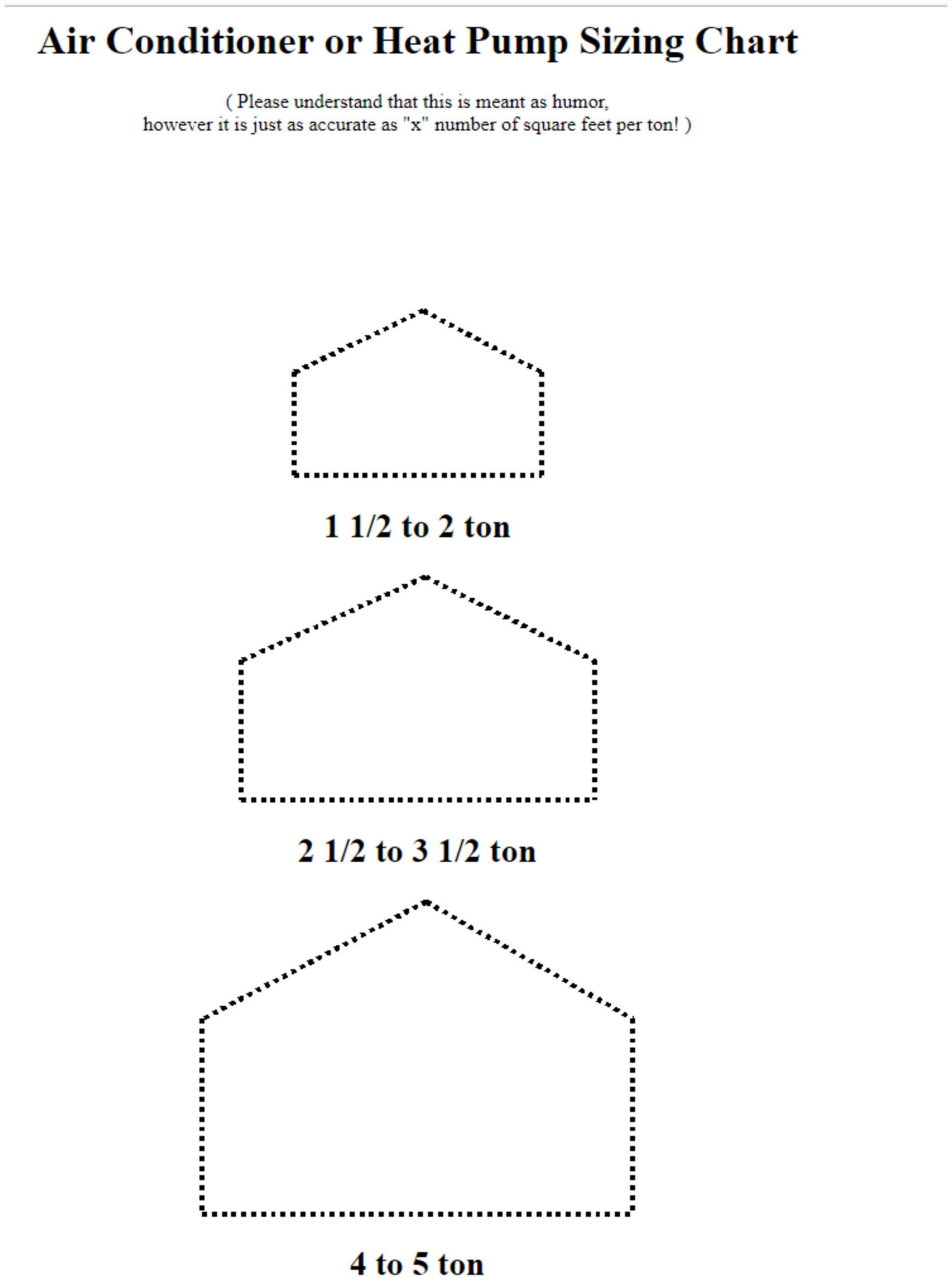
MANUAL J – HEATING AND COOLING LOAD

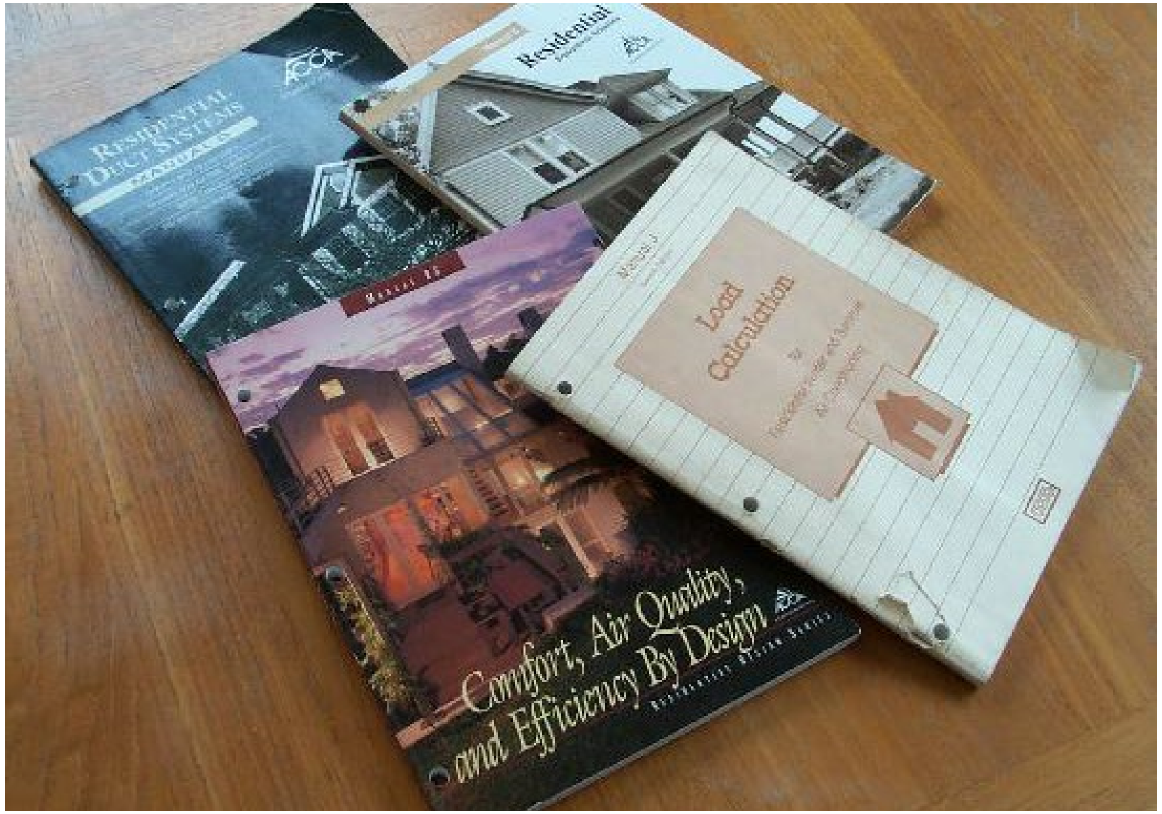
Sizing – Bad Rules of Thumb

- One ton per 400 square feet
- One cfm per sq. ft. of house
- Tonnage = half the number of cylinders in the customer's biggest car/truck
- What's in the shop today
- ½ ton bigger than their neighbor
- Other



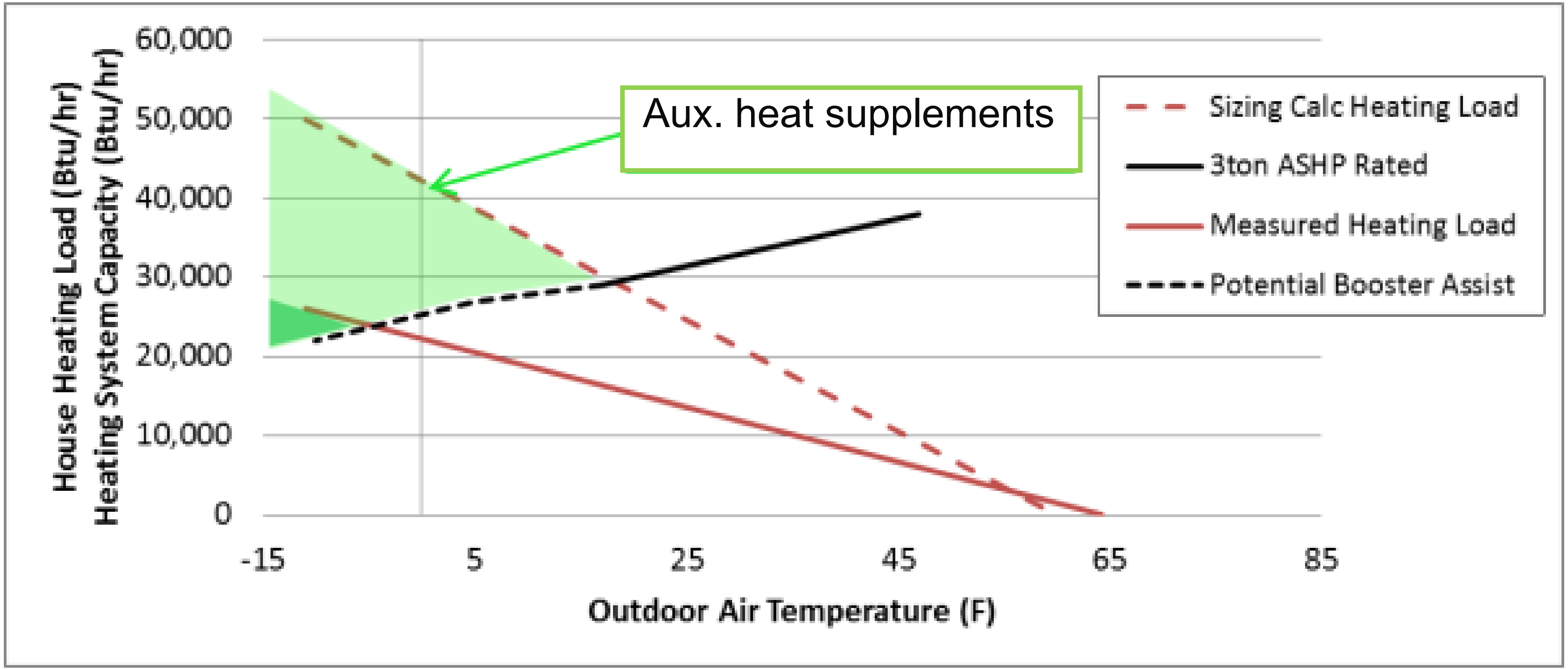
The ACCA Work Process

- Manual “J” calculates heat loss/heat gain
- Manual “S” the selection process
- Manual “D” the duct design process



