbis      1431      41      -2      95      73      123      30      M        Gardi blank AP      1841      41      -2      96      71      13      40      14        Mesany      131	and the second s	Elevation	Latitude	Winter	[		Sur	mer				
Missola AP      253.4      44      1-13      93      95      2.23      1-13      9.03      9.15      1.13      9.15      1.13      9.13      9.13      9.13      9.13      9.13      9.13      9.13      9.13      9.13      9.13      9.13      9.14      9.14      9.14      9.14      9.14      9.15      9.16      9.15      9.16      9.15      9.16      9.15      9.16      9.15      9.16      9.15      9.16      9.15      9.16      9.15      9.16      9.15      9.16      9.15      9.16 <t< th=""><th>Location</th><th></th><th>Degrees</th><th>Heating 99%</th><th>. 1%</th><th></th><th>Design Grains</th><th>Design Grains</th><th>Grains</th><th>Range</th></t<>	Location		Degrees	Heating 99%	. 1%		Design Grains	Design Grains	Grains	Range		
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Carson City      4675      39      9      91      59      -47      -40      -34      H        Elk AP      5050      40      1      92      59      -48      -41      -35      H        Ely AP      6283      39      0      87      56      -55      -48      -41      -35      H        Lav Vegas AP      6263      30      106      66      -39      -32      -26      H        Lovelock AP      3004      40      12      96      63      -35      -28      -22      H        Mercury      3310      36      28      100      64      -38      -31      -25      H        North Las Vegas, Nellis AFB      1412      39      13      92      60      -44      -37      -31      H        Reno CO      5046      39      11      93      60      -45      -38      -32      H        Tonapath AP      5426      38      13      94      60      -48      -51	Neveda											
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Ely AP      283      39      0      87      56      -55      -48      -42      H        Lax Vegas AP      2162      36      300      106      666      -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        Winnemucca AP      4301      40      7      94      69      12      19      25      M        Claremont      545      43      -4      86      70      14      21 <t< td=""><td></td><td></td><td></td><td></td><td>1</td><td></td><td></td><td></td><td></td><td></td></t<>					1							
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Newark AP 7 40 14 90 73 25 32 38 M	Long Branch	36	40	13	90	73	24	30	37	м		
	Millville	82	39	15	89	74	33	40	46	м		
			1	1	90	73	25					
									1			
Patterson 186 40 10 91 73 22 29 35 M	Patterson	186		10	91		22	29	35	м		

Table 1A

# **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 <u>estimate</u>.

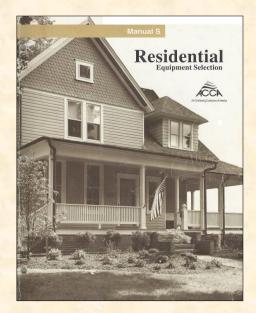
Sensible Heat Ratio Versus TD Value									
Home's SHR	ΔΤ								
Below 0.80	21°F								
0.80 - 0.85	19°F								
Above 0.85	17°F								
$\Delta T = Entering dry bulb - Leaving$	dry bulb								



### **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.



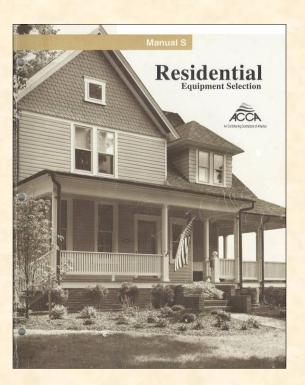
			Outdoor Ambient Temperature											
				85	۴F		95°F							
			E	nterin	g Indo	or We	t Bulb	Temp	eratur	е				
IDB	Air	flow	59	63	67	71	59	63	67	71				
			1		12									
		MBh	24.5	25.2	27.5	29.3	23.5	24.6	26.7	28.6				
		S/T	0.83	0.74	0.66	0.36	0.85	0.76	0.58	0.37				
	$\frown$	ΔT	21	20	16	11	21	20	16	11				
	875	kW	2.18	2.23	2.29	2.36	2.28	2.33	2.40	2.47				
	$\smile$	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				
	- 6.1	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				
	1000	ΔT	21	19	16	11	21	19	16	11				
75		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				
		HIPR	289	311	328	342	329	354	374	390				
	1	Lo PR	120	128	140	149	126	134	147	156				
		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				
		ΔΤ	20	19	15	10	20	19	15	11				
	1125	kW	2.25	2.29	2.36	2.43	2.35	2.40	2.47	2.55				
	1	Amps	8.3	8.4	8.7	9.0	8.8	9.0	9.3	9.6				
	100	Hi PR	292	314	331	346	332	358	378	394				
		Lo PR	121	129	141	150	128	136	148	158				

