A Primer on Designing and Installing Heating & AC Systems in ENERGY STAR Certified Homes

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RESNET Conference

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Agenda

- Value of proper heating & AC design and commissioning.
- 3 major steps of heating & AC design:
  - Calculate heating and cooling loads.
  - Select equipment.
  - Design ducts.
- 3 major commissioning tests:
  - Measuring HVAC fan airflow.
  - Checking refrigerant charge.
  - Measuring airflow at registers.

Value of Proper Heating & AC Design and Commissioning

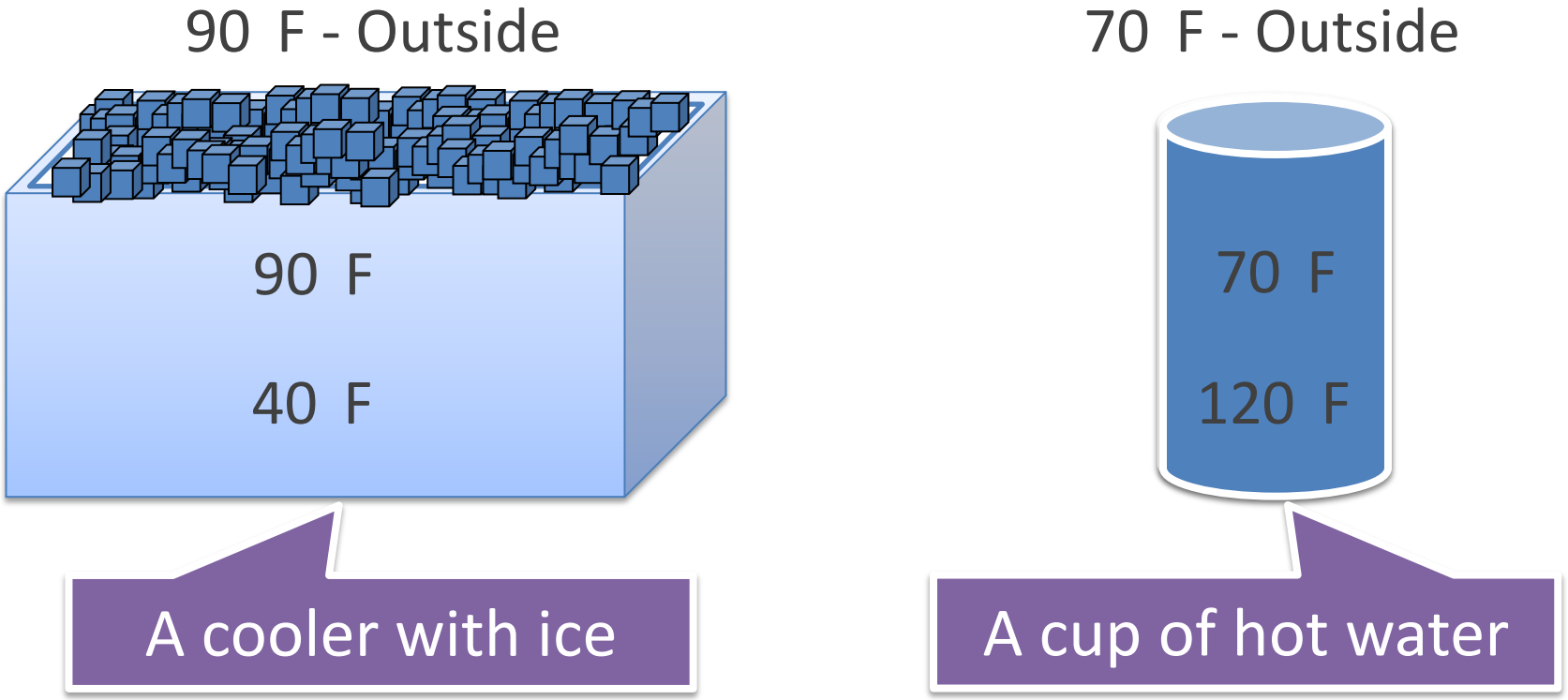
Thermal enclosure system

Thermal Enclosure System

- A well-insulated and air-sealed home, with good windows and doors, reduces the amount of energy needed to keep the home comfortable.

Thermal enclosure system

1. Energy moves from more to less.
2. Over time, differences in temperatures dissipate.



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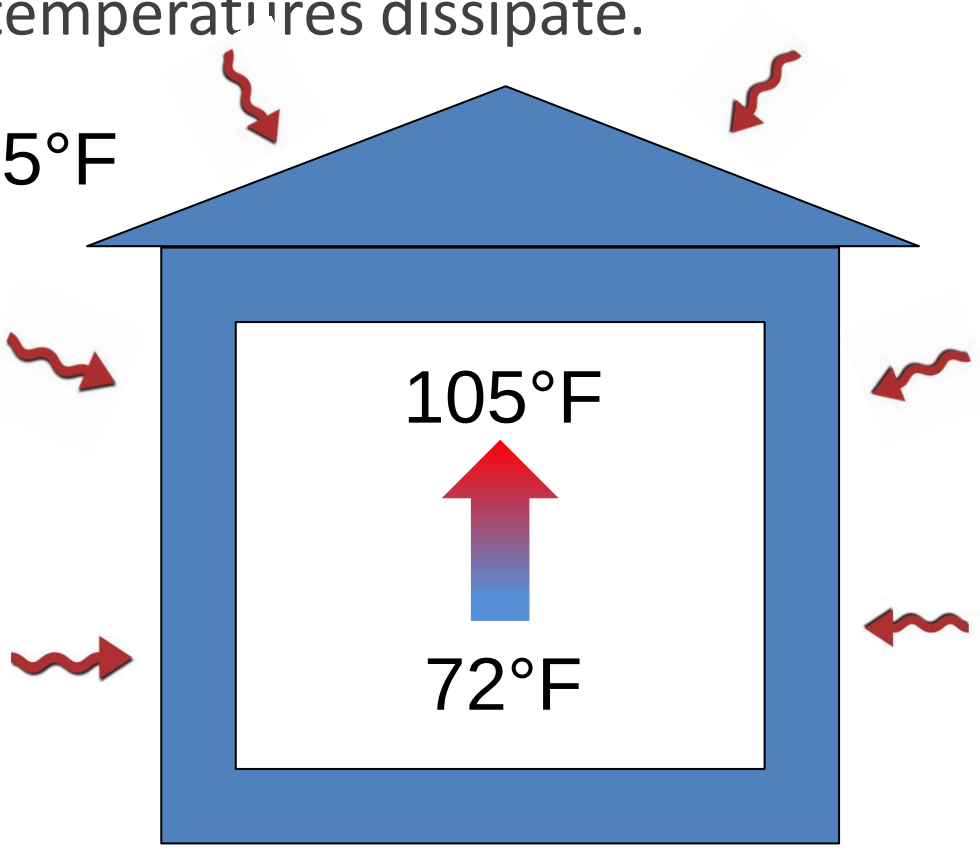
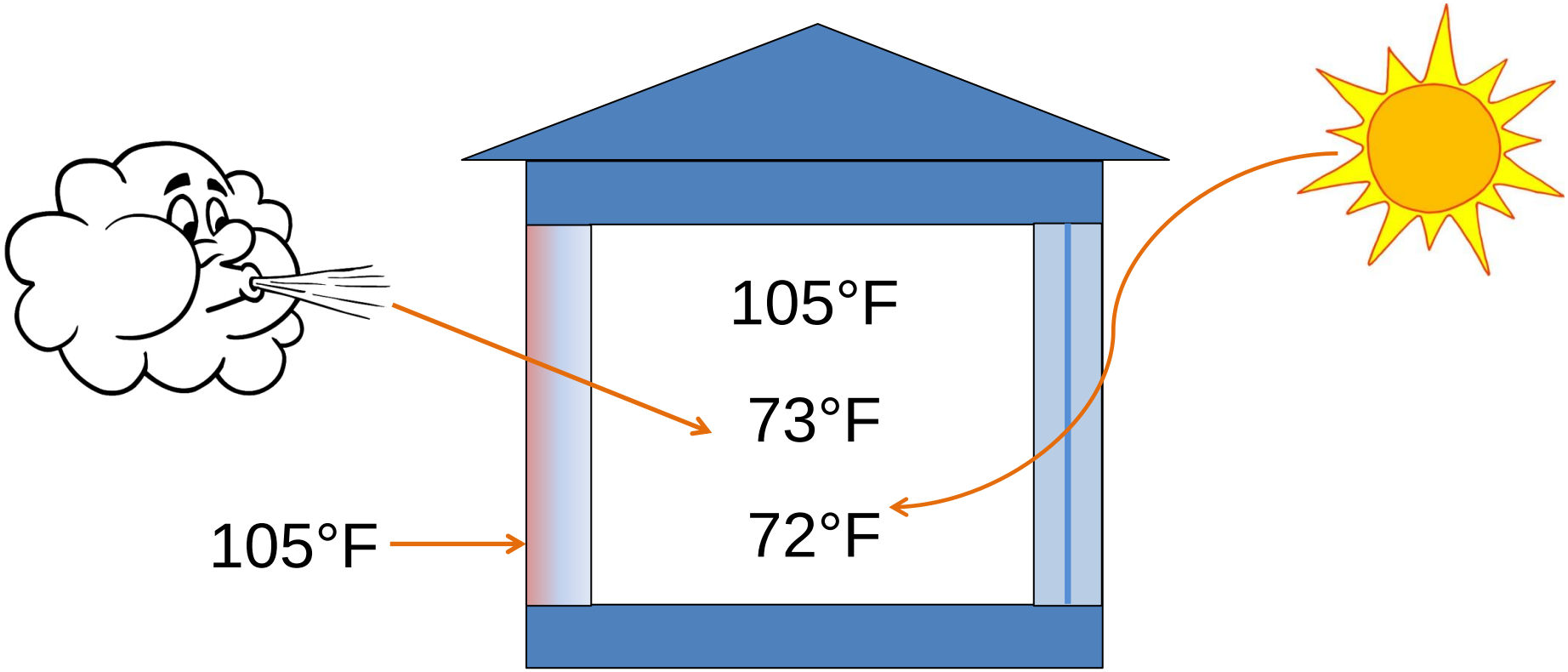


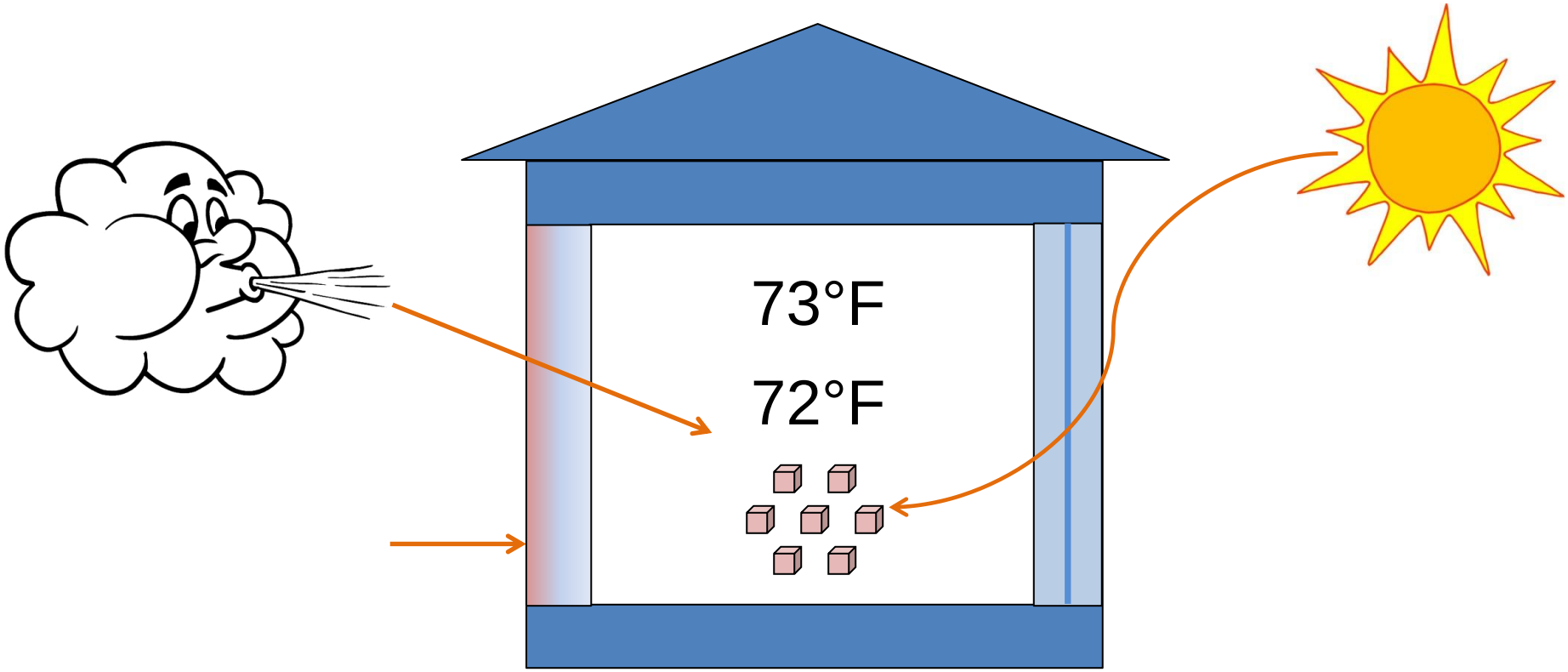
Thermal enclosure system



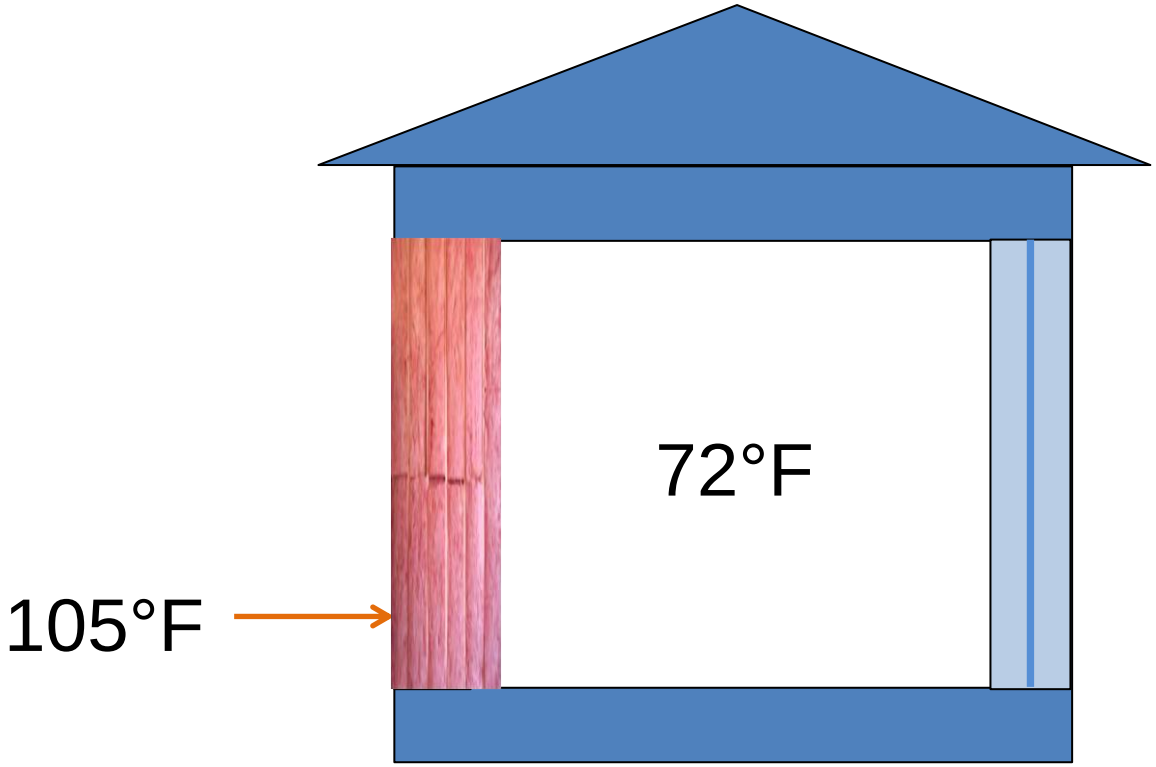
Thermal enclosure system

- Heat transfer can be quantified in British Thermal Units (Btu's).
- 1 Btu is approximately equal to the energy in a single match.