Shows Measured Load vs. Manual J

Illustrates that there is already a “fudge” factor in Manual J



Source: CEE field research study

Definitions: Design Conditions

Design Temperature is not the coldest day or hottest day of the year

Winter Design Conditions: It only gets colder than this 1%-2.5% of the time

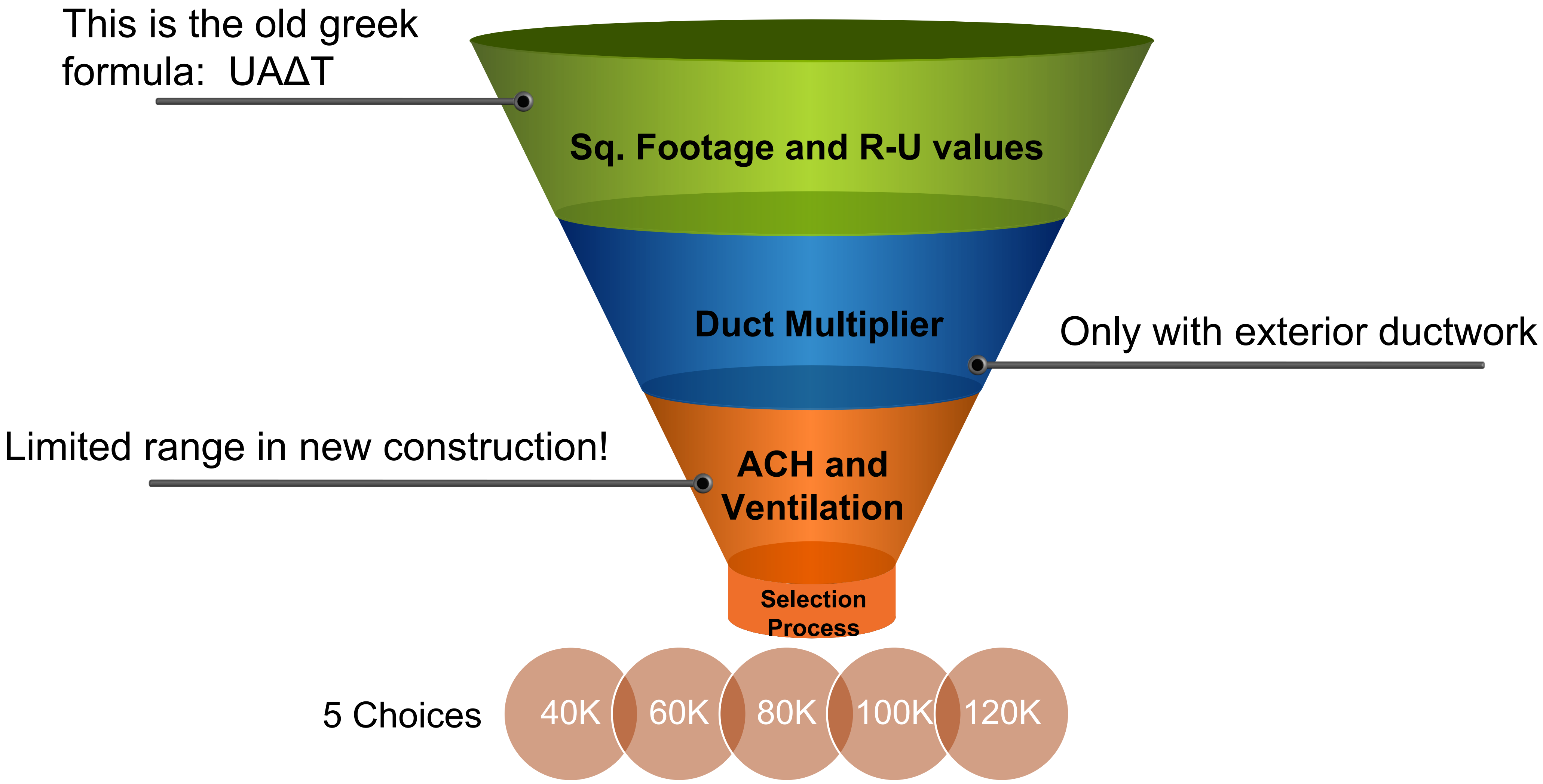
Denver:

Winter Design Condition is -3° F

Summer Design 91°F with 59°F wet bulb

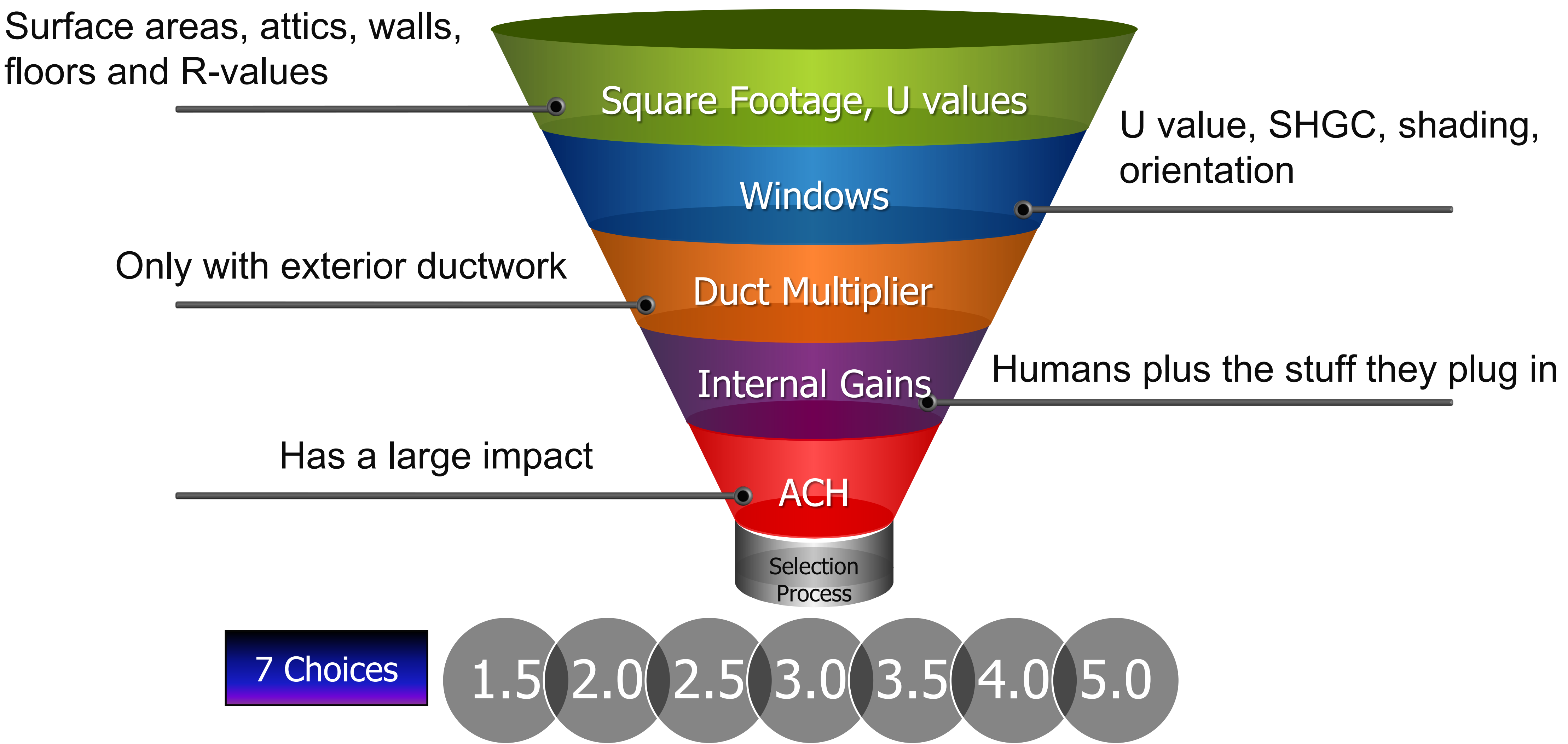
Note – use the correct weather station!