### **Residential Equipment Selection - Heating**

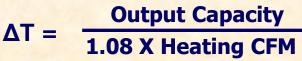
Manual S: Equipment Selection

For heating:

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

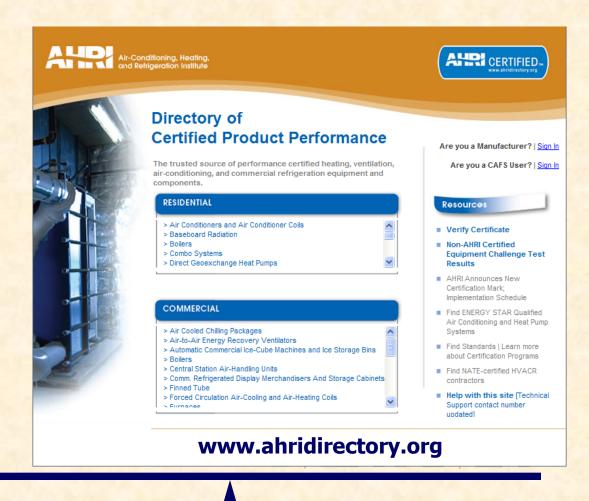






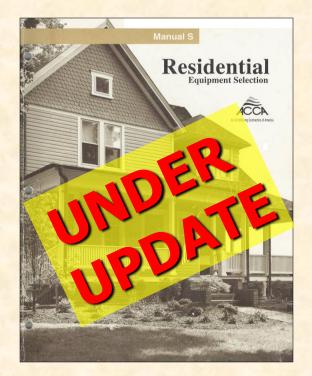
### **Ensure Matched Systems Equipment Selection**

- 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**

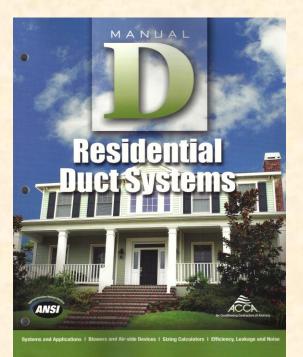
- Objectives:
- Improve / update guidance for staged and variable speed equipment
- Explore sizing / selection rules for
  - heat pumps
  - varied weather climates.



#### **Next - Residential Duct Design**

Manual D: Duct Design

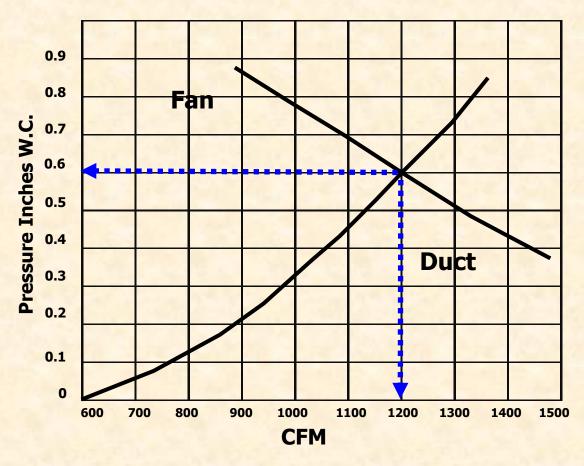
- Equipment selection required prior to duct design
- Furnace blower data must be referenced for duct calculations
  - Design the duct system to match equipment and blower fan capabilities.