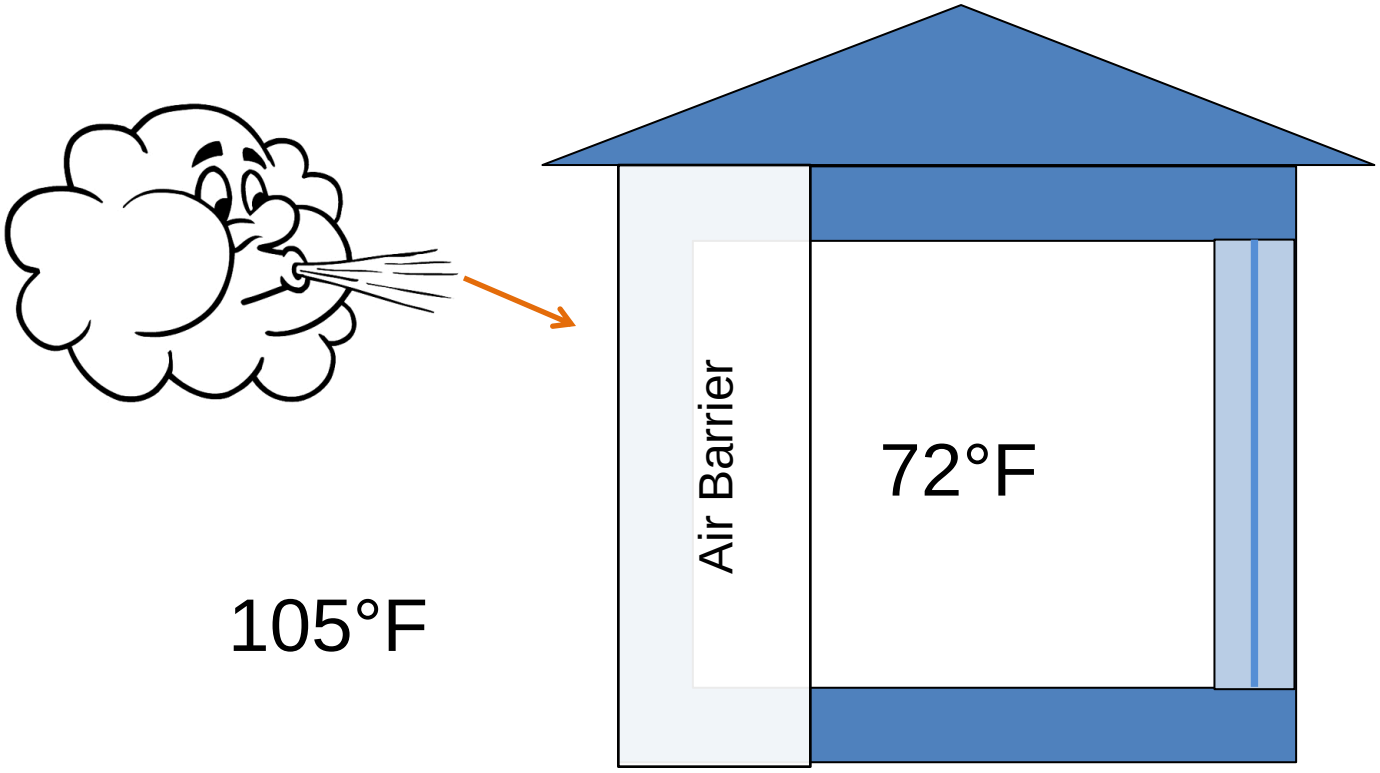
Thermal enclosure system



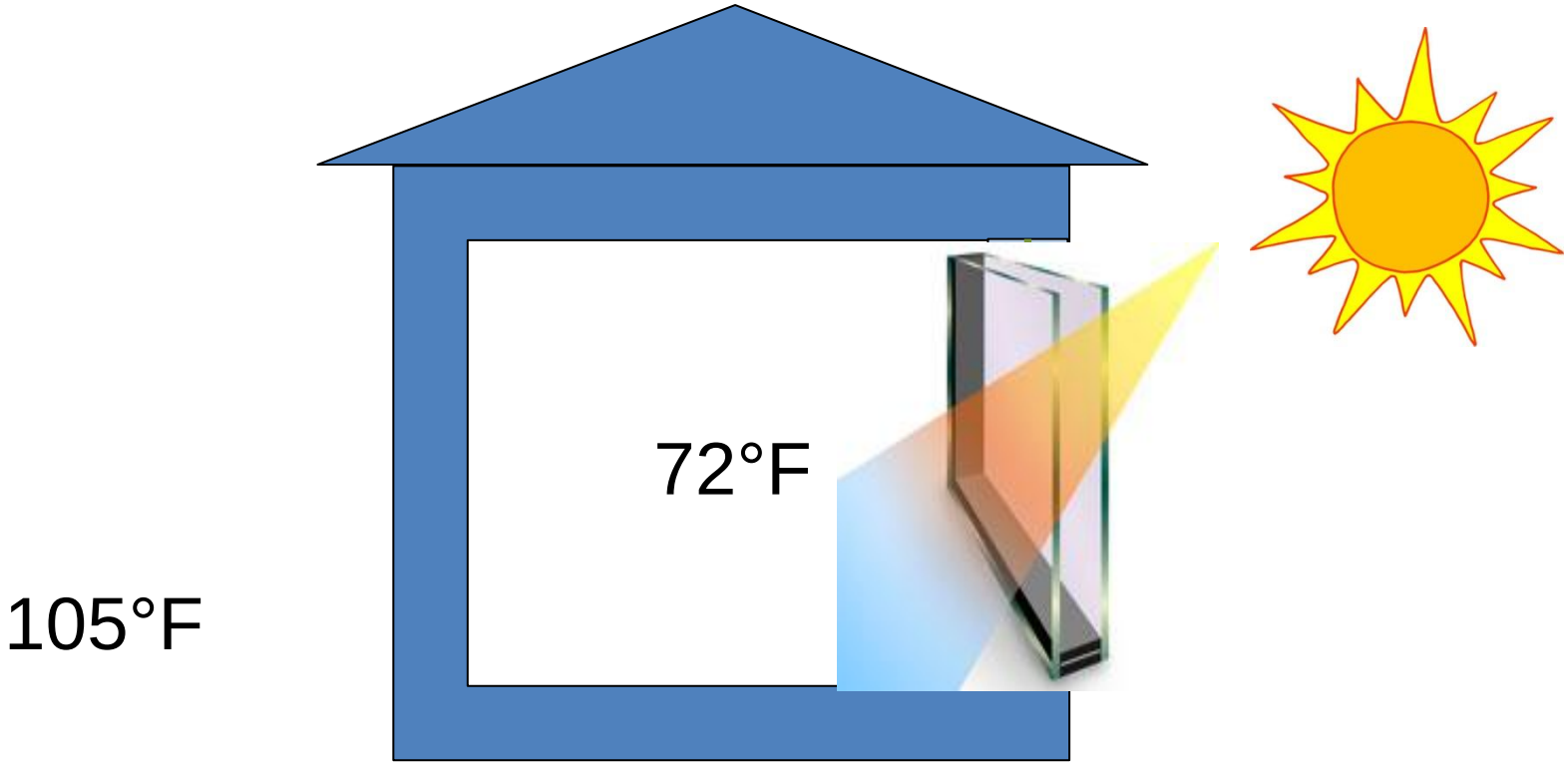
Thermal enclosure system



Thermal enclosure system



Thermal enclosure system



Summary – Thermal enclosure system

- Energy moves from more to less.
- Over time, differences in temperatures dissipate.
- Heat transfer can be quantified in Btu's.
- A complete thermal enclosure system is critical to creating a home that is more comfortable using less energy.

Heating & cooling systems

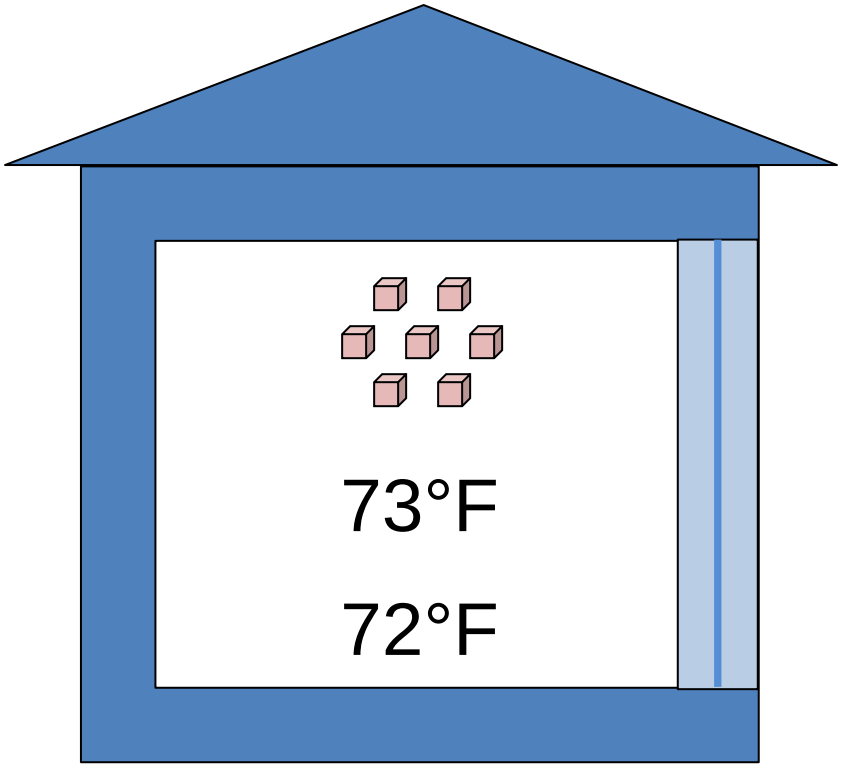
Heating, Cooling, & Ventilation System

- Heating and cooling equipment that is:
  - High efficiency
  - Properly designed and installed
  - Combined with a duct system that's insulated, sealed, and balanced

… maintains comfort with less energy.

Heating & cooling systems

105°F



Three major steps to design an HVAC system

1. Calculate the heating and cooling loads.
2. Select equipment that meets those loads.
3. Design a duct system that gets air from the heating & cooling equipment to the rooms in the house, and then from the rooms back to the equipment.

Step 1:
Calculate Heating & Cooling Loads

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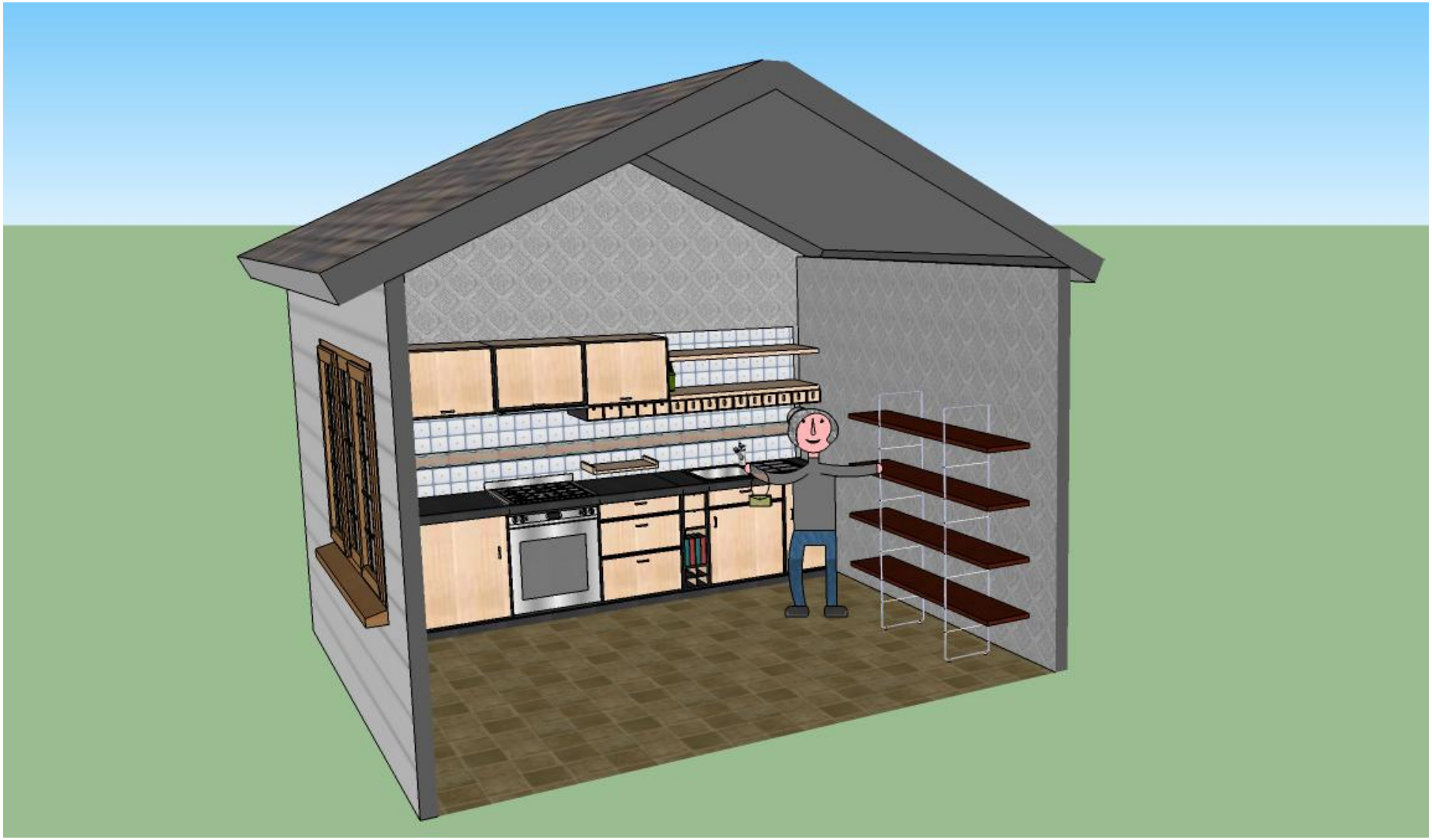
Calculate heating & cooling loads

- Cooling load is the maximum Btu's likely to be added to the home in a single hour during the year.

Step 1:
Calculate heating & cooling loads



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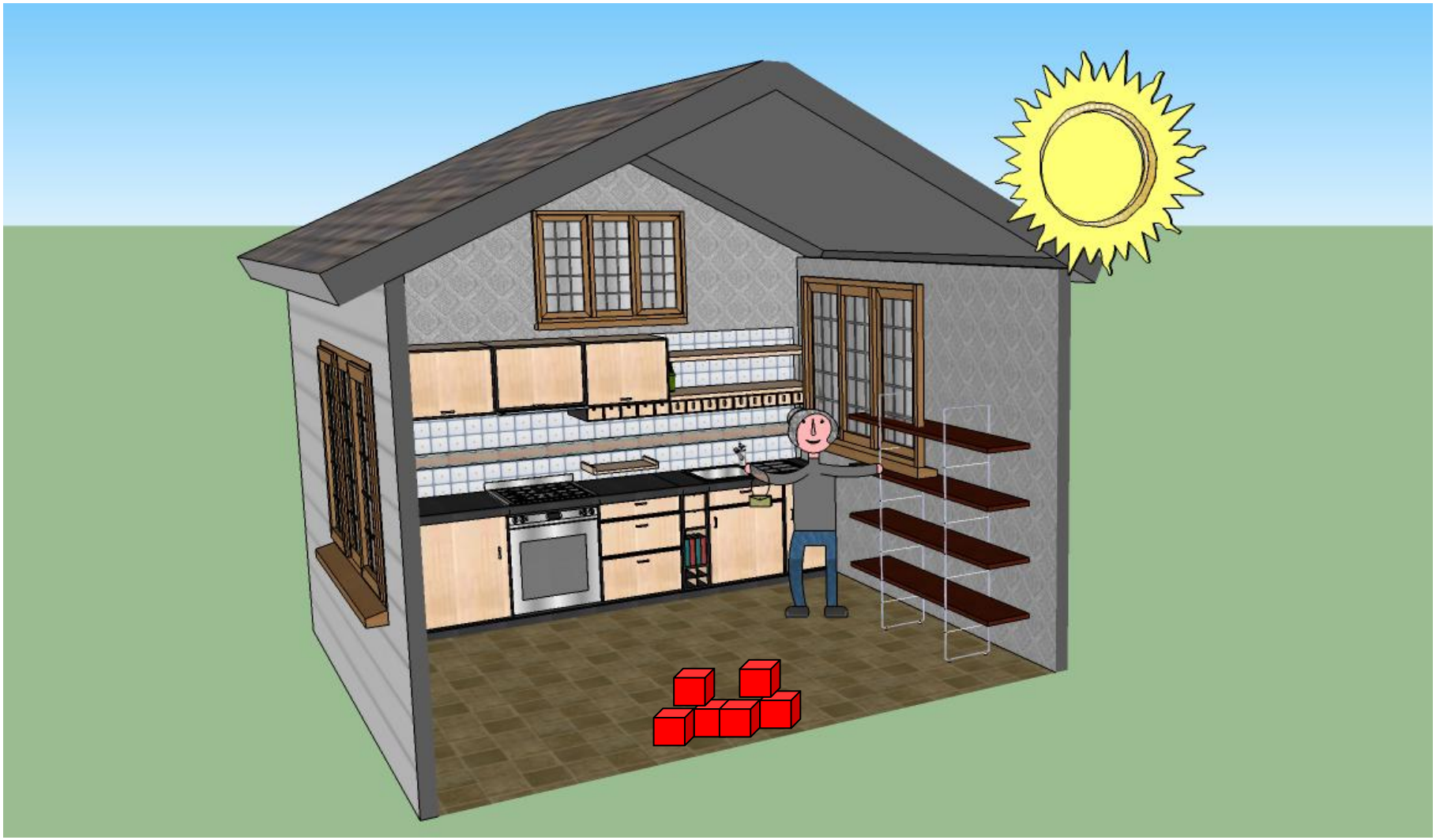

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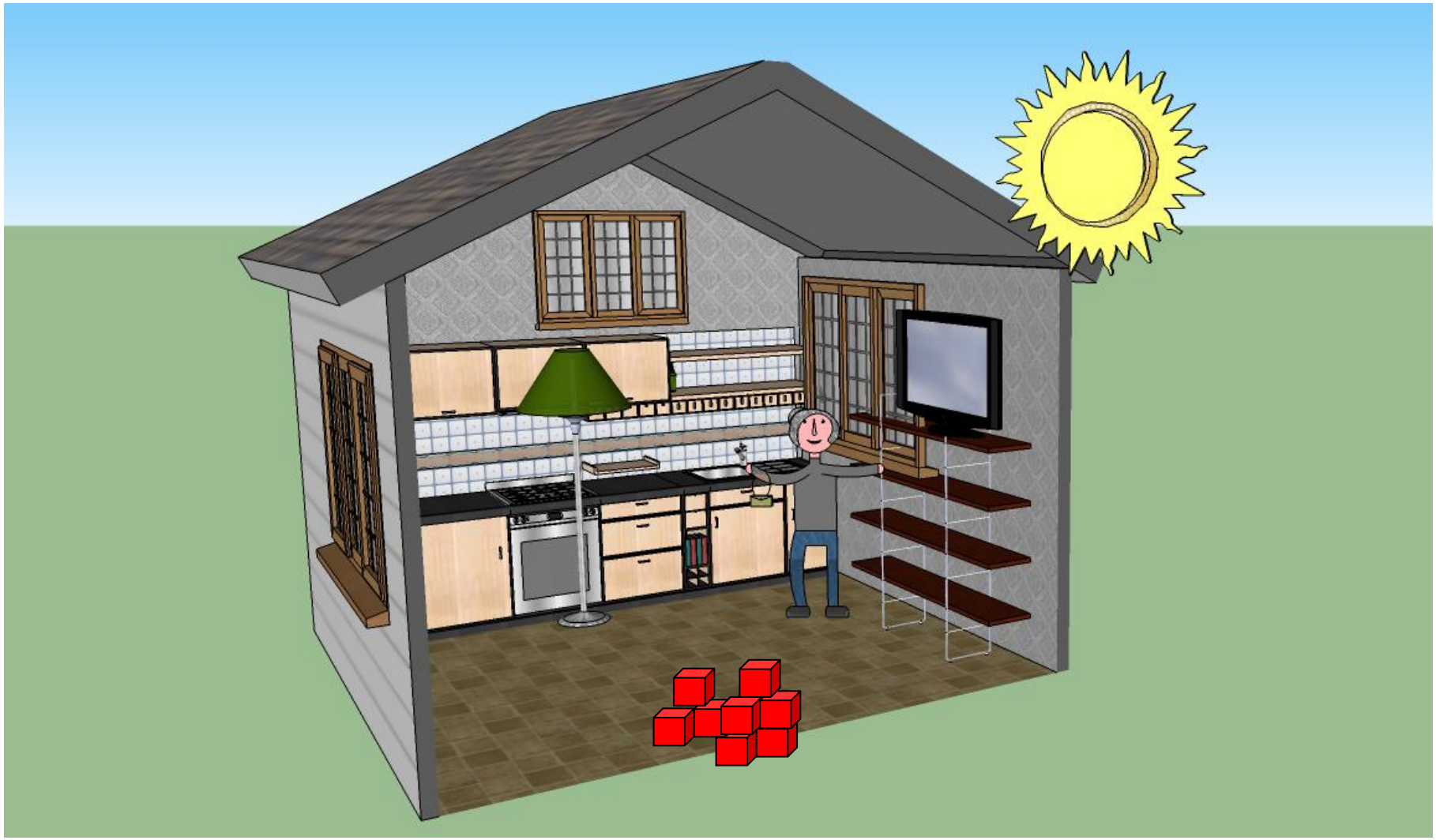
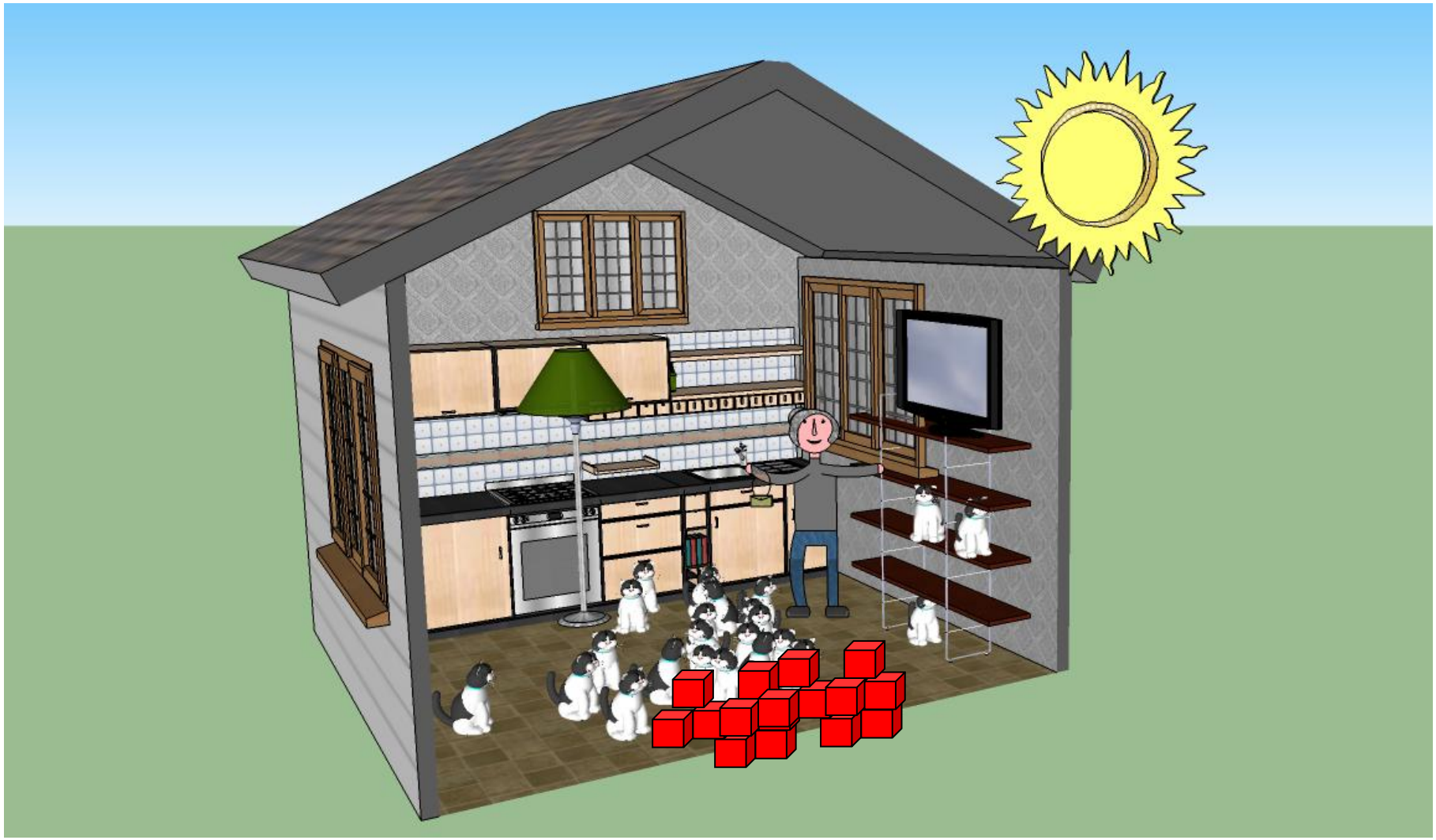
Calculate heating & cooling loads



Step 1:
Calculate heating & cooling loads



Step 1:
Calculate heating & cooling loads

- Heating load is the maximum Btu's likely to be lost from the home in a single hour during the year.

