HVAC SIZING AND DESIGN PRINCIPLES

ABOUT SOUTHFACE

Southface promotes sustainable homes, workplaces and communities through education, research, advocacy and technical assistance.

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WHO ARE YOU?

- Name
- Organization/company
- How long have you been in the design, construction, contractor or enforcement industry?

LEARNING OBJECTIVES

- Identify code requirements regarding sizing, design, and selection of HVAC equipment and ducts
- Explain how the ACCA Manual J, S and D load calculation standards are used to determine appropriate sizing and design of ducts and HVAC equipment
- Describe the role the HVAC system plays in moisture control and the effect excessive moisture has on building durability and occupant comfort and health
- Define sensible and latent heat
- Review a completed load calculation printout for common errors and intentional inputs of incorrect data and identify examples of such errors
- Compare installed HVAC and duct systems to outputs of Manual J, S, and D to verify proper sizing and design
- Describe the consequences of improperly sized HVAC systems

AGENDA

Morning:

1. Introduction
2. The systems approach
3. HVAC Overview

LUNCH

Afternoon:

- How HVAC systems are sized & selected
- Distribution
- Practical applications

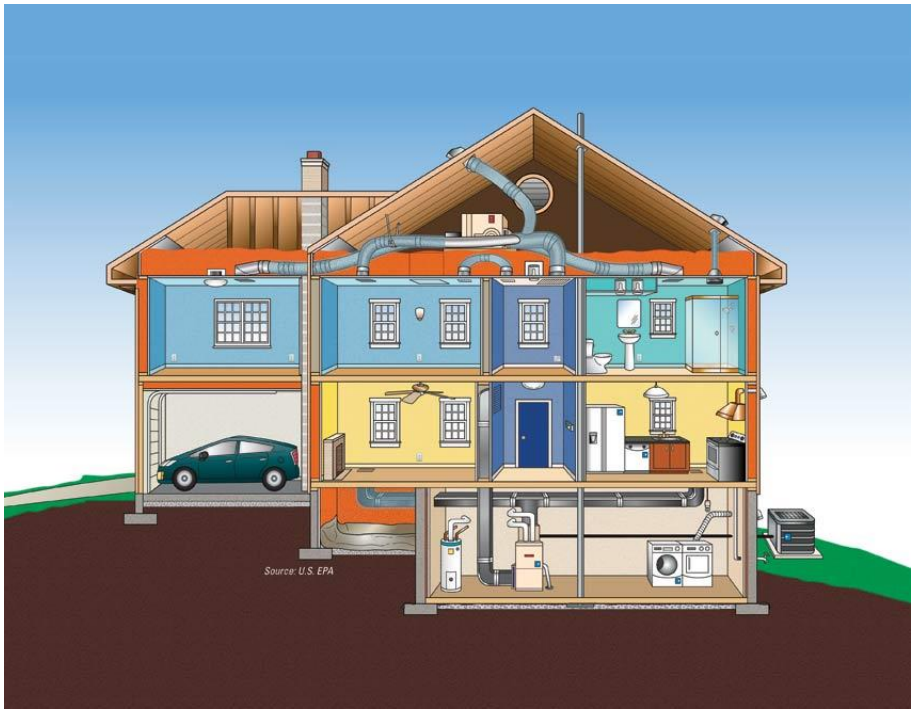
Please set phones to silent!

We will have breaks!

THE SYSTEMS APPROACH

A house is a system made up of interrelated parts:

- The building envelope
- Heating & cooling
- Ventilation (controlled)
- Water heating & distribution
- Lighting & appliances



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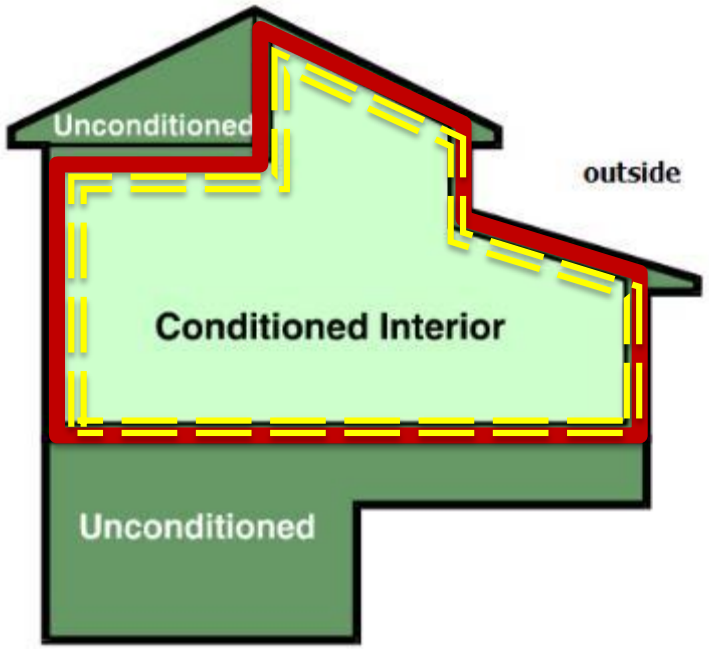
THE BUILDING ENVELOPE

Building Thermal Envelope

- Continuous Air Barrier (Pressure Boundary)
- Complete Insulation Coverage (Thermal Boundary)

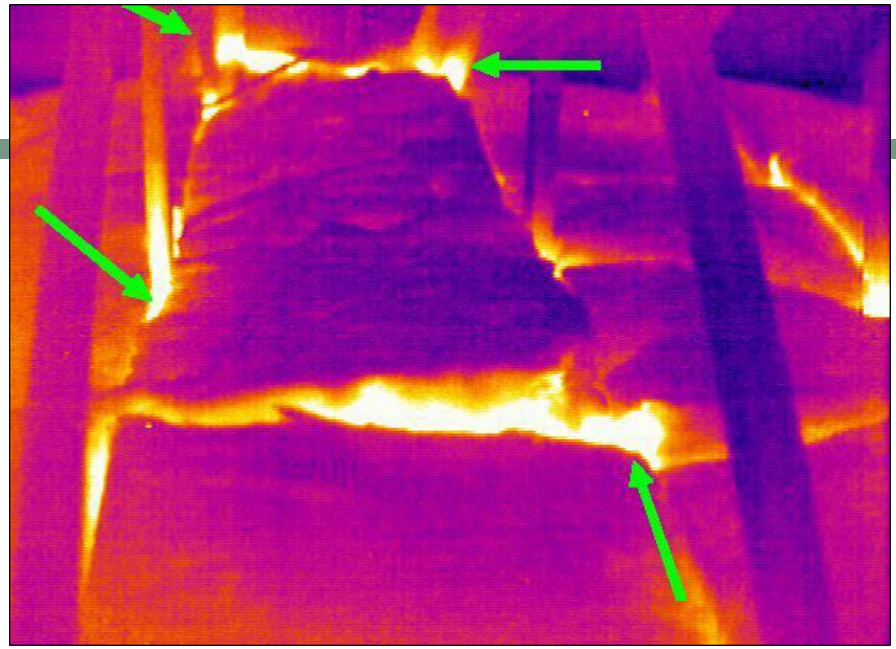


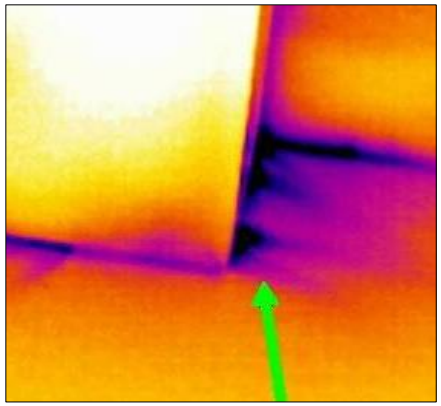
Thermal and Pressure Boundaries Make up the Building Envelope

HOUSES ARE SYSTEMS

How do the following factors affect the performance of the HVAC system?

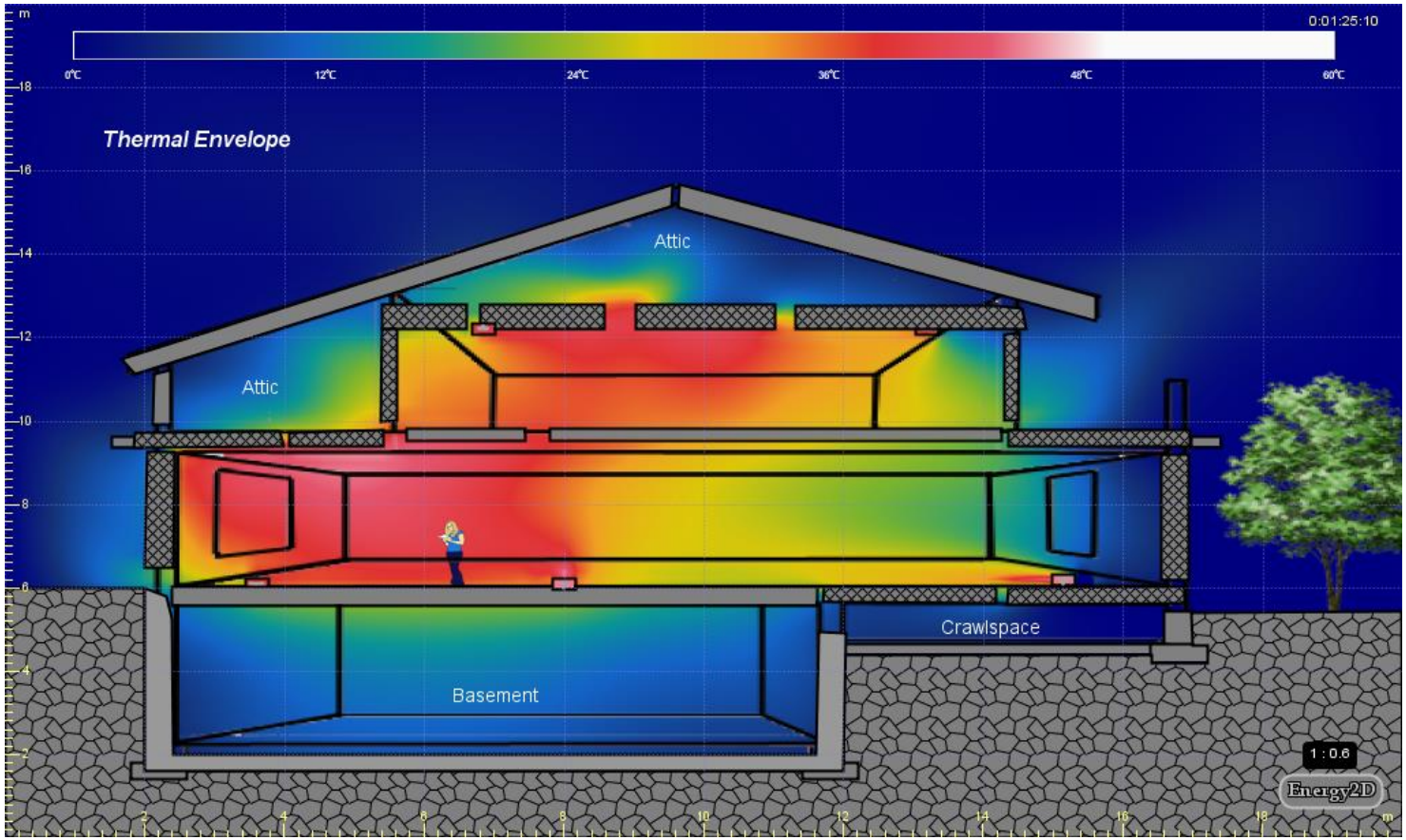
- Air tightness of building envelope
- Insulation installation
- Lighting & appliances
- Others?





**KY code requires 50% high efficacy lighting*

HOUSES ARE SYSTEMS



HVAC effectiveness is affected by other building components!

QUALITY COUNTS!

Improper HVAC design & installation can severely affect home performance!

- Poor comfort
- High energy consumption & cost
- Unhealthy IAQ
- Equipment & building durability
- Combustion safety

THE FUTURE IS NOW!