#### **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.

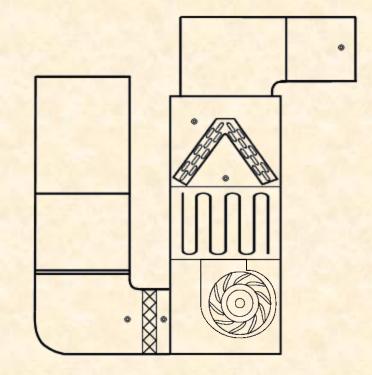
Equipment pressure drop:

•	Filter	•		•			•	•		•	•	:	0.14 ″
•	Coil .											:	0.20 ″

Air-side device pressure drop:

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

Net blower pressure remaining . : 0.17 IWC

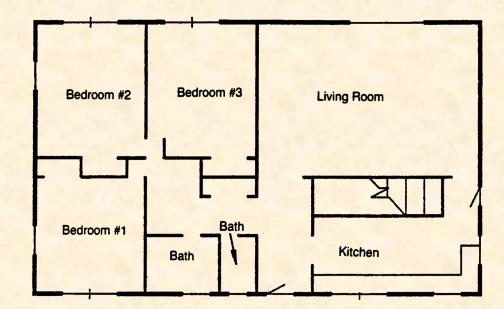


#### **Room / Space CFM Requirements**

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

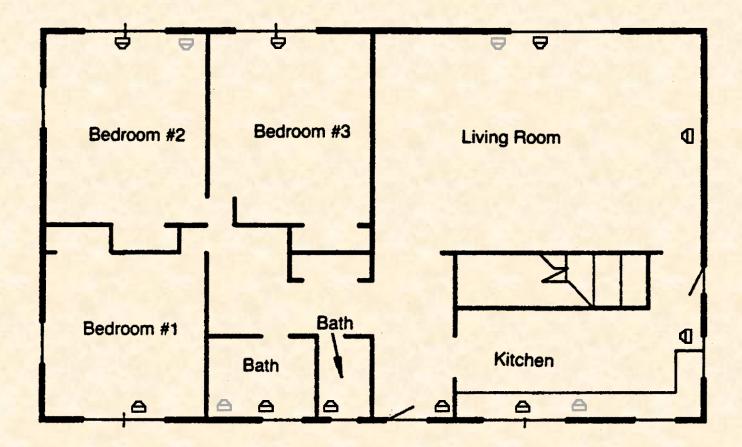
Heating Factor = Blower CFM ÷ Manual J Heat Loss

Cooling Factor = Blower CFM ÷ Manual J <u>Sensible</u> Heat Gain

### **Initial Duct Routing**

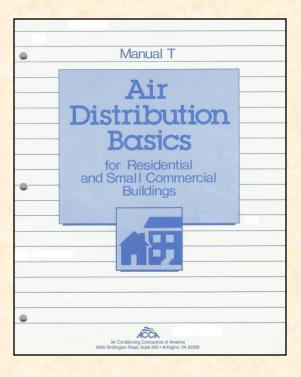
Manual D Procedures:

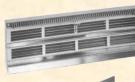
- A reference drawing to define duct pathways must be identified
  - Register, diffuser & grille selection and location must be defined.



#### **Next – Air Terminal Device Selection**

- Manual T: Air Distribution Basics
- Room by room load data is used to select air terminal devices.