Step 1:
Calculate heating & cooling loads

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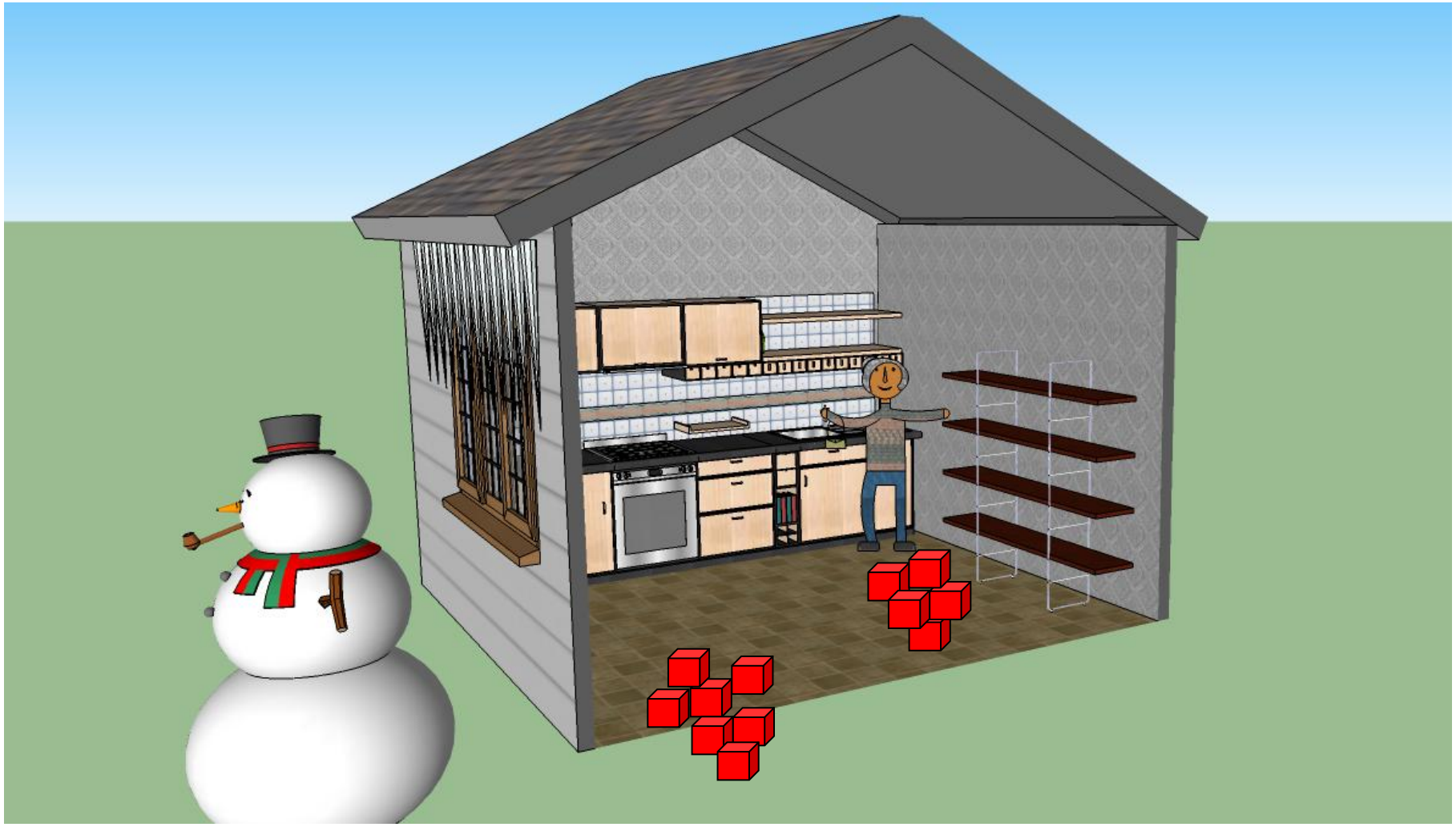
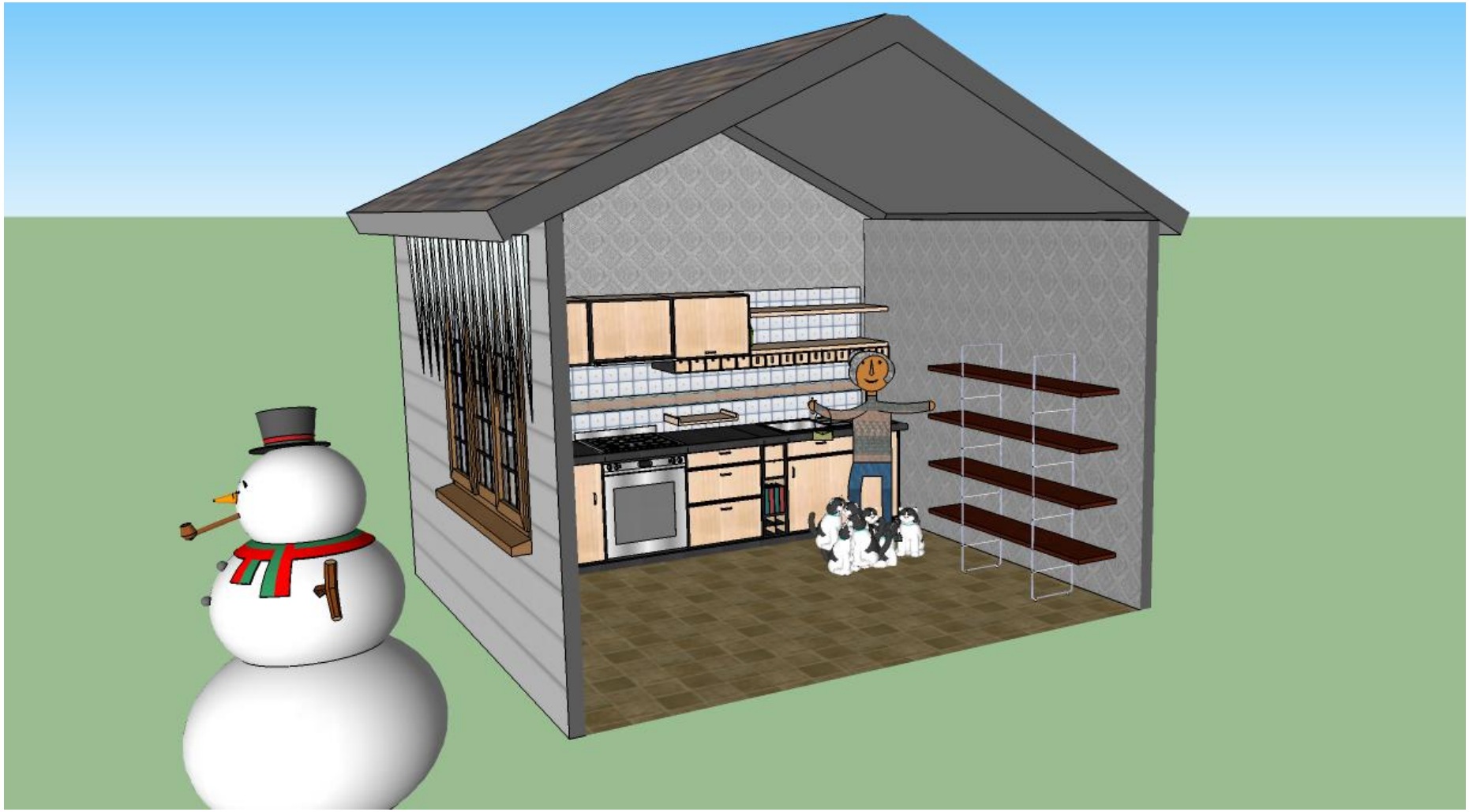
Calculate heating & cooling loads

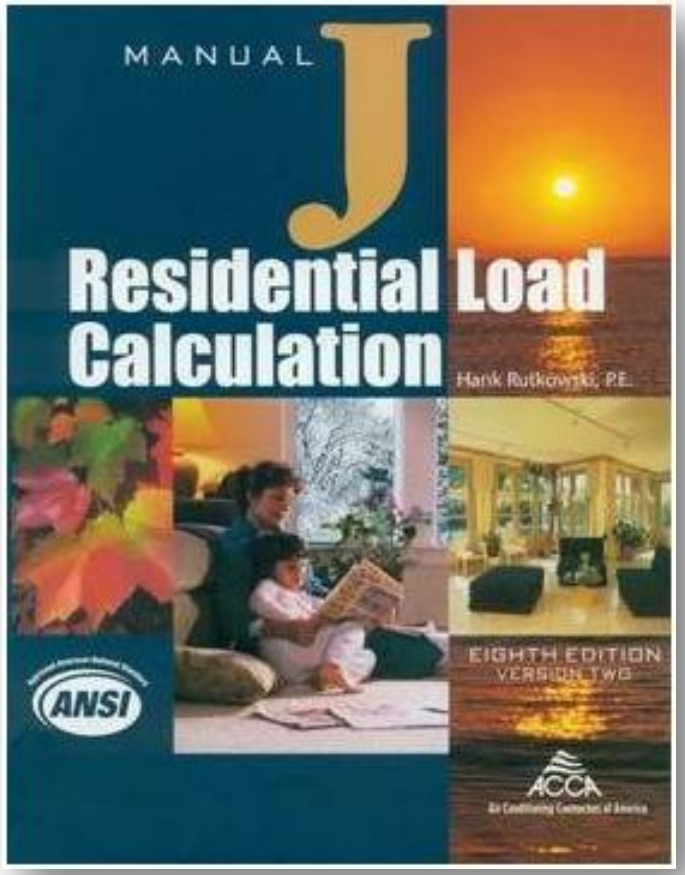


Step 1:
Calculate heating & cooling loads



Step 1:
Calculate heating & cooling loads

- Standard process to calculate loads.
- Defines all parameters that go into load calculations and guidance on what values to use for those parameters.



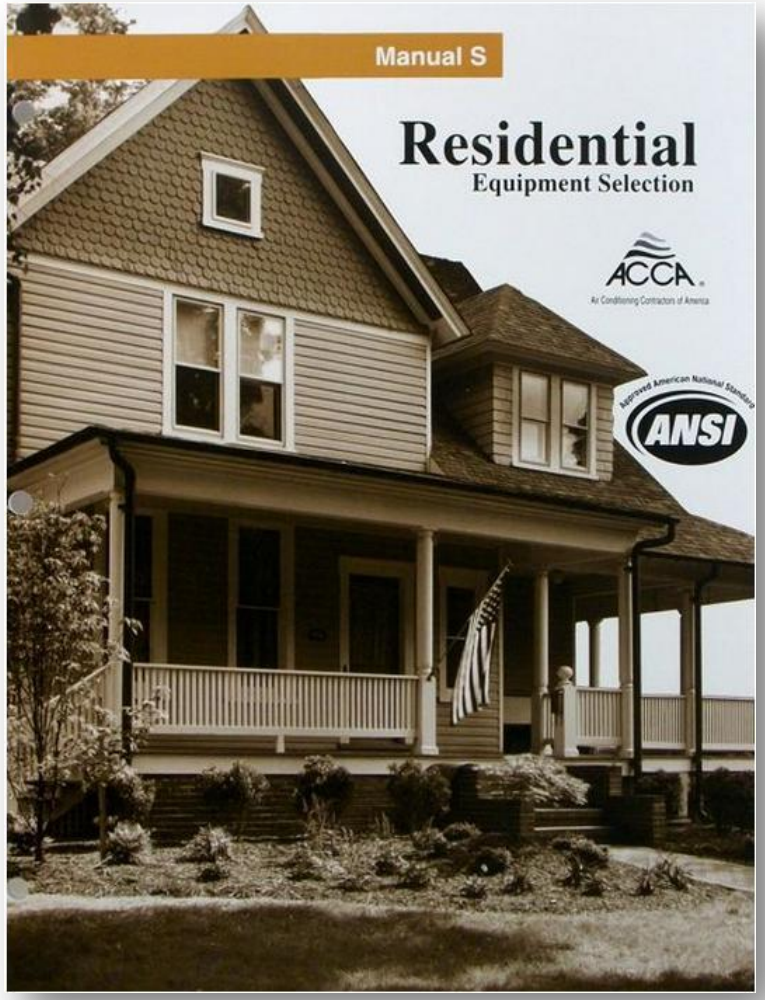
Summary of Step 1: Calculate heating & cooling loads

- The first major step in the design process is to calculate the heating and cooling loads.
- ACCA Manual J provides a reliable standard process for calculating loads.
- By documenting and verifying major design parameters, the ENERGY STAR Certified Homes program helps ensure that the HVAC system has been designed properly.

Step 2:
Select the
Heating & Cooling Equipment

Step 2:
Select equipment that meets loads

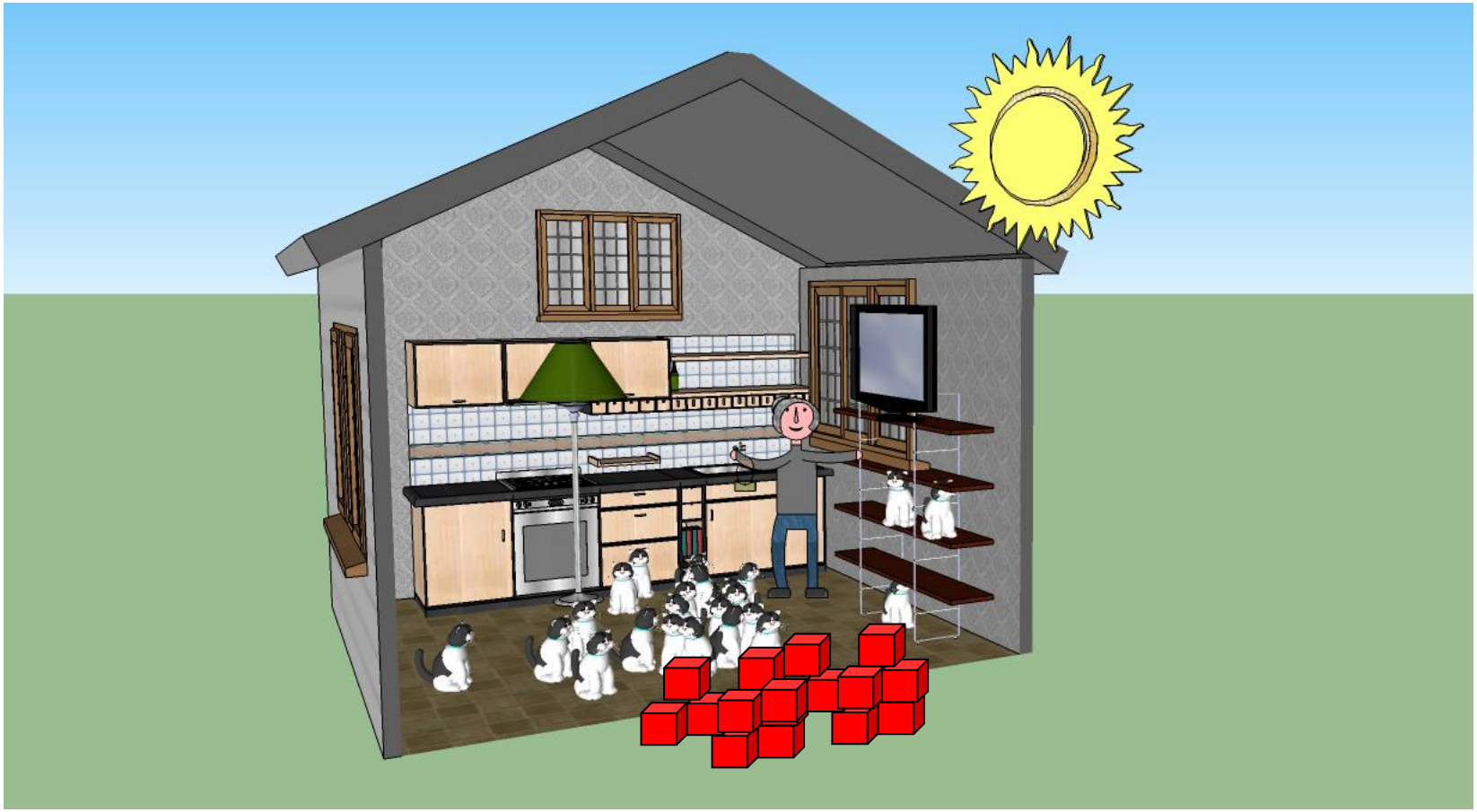
- Standard process to select equipment using the calculated loads.



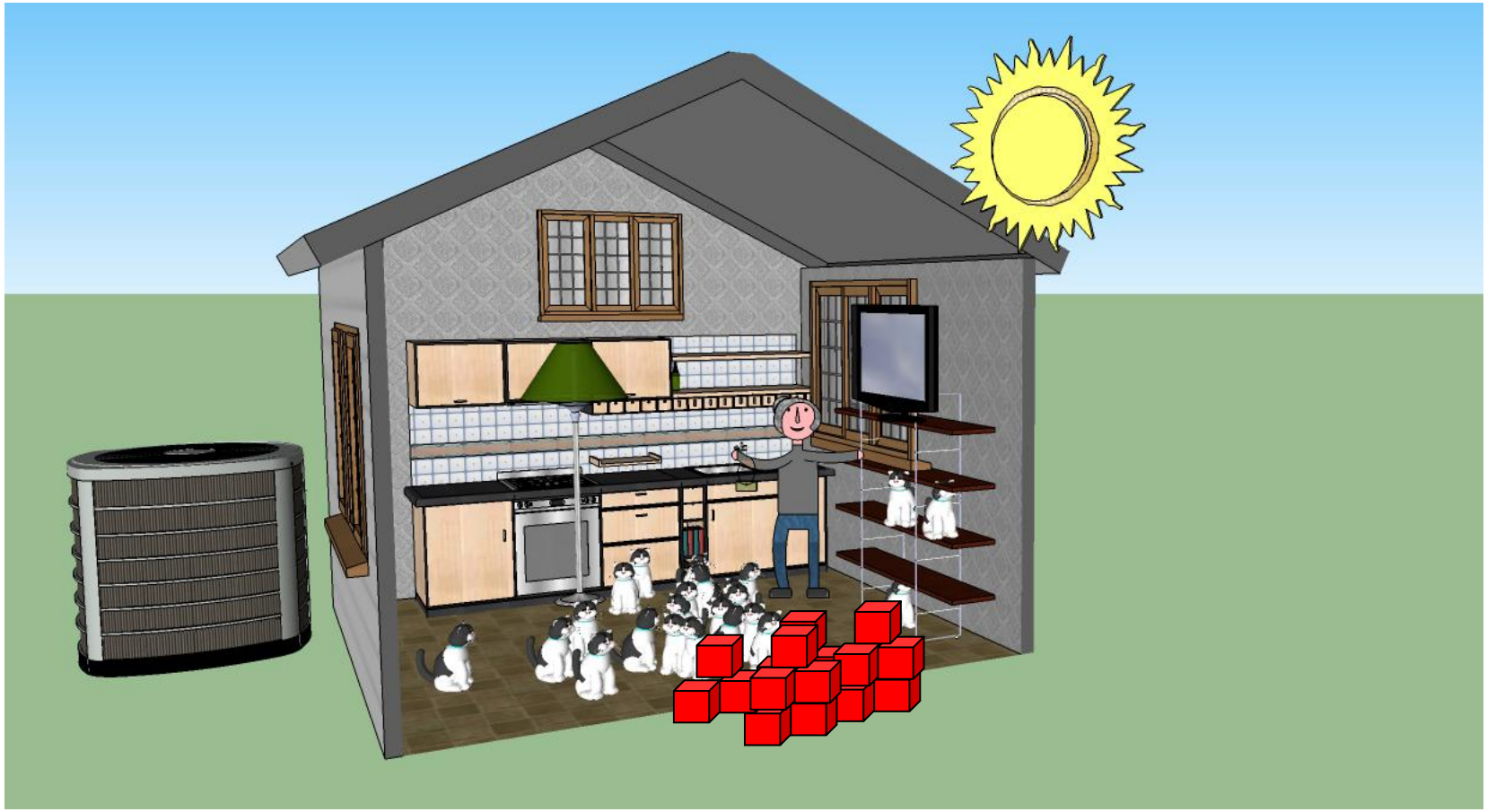
Step 2:
Select equipment that meets loads

- Cooling Load – Btu's per hour added to the home.
- Cooling Capacity – Btu's per hour that equipment can remove from the home.