Manual J Heating Load Inputs (Gas Furnaces)



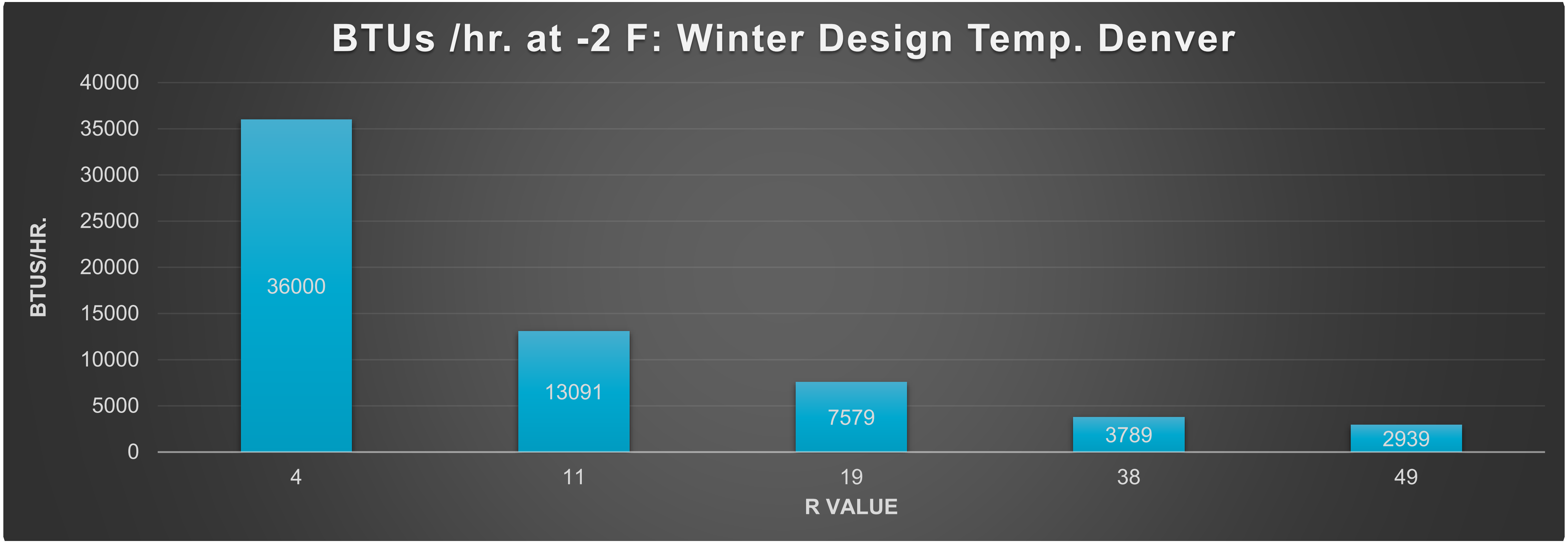
Manual J Cooling Load Inputs

Critical inputs include windows and internal gain



It's The Heat Loss Not The Square Footage

Heat loss through 2,000 sq. ft attic at various R-values

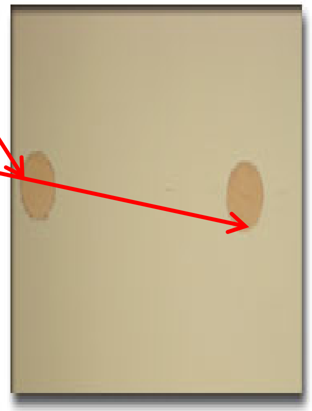


Denver Area Insulation History

Decade	Ceiling	Wall	Foundation	Windows
1950s	0-10	5-7	0	SP Alum
1960s	10-15	5-7	0	SP Alum
1970s	10-30	7-9	0	DP Alum
1980s	30	11	0	DP Alum
1990s	30-38	13	0	DP Vinyl
2000s	30-38	13	11	DP Vinyl w Low E
2010s	38+	13-15	11-13	DP Vinyl Low E

Checking For Wall Insulation

Wooden plugs that cover insulation access holes before filling and painting



Removing the outlet cover and sliding a non-conductive probe such a plastic crochet hook or a chop stick between the sheetrock and the outlet base can help to determine if the walls are insulated

Walls that have been insulated post construction will have patched holes on the interior walls or exterior walls. Look for 2-1/2 inch holes that have been filled and painted over

Basements: The Critical Details

- First Question: Are you planning on conditioning the basement?
- How many feet below and above grade?
- Is it insulated?
- Does the sun actually “see” the glass?
- F-value vs R-value

Manufactured Home R Value Guide

Manufactured Home R Value Guide				
Timeframe	Ceiling	Floor	Wall	Windows
Pre 1975	7	7	7	1.1
76- 94 HUD Code	11	11	11	0.75
90 -94 Super Good Cents	38	33	21	0.38
Present HUD Code	22	22	11	0.48
2000 to Present Energy Star	40	33	21	0.36

Determining How Leaky or Tight a House is

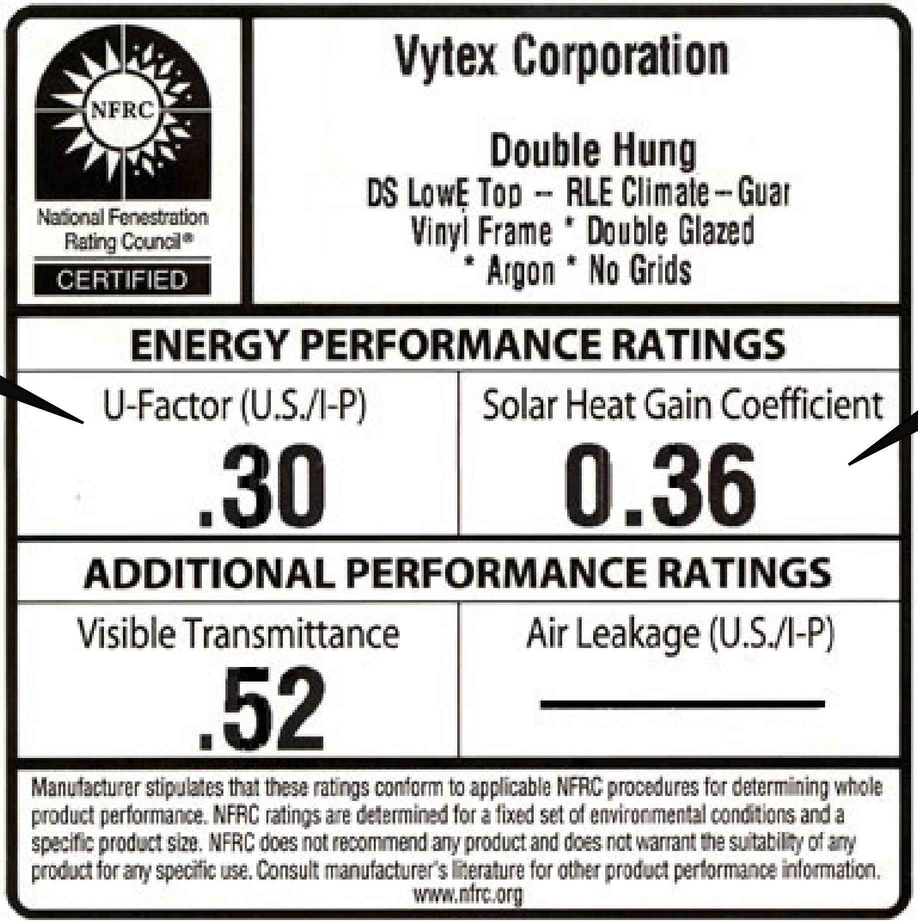
Air Changes Per Hour (ACH) Rates: Always an Estimate

Year Built	Winter ACH	Summer ACH
Non 4 X 8 Sheet Goods	1	.5
4 X 8 Sheet Goods pre-1970	.70	.25
1970 to 1990	.5	.25
1990 to 2010	.35	.15
2010 to Present	.25	.15

NOTE – THESE ARE “NATURAL” ACH NO ACH50

What’s On That Window Sticker

U Value



SHGC

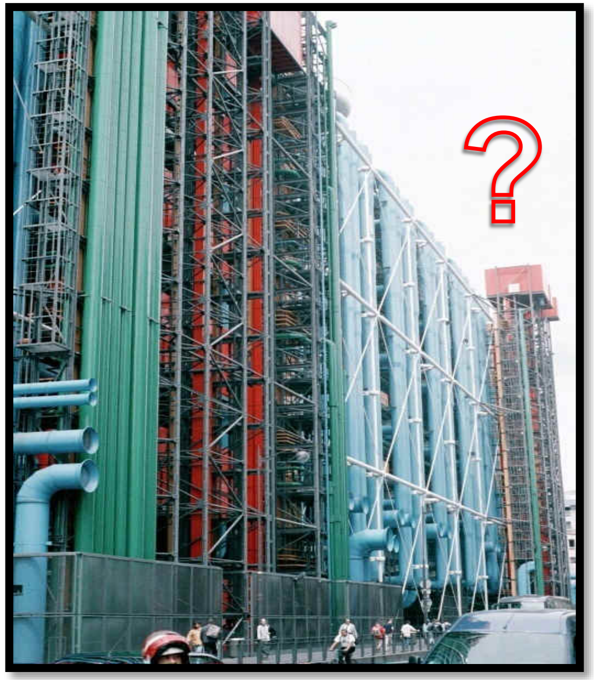
Windows: Sweat the Details

BTUS/HR/Sq.FT. of Window 35 Delta T 40 Degree Latitude.					BTUS/HR. Total		
Orientation	Single Pane U value =.98 SHGC=.74	Double Pane U value =.42 SHGC= .61	Double Pane U value=.42 SHGC =.35	SQ . FT. of Window	Single Pane U value =.98 SHGC=.74	Double Pane U value =.42 SHGC= .61	Double Pane U value=.42 SHGC =.35
North	49	26	19	40	1,960	1,040	760
NE or NW	80	53	32	40	3,200	2,120	1,280
East or West	104	72	42	80	8,320	5,760	3,360
SE or SW	93	63	37	40	3,720	2,520	1,480
South	65	40	25	40	2,600	1,600	1,000
Totals				240	19,800	13,040	7,880
					11,920	5,160	