Proper design and installation are becoming increasingly important as standards & technology become more advanced

- Codes require envelope & duct sealing measures
- Sophisticated equipment choices require knowledgeable design & installation

HVAC OVERVIEW

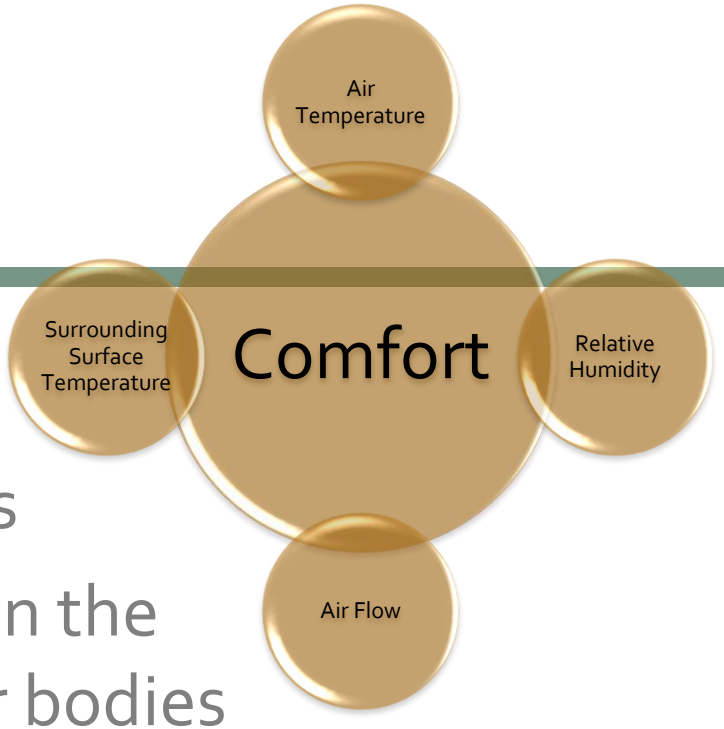
- Purpose
- Function
- Design (sizing)

PURPOSE

The purpose of the HVAC system is to provide the occupants with a comfortable & healthy living environment

- It does more than just control air temperature
- It also provides moisture control
- Controlling relative humidity is important for comfort, IAQ, and building durability

MOISTURE AND COMFORT

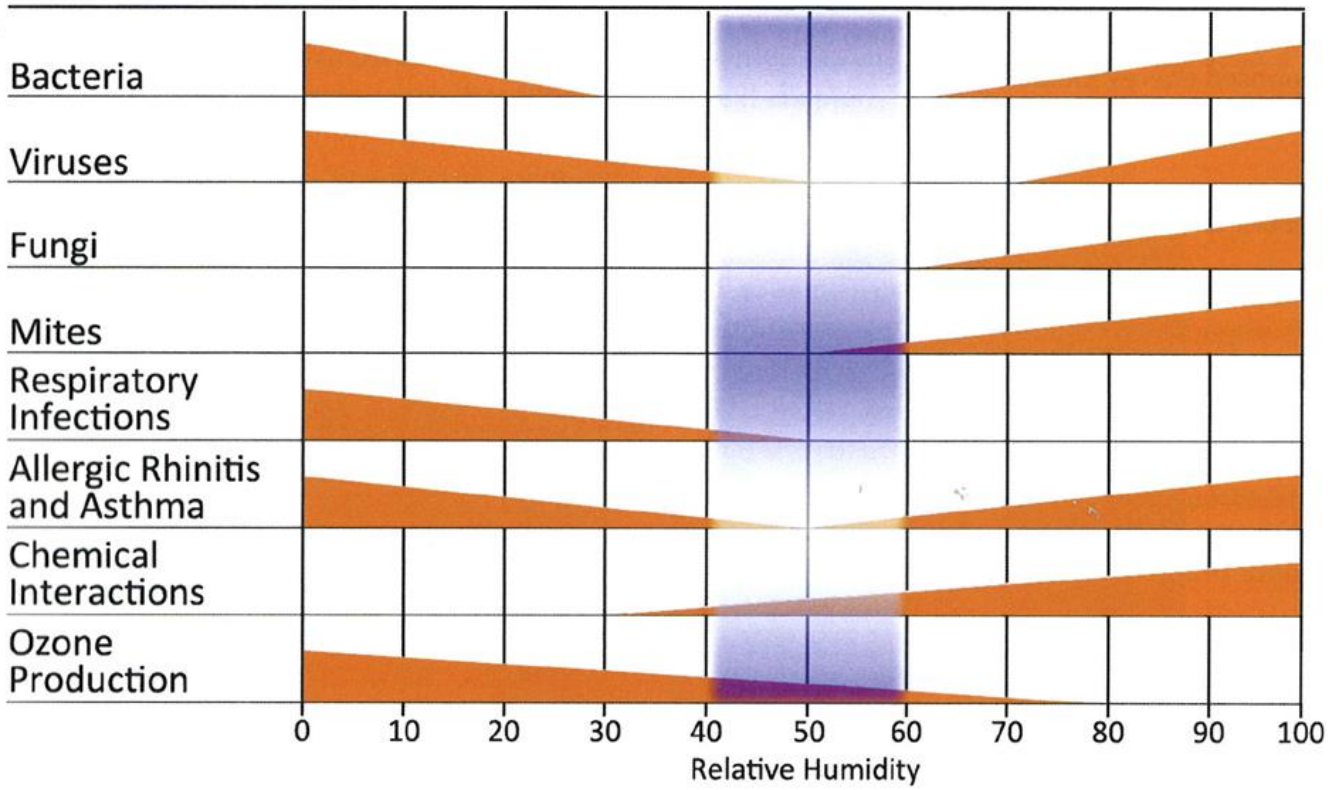


Human Thermal Comfort:

- Humans make poor thermometers
- Our sense of hot or cold is based on the rate heat is leaving or entering our bodies
- This is affected by a variety of factors – not just ambient air temperature
- Since we regulate our body temperature by perspiration, our comfort level is affected by the moisture level in the air around us

MOISTURE AND INDOOR AIR QUALITY

Relative humidity levels have a significant impact on a variety of IAQ issues



Indoor air quality issues occur at high and low relative humidity; optimum range is 40%-60%.

Source: BPI Building Science Principles Reference Guide

VENTILATION – THE "V" IN HVAC

HVAC is not just heating & cooling

- Spot ventilation is used primarily to remove moisture & pollutants at the source
- Whole house ventilation is used to ensure occupants have fresh air provided in a controlled manner
- Air exchanges through leaks are irregular, ineffective, inefficient, and unhealthy!

VENTILATION

- Mechanical ventilation is required by code if the tightness of the home is <5 ACH50
- Ventilation should be sized to comply with table in code

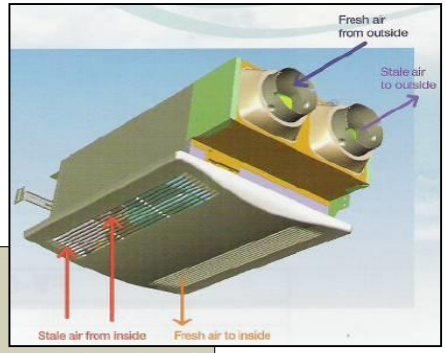
DWELLING UNIT FLOOR AREA (square feet)	NUMBER OF BEDROOMS				
	0 - 1	2 - 3	4 - 5	6 - 7	> 7
	Airflow in CFM				
< 1,500	30	45	60	75	90
1,501 - 3,000	45	60	75	90	105
3,001 - 4,500	60	75	90	105	120
4,501 - 6,000	75	90	105	120	135
6,001 - 7,500	90	105	120	135	150
> 7,500	105	120	135	150	165

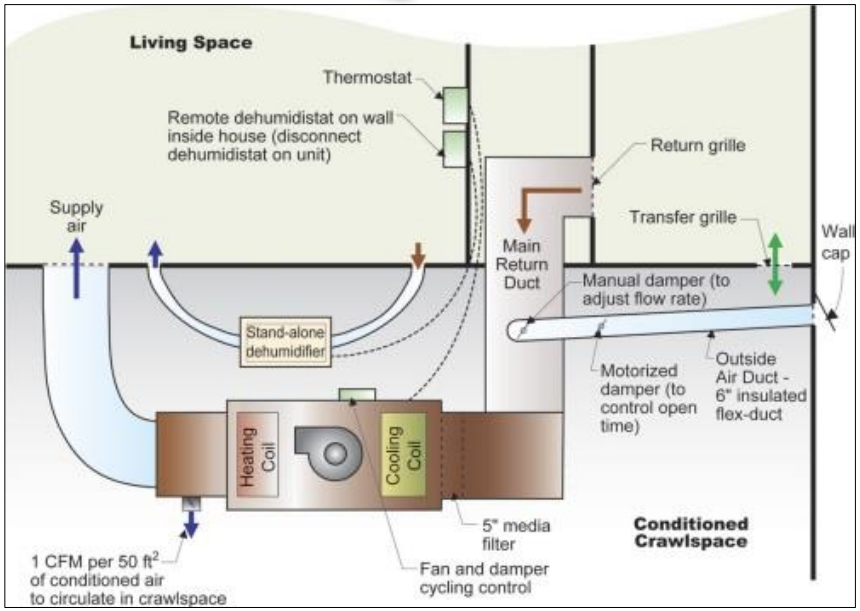
TABLE M1507.3.3(1) CONTINUOUS WHOLE-HOUSE MECHANICAL VENTILATION SYSTEM AIRFLOW RATE REQUIREMENTS

TYPES OF WHOLE HOUSE VENTILATION

There are a variety of whole house ventilation strategies:

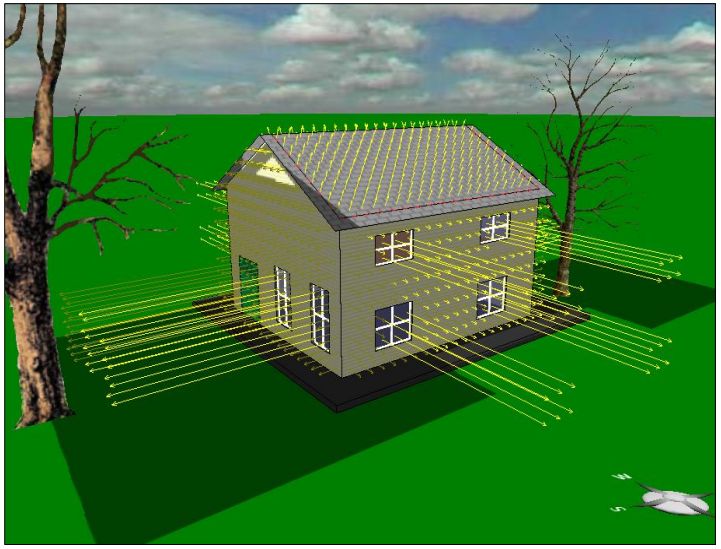
- Exhaust only
- Supply only
- Balanced





FUNCTION – HEATING & COOLING

- There are a variety of types of heating and cooling systems
- We will focus on forced air ducted systems
- Furnaces & heat pumps essentially replace heat that is lost across the building envelope
- Air conditioning removes heat & moisture (sensible & latent)



HOW AIR CONDITIONING REMOVES MOISTURE

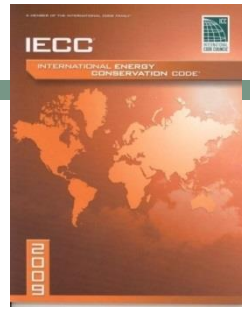
- Warm humid indoor air is blown across a cold coil
- Water vapor in the air condenses on the coil, collects, then exits the home through the condensate line
- This process takes time
- Oversized systems reach the thermostat set point before moisture is removed from home