Step 2:
Select equipment that meets loads



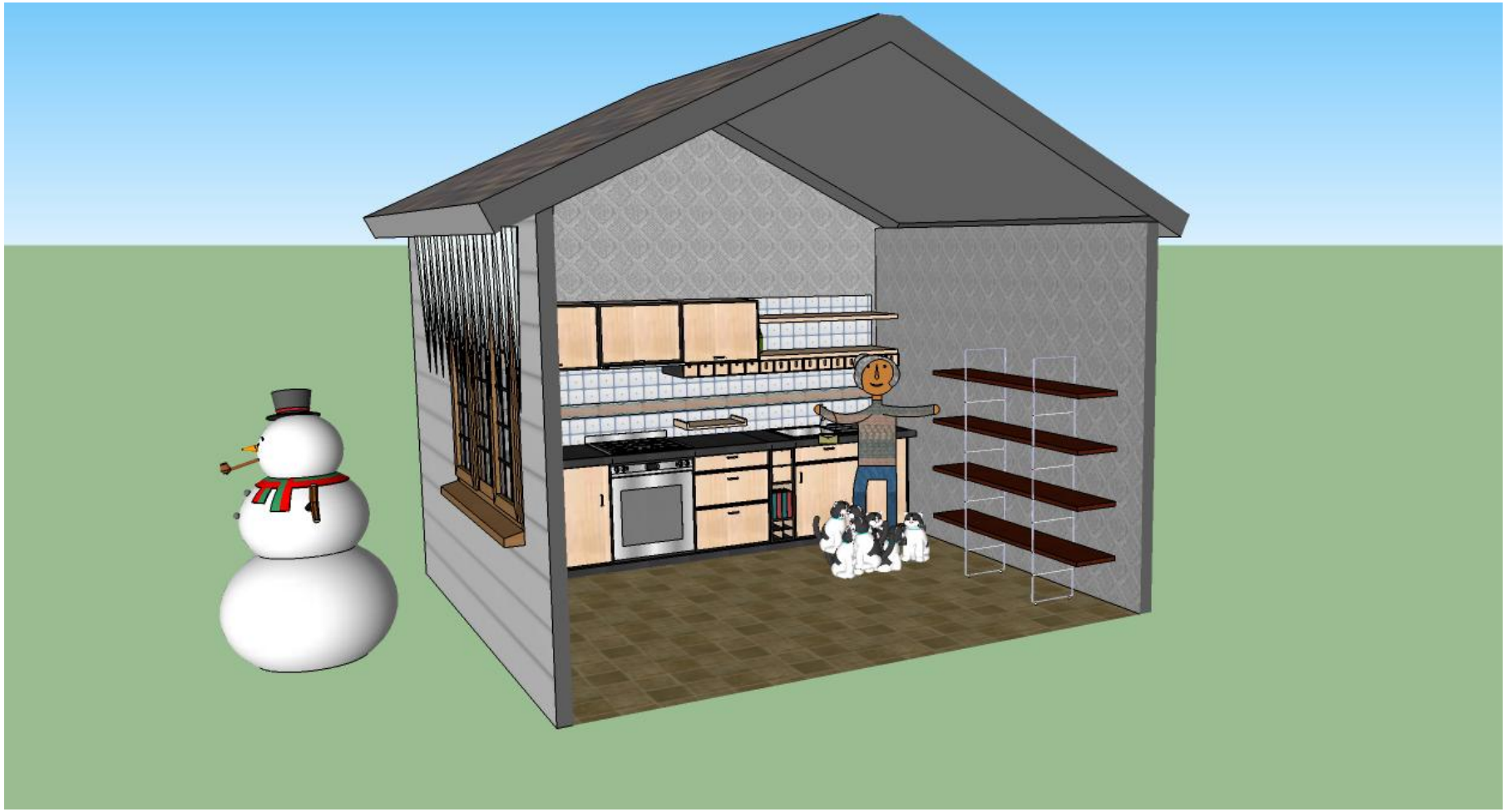
Step 2:
Select equipment that meets loads



Step 2:
Select equipment that meets loads

- Heating Load – Btu's per hour lost from the home.
- Heating Capacity – Btu's per hour that equipment can add to the home.

Step 2:
Select equipment that meets loads



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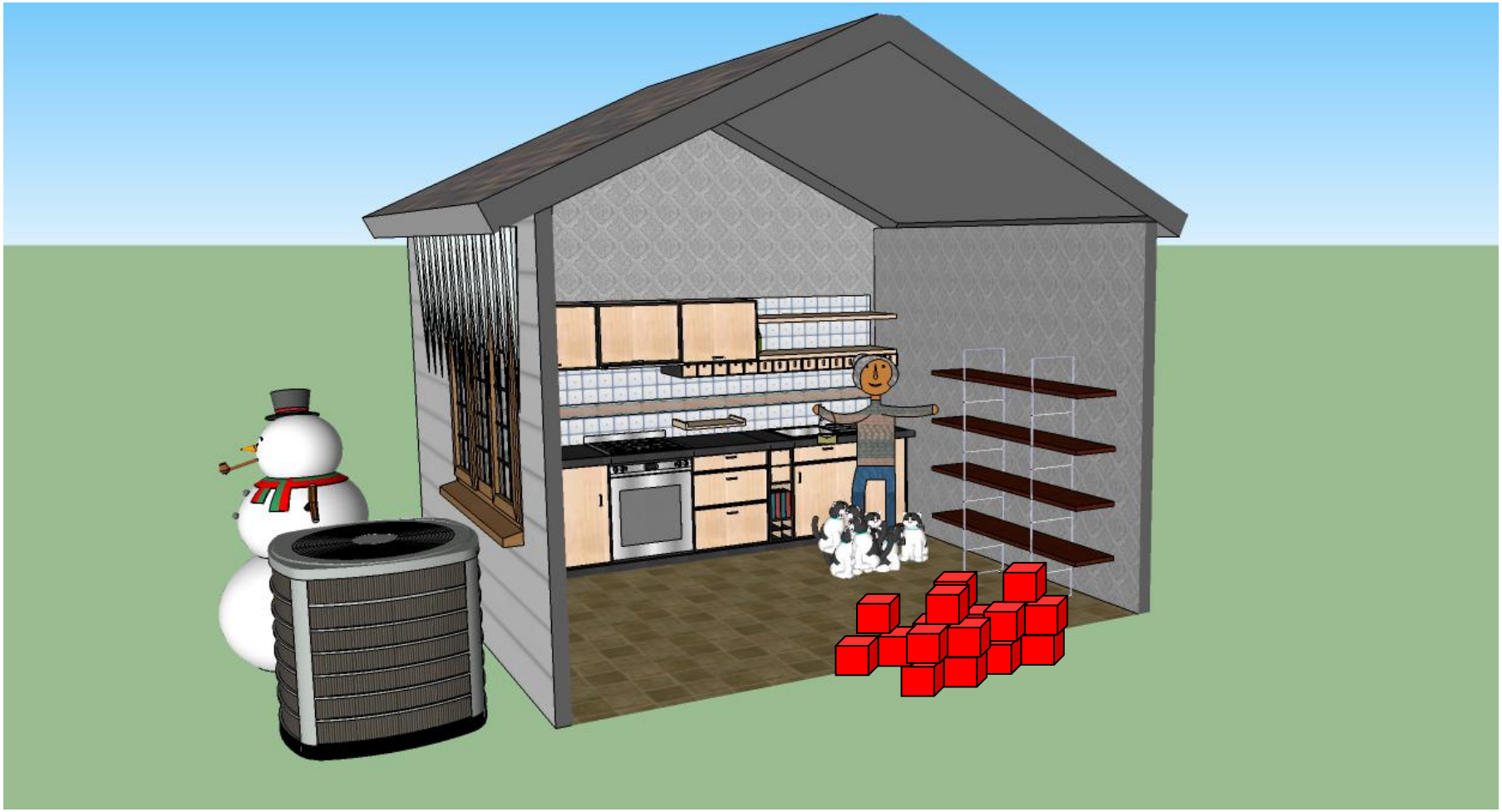

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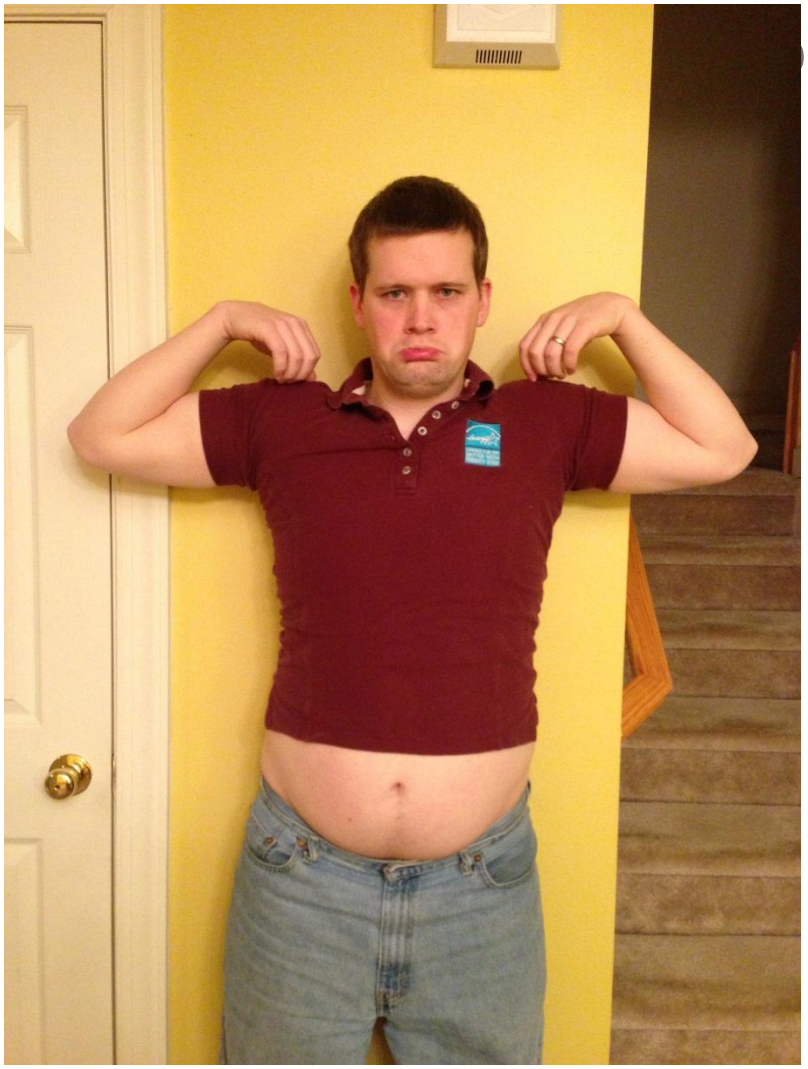


Step 2:
Select equipment that meets loads

Equipment capacity can be determined using manufacturer's expanded performance data…

O.D. D.B.	I.D. W.B.	TOT. CAP.	SENS. CAP. AT ENTERING D.B. TEMP. 72	75	78	80	TOTAL KW
	59	25.3	16.5	19.9	23.2	25.3	2.16
85	63	26.3	15.2	18.2	21.3	23.2	2.17
	67	28.4	13.1	15.7	18.3	20.0	2.21
	71	30.6	10.8	13.0	15.2	16.6	2.23
	59	24.0	16.2	19.5	22.7	24.0	2.34
95	63	25.0	14.9	17.9	20.9	22.8	2.35
	67	27.0	12.8	15.4	18.0	19.7	2.39
	71	29.1	10.6	12.8	14.9	16.3	2.41
	59	22.7	15.8	19.0	22.2	22.7	2.51
105	63	23.7	14.5	17.5	20.4	22.3	2.53
	67	25.5	12.5	15.1	17.6	19.2	2.57
	71	27.6	10.4	12.5	14.6	15.9	2.59
	59	21.5	15.4	18.5	21.5	21.5	2.69
115	63	22.4	14.1	17.0	19.8	21.7	2.71
	67	24.1	12.2	14.7	17.1	18.7	2.75
	71	26.0	10.1	12.2	14.2	15.5	2.78

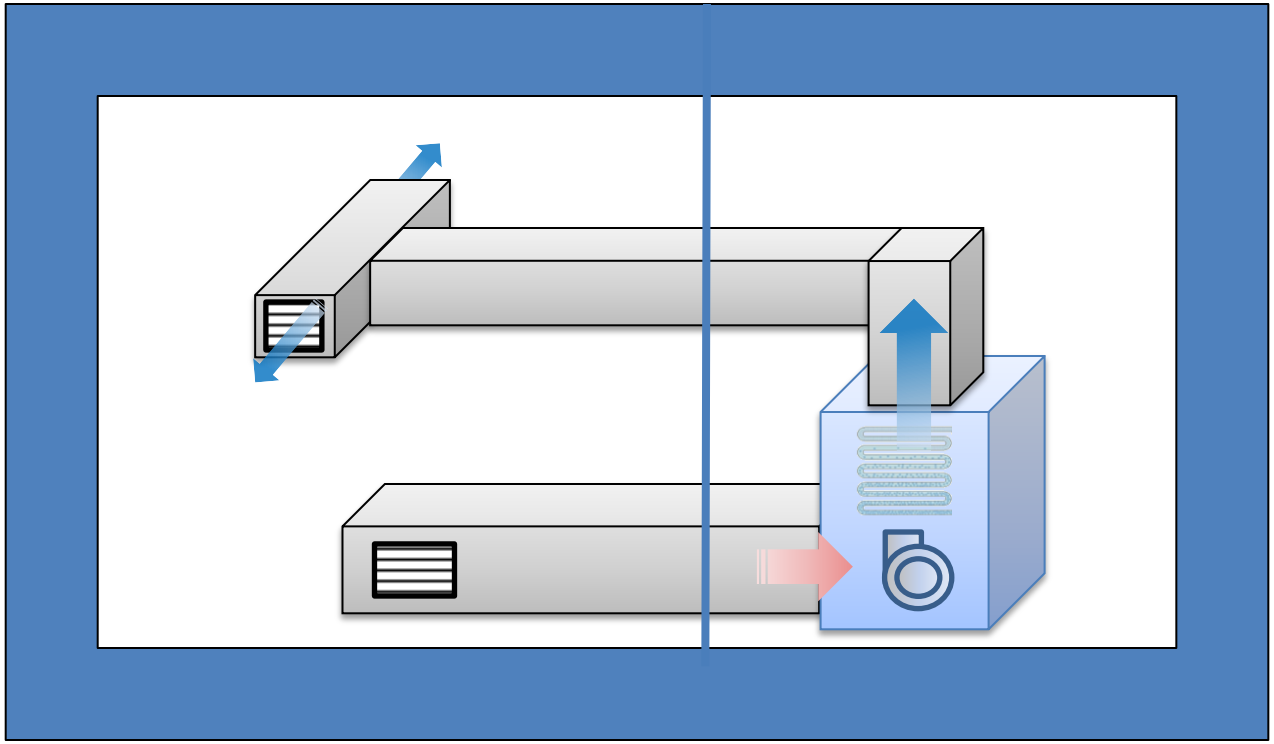
Summary of Step 2: Select equipment that meets loads

- The second major step in the design process is to select equipment using the calculated heating & cooling loads.
- ACCA Manual S provides a reliable standard process for doing this and includes limitations on over-sizing.
- By requiring that equipment be selected using this process, the ENERGY STAR Certified Homes program helps ensure that the HVAC system is efficient, durable, and effective.

Step 3:
Design the Duct System

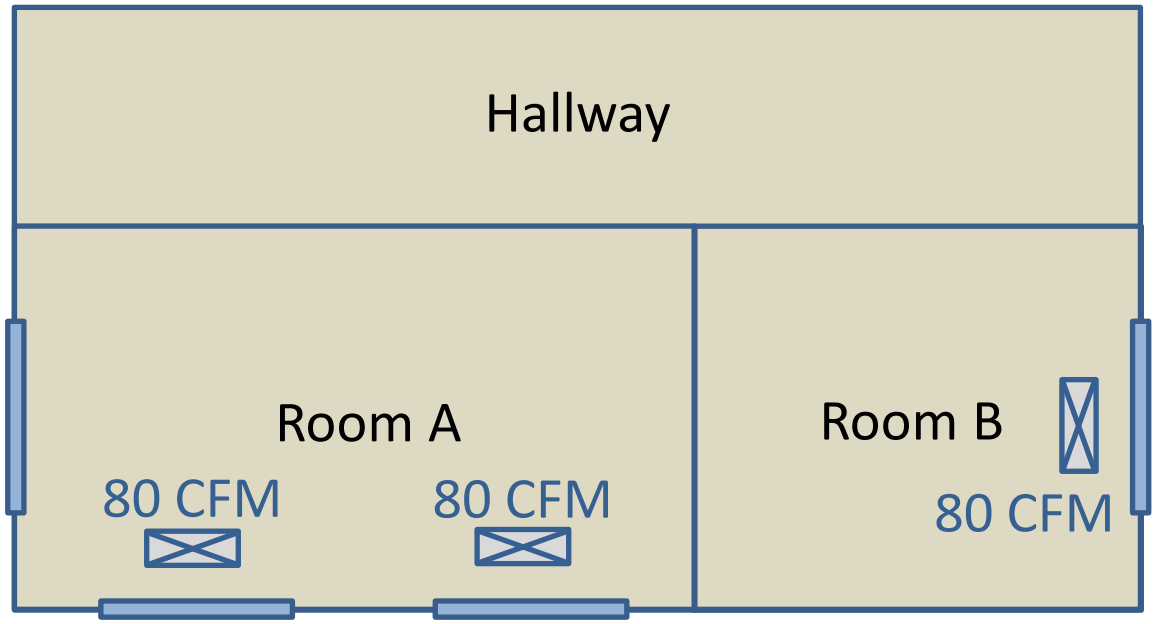
Step 3:
Design the duct system

- Design a duct system that distributes air from the heating & cooling equipment to each room, and back to the equipment.