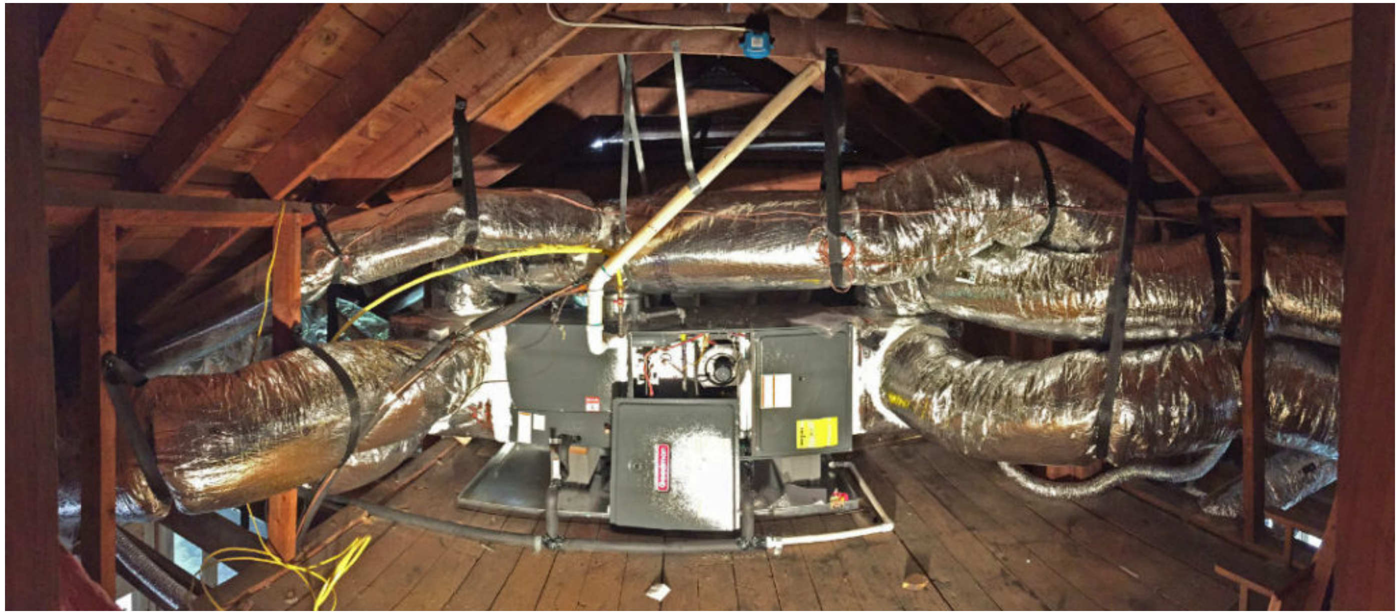
.5 ton difference

1 ton difference

Inside vs. Outside



NOTE: If any portion of the duct system is outside the conditioned space, be sure to have a duct multiplier



Duct Multipliers

If ducts are outside the thermal envelope of the house, then a duct multiplier is added to the heating load.

Example:

Heat loss at design temp:	42,000 BTU/hr.
Duct Multiplier	10%
Total heat loss	46,200 BTU/hr

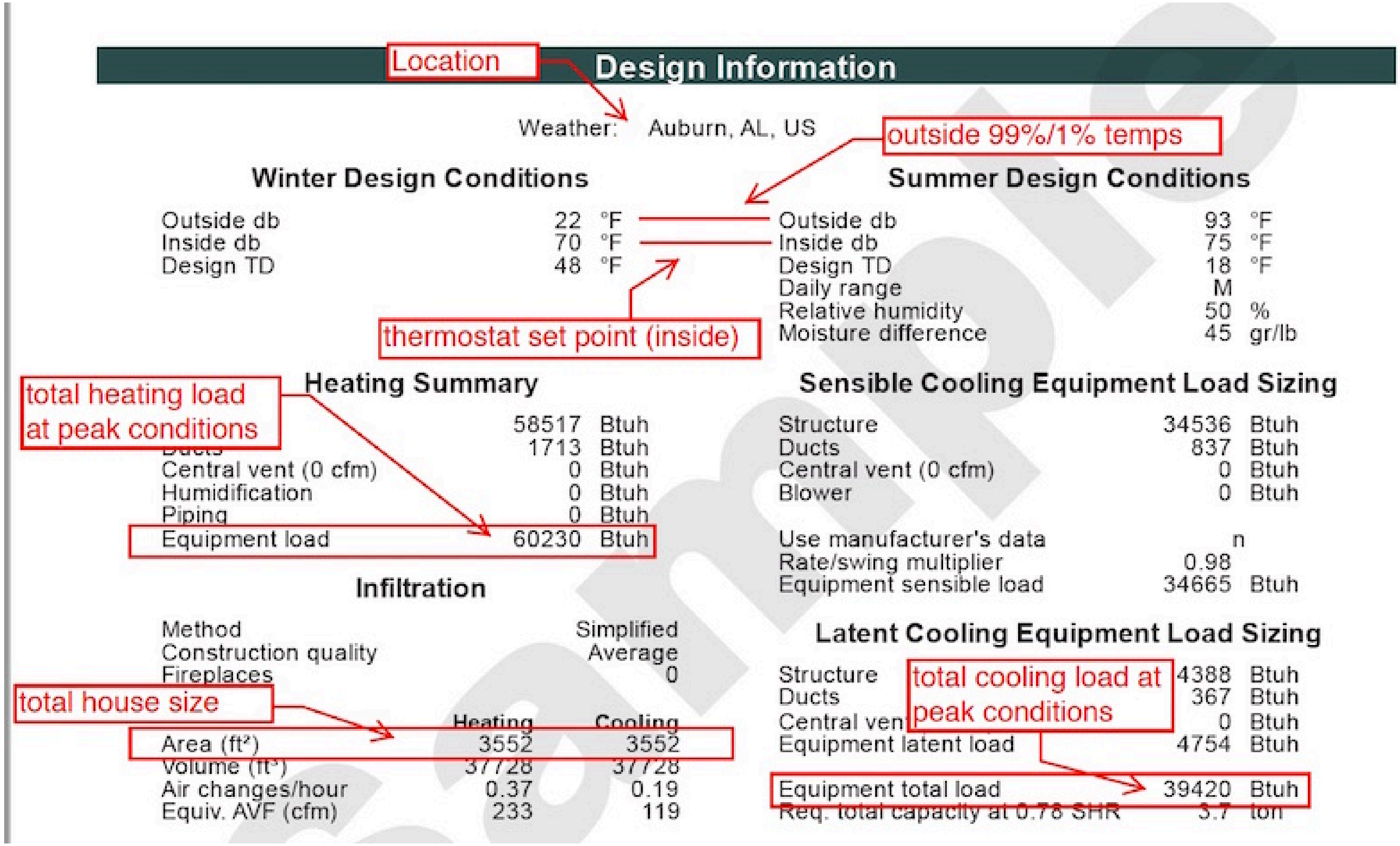
What Contributes to the Cooling Load?

- Conduction through walls and attics
- Solar gain and conduction through windows and skylights
- Floors exposed to outside temperatures
- People
- Ducts outside conditioned space (conduction and leakage)
- Infiltration/exfiltration
- Appliances
- Ventilation

What Contributes to the Heating Load?

- Conduction through walls and attics
- ACH rate
- Floors exposed to outside temperatures
- Ventilation
- Ducts outside conditioned space (conduction and leakage)
- Infiltration/exfiltration
- Not fudging the inputs

So, We Know the Loads, The Next Step is Selection



Location

Design Information

Weather: Auburn, AL, US

outside 99%/1% temps

Winter Design Conditions

Outside db	22	°F
Inside db	70	°F
Design TD	48	°F

Summer Design Conditions

Outside db	93	°F
Inside db	75	°F
Design TD	18	°F
Daily range	M	
Relative humidity	50	%
Moisture difference	45	gr/lb

thermostat set point (inside)

total heating load at peak conditions

Heating Summary

	58517	Btuh
Ducts	1713	Btuh
Central vent (0 cfm)	0	Btuh
Humidification	0	Btuh
Piping	0	Btuh
Equipment load	60230	Btuh

Sensible Cooling Equipment Load Sizing

Structure	34536	Btuh
Ducts	837	Btuh
Central vent (0 cfm)	0	Btuh
Blower	0	Btuh
Use manufacturer's data	n	
Rate/swing multiplier	0.98	
Equipment sensible load	34665	Btuh

Infiltration

Method	Simplified
Construction quality	Average
Fireplaces	0

total house size

	Heating	Cooling
Area (ft²)	3552	3552
Volume (ft³)	37728	37728
Air changes/hour	0.37	0.19
Equiv. AVF (cfm)	233	119

Latent Cooling Equipment Load Sizing

total cooling load at peak conditions

Structure	4388	Btuh
Ducts	367	Btuh
Central vent	0	Btuh
Equipment latent load	4754	Btuh
Equipment total load	39420	Btuh
Req. total capacity at 0.78 SHR	3.7	ton