http://www.youtube.com/watch?v=L5jQqmaFKOE

https://www.youtube.com/watch?v=14MmsNPtn6U

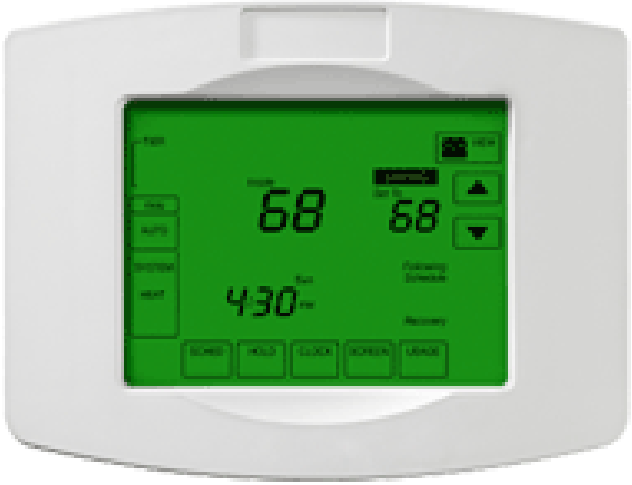
SECTION 403.1 - HVAC CONTROLS

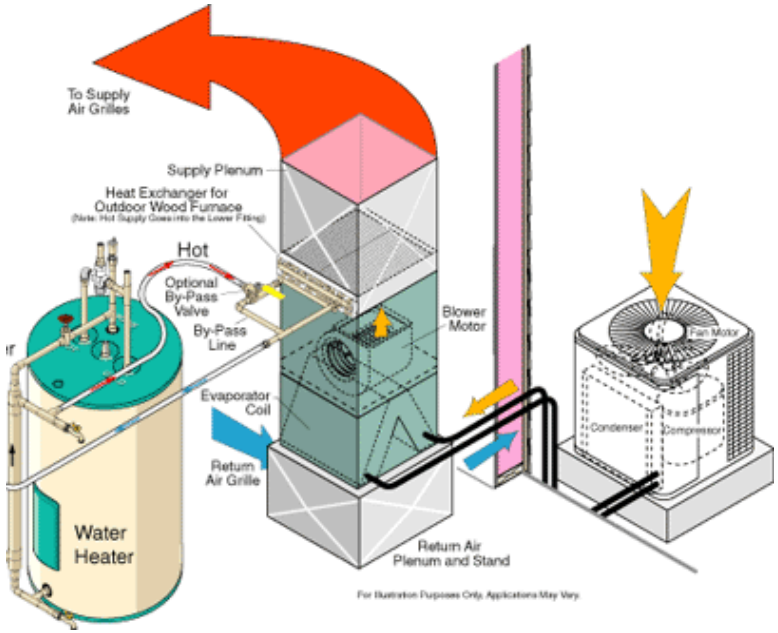
Mandatory Requirement



Programmable thermostat required for furnace

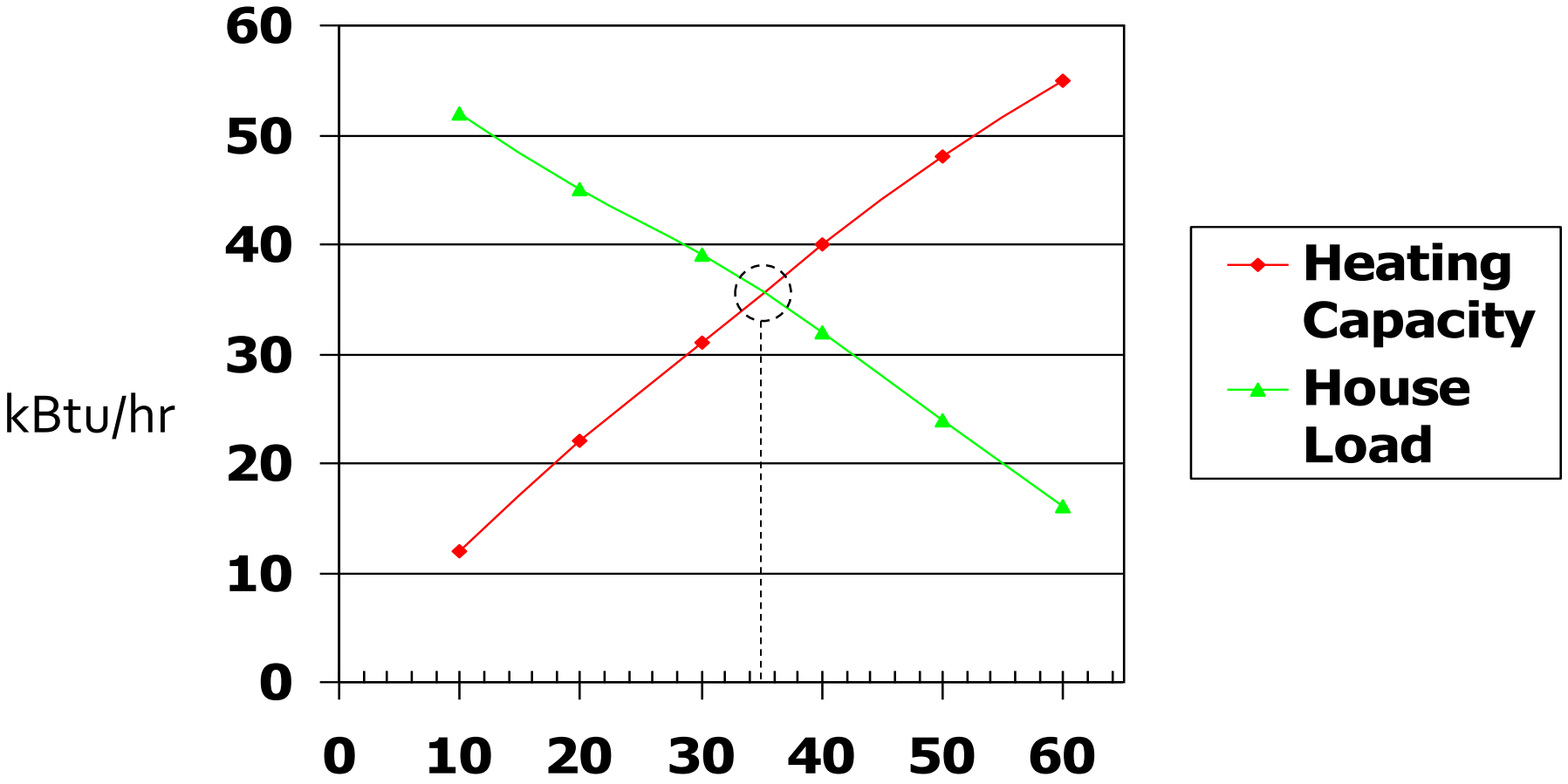
Heat Pump requires lockout capability to prevent unnecessary strip heat





HEAT PUMP BALANCE POINT

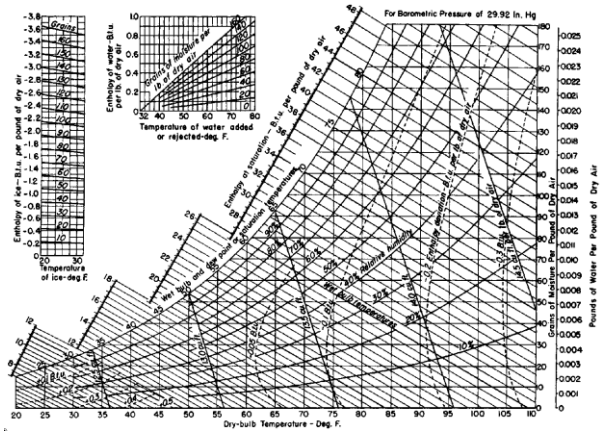
The temperature at which the heat pump can deliver exactly the same amount of Btu's that the house is losing



TYPES OF COOLING LOAD

Sensible Load

Latent Load



Total = Sensible + Latent

AHRI CERTIFIED™
www.ahridirectory.org

Certificate of Product Ratings

AHRI Certified Reference Number: 3251832 Date: 3/9/2011

Product: Split System: Air-Cooled Condensing Unit, Coil with Blower
Outdoor Unit Model Number: 24ABB442(A,W)30
Indoor Unit Model Number: CNPH*4221A**
Furnace Model Number: 58CV(A,X)070-12
Manufacturer: CARRIER AIR CONDITIONING
Trade/Brand name: BASE 14 PURON AC

Manufacturer responsible for the rating of this system combination is CARRIER AIR CONDITIONING

Rated as follows in accordance with AHRI Standard 210/240-2008 for Unitary Air-Conditioning and Air-Source Heat Pump Equipment and subject to verification of rating accuracy by AHRI-sponsored, independent, third party testing:

Cooling Capacity (Btuh):	39500
EER Rating (Cooling):	12.00
SEER Rating (Cooling):	14.00

Indoor/Outdoor Coil Match!

* Ratings followed by an asterisk (*) indicate a voluntary rerate of previously published data, unless accompanied with a WAS, which indicates an involuntary rerate.

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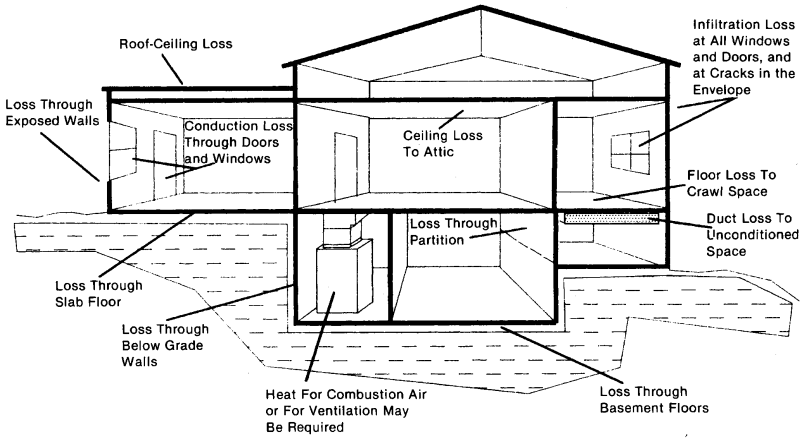
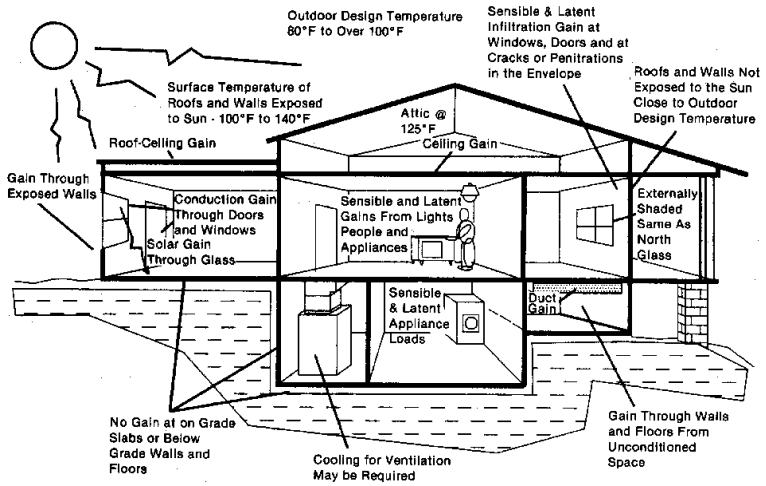
HVAC AND MOISTURE

It's Not the Heat, It's The Humidity..

Atlanta, GA									
Bin Temperature	70-75	75-80	80-85	85-90	90-95	95-100	100-105	105-110	Total
# of Hours of Occurrence	1188	880	620	361	172	23	2	0	3246
	37%	27%	19%	11%	5%	1%	0%	0%	
	83%			**17%**					
Manual J Design, Load based on Temperature					92°	99	gr/lb		
ASHRAE Humidity Design, Load based on Moisture					82°	133	gr/lb		
Approximate Extra Moisture Added per 100 CFM Of O.S.A.					3.9	pts/hr	or	93.9	pts/day

HVAC EQUIPMENT SIZING





Source: ACCA Manual J (2011)
Used courtesy of ACCA

Systems are sized in order to best fulfill their function

- Heating is sized at a rate to replace lost BTUs
- AC sized for both sensible & latent
- Climate is important (design temps)

HAZARDS OF IMPROPER SIZING

Improper sizing can create a variety of problems
This is especially important for air conditioning!

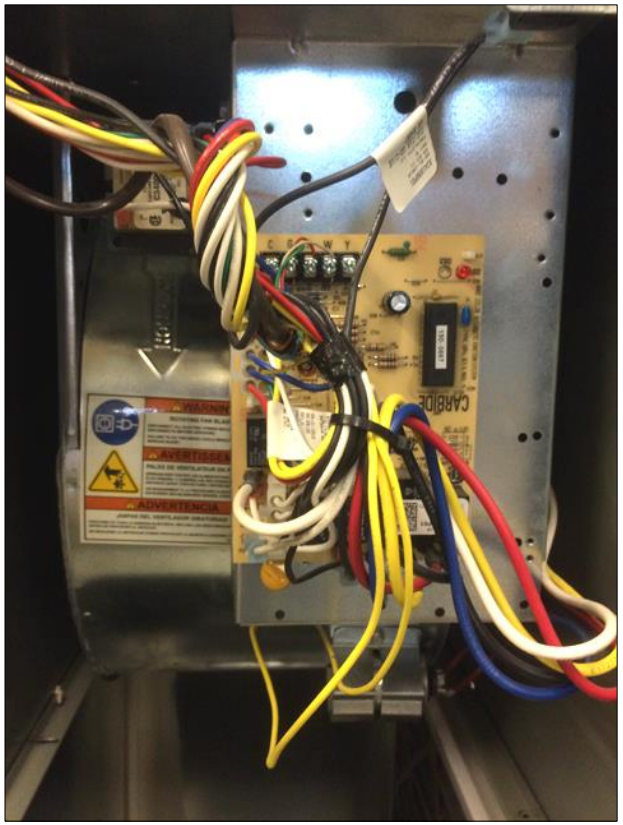
Tendency to oversize AC results in:

- Ineffective moisture removal
- Poor comfort
- IAQ concerns
- Durability issues

Heating:

- Too small – poor comfort
- Too big – short cycling

SYSTEM AIRFLOW



Proper system airflow rates are essential for effective HVAC performance

- Too fast – poor comfort & ineffective moisture removal
- Too slow – poor comfort and equipment issues

BEST OF BOTH WORLDS

Variable speed systems:

- Provide effective strategies for consistent performance
- But performance can be compromised by poor duct design, sizing & installation (also filters)
- Proper design & installation is essential for advanced equipment

HVAC SIZING & SELECTION PROCESS

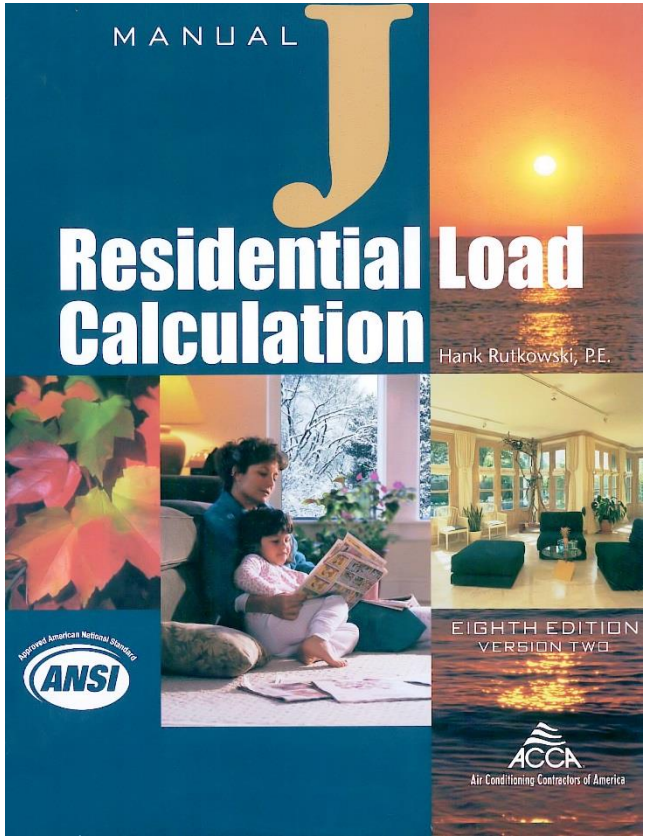
ACCA Manual J & S are the code required methods used to size and select heating & cooling equipment

- Manual J – used to determine heating & cooling loads of home
- Manual S – used to select equipment based upon Manual J

Used courtesy of ACCA

ACCA MANUAL J

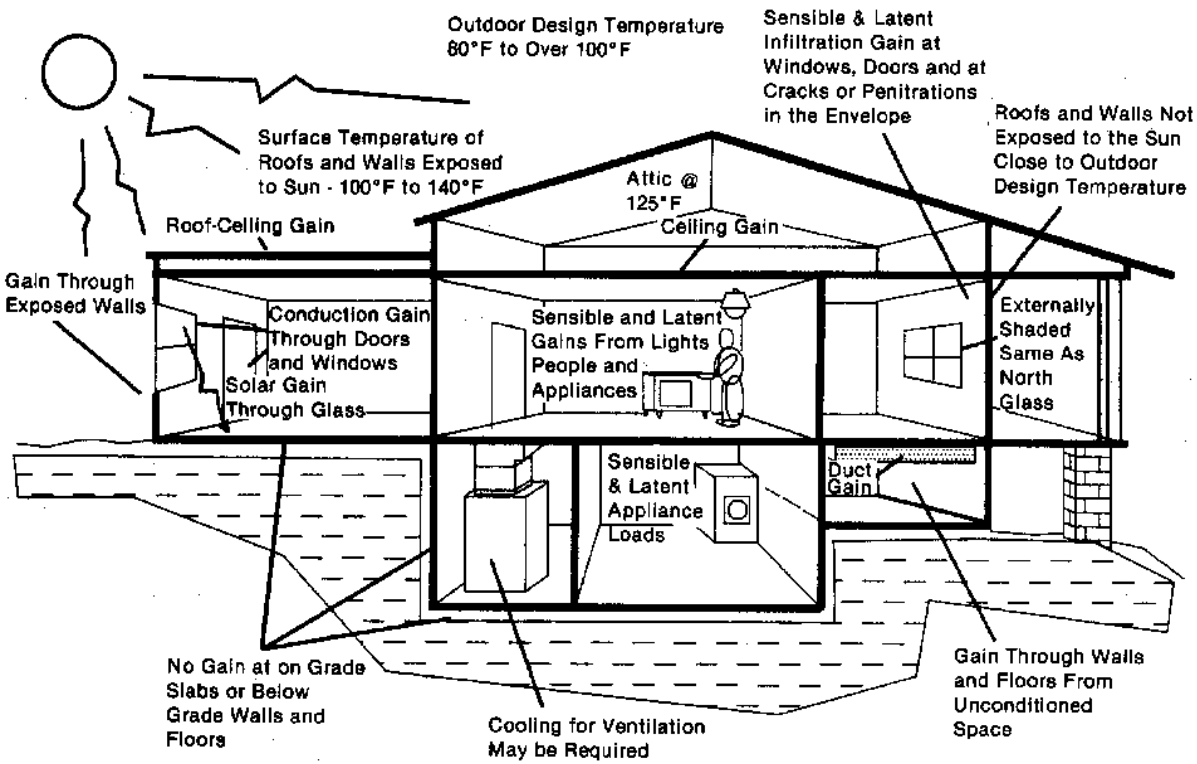
- Required by code
- Determines heating and cooling loads (room by room for new construction)
- Necessary for selection, but not intended to be solely used for such



Used courtesy of ACCA

HOW DOES MANUAL J WORK?

- Location
- Orientation
- Envelope
- Duct & envelope tightness
- Internal gains



Source: ACCA Manual J (2011)
Used courtesy of ACCA

LOAD CALCULATION PROCESS

- Select Design Conditions
  - Weather location
  - Indoor conditions
- Fill out Building Description
  - Building Type
  - Construction Materials
  - Construction Tightness

LOAD CALCULATION PROCESS

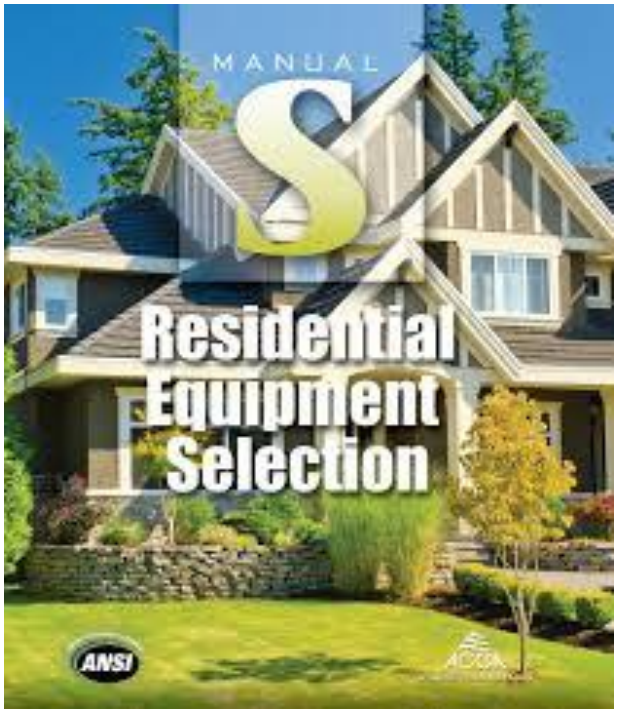
- Choose System Type
  - Example: Split system AC with gas furnace
  - May be generic or specific systems
- Select Distribution Preferences
  - Duct Materials
  - Registers, register locations

LOAD CALCULATION PROCESS

- Draw the room-by room floor plan
  - As this is completed, the software generates the load calculation
- Select equipment type
  - Choose type of system: split AC with furnace, heat pump, etc.
- Draw ducts
  - Select basic layout (e.g. trunk and branch or radial)
- Generate report

ACCA MANUAL S

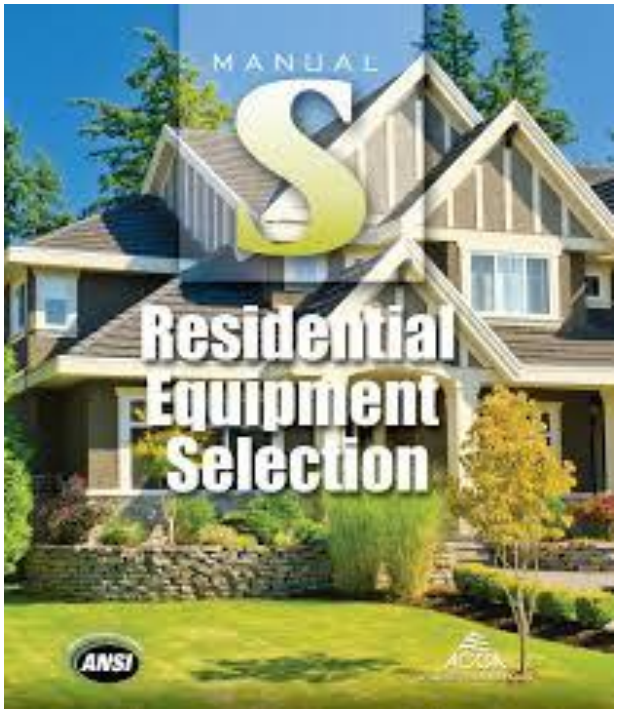
- Required by code (2012 IRC)
- Uses load information from Manual J to select equipment



Used courtesy of ACCA

ACCA MANUAL S - SIMPLIFIED

- Heating
  - Between 100% - 140% capacity of Manual J
- Cooling
  - Equipment must meet both sensible & latent heat loads
  - No greater than 115% of specified size or next nominal size



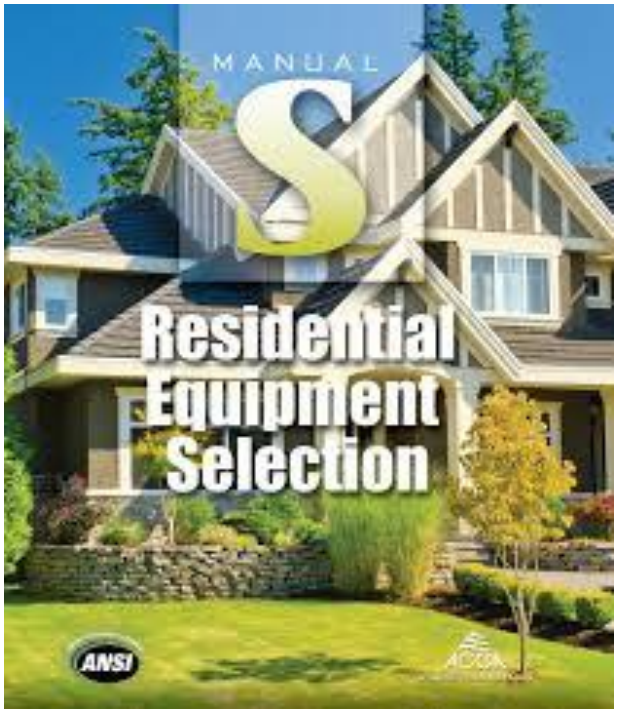
Used courtesy of ACCA

ACCA MANUAL S – DIGGING DEEPER

The actual capacity of air conditioning equipment depends upon:

- Outdoor temperature
- Indoor temperature
- Indoor humidity
- System airflow

Actual capacity may differ from equipment data plate!



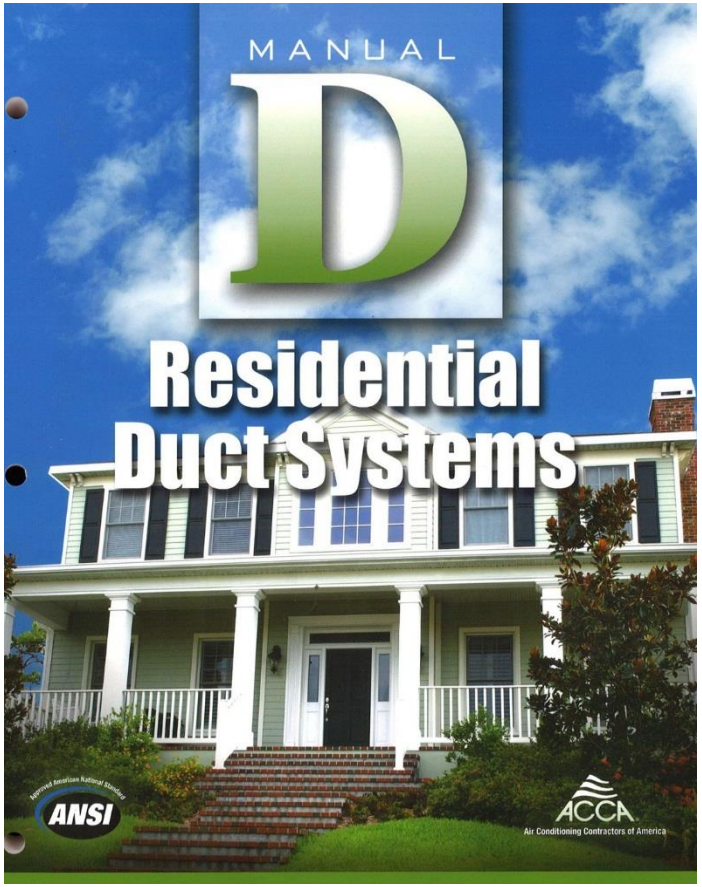
Used courtesy of ACCA

ACCA Manual S is necessary to properly select equipment based upon local conditions!