Step 3:
Design the duct system

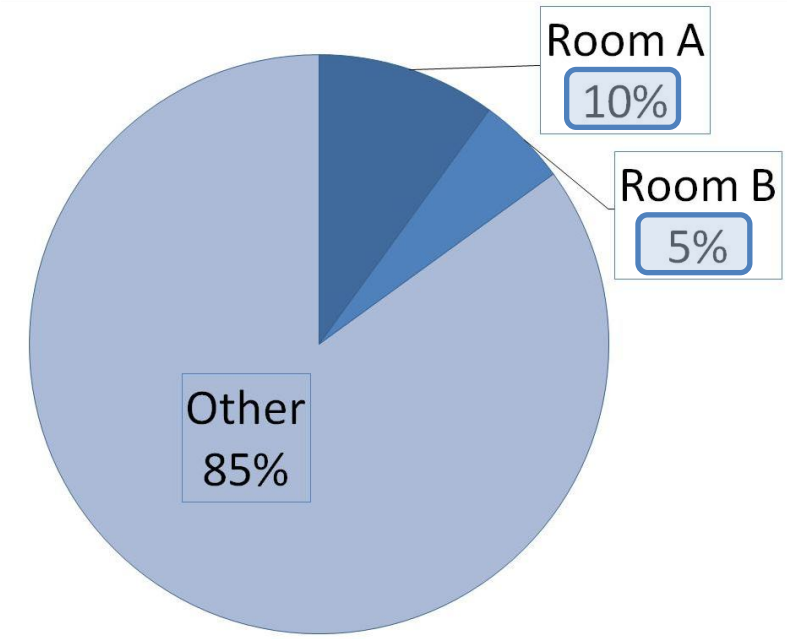
- The airflow needed by each room is directly related to its heating and cooling load.



Step 3:
Design the duct system

- The airflow needed by each room is directly related to its heating and cooling load.

Load Distribution

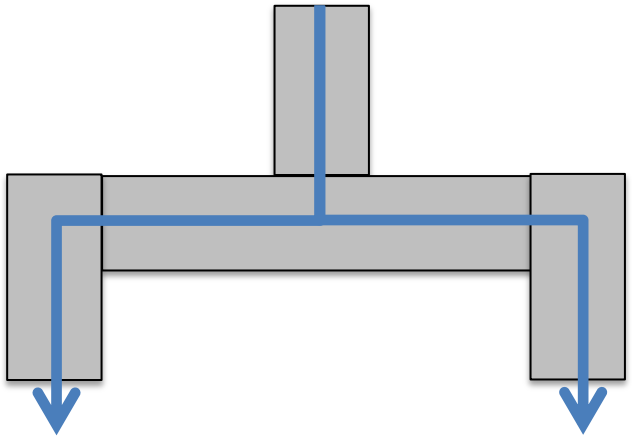


Airflow Distribution

Location	% Airflow	Airflow (CFM)
Room A	10%	160
Room B	5%	80
Other	85%	1,360
Total Equipment Airflow	100%	1,600

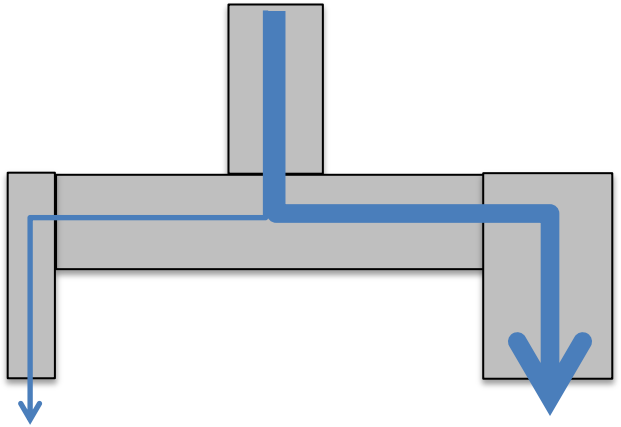
Step 3:
Design the duct system

1. Air follows the path of least resistance.



Room A Room B

Equal resistance, equal flow

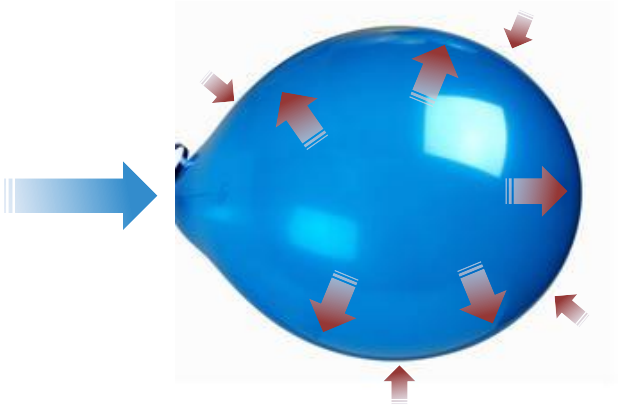


Room A Room B

Higher resistance, less flow

Step 3:
Design the duct system

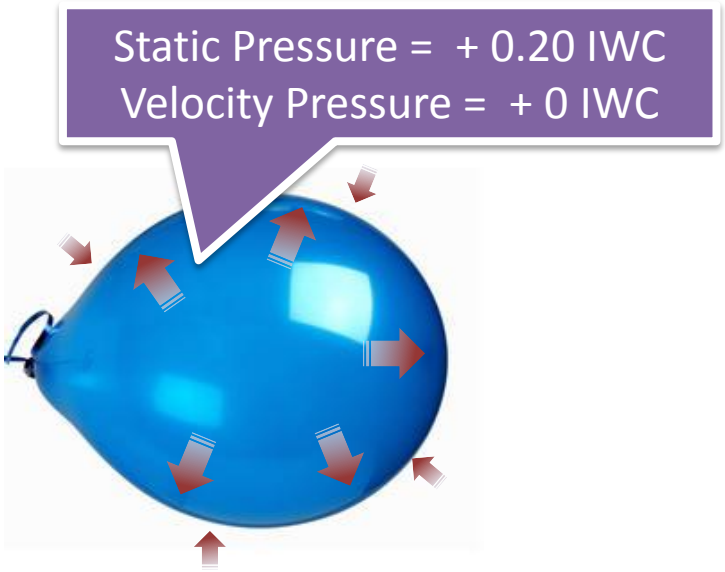
A fan uses energy to push air



Like we use energy to push air into a balloon

Step 3:
Design the duct system

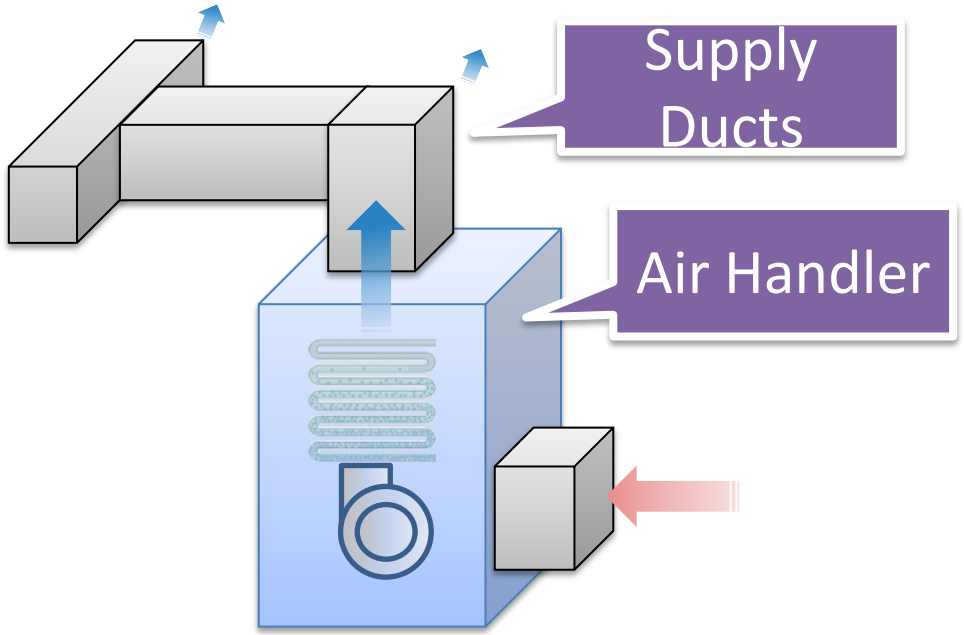
- Example: Inflating balloon



The pressure inside the inflated balloon is the Static Pressure

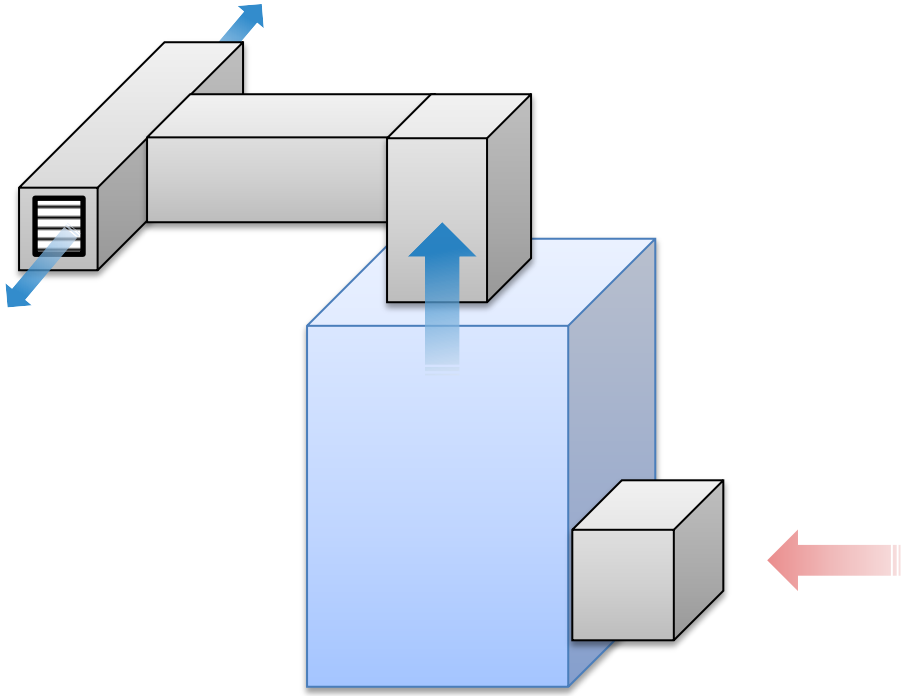
Step 3:
Design the duct system

- Example: Duct system without registers and sealed tightly.



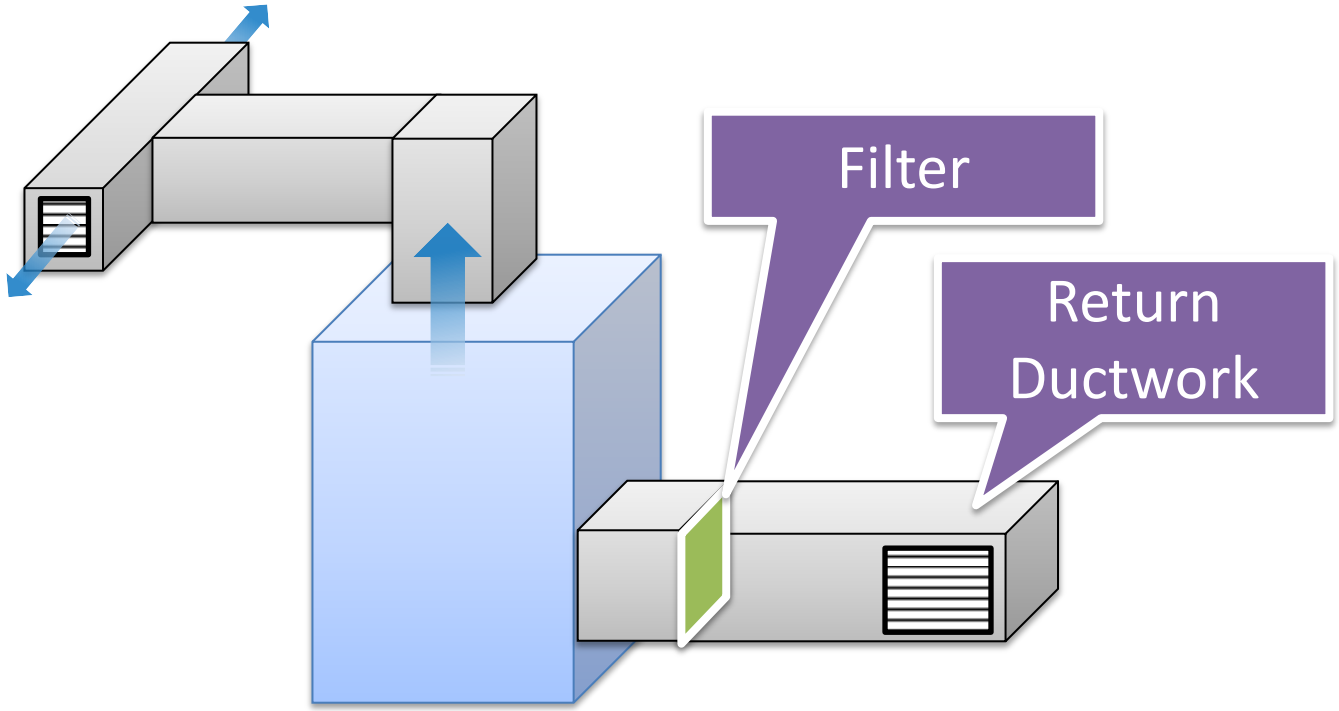
Step 3:
Design the duct system

- Example: Supply duct with registers



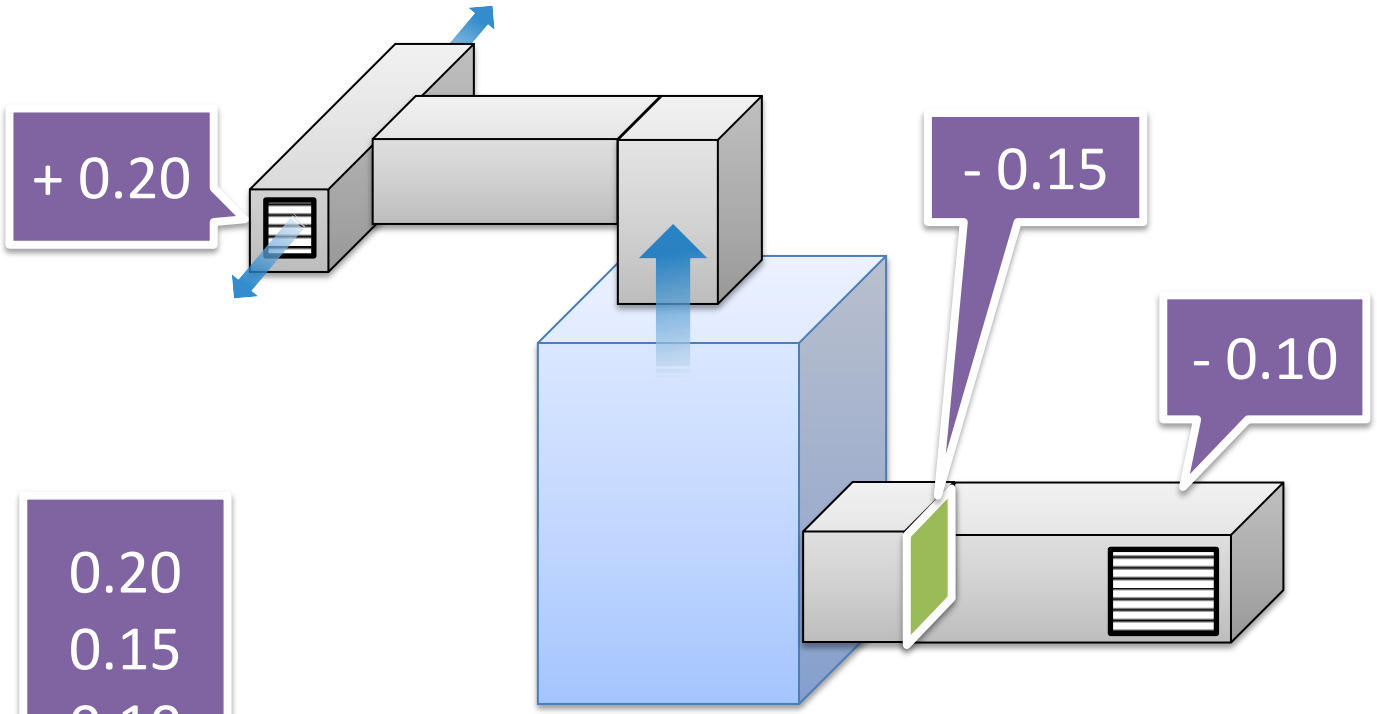
Step 3:
Design the duct system

- Example: Return side ducts and filters add additional static pressure to the system.



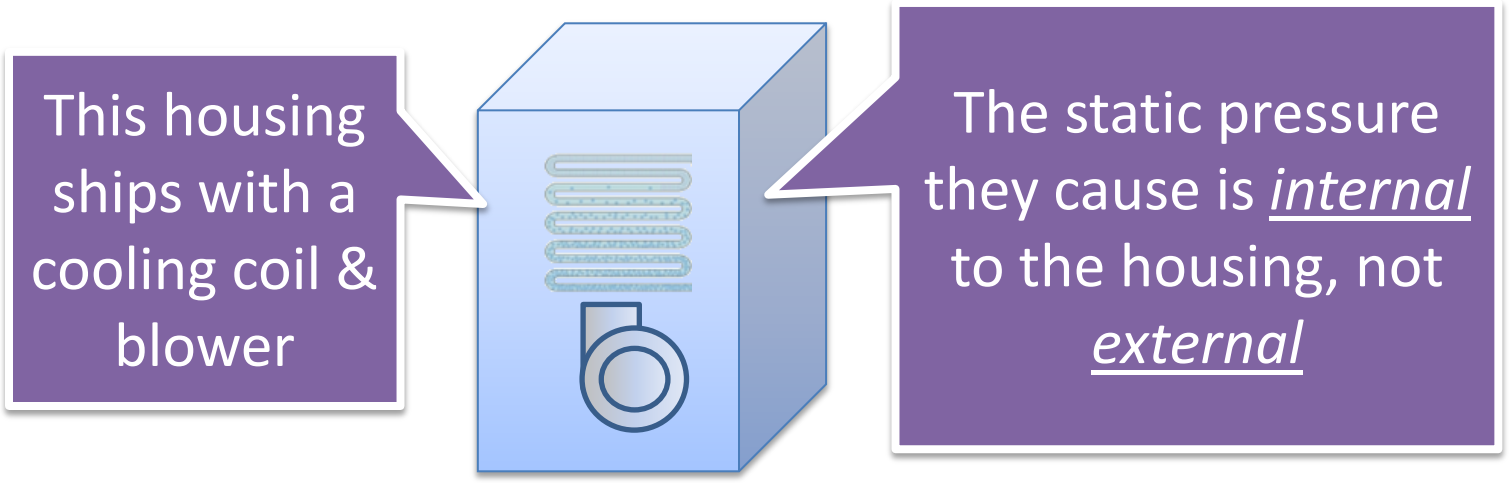
Step 3:
Design the duct system

- The total static pressure of the duct system includes both the supply and return side.