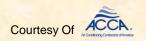








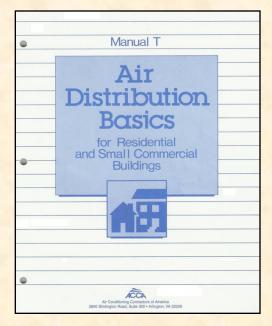




#### **Air Terminal Device Selection**

Manual T: Air Terminal Devices

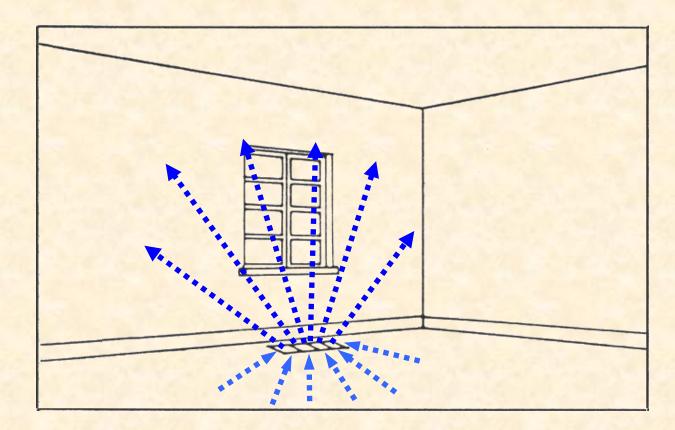
- Use manufacture data to select based on:
  - Size
  - Btuh capacity
  - CFM
  - Pressure drop
  - Velocity
  - Throw
  - Spread.



NOMINAL	FREE	Heating BTU/h	3045	4565	6090	7610	9515
CITE	AREA	Cooling BTU/h	855	1280	1710	2135	2670
SIZE SQ. IN.		C.F.M.	40	60	80	100	125
		T.P. Loss	.009	.015	.027	.037	.050
21/ / × 12/	21	Vert. Throw (ft.)	3	4	5	6	8
2¼″ x 12″	21	Vert. Spread (ft.)	6	8	10	11	14
		Face Velocity	280	420	565	705	880
2¼″ x 14″		T.P. Loss	.006	.010	.021	.031	125 .050 8 14
	24	Vert. Throw (ft.)	3	4	4.5	5.5	
	24	Vert. Spread (ft.)	6	8	9	11	14
		Face Velocity	245	365	490	610	760
		T.P. Loss		.008	.021	.026	.032
A" x 10"	22	Vert. Throw (ft.)		3	4	5	7
4" x 10"	32	Vert. Spread (ft.)		6	8	9	12
		Face Velocity		265	355	445	555

#### **Air Terminal Device Selection**

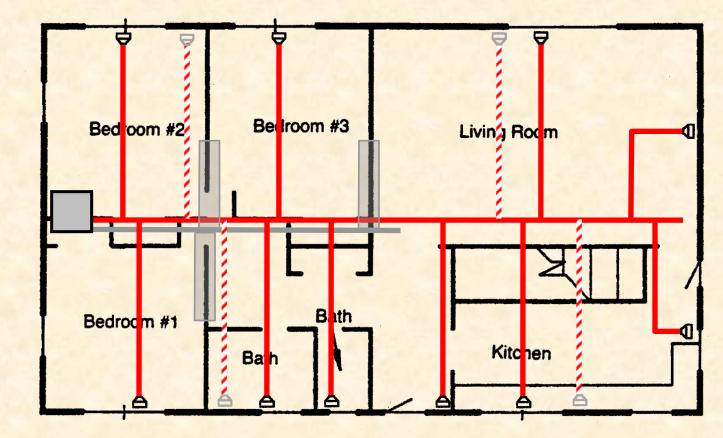
- Air terminal device selection impacts air flow patterns and coverage
  - Primary air stream
  - Secondary air stream.



### **Initial Duct Routing**

Back to Manual D Procedures:

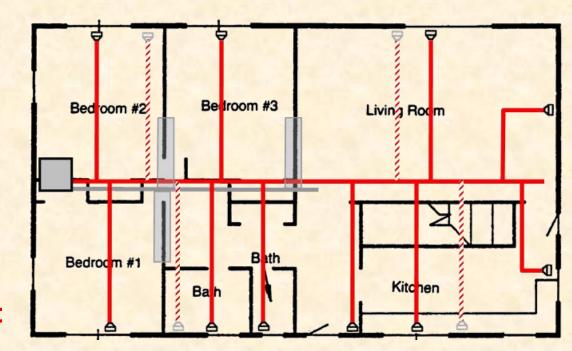
- Following register, diffuser & grille selection, continue with location of:
  - Equipment
  - Main Trunk
  - Branch Runs
  - Returns.