DISTRIBUTION

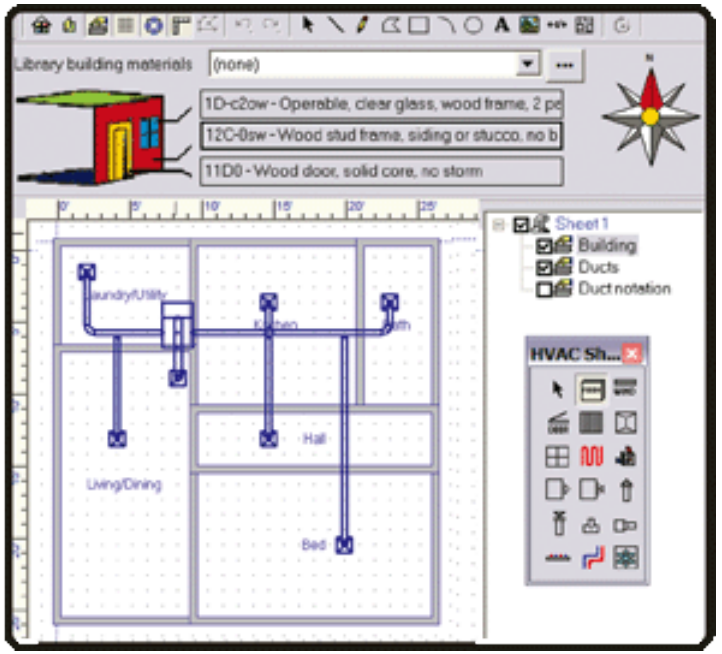
- Duct design (Manual D)
- Installation

ACCA MANUAL D

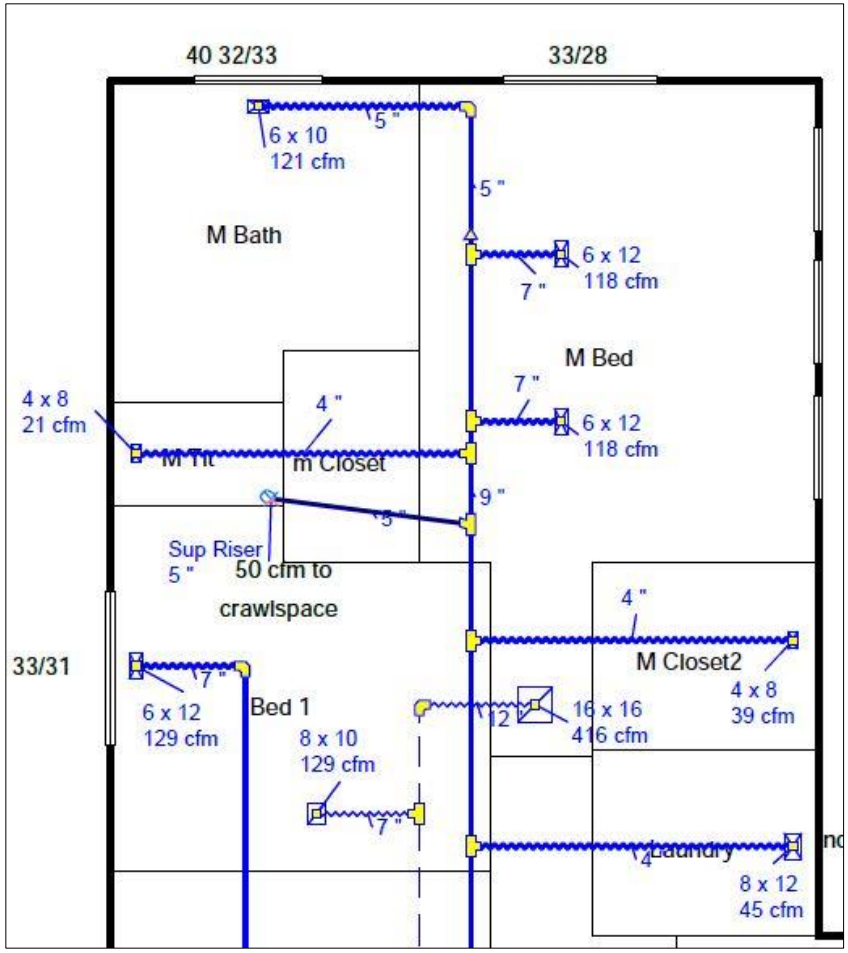


Used courtesy of ACCA

- Used to design duct system
- Duct layout
- Duct diameters & cfm



FLOW TESTING



- Each room has a specific airflow requirement
- Flow rates should be field verified (best practice)

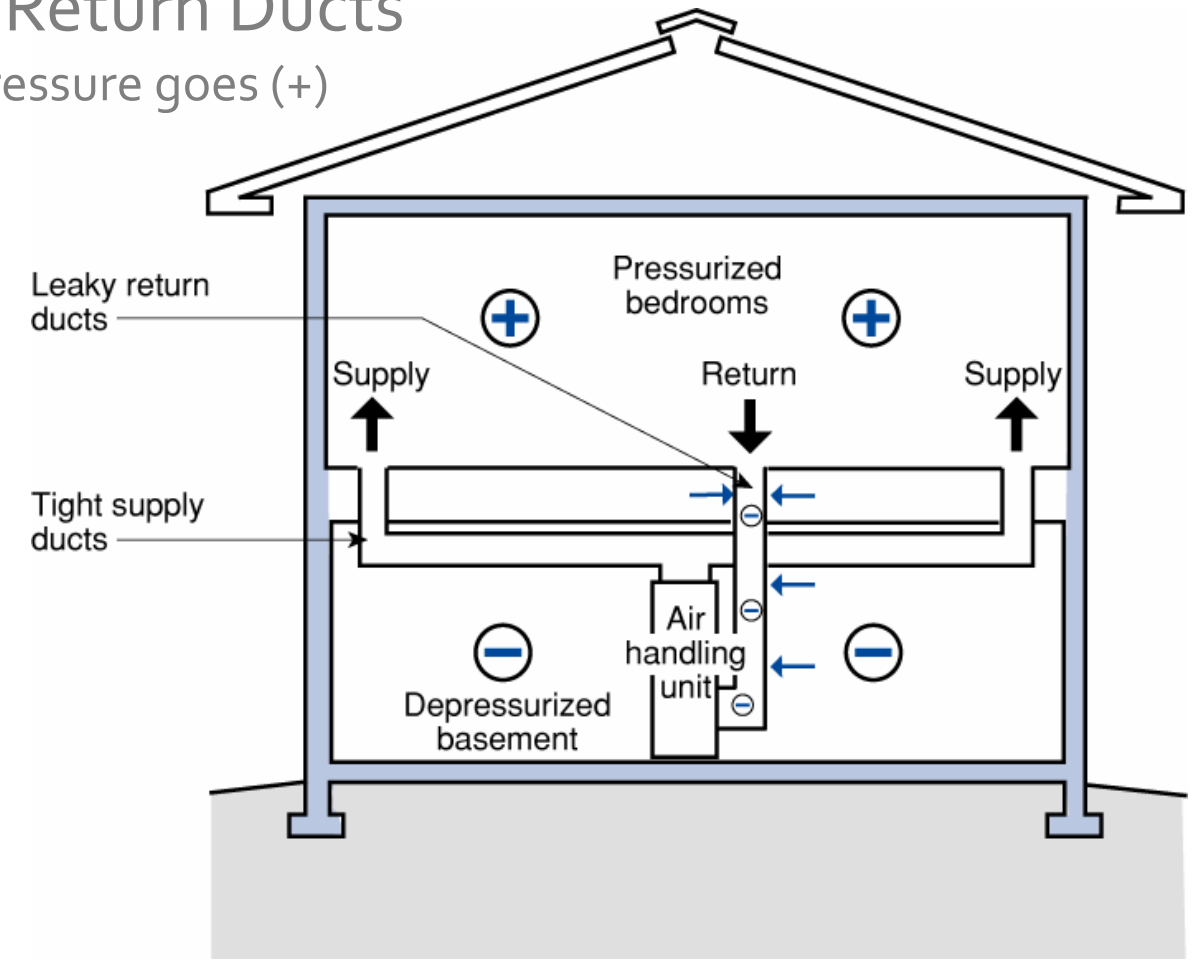
DUCT SEALING IS CRITICAL!

- Duct sealing & testing are required by code
- Ducts should be sealed regardless of location
- Mastic is the preferred material for sealing

DUCT LEAKAGE & HOUSE PRESSURE

Leaky Return Ducts

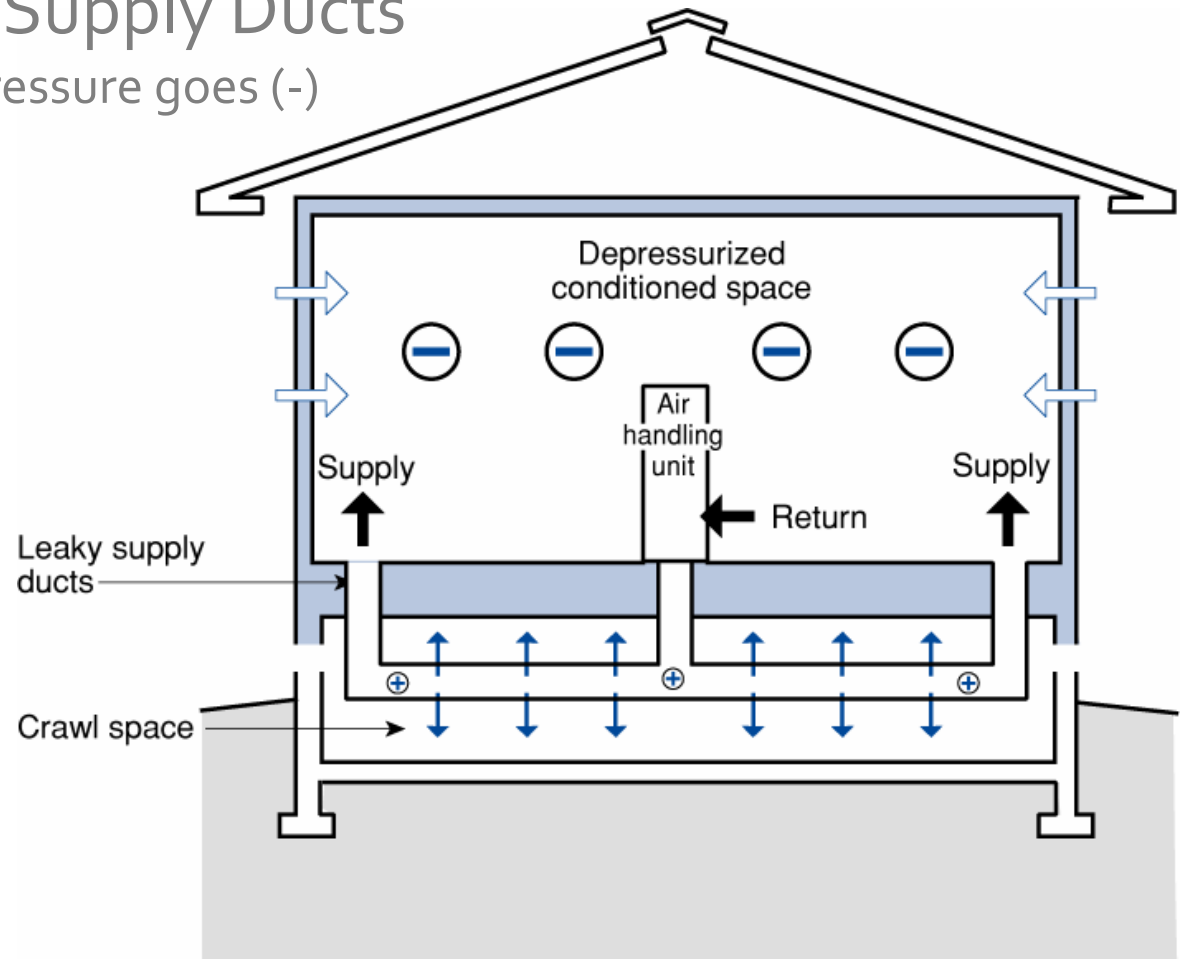
House pressure goes (+)