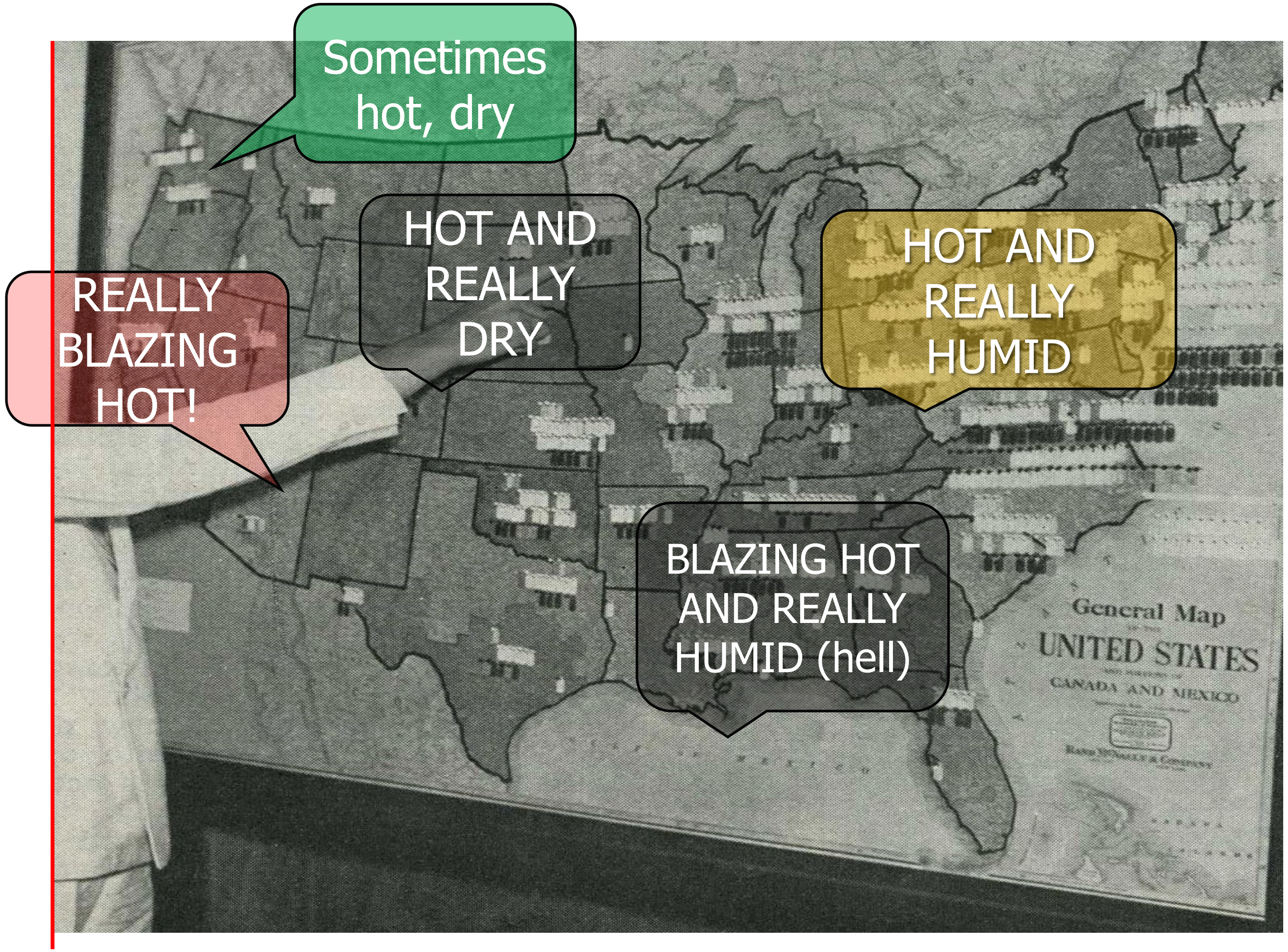
MANUAL S – EQUIPMENT SELECTION

What Is Meant by Equipment Sizing?

The goal of all HVAC equipment sizing is to find the best match between the house and the equipment.

Optimal size is the best match, or balance, between the rate of heat loss or heat gain of the house and the capacity of the HVAC equipment.

The Official Summer Climate Map of America



Sling Psychrometer

Wet Bulb

Total Cooling Load: Sensible Plus Latent

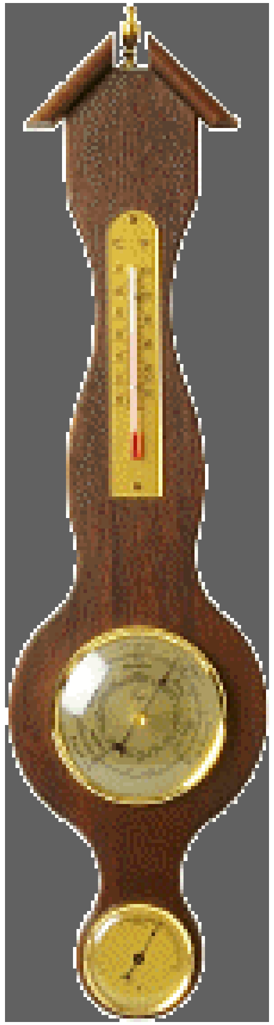
Sensible cooling load:

- The part of the cooling load that involves lowering the dry bulb temperature.

Latent cooling load:

- The part of the cooling load that involves removing water vapor from the air (dehumidification).

Cooling process will reduce both temperature and moisture



What Manual S Says About Cooling

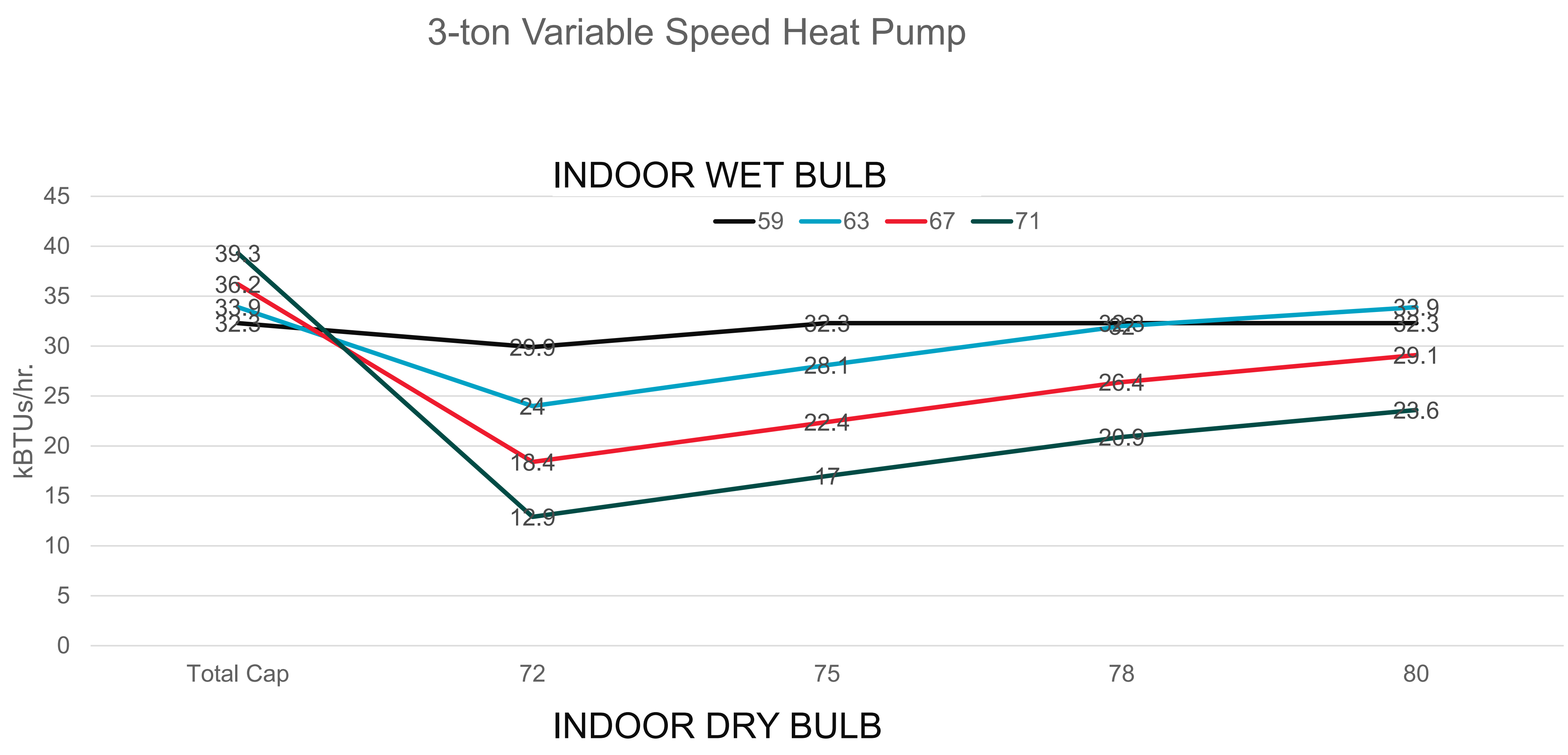
Misnomer - Don’t oversize by more than 115% or 125% if it’s a heat pump.