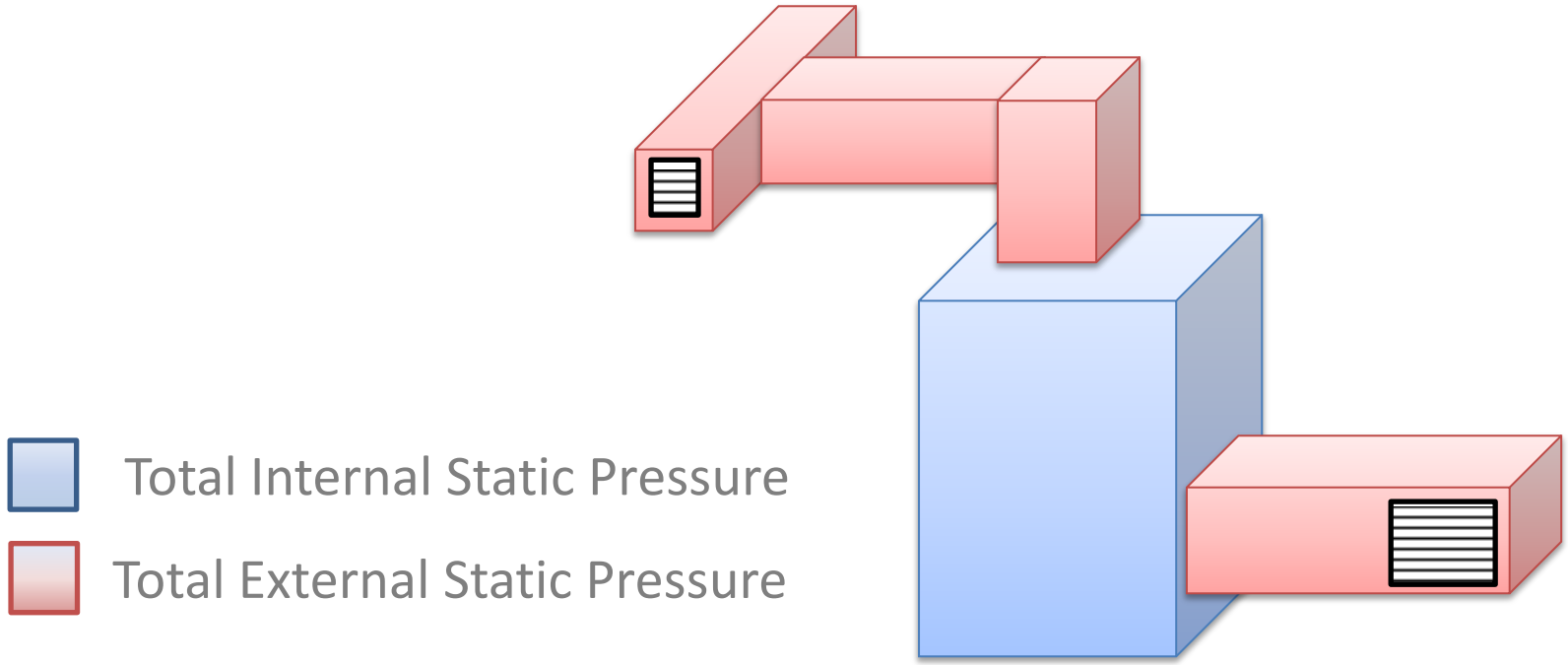
Step 3:
Design the duct system

- Manufacturers have already taken into account the static pressure caused by the components inside the housing.



Step 3:
Design the duct system

- Tables are provided by manufacturers that note airflows at various total external static pressures.



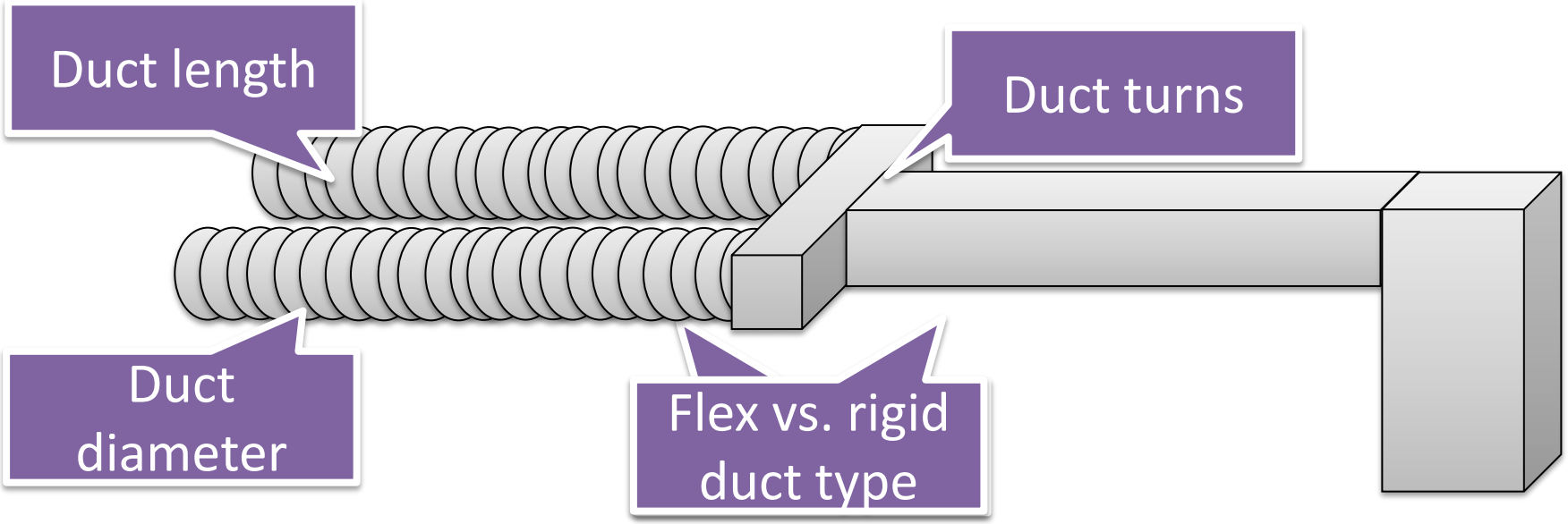
Step 3:
Design the duct system

- This table can be used to determine what total external static pressure to design the ducts to in order to produce the design airflow.

Nominal Cooling Capacity Tons	Manufacturer Recommended Air-Flow Range (Min/Max) CFM	Blower Size / Motor HP / # of Speeds	Motor Speed From Factory	Motor Speed		Model ABC Wet Coil With Filter & Heaters						
						External Static Pressure (IWC)						
						0.1	0.2	0.3	0.4	0.5	0.6	0.7
1.5	827 / 474 CFM	10x6 1/3 HP 2 Speed Dual Voltage	5	3	CFM	827	804	779	740	708	659	608
			5	2	CFM	599	578	544	509	474	-	-
2.0	977 / 708 CFM	10x6 1/3 HP 2 Speed Dual Voltage	5	5	CFM	977	930	898	850	801	746	687
			5	4	CFM	811	785	759	726	708	-	-

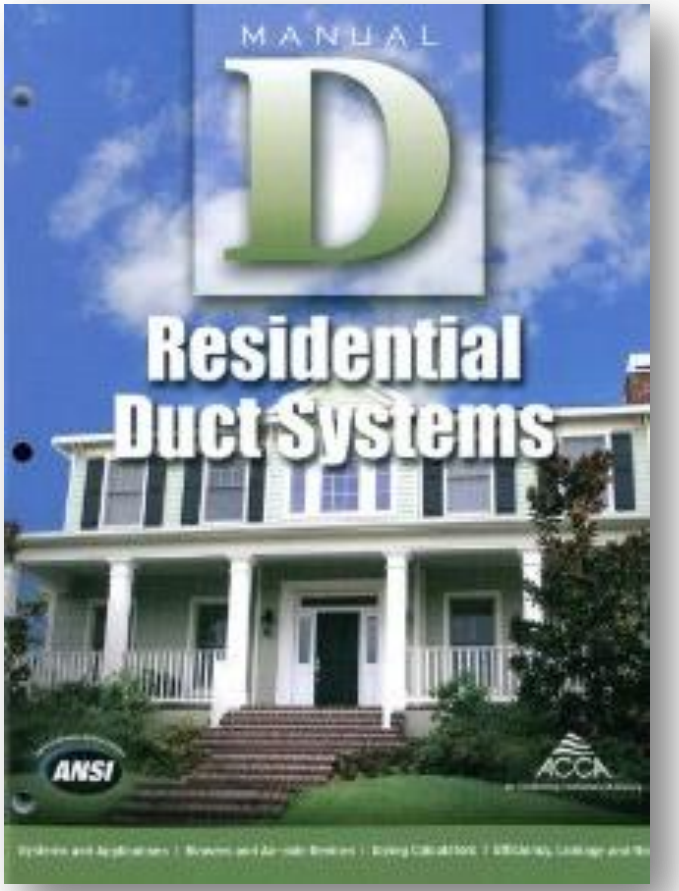
Step 3:
Design the duct system

- Factors that influence the static pressure of the ducts:
  - Duct length
  - Duct diameter
  - Duct type
  - Duct turns
  - Other components, like filters



Step 3:
Design the duct system

- Standard process to design duct system for the loads that were calculated and the equipment that was selected.



Summary of Step 3: Design the duct system

- The third major step in the design process is to design a duct system that works with the selected equipment.
- The amount of airflow through each duct run is determined by the resistance, or static pressure, of that duct run.
- ACCA Manual D provides a standard process for doing this. It ensures that the static pressure of the duct system and the air velocity are not too high.
- These requirements in the ENERGY STAR Certified Homes program help ensure that the home is efficient, quiet, and comfortable.

Heating & cooling design summary

- A complete thermal enclosure system is critical to creating a home that is more comfortable using less energy.
- The HVAC design process has three major steps:
  - Step 1 is to calculate the heating and cooling loads.
  - Step 2 is to select equipment with a capacity that can meet those loads.
  - Step 3 is to design a duct system that can get that heated & cooled air from the equipment to the rooms and back.
- The ENERGY STAR Certified Homes program requires this important design process to help maintain the efficiency, comfort, and quality of every certified home.

Heating & Cooling Commissioning

Heating & Cooling Commissioning Tests

- Measuring air handler airflow
- Checking refrigerant charge
- Measuring airflow at registers

Measuring
Air Handler Airflow

Measuring air handler airflow

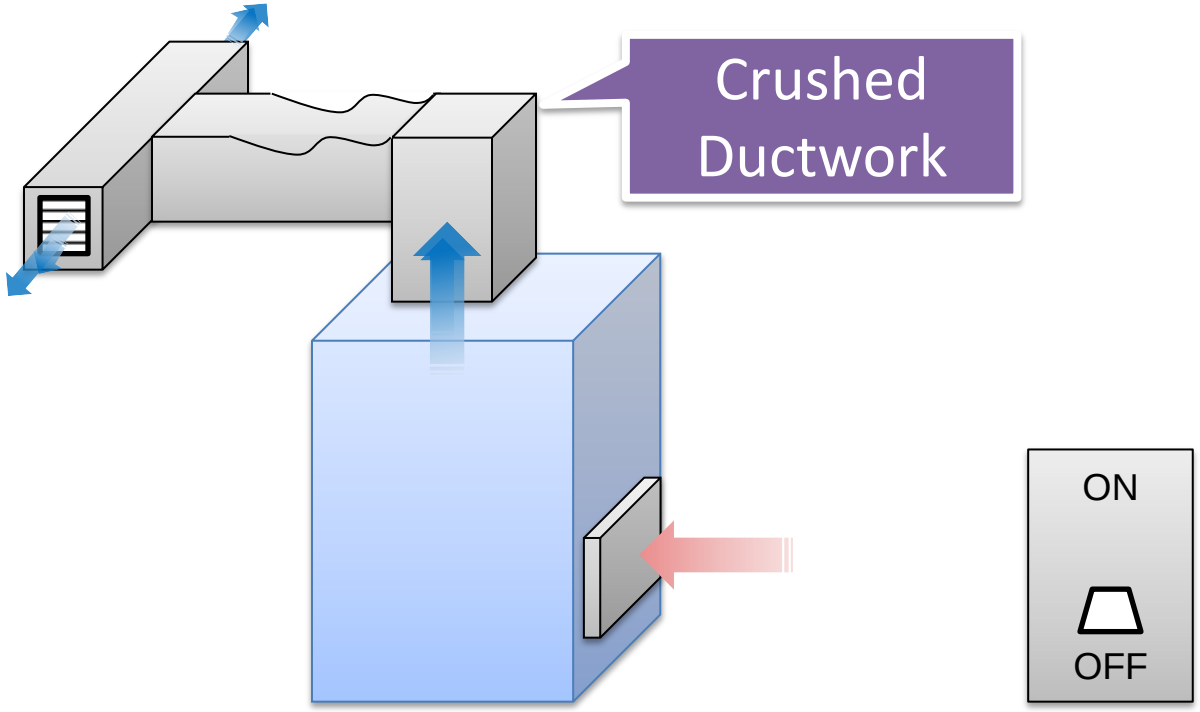
- During design phase:
  - Heating and cooling loads were calculated,
  - Heating and cooling equipment were selected,
  - A duct system was designed
- During installation:
  - Heating and cooling equipment was installed
  - Duct system was installed
- Why, then, do we need to check the airflow at the air handler in the field?

Measuring air handler airflow

- Things don't always go according to plan…

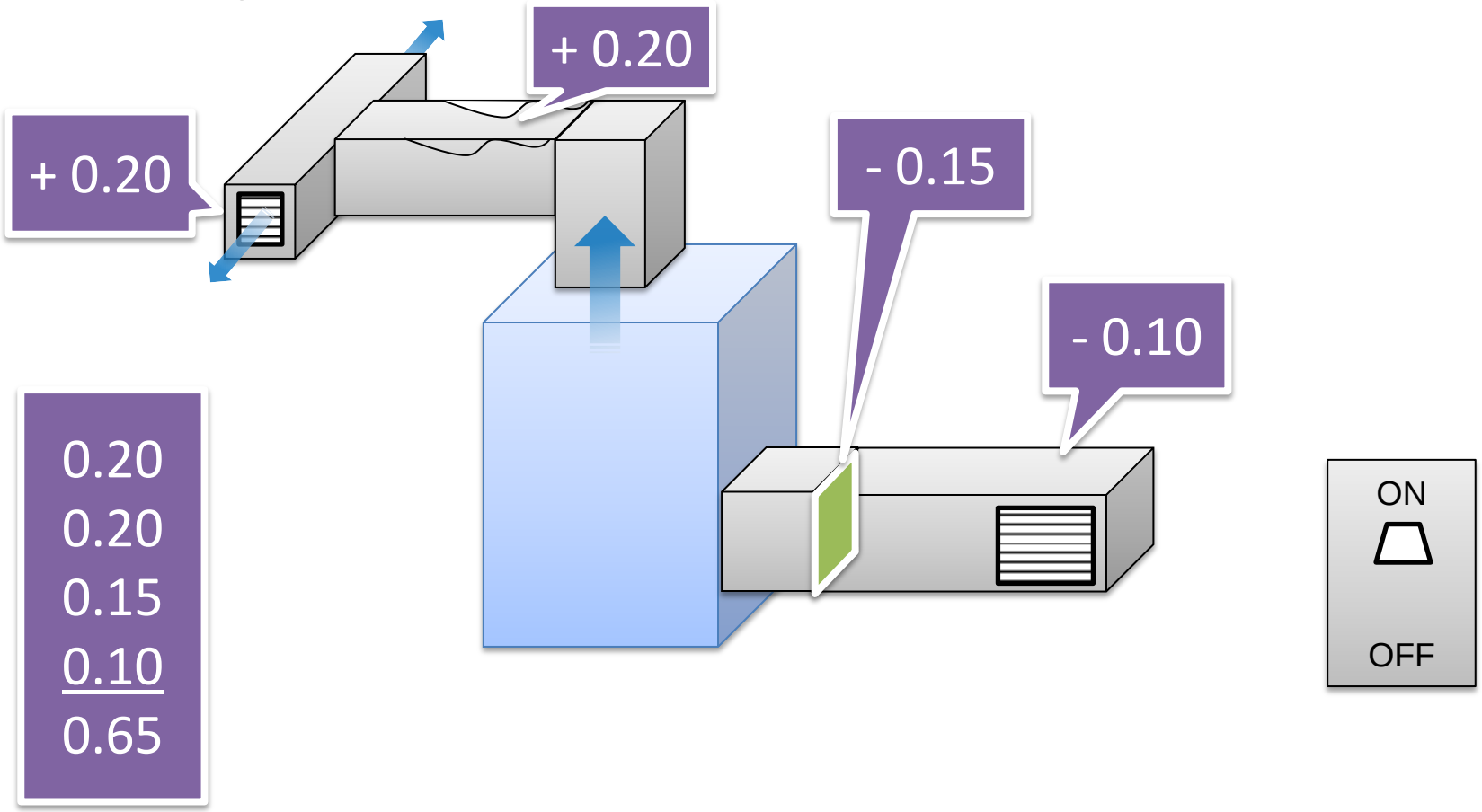
Measuring air handler airflow

- Example: Crushed ducts, sharp bends, and other defects produce additional static pressure in the system.



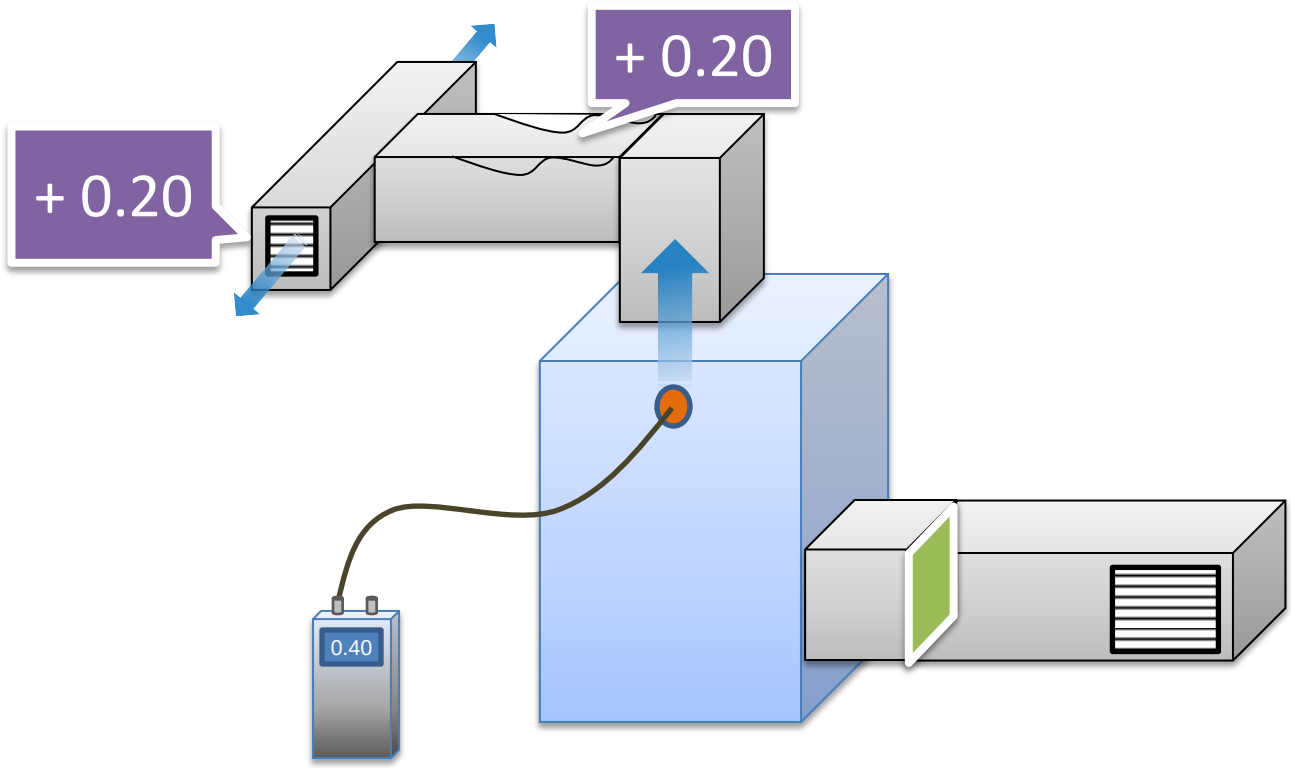
Measuring air handler airflow

- Installation issues will add unanticipated total external static pressure.