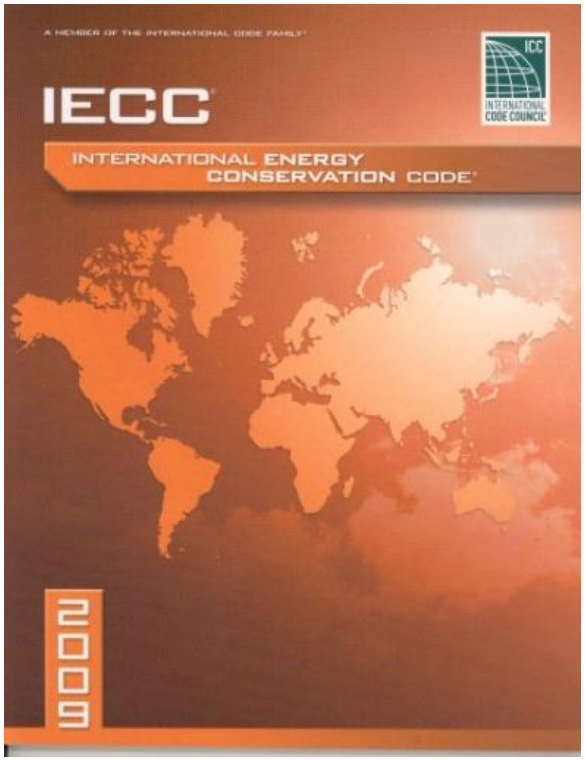
DUCT LEAKAGE & HOUSE PRESSURE

Leaky Supply Ducts

House pressure goes (-)



DUCT TESTING REQUIREMENTS



- Kentucky code requires leakage testing of ducts (unless located within conditioned space)
- Even if ductwork is exempt from testing, it still must be sealed

DUCT TESTING REQUIREMENTS

Duct leakage must meet one of the following:

- Post-construction duct leakage to outdoors ≤ 8 cfm per 100 ft2
- Post-construction total duct leakage ≤ 12 cfm per 100 ft2
- Rough-in total duct leakage w/AHU ≤ 6 cfm per 100 ft2
- Rough-in total duct leakage without AHU ≤ 4 cfm per 100 ft2

WHAT DOES IT MEAN?

- Theory is nice, but how does this relate to the real world?
- Practical applications

THE REAL WORLD

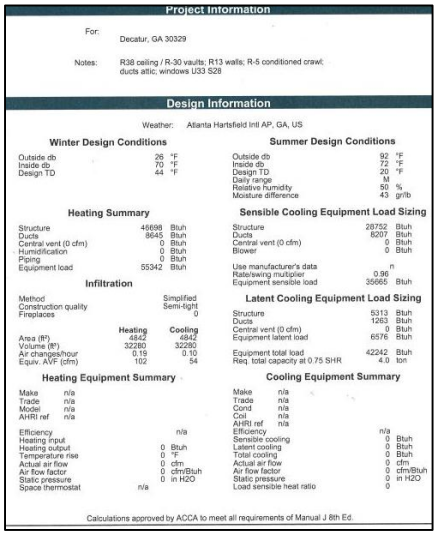
- Manual J & S are both necessary & required for selection
- However, Manual J is typically the most available document
- Is there a way to make practical decisions with limited information?

MANUAL J DOCUMENTATION

www.acca.org/standards/approved-software

- There are a variety of ways to perform a Manual J
- Software packages are increasingly being used
- ACCA approved software is listed on ACCA's website
- Some software packages also incorporate Manuals S & D
- Software typically generates a variety of reports

EXAMPLE MANUAL J SCENARIO



Project Information

For: Decatur, GA 30329

Notes: R38 ceiling / R-30 vaults; R13 walls; R-5 conditioned crawl; ducts attic; windows U33 S28

Design Information

Weather: Atlanta Hartsfield Intl AP, GA, US

Winter Design Conditions

Outside db	26	°F
Inside db	70	°F
Design TD	44	°F

Summer Design Conditions

Outside db	92	°F
Inside db	72	°F
Design TD	20	°F
Daily range	M	
Relative humidity	50	%
Moisture difference	43	gr/lb

Heating Summary

Structure	46698	Btuh
Ducts	8645	Btuh
Central vent (0 cfm)	0	Btuh
Humidification	0	Btuh
Piping	0	Btuh
Equipment load	55342	Btuh

Sensible Cooling Equipment Load Sizing

Structure	28752	Btuh
Ducts	8207	Btuh
Central vent (0 cfm)	0	Btuh
Blower	0	Btuh
Use manufacturer's data	n	
Rate/sizing multiplier	0.96	
Equipment sensible load	35665	Btuh

Infiltration

Method	Simplified
Construction quality	Semi-tight
Fireplaces	0

	Heating	Cooling
Area (ft²)	4842	4842
Volume (ft³)	32280	32280
Air changes/hour	0.19	0.10
Equiv. AVF (cfm)	102	54

Latent Cooling Equipment Load Sizing

Structure	5313	Btuh
Ducts	1263	Btuh
Central vent (0 cfm)	0	Btuh
Equipment latent load	6576	Btuh
Equipment total load	42242	Btuh
Req. total capacity at 0.75 SHR	4.0	ton

Heating Equipment Summary

Make	n/a
Trade	n/a
Model	n/a
AHRI ref	n/a
Efficiency	n/a
Heating input	
Heating output	0 Btuh
Temperature rise	0 °F
Actual air flow	0 cfm
Air flow factor	0 cfm/Btuh
Static pressure	0 in H2O
Space thermostat	n/a

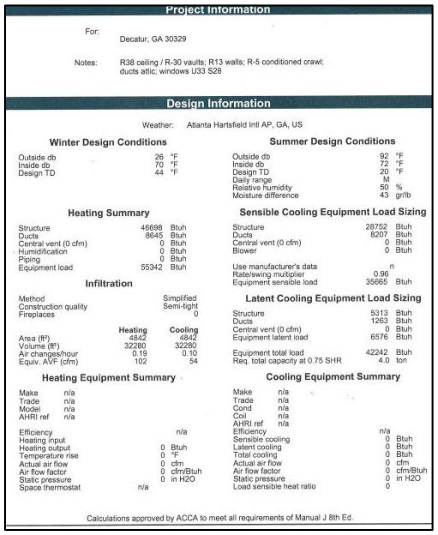
Cooling Equipment Summary

Make	n/a
Trade	n/a
Cond	n/a
Coil	n/a
AHRI ref	n/a
Efficiency	n/a
Sensible cooling	0 Btuh
Latent cooling	0 Btuh
Total cooling	0 Btuh
Actual air flow	0 cfm
Air flow factor	0 cfm/Btuh
Static pressure	0 in H2O
Load sensible heat ratio	0

Calculations approved by ACCA to meet all requirements of Manual J 8th Ed.

- You are performing a field inspection
- You are only provided with some type of Manual J documentation (summary, complete printout, etc.)
- How can you tell if this is a legitimate Manual J and if the equipment was selected properly?

EXAMPLE MANUAL J SCENARIO



Project Information

For: Decatur, GA 30329

Notes: R38 ceiling / R-30 vaults; R13 walls; R-5 conditioned crawl; ducts attic; windows U33 S28

Design Information

Weather: Atlanta Hartsfield Intl AP, GA, US

Winter Design Conditions

Outside db	26	°F
Inside db	70	°F
Design TD	44	°F

Summer Design Conditions

Outside db	92	°F
Inside db	72	°F
Design TD	20	°F
Daily range	M	
Relative humidity	50	%
Moisture difference	43	gr/lb

Heating Summary

Structure	46698	Btuh
Ducts	8645	Btuh
Central vent (0 cfm)	0	Btuh
Humidification	0	Btuh
Piping	0	Btuh
Equipment load	55342	Btuh

Sensible Cooling Equipment Load Sizing

Structure	28752	Btuh
Ducts	8207	Btuh
Central vent (0 cfm)	0	Btuh
Blower	0	Btuh
Use manufacturer's data	n	
Rate/sizing multiplier	0.96	
Equipment sensible load	35665	Btuh

Infiltration

Method	Simplified
Construction quality	Semi-tight
Fireplaces	0

	Heating	Cooling
Area (ft²)	4842	4842
Volume (ft³)	32280	32280
Air changes/hour	0.19	0.10
Equiv. AVF (cfm)	102	54

Latent Cooling Equipment Load Sizing

Structure	5313	Btuh
Ducts	1263	Btuh
Central vent (0 cfm)	0	Btuh
Equipment latent load	6576	Btuh
Equipment total load	42242	Btuh
Req. total capacity at 0.75 SHR	4.0	ton

Heating Equipment Summary

Make	n/a
Trade	n/a
Model	n/a
AHRI ref	n/a
Efficiency	n/a
Heating input	
Heating output	0 Btuh
Temperature rise	0 °F
Actual air flow	0 cfm
Air flow factor	0 cfm/Btuh
Static pressure	0 in H2O
Space thermostat	n/a

Cooling Equipment Summary

Make	n/a
Trade	n/a
Cond	n/a
Coil	n/a
AHRI ref	n/a
Efficiency	n/a
Sensible cooling	0 Btuh
Latent cooling	0 Btuh
Total cooling	0 Btuh
Actual air flow	0 cfm
Air flow factor	0 cfm/Btuh
Static pressure	0 in H2O
Load sensible heat ratio	0

Calculations approved by ACCA to meet all requirements of Manual J 8th Ed.

Available information:

- Manual J summary (see example report in course materials)
- Data plates on installed equipment (photos on slides)

DISCLAIMER

- This method is presented solely as a means to perform a very basic quality control check in the field!
- Equipment capacities (sizes) listed on data plates are based upon a specific set of operating conditions, which likely differ from local conditions (outdoor & indoor temperatures and RH)!
- More detailed manufacturer data is necessary to accurately determine the actual capacity of a given cooling system!

EXAMPLE MANUAL J SCENARIO

Manual S Equipment Selection Sizing Limitations	
Equipment	Sizing Limits
Furnaces	100% - 140% of total heating load
Boilers	100% - 140% of total heating load
Air conditioners	115% of total cooling load*
Heat pumps (cooling dominant climates)	115% of total cooling load*
Heat pumps (heating dominant climates)	125% of total cooling load*
Supplemental heat (heat pumps)	
• Electric	Based on equipment balance point
• Dual fuel	100% - 140% of total heating load

1. Locate heating and cooling loads on Manual J
2. Determine maximum equipment size by multiplying loads from Manual J by factors derived from Manual S (table)
3. Locate equipment capacities (data plates)
4. Equipment capacities should meet loads from Manual J, but not exceed the results of calculations from step 2

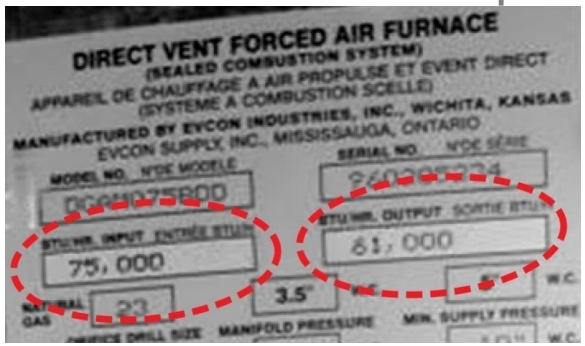
EXAMPLE MANUAL J – FURNACE

From Manual J

Heating Summary

Structure	46698	Btuh
Ducts	8645	Btuh
Central vent (0 cfm)	0	Btuh
Humidification	0	Btuh
Piping	0	Btuh
Equipment load	55342	Btuh

80 AFUE furnace data plate



Note: 75,000 x 0.8 = 60,000

1. The heating load from the Manual J is 55342 Btuh
2. 140% of the heating load is 77,479 Btuh (1.4 x 55342)
3. The output capacity of the installed furnace is 61,000 Btuh
4. The installed furnace meets the heating load from the Manual J, but is not larger than 140% of this load (55k < **61k** < 77k Btuh)
5. The furnace appears to be sized appropriately

