U.S. Department of Energy
Energy Efficiency and Renewable Energy
Building Technologies Program

Residential Heating and Cooling Loads

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For:
Affordable Comfort Conference
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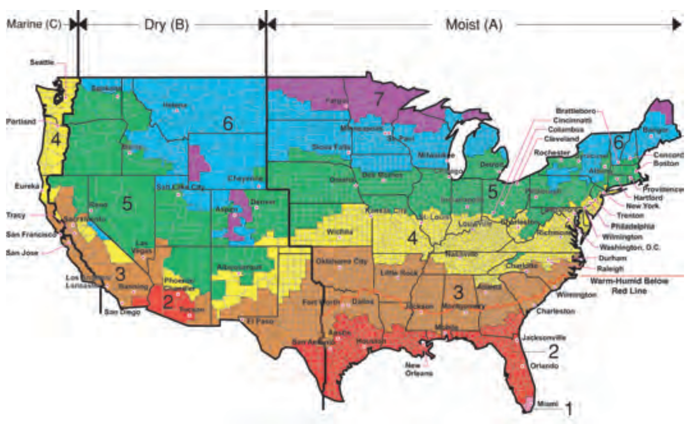
OVERVIEW

- Brief systems engineering introduction
- Discussion of heating and cooling loads by way of examining the system sizing process.



SYSTEM ENGINEERING TRADE-OFFS

- Better Envelopes
  - Allow for reduced cooling system size
  - Decrease energy consumption
  - Increase occupant comfort
  - Make overall performance more predictable
  - Improve the more permanent features of a home which has longer-term sustainability benefits to society

SYSTEM ENGINEERING TRADE-OFFS

- Reduced cooling system size
  - Helps pay for a better envelope
  - Avoids cooling system short-cycling
    - which improves moisture removal
    - allows the system to operate at higher average efficiency

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SYSTEM ENGINEERING TRADE-OFFS

- More efficient systems
  - Are most cost effective when the load is high
    - this is in circular conflict with our premise to first reduce loads through improved envelopes
  - High efficiency cooling systems generally have a higher evaporator coil temperature which reduces moisture removal
    - some of this can be altered with effective control of ECM air handlers

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High performance building envelopes deserve high performance comfort conditioning systems.

Especially for refrigerant based cooling systems, proper sizing and startup procedures are critical.

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Do this before you start

- Builder must commit to these
  1. Building enclosure leakage <= 0.35 cfm50/ft^2 enclosure surface area
  2. Ducts inside conditioned space. or duct leakage <= 5% to outside
  3. Glazing U-value and SHGC <= 0.35
  4. Proper return air provision to assure < 3 Pa pressure differential between rooms to common area

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Room Transfer Air

Room supply cfm	Transfer grille height required for listed width in inches 10 (in)	12 (in)	14 (in)	Jump Duct Diameter (in)
<=100	6	6	4	8
>100 and <=125	8	6	6	8
>125 and <=150	10	8	8	10
>150 and <=175	12	10	8	10
>175 and <=225	14	12	10	12

SYSTEM SIZING SPECIFICATION

- 1. Computer software adhering to ACCA Manual J version 8 will be used to calculate loads for cooling and heating systems.
  - RHVAC from Elite Software (www.elitesoft.com)
  - Right-J from Wrightsoft (www.wrightsoft.com)

SYSTEM SIZING SPECIFICATION

- 2. Duct gain and loss:
  - Best to locate entire air distribution system inside conditioned space, duct gain and loss=zero
  - If not in conditioned space, then air seal with mastic, insulate to R-8 with metalized insulation wrap;
  - Duct gain and loss will be calculated by the software, however, divide the total conditioned floor area used to calculate the duct surface area by two.

SYSTEM SIZING SPECIFICATION

- 3. One appliance will be equal to 600 Btu/h. Put one appliance in the laundry, and two appliances (1200 Btu/h) in the kitchen. If an auxiliary entertainment area (or equivalent space) exists, then put one appliance there.
  - Use Energy Star appliances and electronics, put less heat back into the space

SYSTEM SIZING SPECIFICATION

- 4. Gain from people will be set at 300 Btu/h sensible and 300 Btu/h latent, per person.
  - Could be as low as 230 sensible and 200 latent, but not worth arguing over

SYSTEM SIZING SPECIFICATION

- 5. People will be placed around the house as follows:

Basic house

Total people in house = the number of bedrooms plus 1

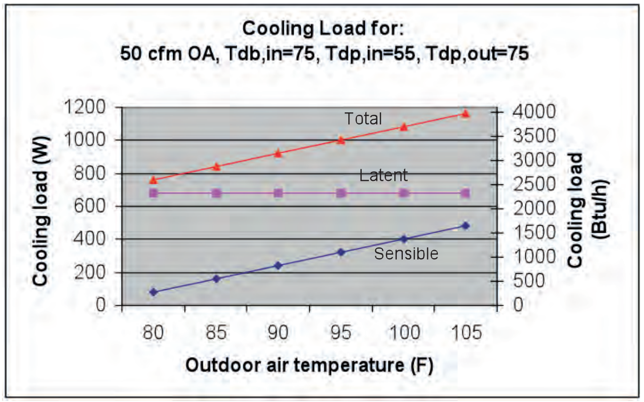
# bedrooms	Total people	People in master bedroom	People in family and/or living room	People in kitchen
2	3	1	2	0
3	4	1	2	1
4	5	1	2	2

SYSTEM SIZING SPECIFICATION

- 6a. Infiltration
  - For houses with tested building enclosure leakage below 0.35 cfm50/ft² CFA set at 0.2 ach summer and 0.3 ach winter.
  - For houses with tested building enclosure leakage below 0.25 cfm50/ft² CFA set at 0.1 ach summer and 0.1 ach winter.
- 6b. Ventilation
  - Set at ASHRAE 62.2 rate both summer and winter.

