

HVAC System Design

The Sequential Process for Calculating
Loads, Sizing Appliances & Designing
Distribution Systems

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ACCA Method

- ACCA - Air Conditioning Contractors of America
- Publish a series of manuals with step by step instructions detailing how to size and design a residential heating and cooling system
- Manual-J - heating & cooling loads
- Manual-S - sizing appliances
- Manual-D - sizing duct systems
- Manual-T - termination devices/locations

Manual-J

- Step by step process to calculate heating & cooling loads
- Simple approach for dealing with infiltration
- Breaks cooling load into sensible and latent loads for proper A/C sizing
- Output should have necessary information to properly size appliances

Heat Transfer

- How does the heat/cooling get in or out
- Conduction: transfer of heat when two materials touch each other
- Convection: movement of heat on air currents (drafts)
- Radiation: Movement of heat between two objects that aren't touching
- All 3 types must be accounted for in H/C Calculation

Step 1: What are the Loads on the House?

- Conductive
- Convective
- Latent Loads
- Internal Gains
- Duct Losses & Gains
- Ventilation (if necessary)

Calculating Conduction Heat Transfer

- UAT- “U A delta T” is the basic formula for calculating heat transfer due to conduction.
- HTM- Manual J combines the u-value and the delta T and calls it a heat transfer multiplier.
- Manual J has complete set of tables with HTMs listed for windows, walls, doors, floors and ceilings for both heating and cooling.
- Cooling HTMs take radiation gains and losses into account for windows. Orientation matters.

Calculating Convective Losses/Gains

- Determine ACH_{nat} for summer and winter (BD or Table 5).
- ACH, Volume and Delta T are used in a series of simple equations to calculate “convective” HTM for heating & cooling.
- These HTMs are multiplied by the window and door area.
- Summer infiltration is broken into latent and sensible gain.

Manual-J Worksheet

1	Name of Room			Entire House			
2	Running ft. of Exposed Wall						
3	Room Dimension, ft						
4	Ceiling Ht,		Direction Room Faces				
TYPE OF Exposure		Const. No.	HTM		Area or Length	Btuh	
			HTG	CLG		HTG	CLG
5	Gross Exposed Walls and Partitions	a					
		b					
		c					
		d					
6	Windows and Glass Doors (Heating)	a					
		b					
		c					
		d					

Plan or Site Takeoffs

- Need to calculate the area of the exterior walls, ceilings, floors, windows and doors
- These areas in conjunction with the HTMs for that component, give us the load per hour in BTUs for that assembly
- Blower Door and Duct Leakage Tests
- Can do a whole house calculation for appliance sizing
- Room by Room for duct design or length of baseboard needed in a room

Duct Losses

- Duct Losses (heating) are in Table 7A.
Use air delivery temp to decide if Case 1 (below 120) or Case 2 (above 120)
- Duct location
- Level of insulation
- Winter Design Temp
- Derive a multiplier to use on house, zone or room load

Duct Gains

- Duct Gains are listed in Table 7B
- Delivery temp. is not a factor
- Location
- Insulation Level
- Modifier to multiply house, zone or room cooling load

Room by Room Loads

- Entire house loads allow us to size appliances
- Room by Room loads allow us to size distribution systems

Manual-S

Using Calculated Loads to Size
Heating & Cooling Appliances

Step 2: How Do I Get Started?

- Accurate load calculation (no rules of thumb)
- Operating conditions at the building site

Operating Conditions at Building Site

- The capacity of DX coils will be affected by outdoor air temp. for air source
- The capacity of water source cooling will be affected by entering water temp.
- Should choose the Manual-J 2 ½ % dry bulb temp for AS. (some exceptions)
- For water source, local groundwater temp for “open” loop or for “closed” loop the water temp of the circulating water.

Estimating Cooling CFM

- Calculate the sensible heat ratio (SHR)
sensible load/total load
- Determine best temperature for supply air
 - SHR is high, LAT can be warmer (58 F)
 - SHR is low, LAT has to be cooler (54 F)

SHR, LAT & DT

- How are they related?
 - SHR < .80, the LAT=54 and the DT is 21 F
 - SHR > .80 but < .85, the LAT=56 and the DT is 19 F
 - SHR > .85, the LAT=58 and the DT is 17 F

Sensible Heat Equation

- Once the TD is calculated the cooling CFM can be calculated.

$$\text{CFM} = \text{Sensible Load} / 1.1 \times \text{TD}$$

- Cooling CFM will determine blower size

Blower Performance Data

- Supplied by the equipment manufacturer
- Can be a table or fan curve
- Should show the designer
 - Model number and btu capacity
 - CFM flow at different speeds
 - CFM flow should vary by ESP

Sample Blower Table

Footnotes

- 1. Filter pd included
- 2. DX coil not included

Model	Speed	.4 ESP	.5 ESP	.6 ESP
HC40-60	Low	535	407	350
	Med	575	445	405
	High	602	500	450
HC40-80	Low	625	595	550
	Med	735	675	625
	High	812	780	730
HC60-80	Low	625	595	550
	Med	735	675	625
	High	812	780	730