EXAMPLE MANUAL J – AIR CONDITIONING

From Manual J

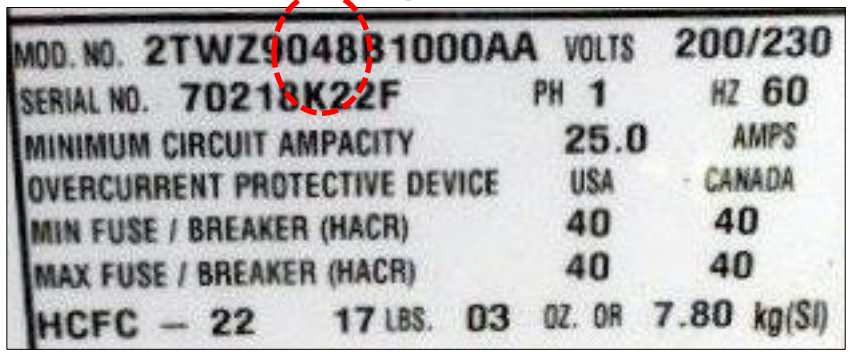
Sensible Cooling Equipment Load Sizing

Structure	28752	Btuh
Ducts	8207	Btuh
Central vent (0 cfm)	0	Btuh
Blower	0	Btuh
Use manufacturer's data	n	
Rate/swing multiplier	0.96	
Equipment sensible load	35665	Btuh

Latent Cooling Equipment Load Sizing

Structure	5313	Btuh
Ducts	1263	Btuh
Central vent (0 cfm)	0	Btuh
Equipment latent load	6576	Btuh
Equipment total load	42242	Btuh
Req. total capacity at 0.75 SHR	4.0	ton

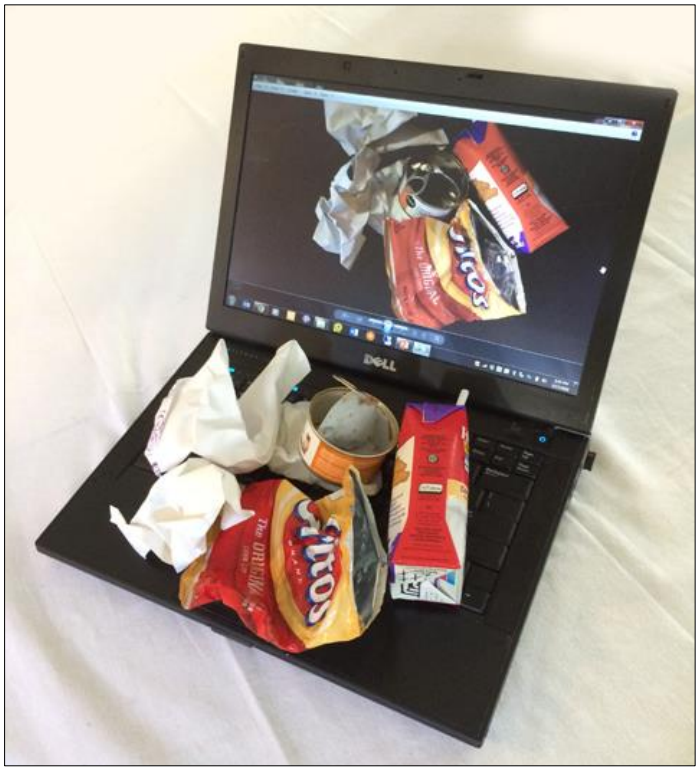
A/C condensing unit data plate



Note: "048 " in model no. represents 48,000 Btuh
48k Btu @ 12k Btu/ton = 4 tons

1. The total cooling load from the Manual J is 42,242 Btuh & 4.0 tons is specified
2. 115% of the cooling load is 48,578 Btuh (1.15 x 42,242)
3. The installed air conditioner is ~48,000 Btuh (4 tons) based upon model number
4. The unit meets the total cooling load from the Manual J, but does not appear to be larger than 115% of this load
5. This is VERY simplified & should only be used to identify major red flags!

COMMON PROBLEMS WITH MANUAL J INPUTS

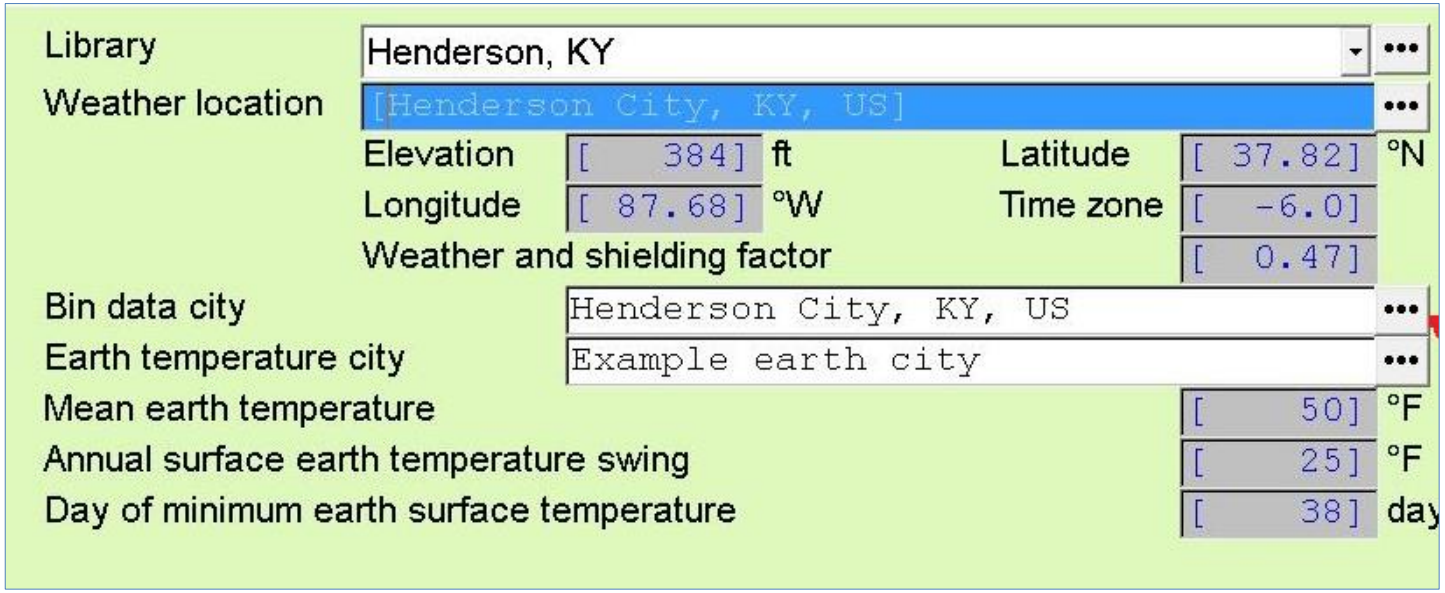


- Manual J's are often not correct – both unintentionally & intentionally
- The results of a Manual J are only as meaningful as the input data (GIGO)
- There are several common input errors that are often found

THE USUAL SUSPECTS

- Design temperatures
- Building orientation
- Number of occupants
- Window area & U-value
- Air leakage

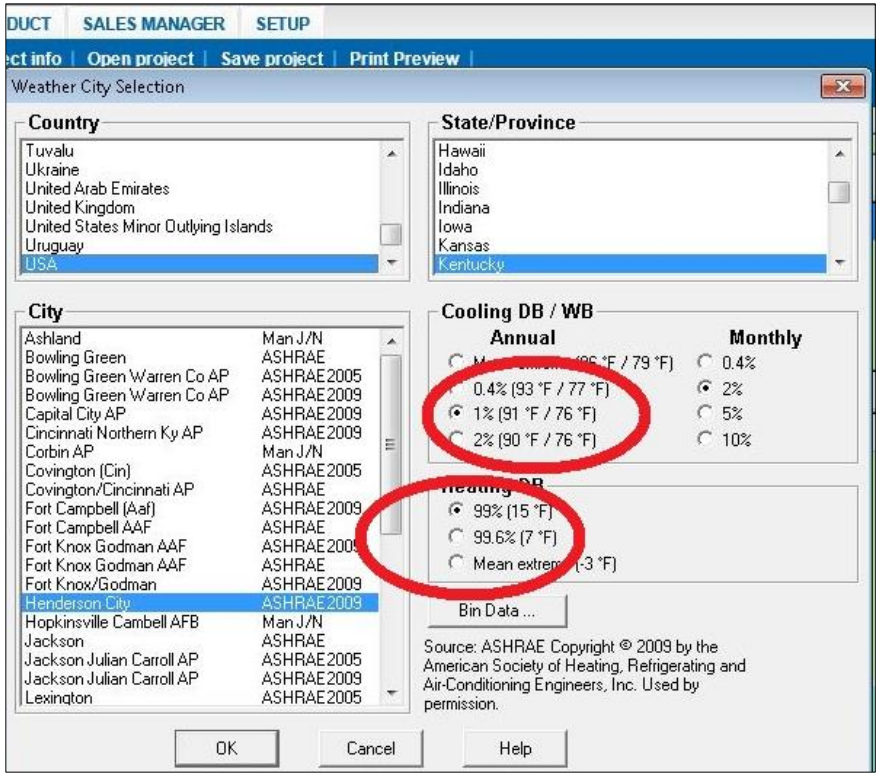
OUTDOOR DESIGN CONDITIONS



- The location & design temperatures should be accurately entered into the software
- Typically, city is selected from a menu

OUTDOOR DESIGN CONDITIONS

- Outdoor design temps are listed in a table in Manual J & within approved software databases
- The 99% design conditions should be used
- Technicians often override inputs to adjust results



INDOOR DESIGN CONDITIONS

ACCA specifies 70° for heating and 75° & 50% RH for cooling

Design Information

Weather: Atlanta Hartsfield Intl AP, GA, US

Winter Design Conditions			Summer Design Conditions		
Outside db	26	°F	Outside db	92	°F
Inside db	70	°F	Inside db	72	°F
Design TD	44	°F	Design TD	20	°F
			Daily range	M	
			Relative humidity	50	%
			Moisture difference	43	gr/lb

These numbers are often subjectively adjusted!

SECTION 302
DESIGN CONDITIONS

302.1 Interior design conditions. The interior design temperatures used for heating and cooling load calculations shall be a maximum of 72°F (22°C) for heating and minimum of 75°F (24°C) for cooling.

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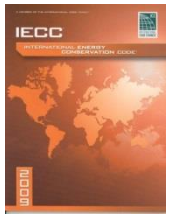
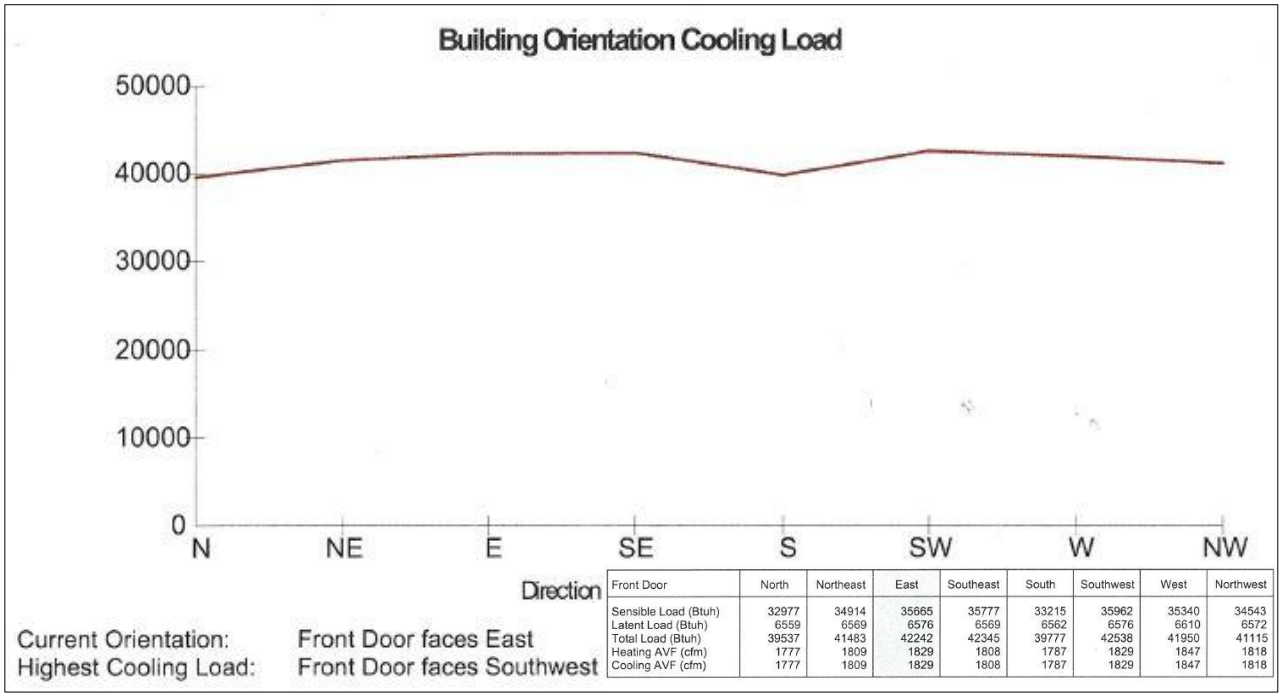
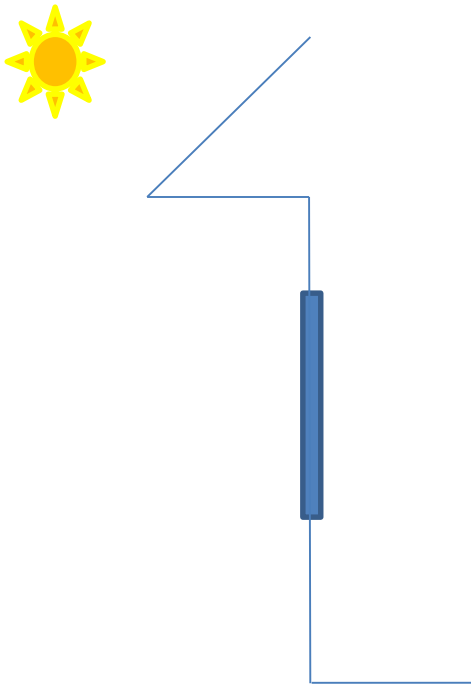