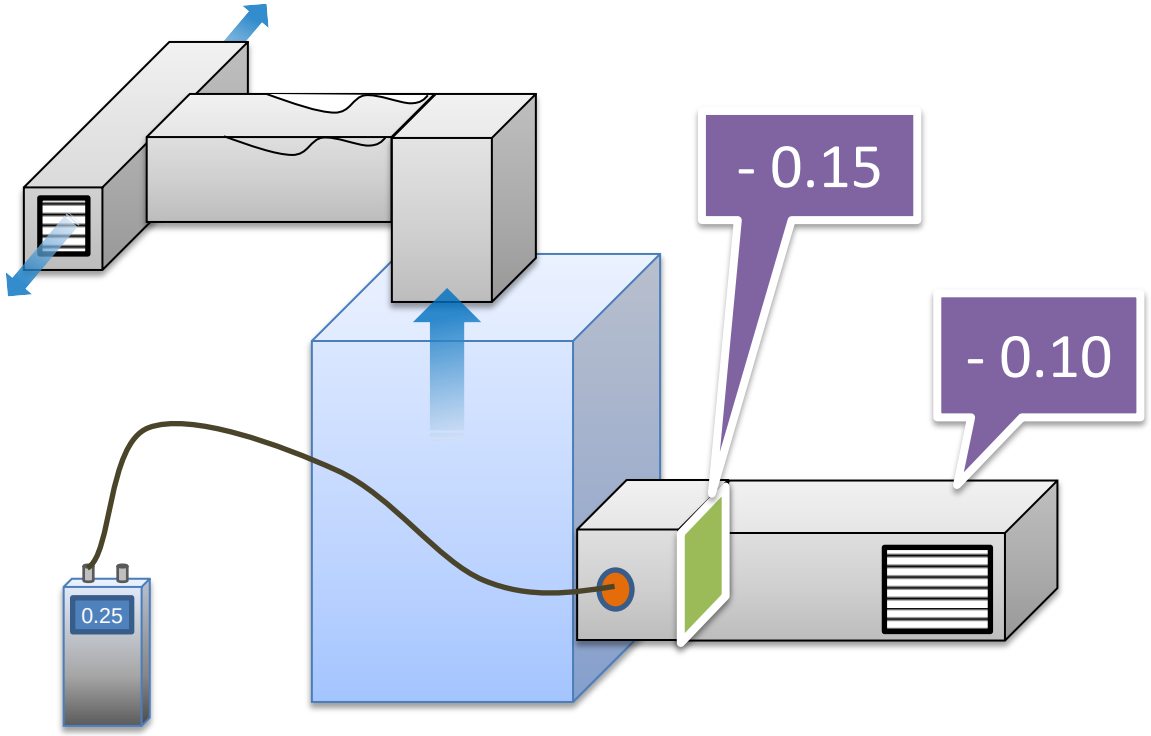
Measuring air handler airflow

- A digital manometer can be used to measure the external static pressure in the supply side.



Measuring air handler airflow

- And the external static pressure in the return side.



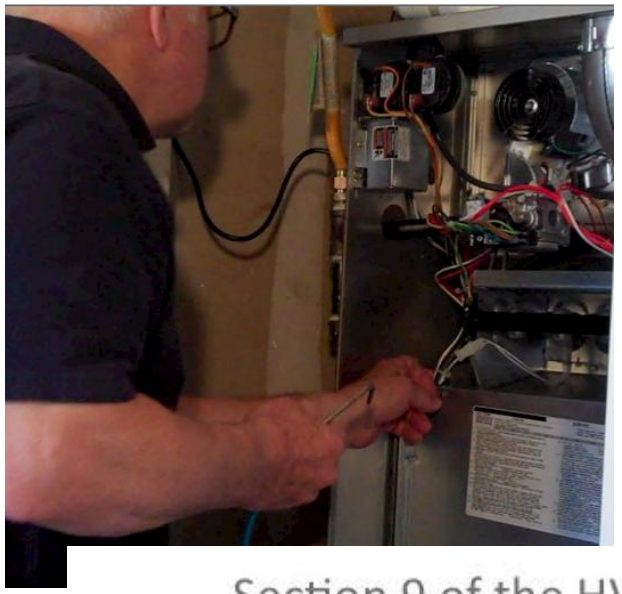
Measuring air handler airflow

- The manufacturer's table can be used to determine the actual airflow using the measured total external static pressure.
- From this, you can assess whether your system is operating within 15% of the design airflow.

Nominal Cooling Capacity Tons	Manufacturer Recommended Air-Flow Range (Min/Max) CFM	Blower Size / Motor HP / # of Speeds	Motor Speed From Factory	Motor Speed		Model ABC Wet Coil With Filter & Heaters						
						External Static Pressure (IWC)						
						0.1	0.2	0.3	0.4	0.5	0.6	0.7
1.5	827 / 474 CFM	10x6 1/3 HP 2 Speed Dual Voltage	5	3	CFM	827	804	779	740	708	659	608
			5	2	CFM	599	578	544	509	474	-	-
2.0	977 / 708 CFM	10x6 1/3 HP 2 Speed Dual Voltage	5	5	CFM	977	930	898	850	801	746	687
			5	4	CFM	811	785	759	726	708	-	-

Measuring air handler airflow

- Visit www.energystar.gov/newhomeseducation
- Click on “Videos” link for air handler airflow video.



Section 9 of the HVAC System QI Contractor Checklist

9. Air Flow Tests				Cont. Verified	N/A
9.1 Air volume at evaporator:	1,005 CFM			☑	☐
9.2 Test performed in which mode?	☐ Heating	☑ Cooling		☑	☐
9.3 Return duct static pressure:		0.10 IWC	Test Hole Location: [21] Left top of cabinet	☑	☐
9.4 Supply duct static pressure:		0.18 IWC	Test Hole Location: [21] Left front of cabinet	☑	☐
9.5 Test hole locations are well-marked and accessible [21]				☑	☐
9.6 Airflow volume at evaporator (Value 9.1), at fan design speed and full operating load, ± 15% of the airflow required per system design (Value 2.16) or within range recommended by OEM				☑	☐

Summary – Measuring air handler airflow

- HVAC fans are designed to move a specified amount of air across the heating or cooling coils and then through the ducts to the rooms.
- The airflow of the fan can be determined by measuring the total external static pressure. A manufacturer blower table can then be used to look up this pressure and read the corresponding airflow.
- This ensures that the system is operating as designed, so that the equipment can heat and cool the home as efficiently as possible.

Checking Refrigerant Charge

Checking refrigerant charge

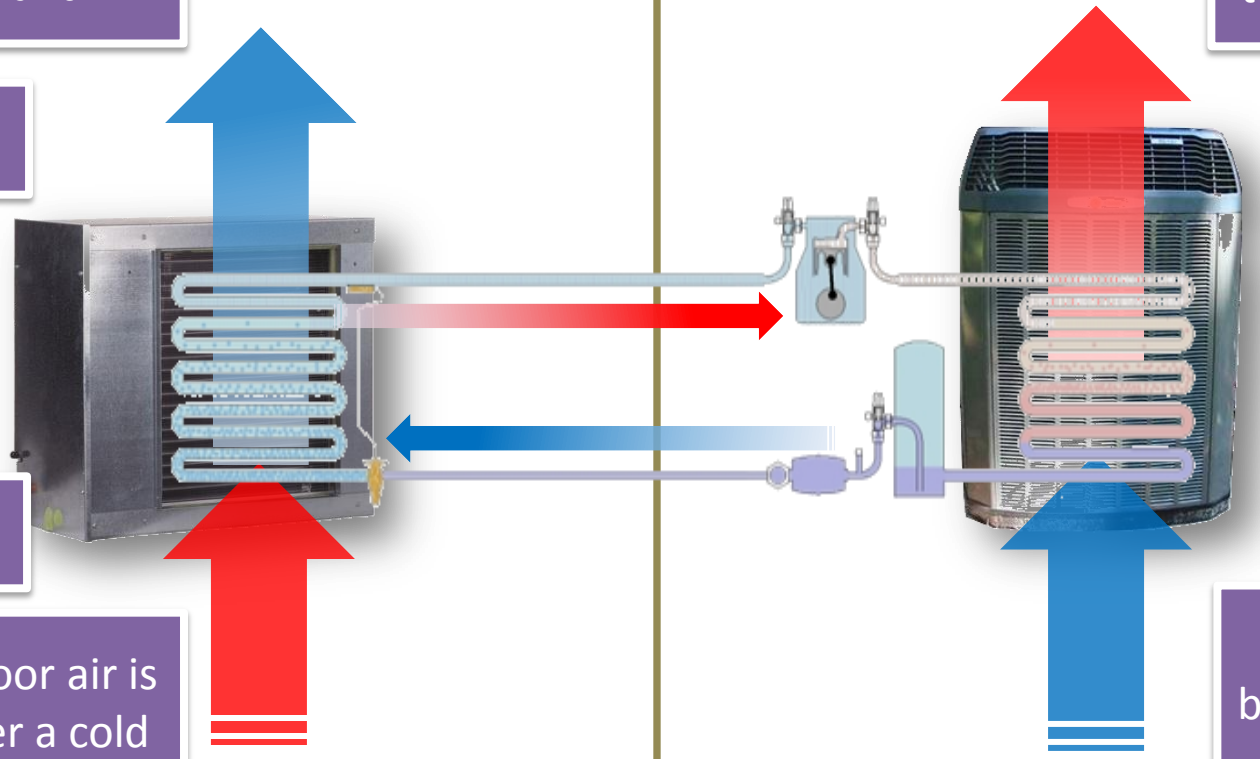
The air's heat is transferred to the refrigerant.

2

Inside the House

1

Warm indoor air is blown over a cold refrigerant coil.



The refrigerant's heat is transferred to the outdoor air.

4

Outside the House

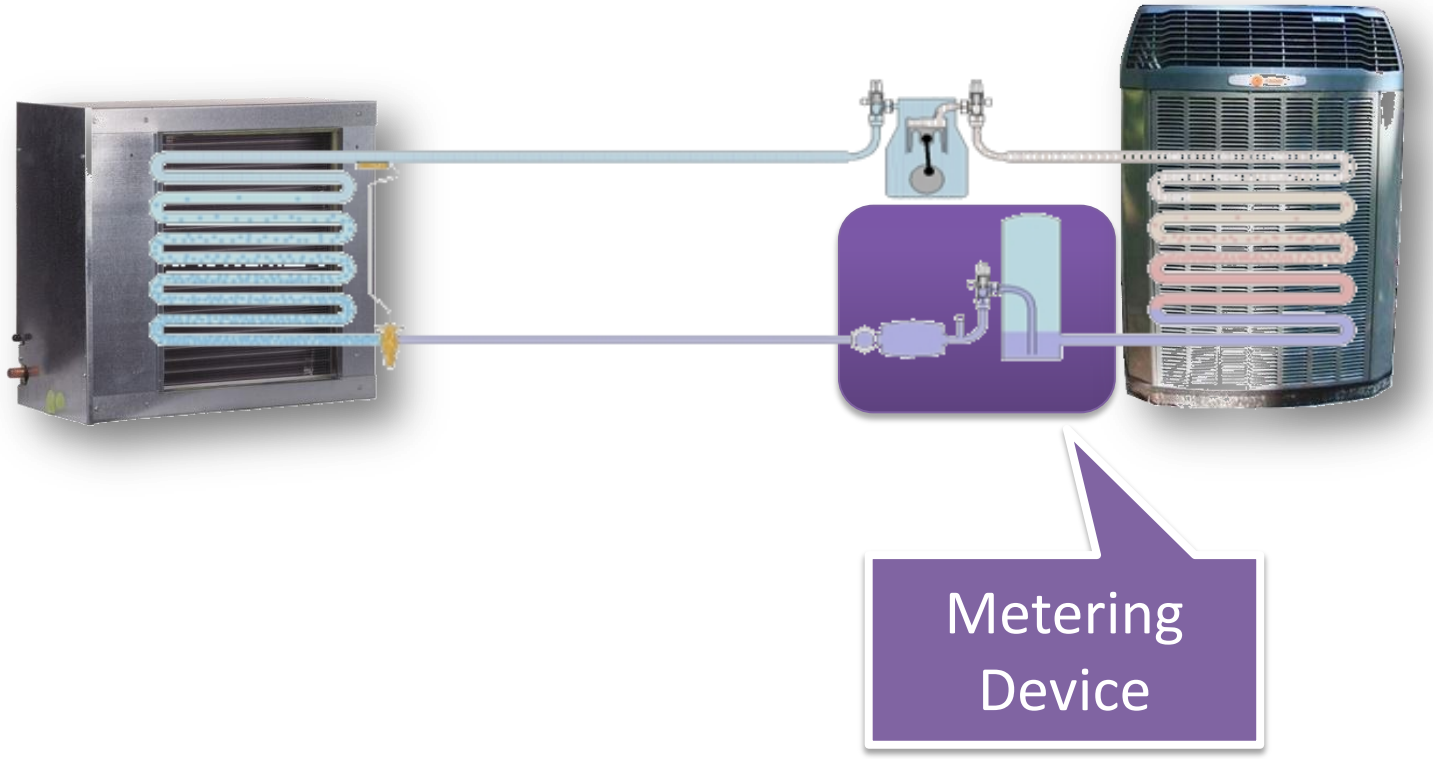
3

Outdoor air is blown over the hot refrigerant coil.

Checking refrigerant charge

Step 1: Metering Device

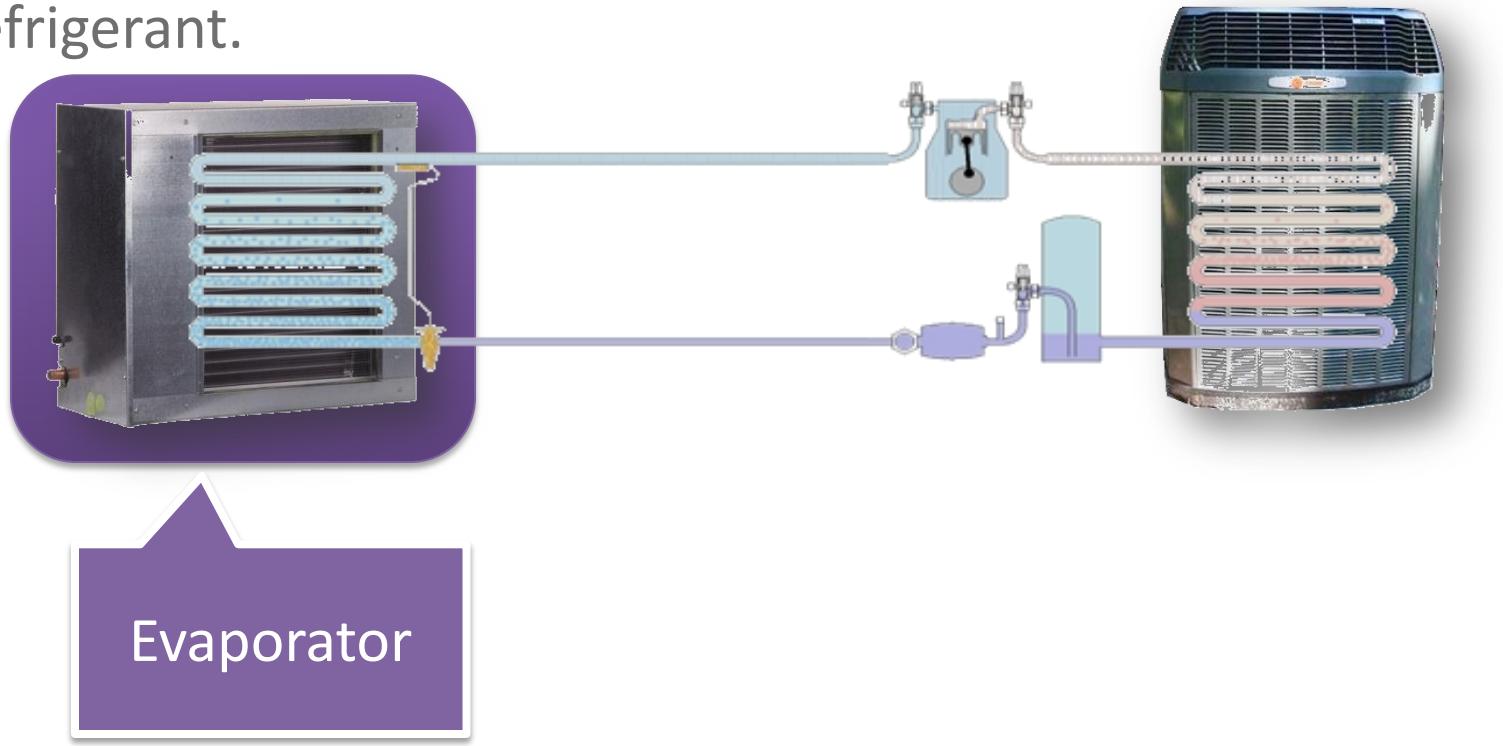
- The metering device controls how much refrigerant is released to the evaporator inside the home.



Checking refrigerant charge

Step 2: Evaporator

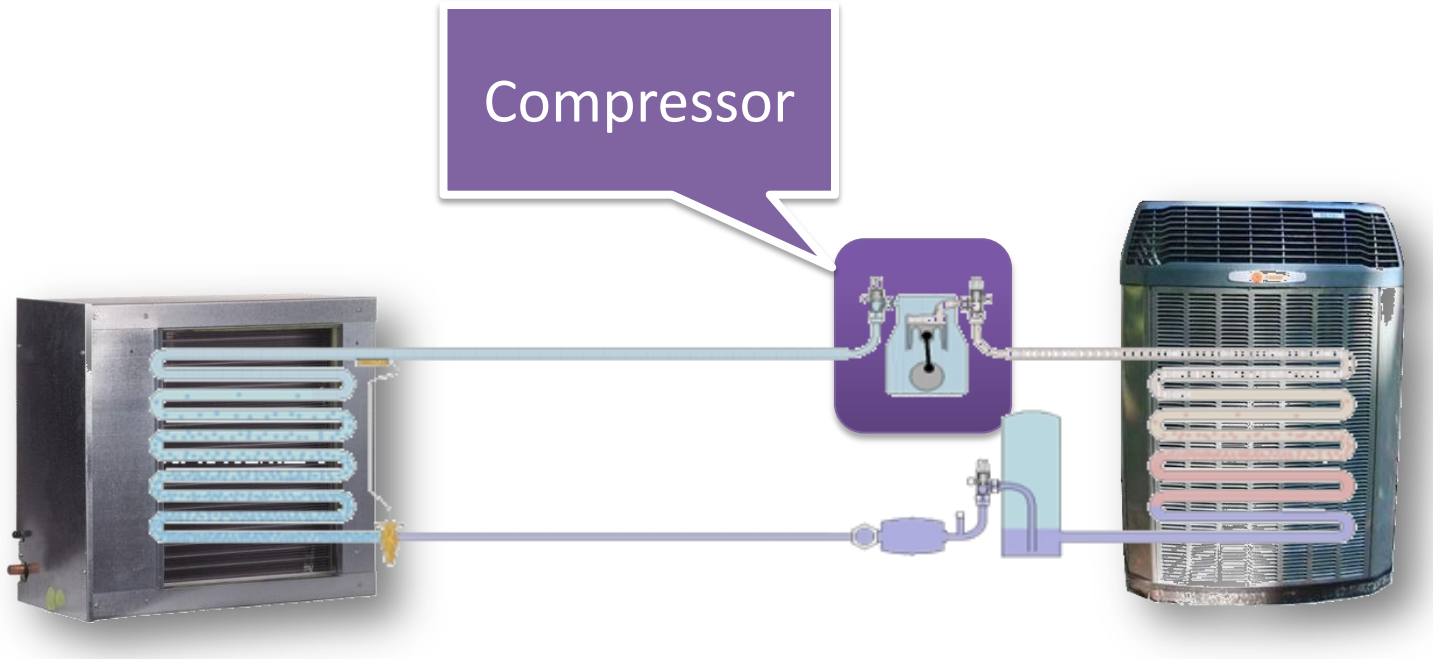
- The refrigerant flows through the evaporator or cooling coil in the air handler unit, transferring heat between the air and the refrigerant.