Equipment Selection Summary Data

Design Loads: Latent & Sensible, Heating	Outdoor Conditions: Summer dry & wet bulb, winter dry bulb
Room Conditions: Dry bulb cooling, relative humidity, dry bulb heating	Air @ Indoor Coil: Dry bulb cooling, wet bulb cooling, dry bulb heating
Air Flow Estimate: TD from Table 1-4 & CFM from equation	Water Temperature: Late Summer, late Winter

AHRI Certification Data

- AHRI data is only for comparing performance of various makes and models of cooling units and heat pumps
- It is not the same as manufacturer's data
- AHRI only provides a units TC not its latent or sensible capacities
- Coil performance is based on CFM, AHRI no data
- AHRI data is not site specific

Choosing the Appliances

- Has to satisfy BTU (both heating and cooling (latent & sensible))
- Fan has to be able to supply needed CFM at a reasonable ESP
- Read the footnotes on the table/chart, these will tell you what air side devices have or have not been accounted for

Air Source Heat Pumps

- Sizing should be based on the cooling load
- After equipment selection a “balance point diagram” can be used to evaluate heating
- Equipment selection for ASHP cooling is same as for cooling only

Balance Point Diagram

- Balance point of a system is when the capacity of the heat pump = the load on the structure.
- The balance point can be found by graphing the structure heat load and the system heating capacity on the same graph.
- The intersection is the balance point.

Manuals D & T

ACCA Manual D Method for
Sizing Heating & Cooling Ducts

Manual D

- Loaded with very good information that every residential HVAC designer should know
- If you only ever read a few chapters, make it 3 & 8
- Appendix 3 is crucial to process
- Appendix 1 has all of the design equations

Design Considerations

- Rambling Floor Plans: Have very diverse loads at diverse times. Should zone.
- Multi-Level Plans: Connected by open stairwells or balconies. Heat stratification is a problem. Careful design and continuous low speed fan operation can minimize this.
- Incompatible Construction Features: Rooms on slabs, conditioned basements, attic rooms, etc.
- Incompatible Glass Areas: East glass vs. West glass, thermostat placement etc.
- Summer Loads vs. Winter Loads: Seasonal branch damper adjustments
- Occupants

Supply Duct System Types

Classified by Geometry, Supply Outlet Location, and Material

1. Geometry: Trunk & Branch, Radial, Perimeter Loop (pros & cons Sect. 1-6,7,& 8)
2. Supply Outlet Location: Perimeter, Ceiling, Inside Wall. (ACCA Manual T)
3. Material: Many different materials. Generally see “hard duct”, flex duct, duct board, PVC (high velocity)

Return Duct System Types

Return duct systems primarily described by number of return openings.

1. Central
2. Multiple
3. Every Room

Secondary Return Classifications

- Location: High Wall, Low System (floor or low wall)
 - Place returns where convenient and aesthetic. Returns DO NOT affect air movement or patterns in the room (Manual T, section 7).
- Geometry: like supplies, they can be trunk & branch, radial, perimeter

Duct Efficiency

- Try to place appliances and ducts in conditioned space.
- If ducts are run in unconditioned space they must be sealed and insulated.
- Thoroughly sealed, lots of insulation
- Cooling ducts must have vapor retarders
- Seal and insulate the ducts

Air Side Devices

- Secondary equipment consists of optional components that are added to the base system.
 - DX coils
 - Dampers
 - Humidifiers
 - Media, HEPA, or Electro-Static Filters
- Secondary equipment causes an increase in the resistance to the air flow. This must be accounted for.

Duct Performance

- The resistance that the blower works against is created by the air side devices and the duct work.
- Duct performance can be graphed also.
- When duct performance and blower performance are plotted on the same graph, we get the “system operating point.”
- If the system operating point does not supply the required CFM:
 - Change the fan speed
 - Alter the duct geometry
 - Change the duct material (flex to hard)

Pressure Drop vs. Friction Rate

- Pressure Drop is equal to the total pressure loss that occurs between any two points in a system (expressed in IWC).
- Friction Rate is equal to the pressure loss that occurs between two points in a system that are separated by a specific distance. Friction charts and slide rules use 100' as the reference distance (expressed in IWC/100).
- To use the duct calculator, pressure drop data must be converted to the friction rate that is associated with 100' of duct run.

Step 3: Friction Rate Equation

- Friction rates are not chosen
- Friction rates are calculated
 - “a 6-inch duct will deliver 100 cfm”
 - “I always design my system using .1 as the friction rate”

$$FR = \frac{\text{Available Static Pressure} \times 100}{TEL}$$

Basis for Calculating Available Static Pressure

- Based on Blower Performance Data
- Air Side Accessory Device Pressure Drop Data
- These two sets of data are used to determine Available Static Pressure (ASP)
- ASP is the amount of pressure left over after all of the air side device pressure drops have been subtracted from the ESP that a fan can produce.