ORIENTATION



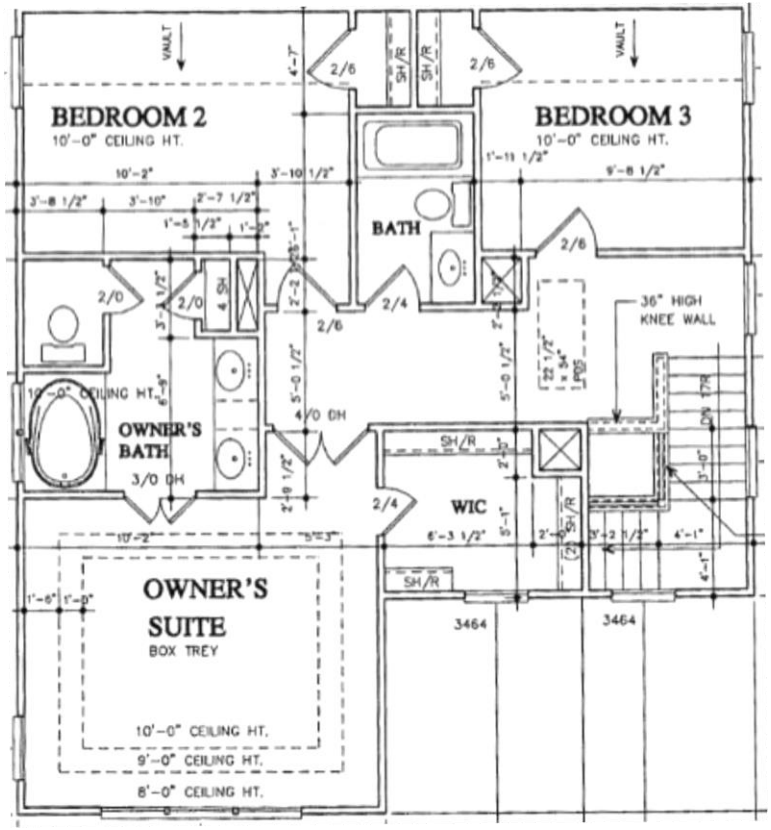
Front Door	North	Northeast	East	Southeast	South	Southwest	West	Northwest
Sensible Load (Btuh)	32977	34914	35665	35777	33215	35962	35340	34543
Latent Load (Btuh)	6559	6569	6576	6569	6562	6576	6610	6572
Total Load (Btuh)	39537	41483	42242	42345	39777	42538	41950	41115
Heating AVF (cfm)	1777	1809	1829	1808	1787	1829	1847	1818
Cooling AVF (cfm)	1777	1809	1829	1808	1787	1829	1847	1818

Current Orientation: Front Door faces East
Highest Cooling Load: Front Door faces Southwest

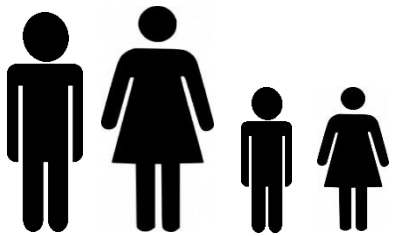


- The heating & cooling loads on a house are dependent on the orientation, especially for windows
- Compare the orientation listed on Manual J documentation to the actual orientation of the home

NUMBER OF OCCUPANTS



- Occupants represent internal gains
- ACCA specifies to use the number of bedrooms plus one
- For example, a three bedroom house should have four occupants entered into the Manual J



Q: How many Btuh does Manual J assume for each person?

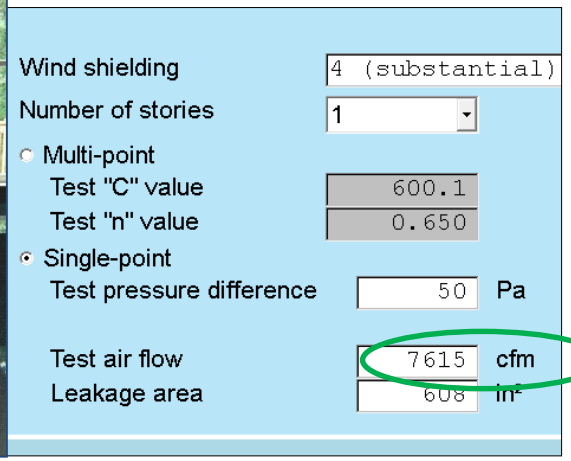
CONSTRUCTION COMPONENTS

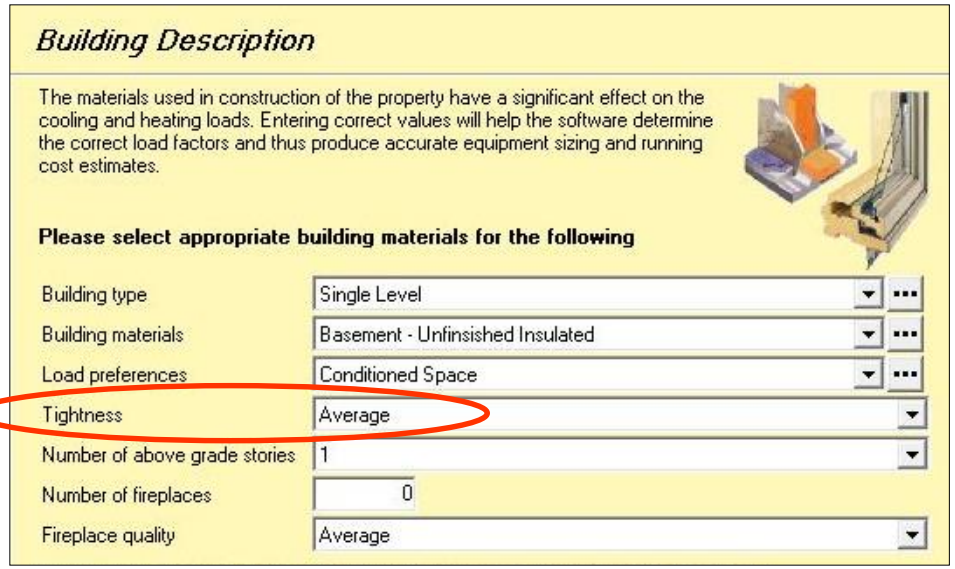
- Manual J requires detailed entry of construction data (R-value, U-value, etc.)
- If available, compare the listed components to what is actually in the house
- Pay particular attention to window areas and specifications

Construction descriptions	Or	Area ft²	U-value Btuh/ft²-°F	Insul R ft²-°F/Btuh
Walls				
12C-0bw: Frm wall, brk 4" ext, 1/2" wood shth, r-13 cav ins, 1/2" gypsum board int fnsh, 2"x4" wood frm, 16" o.c. stud	n	545	0.091	13.0
	ne	17	0.091	13.0
	e	613	0.091	13.0
	s	513	0.091	13.0
	w	486	0.091	13.0
	all	2174	0.091	13.0
15A-4s3oc-4: Bg wall, light dry soil, empty core, concrete block wall, r-4 ins, 8" thk	n	63	0.102	4.0
	n	305	0.093	4.0
	e	232	0.102	4.0
	e	350	0.093	4.0
	s	132	0.102	4.0
	s	205	0.093	4.0
	w	638	0.093	4.0
	all	1924	0.093	4.0
Partitions (none)				
Windows				
U30 S24: U30 S24; NFRC rated (SHGC=0.24); 50% blinds 45°, light; 50% outdoor insect screen; 2 ft overhang (1.5 ft window ht, 1 ft sep.); 6.8 ft head ht	n	18	0.300	0
U33 S31: U33 S31; NFRC rated (SHGC=0.31); 50% blinds 45°, light; 50% outdoor insect screen; 2 ft overhang (3 ft window ht, 1 ft sep.); 6.8 ft head ht	n	9	0.330	0
U32 S29: U32 S29; NFRC rated (SHGC=0.29); 50% blinds 45°, light; 50% outdoor insect screen; 2 ft overhang (3.3 ft window ht, 1 ft sep.); 6.8 ft head ht	e	41	0.320	0
	s	41	0.320	0
	all	83	0.320	0

AIR LEAKAGE

- Software typically has generic tightness categories that are selected from a menu
  - Tight
  - Semi-tight
  - Average
  - Semi-loose
  - Loose

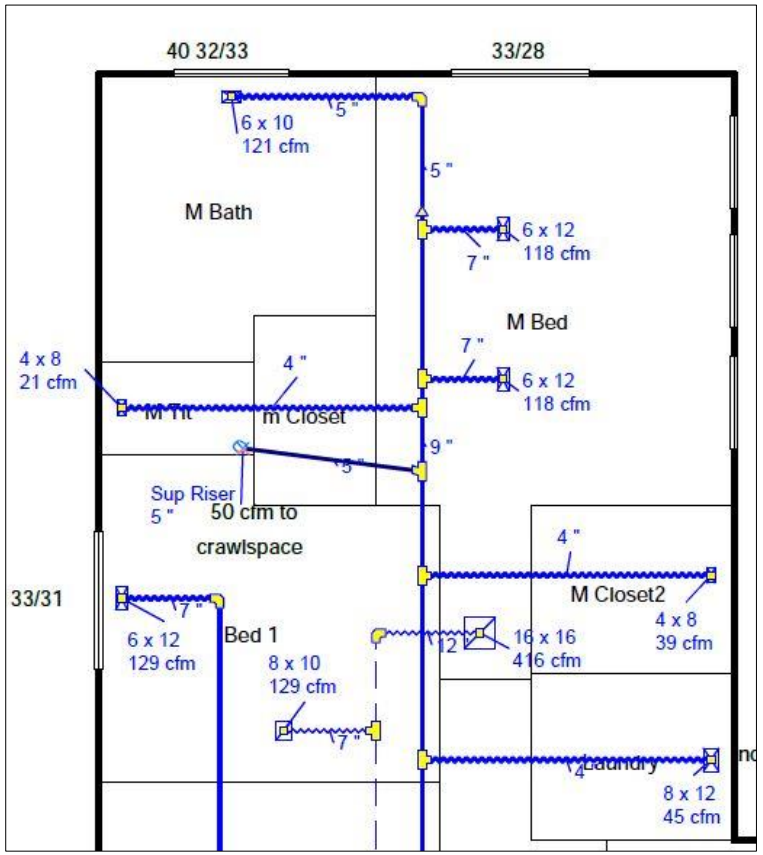




- More detailed options allow input of the actual infiltration (blower door)
- Using the actual (tested) infiltration will result in a more accurate Manual J

DUCT INSTALLATION - INSPECTION

- Compare duct layout and diameters to Manual D
- If Manual D not available, look for red flags
- Crimps, length, inadequate supports, etc.



DUCT INSTALLATION - INSPECTION

DUCT INSTALLATION - INSPECTION

DUCT INSTALLATION - INSPECTION

- Compare installed duct insulation with code requirements
- R-8 required for attics & exterior
- R-6 for other locations

SUMMARY

- Proper HVAC design and installation is not only code required, but important for quality construction
- As technology improves, this is becoming even more crucial
- Design and installation issues can lead to all sorts of problems

SUMMARY

- Man J, S, and D are established protocols that should be performed
- Although things can be complicated, there are practical methods to verify installed components and identify red flags
- Field inspection methods should be used in an appropriate context

QUESTIONS OR COMMENTS?