#### **Determining Duct Size**

Manual D Procedures:

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





#### **Fitting Geometry Affects Performance**



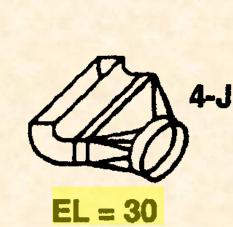
#### **Fitting Geometry Affects Performance**

 Equivalent lengths for various branch fittings can be very different.

EL = 80



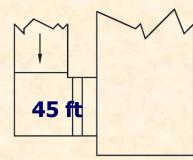
EL: Equivalent Length

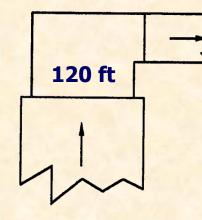


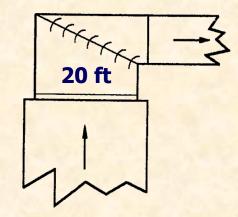
4-G

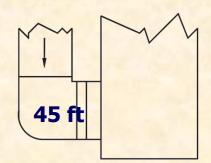
#### **Fitting Impact on Equivalent Length**

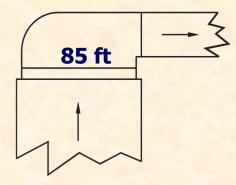
Comparison of furnace plenum geometry:

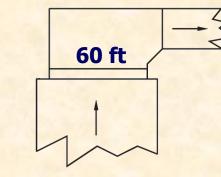


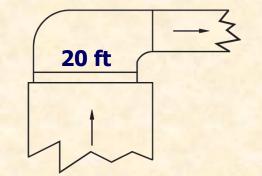






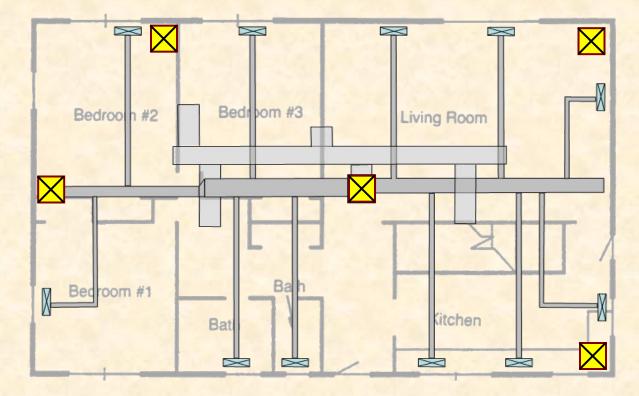






#### **Equipment Location Impacts Design**

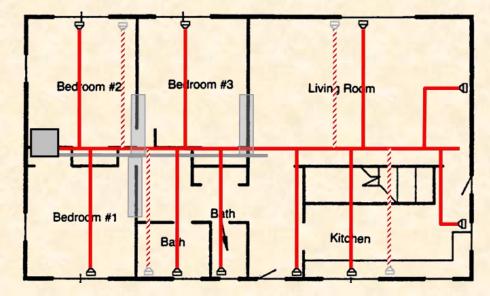
- Duct size and performance is affected by:
  - floor plan
  - equipment location

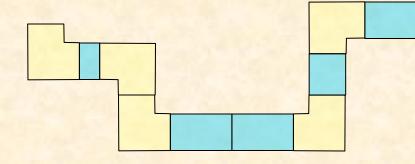


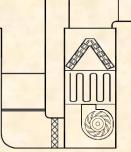
#### **Duct Total Effective Length**

#### Manual D Procedures:

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







#### **Equivalent Length & Duct Friction Rate**

 Adjust net blower pressure based on design total effective length.