Why:

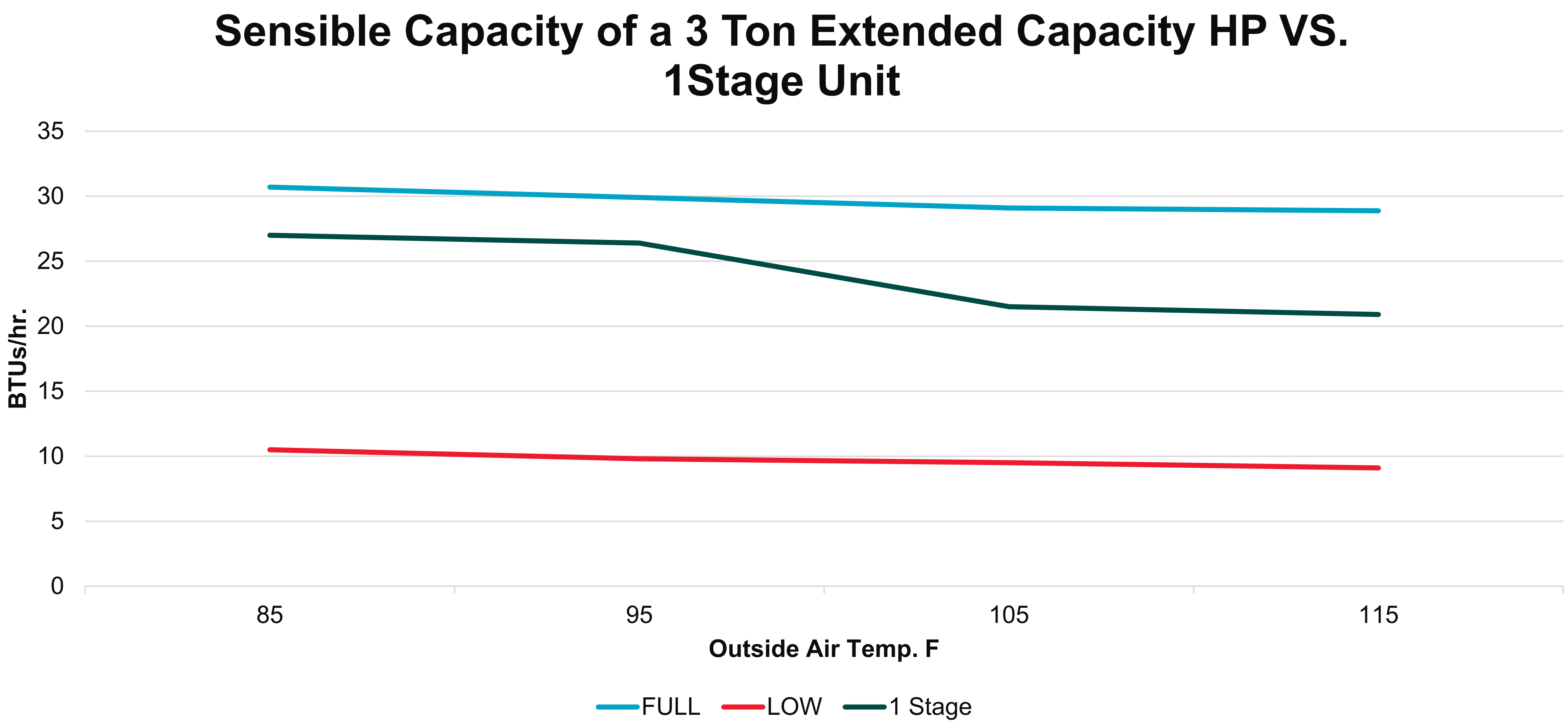
- Because they are very concerned about dehumidification
(but CO is not humid).

- With VSHPs dehumidification is not a worry, especially in CO. VSHPs modulate down to lower capacities.

Total and Sensible Capacity at 100%



Sensible Capacity 3 ton Extended Capacity vs. 1 Stage



Sizing for Cooling

REMEMBER WE LIVE IN A DRY SUMMER CLIMATE!

1. Find the outside design temp.
2. Determine your cfm.
3. Pick the lowest entering wet bulb (EWB) temp
4. Locate the sensible capacity

SPECIFICATIONS

DETAILED COOLING CAPACITIES*

Evaporator Air		CONDENSER ENTERING AIR TEMPERATURES °F											
		85			95			105			115		
CFM	EWB	Capacity MBtuh† Total	Capacity MBtuh† Sens‡	Total System KW**	Capacity MBtuh† Total	Capacity MBtuh† Sens‡	Total System KW**	Capacity MBtuh† Total	Capacity MBtuh† Sens‡	Total System KW**	Capacity MBtuh† Total	Capacity MBtuh† Sens‡	Total System KW**
544B024 Outdoor Section With 517EN030 Indoor Section													
800	72	26.3	13.1	2.41	24.8	12.6	2.60	23.3	12.0	2.78	21.8	11.5	2.95
	67	23.9	16.8	2.36	22.5	16.2	2.54	21.1	15.7	2.71	19.8	15.1	2.87
	62	21.7	20.3	2.32	20.5	19.6	2.48	19.3	18.9	2.65	18.2	18.1	2.81
	57	21.2	21.2	2.31	20.2	20.2	2.48	19.2	19.2	2.64	18.2	18.2	2.81
900	72	26.6	13.6	2.46	25.1	13.1	2.65	23.6	12.5	2.83	22.0	12.0	3.01
	67	24.2	17.7	2.41	22.8	17.1	2.59	21.4	16.6	2.77	20.0	16.0	2.93
	62	22.2	21.4	2.37	20.9	20.6	2.54	19.8	19.8	2.71	18.7	18.7	2.88
	57	21.9	21.9	2.37	20.8	20.8	2.54	19.8	19.8	2.71	18.7	18.7	2.88
1000	72	26.9	14.1	2.51	25.3	13.5	2.70	23.8	13.0	2.88	22.2	12.4	3.07
	67	24.5	18.5	2.46	23.0	17.9	2.64	21.6	17.3	2.82	20.1	16.8	2.99
	62	22.5	22.3	2.43	21.4	21.4	2.60	20.2	20.2	2.77	19.1	19.1	2.95
	57	22.5	22.5	2.42	21.4	21.4	2.60	20.2	20.2	2.77	19.1	19.1	2.95

Multipliers for Determining the Performance With Other Indoor Sections

Details Matter

REMEMBER WE LIVE IN A DRY SUMMER CLIMATE!

1. Find the outside design temp.
2. Determine your cfm.
3. Pick the lowest Entering Wet Bulb (EWB) temp
4. Locate the sensible capacity

6H4036B WITH ADD100R9V5+TXC037E5 AT 1200 CFM

O.D. D.B.	I.D. W.B.	TOT CAP.	SENS. CAP. AT ENTERING D.B. TEMP 72	75	78	80	TOTAL KW
85	59	33.5	27.0	30.2	33.5	34.4*	2.75
	63	36.0	22.7	25.9	29.2	31.4	2.78
	67	38.6	18.0	21.2	24.5	26.7	2.80
95	59	32.3	26.4	29.7	32.6*	33.3*	3.02
	63	34.6	22.1	25.4	28.6	30.8	3.06
	67	37.1	17.4	20.7	23.9	26.1	3.09
105	63	33.1	21.5	24.8	28.0	30.2	3.40
	67	35.4	16.8	20.0	23.3	25.4	3.44
	71	37.8	12.0	15.2	18.5	20.6	3.49
115	63	31.5	20.9	24.1	27.4	29.6	3.75
	67	33.7	16.1	19.4	22.7	24.8	3.80
	71	36.0	11.3	14.6	17.8	20.0	3.85

CORRECTION FACTORS - OTHER AIRFLOWS (MULTIPLY OR ADD AS INDICATED)

AIRFLOW	1050	1350	AIRFLOW	1050	1350
TOTAL CAP	X0.98	X1.01	SENS. CAP	X0.94	X1.06

Selecting the Unit

- Where does the 60% sensible 40% latent myth come from?
- 21,600/ 36000 = 60%
- This is one hot muggy house!
- This is not anyplace in the west.

Performance Data @ ARI Standard Conditions—Cooling: RANL- JEZ

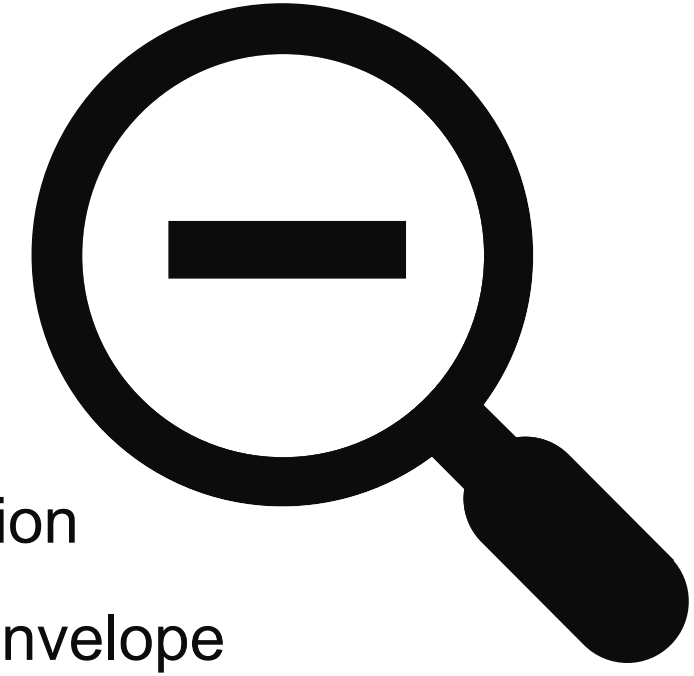
Outdoor Unit RANL-	Model Numbers	80°F [26.5°C] DB/67°F [19.5°C] WB Indoor Air 95°F [35°C] DB Outdoor Air				
	Indoor Coil and/or Air Handler	Total Capacity BTU/H [kW]	Net Sensible BTU/H [kW]	Net Latent BTU/H [kW]	EER	SEER
Revised 9/12/2008						
	RCFL-A*3621B* (RGLR-07?BRQ?)	29,400 [8.6]	21,600 [6.3]	7,800 [2.3]	12.00	14.00
	RCFL-A*3621B* (RGPR-05?BMK?)	29,000 [8.5]	21,250 [6.2]	7,750 [2.3]	11.40	13.50
	RCFL-A*3621B* (RGPR-07?AMK?)	29,200 [8.6]	21,450 [6.3]	7,750 [2.3]	11.70	13.50
	RCFL-A*3621B* (RGPR-07?BRQ?)	29,400 [8.6]	21,550 [6.3]	7,850 [2.3]	12.05	14.00
	RCFL-H*3617A* (RGFD-07?MCK?)	29,200 [8.6]	21,450 [6.3]	7,750 [2.3]	11.40	13.50
	RCFL-H*3617A* (RGGD-06?MCK?)	29,200 [8.6]	21,450 [6.3]	7,750 [2.3]	11.45	13.50
	RCFL-H*3617A* (RGGD-07?MCK?)	29,000 [8.5]	21,300 [6.2]	7,700 [2.3]	11.35	13.50
	RCFL-H*3617A* (RGJD-06?MCK?)	29,200 [8.6]	21,450 [6.3]	7,750 [2.3]	11.45	13.50
	RCFL-H*3617A* (RGJD-07?MCK?)	29,000 [8.5]	21,300 [6.2]	7,700 [2.3]	11.35	13.50
	RCFL-H*3617A* (RGLR-07?AMK?)	29,200 [8.6]	21,450 [6.3]	7,750 [2.3]	11.65	13.50
	RCFL-H*3617A* (RGLR-07?BRQ?)	29,400 [8.6]	21,600 [6.3]	7,800 [2.3]	11.95	14.00
	RCFL-H*3617A* (RGPR-07?AMK?)	29,200 [8.6]	21,450 [6.3]	7,750 [2.3]	11.65	13.50
	RCFL-H*3621A*	28,800 [8.4]	21,150 [6.2]	7,650 [2.2]	10.95	13.00
	RCFL-H*3621A* (RGFD-07?MCK?)	29,200 [8.6]	21,450 [6.3]	7,750 [2.3]	11.45	13.50