Checking refrigerant charge

Step 3: Compressor

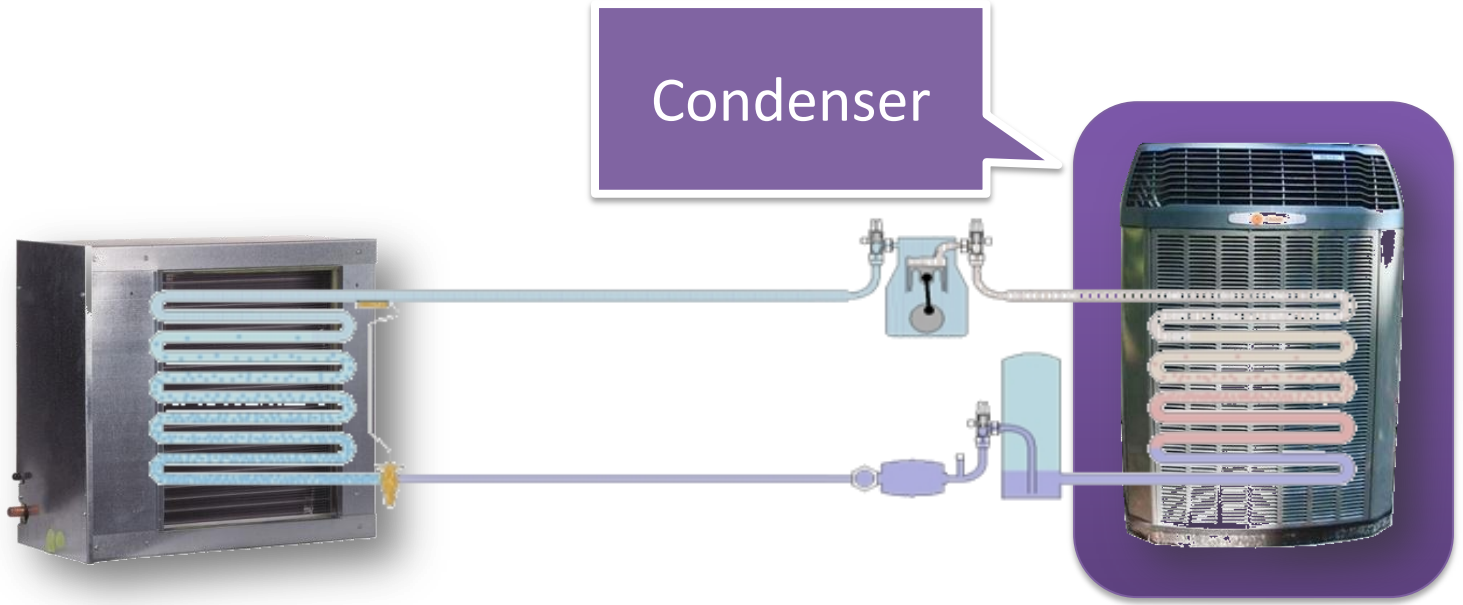
- The compressor is a small mechanical device that compresses the gas, raising its temperature.



Checking refrigerant charge

Step 4: Condenser

- The condenser uses a fan to blow outdoor air across the refrigerant, removing heat, causing it to cool down and condense back into a liquid form.



Checking refrigerant charge

Why is the amount of refrigerant so important to the operation of the A/C unit?

- Keep temperatures within target ranges.
- Keep liquid out of gas side.

Consequences of improper charging:

- Inefficient operation.
- Premature compressor failures.

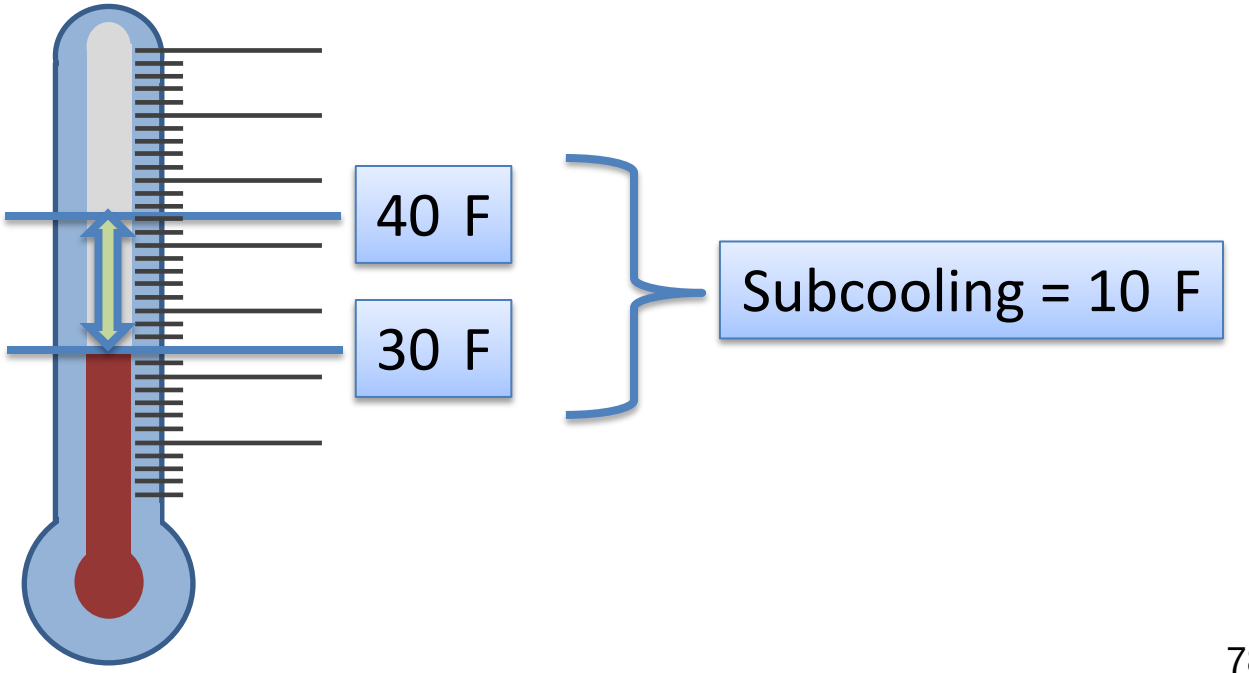
Checking refrigerant charge

Two tests can be done to ensure proper amount of refrigerant:

- Subcooling test: Ensures the refrigerant is in liquid form after it leaves the condenser.
- Superheat test: Ensures the refrigerant is in gas form before it arrives at the compressor.

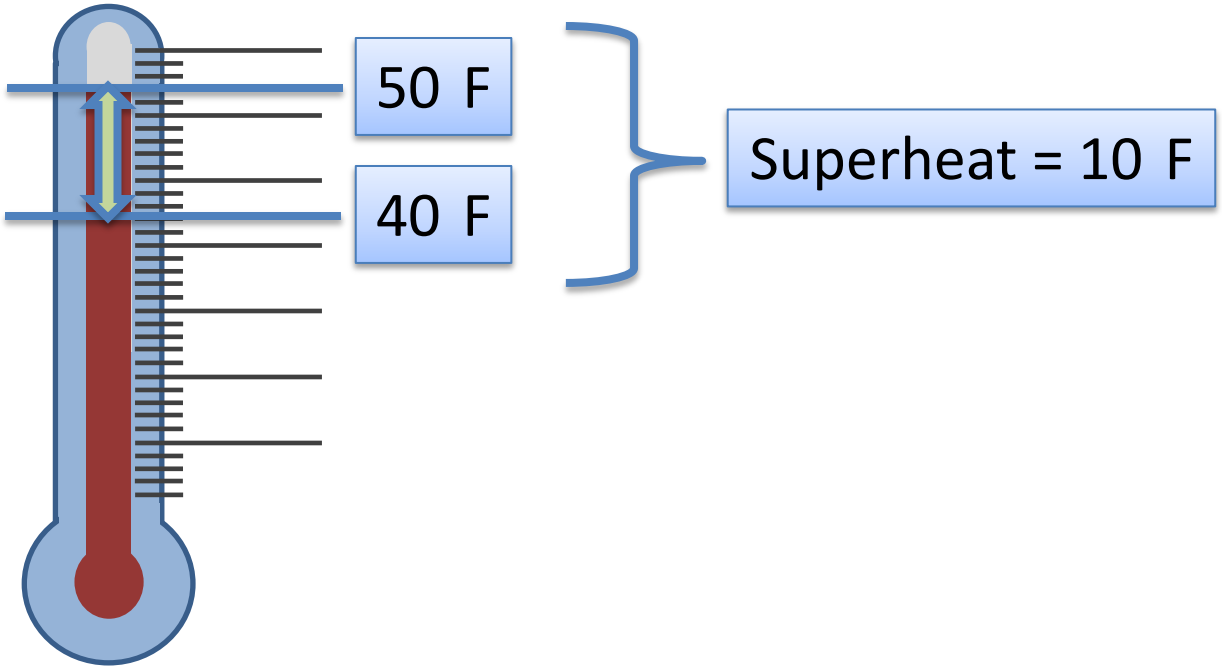
Checking refrigerant charge

- Subcooling is the temperature of the refrigerant below its boiling point (liquid saturation temperature).



Checking refrigerant charge

- Superheat is the temperature of the refrigerant above its boiling point (liquid saturation temperature).

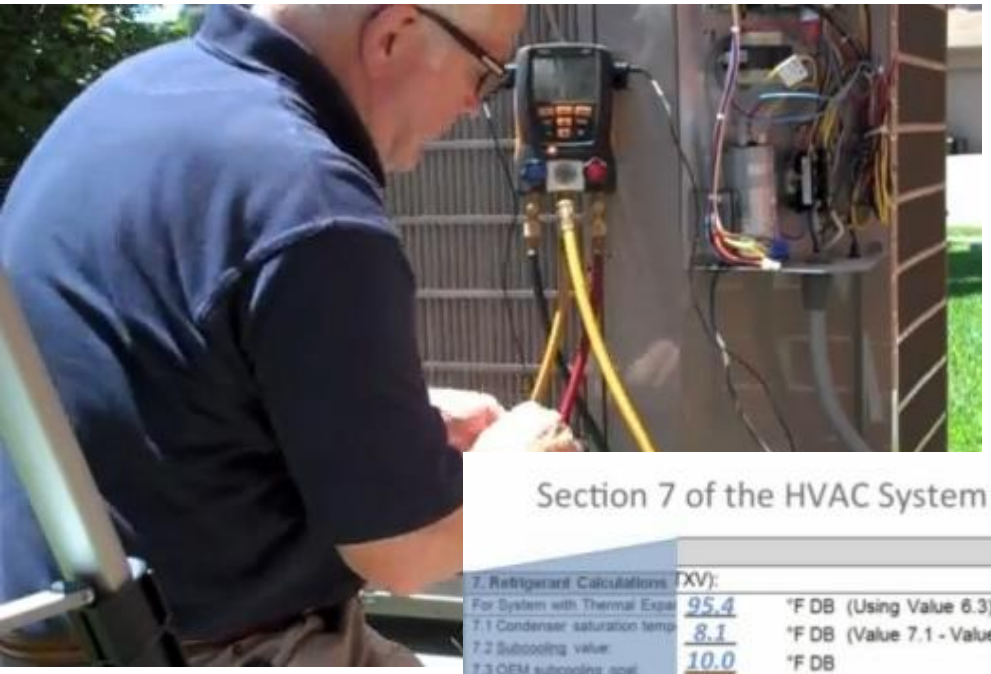


Checking refrigerant charge

- Manufacturer typically defines the subcooling or superheat target for their equipment.

Checking refrigerant charge

- Visit www.energystar.gov/newhomeseducation
- Click on “Videos” link for refrigerant charge video.



Section 7 of the HVAC System QI Contractor Checklist

7. Refrigerant Calculations (TXV):				
For System with Thermal Expa	95.4	°F DB (Using Value 6.3)	☑	☐
7.1 Condenser saturation temp	8.1	°F DB (Value 7.1 - Value 6.4)	☑	☐
7.2 Subcooling value:	10.0	°F DB	☑	☐
7.3 OEM subcooling goal:	1.9	°F DB (Value 7.2 – Value 7.3)	☑	☐
7.4 Subcooling deviation:				
For System with Fixed Orifice:				
7.5 Evaporator saturation temp	42.2	°F DB (Using Value 6.5)	☑	☐
7.6 Superheat value:	18.1	°F DB (Value 6.6 – Value 7.5)	☑	☐
7.7 OEM superheat goal:	12.4	°F DB (Using superheat tables and Values 6.1 & 6.2)	☑	☐
7.8 Superheat deviation:	5.7	°F DB (Value 7.6 – Value 7.7)	☑	☐
7.9 Value 7.4 is ± 3°F or Value 7.8 is ± 5°F			☑	☐

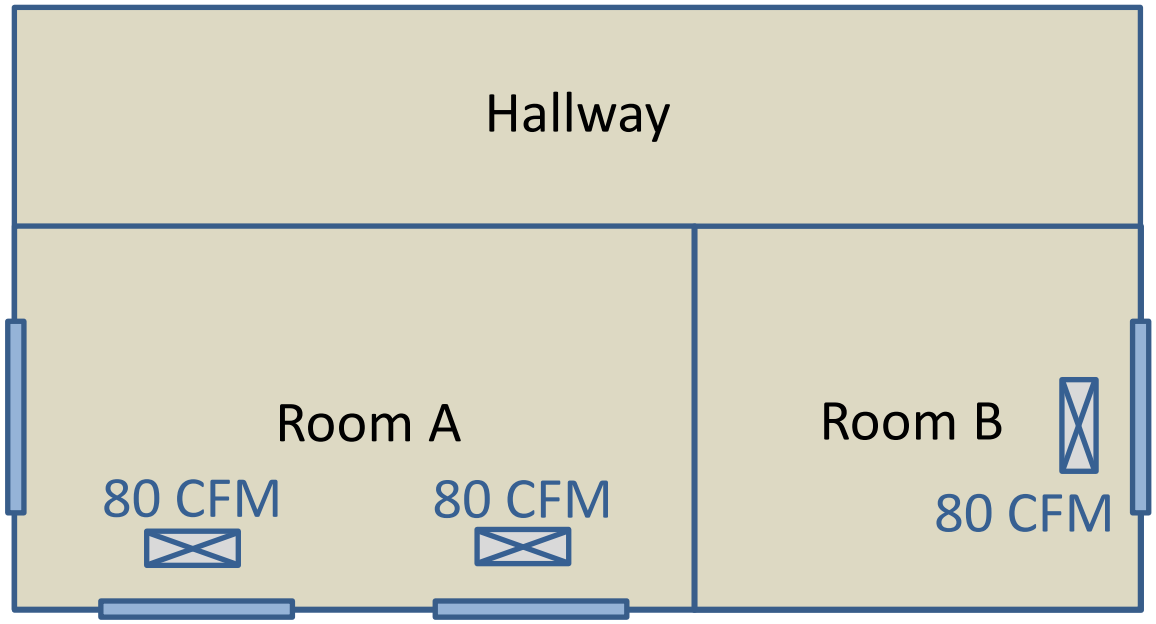
Summary – Checking refrigerant charge

- Refrigerant is a vehicle to transfer heat.
- Too much or too little refrigerant can cause premature compressor failure and inefficient operation.
- Refrigerant charge is tested through superheat and subcooling tests, which ensure that the refrigerant is in the right gas or liquid state at the right time.

Measuring Air Flow at Registers

Air balancing

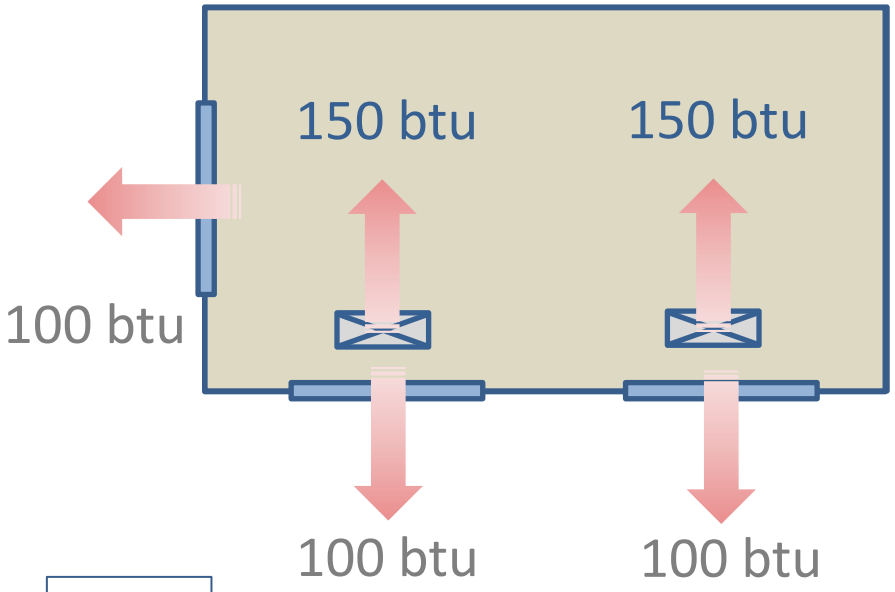
- Remember that the airflow needed by each room is directly related to its heating and cooling load.



Air balancing

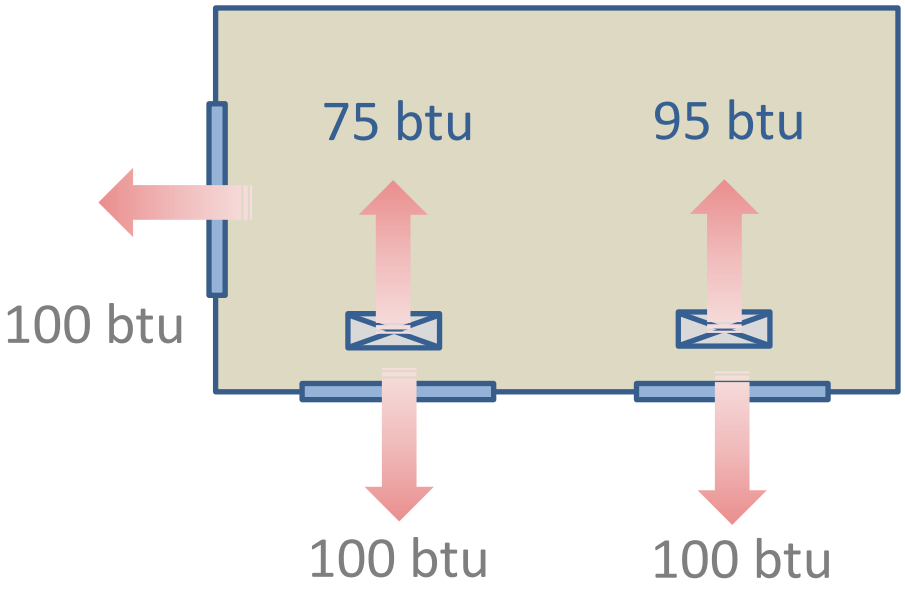
- Proper airflow is needed to deliver or remove the proper amount of heat from each room.

Room A – Correct Airflow



300 btu's out & 300 btu's in

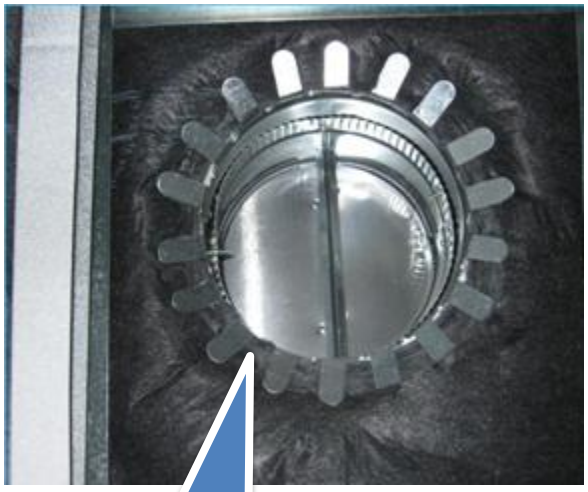
Room A – Incorrect Airflow



300 btu's out & 170 btu's in

Air balancing

- Unforeseen events that impact airflow relative to the design



Closed damper

Electrical wire

Air balancing

- Air balancing ensures that the right amount of airflow reaches each room.
- Measured airflow from each register must be within +/- 20% or 25 CFM of the design airflow for each room.
- Intent is to prevent egregious errors, not minor mistakes.

Design Value (CFM)	Minimum Airflow (CFM)	Maximum Airflow (CFM)
20	0	45
40	15	65
60	35	85
80	55	105
100	75	125
120	95	145
140	112	168
160	128	192

Summary – Air balancing

- Air balancing ensures that the right btu's are added to and removed from each room.
- Large tolerance is allowed for compliance.
- Can find problems caused by work that occurs after the equipment installation and start-up process.

Summary – Heating & Cooling Commissioning

- Measure air handler airflow to ensure the proper amount of heated and cooled air is sent from the equipment to the rooms.
- Check refrigerant charge to ensure that the proper amount of heat is transferred from the inside of the house to the outside.
- Balance airflows at the registers to catch egregious errors that prevent the proper amount of heat from being delivered to or removed from each room.

Summary – Designing & Installing Heat & AC Systems

- Complete thermal enclosure system, and proper heating & cooling design and commissioning, help keep the home more comfortable with less energy.
- There are three major steps of HVAC design:
  - Calculate heating and cooling loads.
  - Select equipment to match those loads.
  - Design ducts to deliver air from the equipment to rooms, and back.
- There are three major commissioning tests:
  - Measuring HVAC fan airflow.
  - Checking refrigerant charge.
  - Measuring airflow at registers.

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