Determining TELs

- The effective length of a duct run is calculated by adding the straight lengths and the equivalent lengths associated with fittings or configurations.
- Fitting and configuration lengths are listed in Appendix 3 of Manual D.
- It is not necessary to calculate length of every run. Only the longest run of the supply and return.
 - Sometimes longest runs can be determined by inspection
 - Don't jump to conclusions, fittings can have a major impact on length.
- Friction Rate is determined only by the longest runs.
- Add the longest supply and return runs to determine system TEL.

A Few Miscellaneous Items

- It is not recommended to design systems with a friction rate below .06 or above .18.
- The velocity of the air inside the system is an important consideration.
 - Supply velocities between 300 – 900 feet per minute (fpm)
 - Return velocities below 700 fpm
- There should be a few bends between the fan and the return grille for sound attenuation.
- When trunk velocity drops to half of the original trunk velocity, it is time to reduce the trunk. New trunk size can be obtained by placing friction rate on remaining CFM in trunk and reading the size off the duct sizing scale.

CFM vs. Velocity

- Noise caused by excessive velocity or poor throw caused by too low a velocity are important considerations.
- Final duct size may be a compromise between getting adequate airflow and keeping the run quiet.
- A duct sizing worksheet has been developed to help with this process.

TEL Worksheet

Effective Length Calculation Sheet									
Element	Supply Run ID Number				Element	Return Run ID Number			
	#	#	#	#		#	#	#	#
Trunk Length					Trunk Length				
Trunk Length					Trunk Length				
Trunk Length					Trunk Length				
Runout Length					Runout Length				
Group 1					Group 5				
Group 2					Group 6				
Group 3					Group 7				
Group 4					Group 8				
Group 8					Group 10				
Group 9					Group 11				
Group 11					Group 12				
Group 12					Other				
Other					Other				
Other					Other				
Other					Other				

Effective Length Worksheet

Sizing Worksheet

Duct Sizing Worksheet								
HF = Blower CFM / Manual J Heat Loss = () / () = _____								FR Value
CF = Blower CFM / Manual J Sensible Heat Gain = () / () = _____								
Supply Duct System								
Run - Trunk	H-BTUH	C-BTUH	H-CFM	C-CFM	Dsn CFM	Round Size	Velocity	Final Size
1 —								
2 —								
3 —								
4 —								
5 —								
6 —								
7 —								
8 —								
9 —								
10 —								
11 —								
12 —								
13 —								
14 —								
15 —								
		Trunk						
		Trunk						
		Trunk						
		Trunk						
Return Duct System								
Run - Trunk	Associated Supply Runs	H-CFM	C-CFM	Dsn CFM	Round Size	Velocity	Final Size	
1 —								

Designer Responsibilities

- Ensure that the pressure drop associated with the longest possible circulation path (longest supply TEL + longest return TEL) does not exceed the ASP.
- Ensure that the velocity that is associated with any section does not exceed the recommended limit.

Balancing Dampers

- Systems could be designed with multiple friction rates, each rate applying to a particular run.
 - very time consuming to design
 - velocity would be an issue
 - non-standard run out sizes would be required
- These factors make this impractical, therefore a properly designed system will not be self-balancing.
- Balancing dampers must be installed at the **BEGINNING** of each supply run out.

Manual T

- Definitions
 - Primary air: air from the supply
 - Secondary air: room air
 - Throw: distance supply air travels before its' velocity drops to a specified rate (usually 50 fpm)
 - Drop: distance bottom edge of air stream falls by the time it reaches throw distance
 - Net Free Area: actual opening area in a grille, register or diffuser

Too Much Information...

- Manual-T is loaded with detailed information about how termination devices affect primary and secondary air entrainment.
- Way too much info. to detail here, so let's hit the most important points...

Returns

- Return grilles (how big): CFM/desired velocity.
- Residential velocity around 300 fpm for gross area (400 for net free), so if we needed to move 1000 cfm/ $300\text{fpm}=3.33$ square feet of gross area or 2.5 square feet of net free area.
- Consider natural convective air movement when considering return locations.

Supplies

- Perimeter floor supplies for heat in cold climates (less important for tight, well insulated homes).
- Near windows to warm/cool surfaces offset radiant cooling/heating.
- Exact location determined by HVAC equipment location, building configuration and architecture.
- Specific model and size by manufacturer's spec.
 - must be able to deliver desired CFM
 - noise level must be acceptable (velocity<700 fpm)
 - Check "throw" keep velocity below 50 fpm in occupied zone
 - Check pressure drop (form Manual-D ASP calculation)

Final Step: Balance the System

- Even a well designed and installed system will not perform satisfactorily if it is not balanced.
- Balance by the “Percentage of Load” method.
 - Need the load calculation
 - Need a method of accurately measuring register air flow.

Contact Information

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