Capacity Correction for Altitude: Generic

2,000 Ft.	4,000 Ft.	6,000 Ft.	8,000 Ft.	10,000 Ft.
.98	.97	.95	.92	.90

Make sure your manual J software is set to the correct location (corrects for altitude)

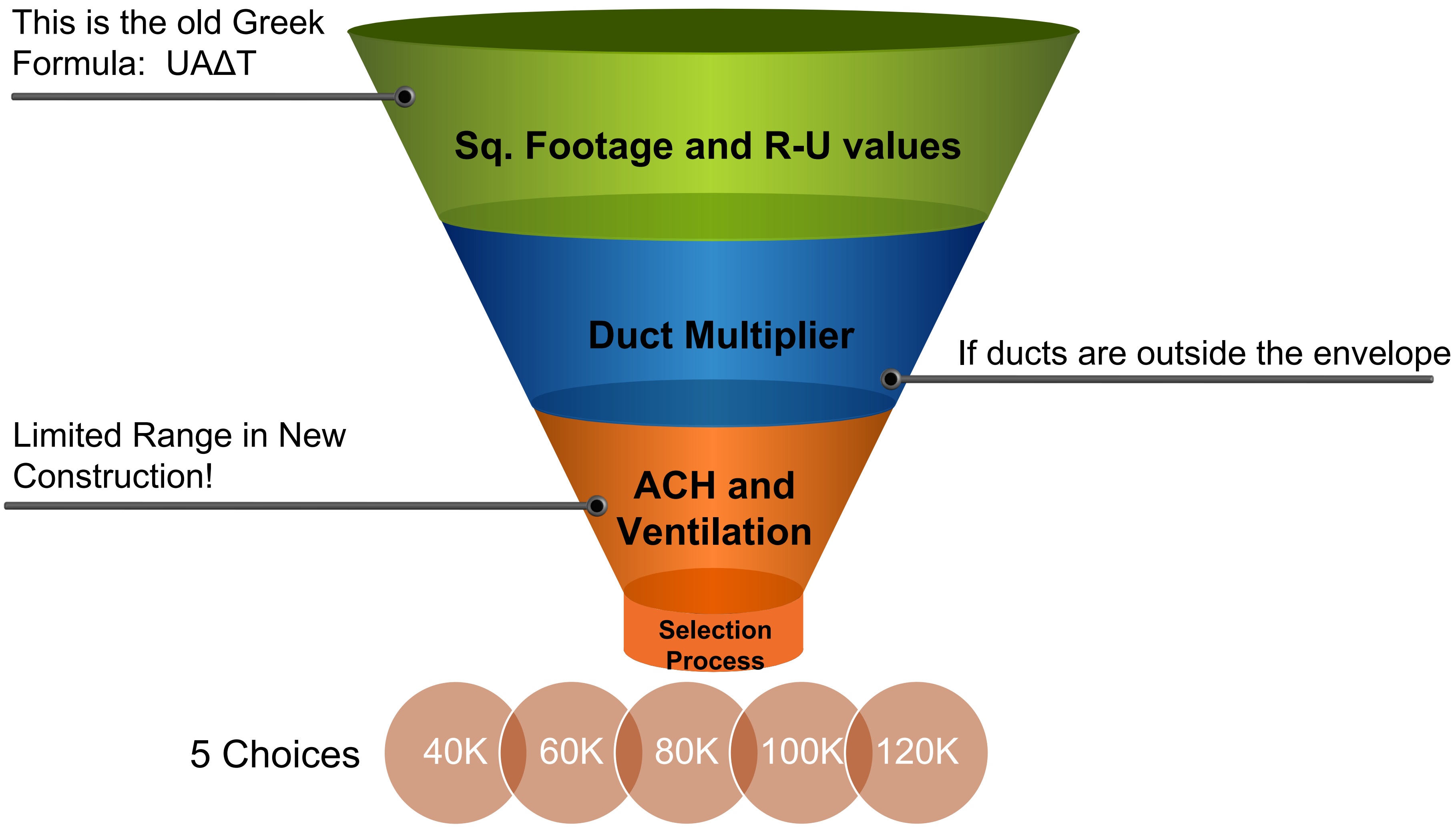
The Sweat The Details Stuff



1. Insulation Levels, (none, some, fair amount a lot!)
2. House Tightness : usually between .35 ACH an .8
3. Windows: Solar Heat Gain Coefficient is critical! Orientation
4. Duct Multiplier: Between 0% and 30%. If it’s outside the envelope
5. House component square footages

EQUIPMENT SIZING - HEATING

Manual J Heating Load Inputs



Gas Furnace Sizing: It's Easy

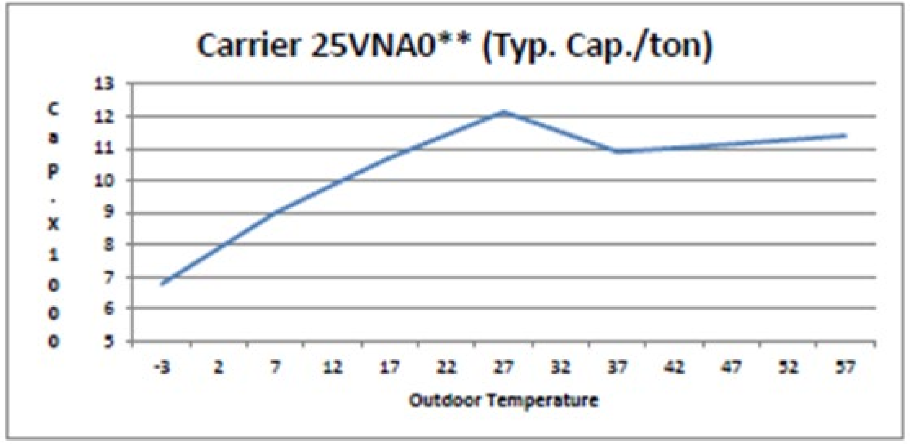
If heat loss of house was 45,000 BTU/hr. what furnace would be the right size?

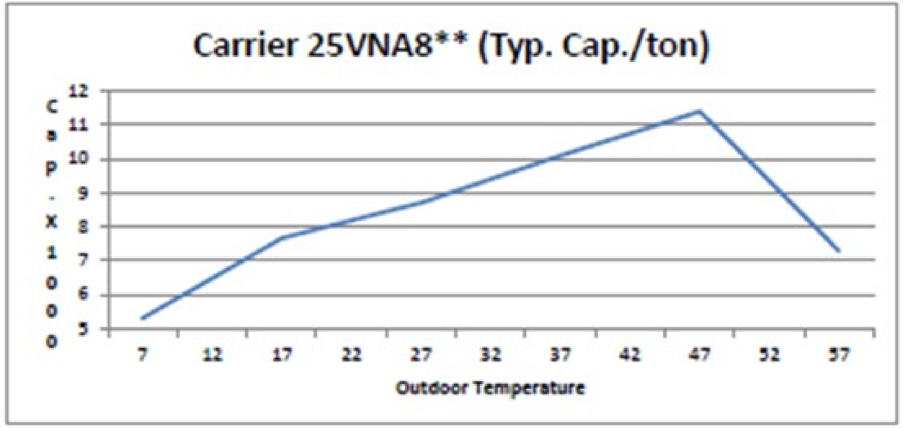
Ratings & Physical / Electrical Data

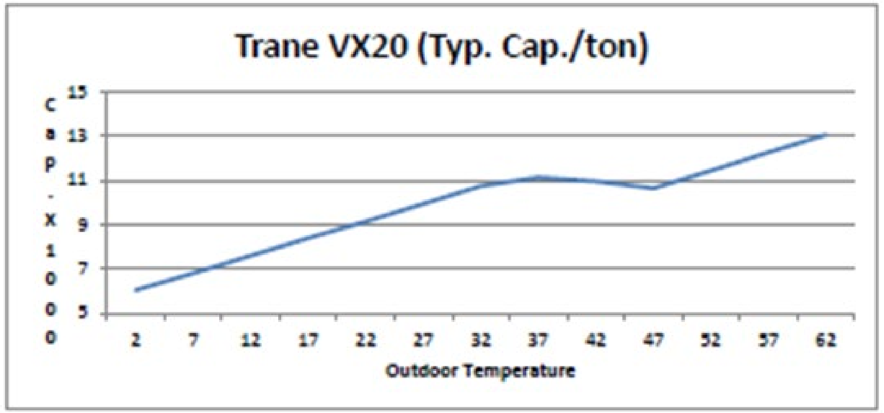
Model	Input High/Low	Output High/Low	Total Unit	AFUE
	MBH	MBH	Amps	%
TM9V040A10MP11	40/26	38/25	9	96
TM9V060B12MP11	60/39	58/37	9	96
TM9V080B12MP11	80/52	77/50	9	96
TM9V080C16MP11	80/52	77/50	12	96
TM9V100C16MP11	100/65	96/62	12	96
TM9V100C20MP11	100/65	96/62	14	96
TM9V120D20MP11	120/78	115/75	14	96

HEAT PUMP SIZING FOR HEATING WITH GAS BACKUP

Know Your Capacity Tables







Definitions: Capacity Balance Point

The lowest outdoor temperature at which the output of the heat pump can heat the house.