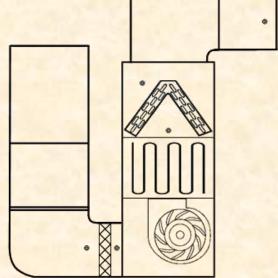
Total available pressure:

- Fan Blower: 0.6 inches W.C. Equipment pressure drop:
- 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

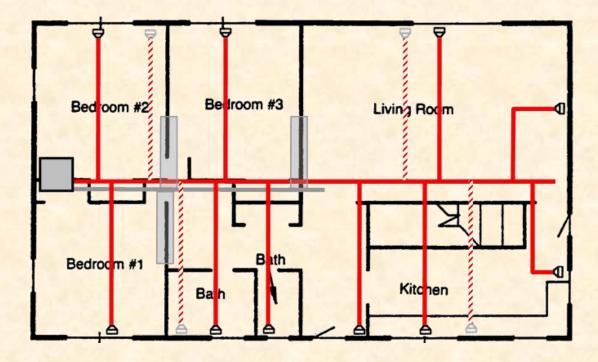


#### Friction Rate: Defined as friction per 100 ' of duct

#### **Residential Duct Design**

#### Manual D Procedures:

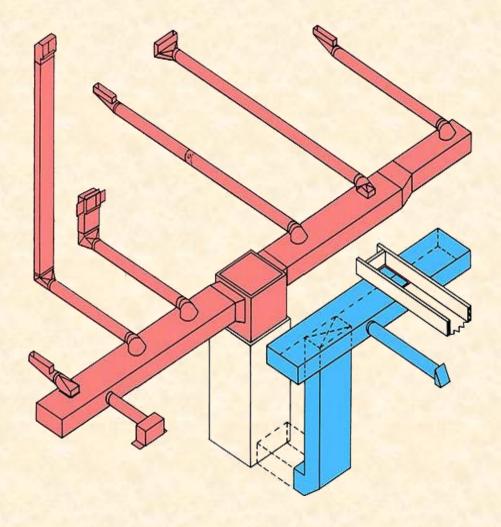
- Size the trunk and branch ducts for:
  - CFM
  - Friction Rate
  - Velocity



#### Next – Fabrication, Installation & Start-up

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

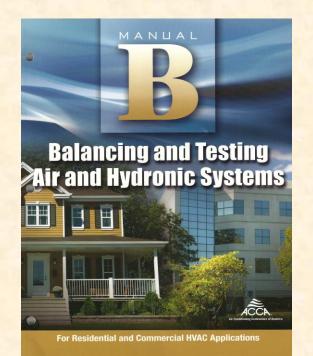


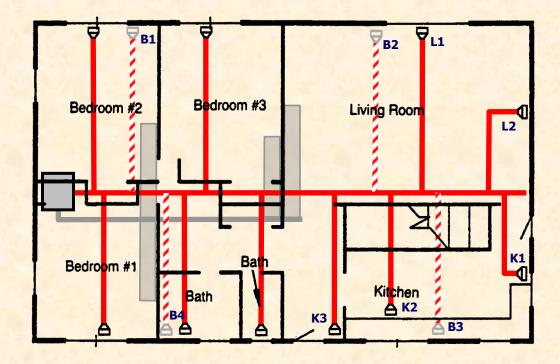


#### **Next – Balance The Duct System**

Manual B: Testing, Adjusting and Balancing

 Duct system must be balanced following installation.





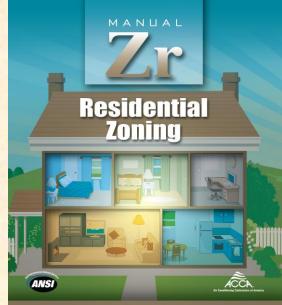






### **NEW - ACCA Manual Zr Residential Zoning**

- 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.



ne Damper Systems | Ductless Split System Zoning | Unitary Equipment Zoning



### **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



The <u>only way</u> to confirm capacity, efficiency and performance:

Test !



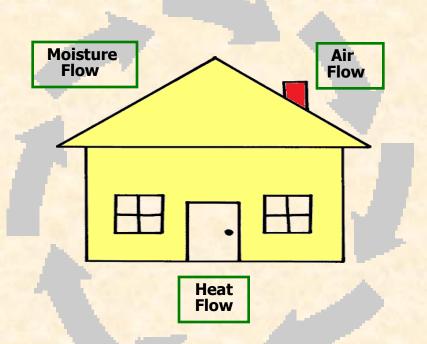
#### **Routine AC System Problems**

- 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.





# **Enjoy the rest of the conference!**