Below this temperature gas backup is needed to meet the heating load.

Energy costs differ by time of day

Time of Use (TOU) rates now in effect

TOU	Times	Summer rates	Winter rates
On-peak	3 - 7 pm	$0.28/kWh	$0.17/kWh
Mid-peak	1 - 3 pm	$0.19/kWh	$0.14/kWh
Off-peak	7 - 1 pm	$0.10/kWh	$0.10/kWh

Standard rate alternative: $0.13/kWh summer, $0.12/kWh winter

Operating Costs – Xcel Energy CO rates

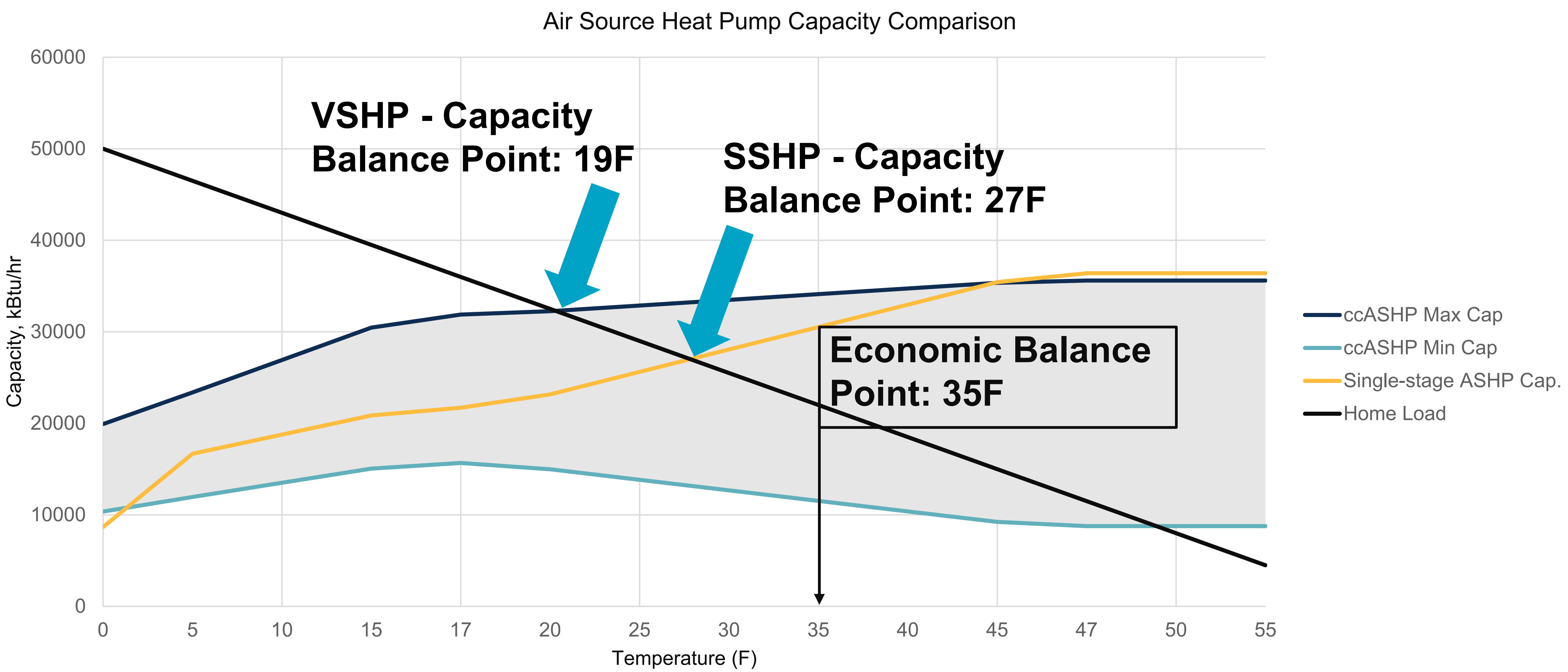
Baseline AC and Furnace or Heat Pump with Varying Switchover Temperatures		Heating and AC Energy Costs	Cost Compar-ison	Heat Pump Heating Hours	AC or ASHP Size in Tons	Carbon Emissions (in Tons)	Carbon Savings Over Baseline (Tons)	% Carbon Reduction
Baseline	~14 SEER AC, 80% AFUE	$ 910			3 ton	5.7		
	~17 SEER AC, 80% AFUE	$ 870	$ (40)		3 ton	5.7	0.0	0%
2-Stage Dual Fuel	45° switchover	$ 880	$ (30)	44%	3 ton	5.1	0.6	11%
	35° switchover	$ 940	$ 30	69%	3 ton	3.8	1.8	32%
	25° switchover	$ 1,010	$ 100	87%	3 ton	2.5	3.2	56%
Variable Capacity (VC) Heat Pump, Dual Fuel	35° switchover	$ 890	$ (20)	69%	3 ton	3.8	1.9	33%
	25° switchover	$ 960	$ 50	87%	3 ton	2.6	3.1	54%
	5° switchover	$ 1,050	$ 140	99%	6 ton*	1.2	4.5	78%
Cold Climate VC Heat Pump, Dual Fuel	25° switchover	$ 910	$ -	87%	3 ton	2.5	3.3	57%
	5° degree switchover	$ 1,000	$ 90	99%	4 ton	1.2	4.5	79%
Cold Climate VC Heat Pump, Elec. Backup	5° w E backup	$ 1,030	$ 120	99%	4 ton	0.99 0.99	4.7	83%

*Not a realistic option. A ccVCHP is recommended

Economic Balance Point (switchover temperature)

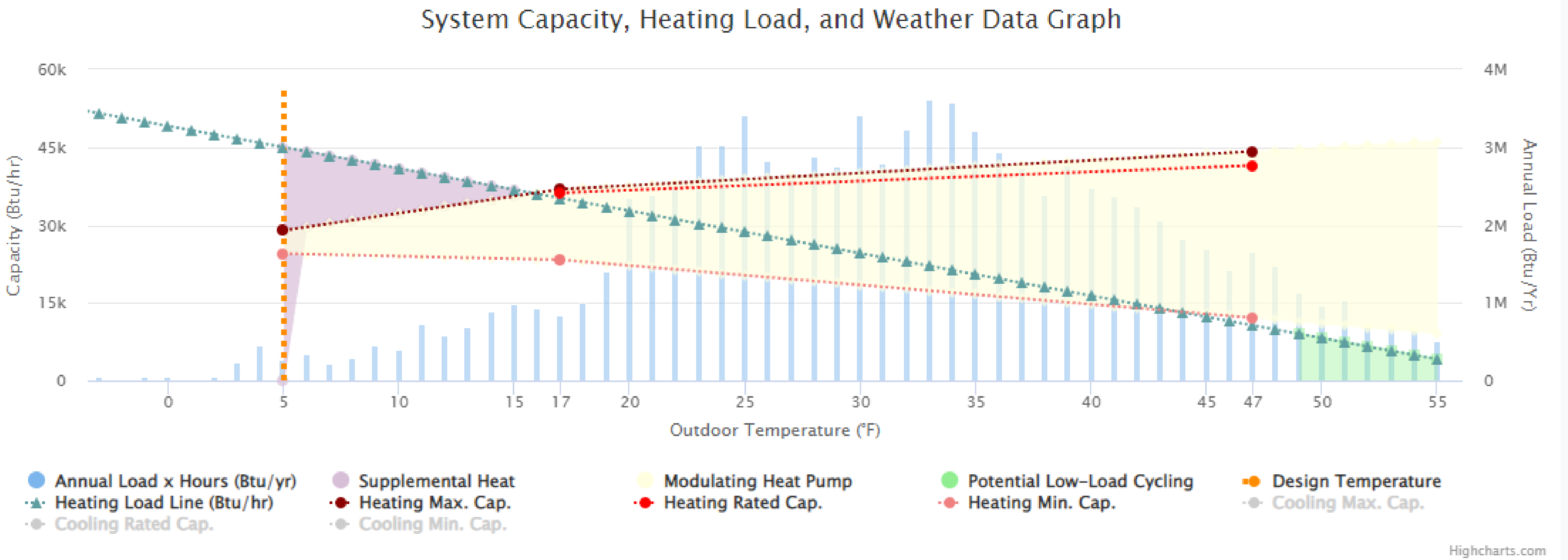
- The lowest temperature at which it is cheaper to heat with the HP compared to the gas furnace
- Use economic considerations to determine balance point, when saving money is their priority
- Based on modeling this is around ~35°F for a typical Denver home

Comparing Capacity, Heating Load, and Economic Balance Point



NEEP Cold-Climate ASHP Product List - ashp.neep.org

- Includes capacity data from manufacturers
- New “advanced data” section
  - HP capacity graph
  - Enter location and design heating load



Setting Switchover Temperature

Ducted dual fuel systems have simple integrated controls

- Use proprietary thermostat when available
- Switchover temperature is controlled through the thermostat
  - Thermostat uses outdoor thermistor or Wi-Fi weather station
- Dual-fuel systems may have capacity failsafe built into controls
  - i.e. if the HP can't meet the load the gas furnace will come on