    $7.5\,(N_{br}+1) + 0.01(A_{floor})$

    50 cfm for 2000 ft² 3 bedroom house



SYSTEM SIZING SPECIFICATION

- 7. Glazing U-value and SHGC must be entered according to the NFRC label for the exact glass being installed (get written confirmation from the purchasing manager).

  U-value and SHGC of less than 0.35 is good

Interior shading will be selected as:

Drapes-medium, 50% drawn, no insect or external shade screens, ground reflectance equal to 0.20 except ground reflectance equal to 0.32 for glass adjacent to concrete areas such as a patio.

Exception: French doors, entry door side glass, and multi-story open-space windows such as used in foyers (not including transom windows) shall have "None" as internal and external shade. Bathroom windows shall have obscured or block glass.

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SYSTEM SIZING SPECIFICATION

- 8. Outdoor design conditions:
  - Heating: set at the Manual J standard value for the closest climate
  - Cooling: set at the ASHRAE 0.4% design for cooling. Indoor cooling design conditions will be set at 75 F drybulb and 63 F wetbulb (50% RH).

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SYSTEM SPECIFICATION

- 10. The building design cooling load shall be calculated for the worst case elevation option at the solar orientation that produces the highest heat gain.

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COOLING SYSTEM SIZING SPECIFICATION

- 11. Equipment selection, Heating
  - Meet design heating load with no more than 50 F temperature rise (supply air – room air). Good target is 110 to 115 F supply air, or 40 to 45 F temperature rise.

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Heating Temperature Rise

Heating setpoint = 70 F

Heating HX temp rise (F)	Heating supply air temp (F)	Heating cfm per kW output	Heating cfm per kBtu/h output	Heating cfm per 12 kBtu/h output	
14	84	222	65	779	
16	86	194	57	682	
18	88	172	51	606	
20	90	155	45	545	
22	92	141	41	496	
24	94	129	38	455	
26	96	119	35	420	
28	98	111	32	390	
30	100	103	30	364	! EGUSA uses 360 cfm/12 kBtu/h, this would be for a heat pump
32	102	97	28	341	
34	104	91	27	321	
36	106	86	25	303	
38	108	82	24	287	
40	110	78	23	273	
42	112	74	22	260	
44	114	71	21	248	! Modern gas furnace
46	116	67	20	237	
48	118	65	19	227	
50	120	62	18	218	
52	122	60	17	210	
54	124	57	17	202	
56	126	55	16	195	! Old scorched air furnaces
58	128	53	16	188	
60	130	52	15	182	

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Heating Temperature Rise

Heating efficiency = 0.78
Heating HX temperature rise = 45 F

Heating system input (kBtu/h)	Heating system output (kBtu/h)	Heating system output (kW)	Heating cfm	Heating cfm/output (cfm/kBtu/h)	Heating cfm/output (cfm/12 kBtu/h)
15	12	3	236	20	242
20	16	5	315	20	242
25	20	6	394	20	242
30	23	7	473	20	242
35	27	8	552	20	242
40	31	9	630	20	242
45	35	10	709	20	242
50	39	11	788	20	242
55	43	13	867	20	242
60	47	14	945	20	242
65	51	15	1024	20	242
70	55	16	1103	20	242
75	59	17	1182	20	242
80	62	18	1261	20	242
85	66	19	1339	20	242
90	70	21	1418	20	242
95	74	22	1497	20	242
100	78	23	1576	20	242
105	82	24	1655	20	242
110	86	25	1733	20	242
115	90	26	1812	20	242
120	94	27	1891	20	242
125	98	29	1970	20	242
130	101	30	2048	20	242

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SYSTEM SIZING SPECIFICATION

- 11. Equipment selection, Cooling
  - Indoor and outdoor coils will be ARI matched
  - The equipment will be selected to meet the design sensible load at the outdoor and indoor design conditions (not ARI standard conditions of 95 outdoor and 80/67 indoor).
    - ARI rating conditions may be very different than actual operating conditions. Extended performance capacity data is important for the designer to properly size the equipment and not resort to common over-sizing habits to compensate for lack of information.
  - Apply 1/2 of the unused latent capacity back to sensible capacity as given by ACCA Manual S.

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SYSTEM SIZING SPECIFICATION

- 11. Equipment selection, Cooling (cont.):

  If the total load (sensible+latent) exceeds the total capacity of the system by more than 600 Btu/h then go to the next larger size.

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58STA/STX, 4-Way Multipoise Induced Combustion Gas Furnace
Input Capacities: 45,000 thru 155,000 Btuh
Product Data

58STA/STX

AIR DELIVERY—CFM (With Filter)*

UNIT SIZE	RETURN-AIR SUPPLY	SPEED	EXTERNAL STATIC PRESSURE (in. wc) 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
045-08	Bottom or Side(s)	High	1085	1035	975	915	845	770	675	565	390	195
		Med-High	920	875	830	770	710	640	555	440	250	—
		Med-Low	820	775	730	680	620	555	470	360	190	—
045-12	Bottom or Side(s)	High	1450	1375	1305	1225	1145	1050	955	845	705	510
		Med-High	1360	1300	1240	1175	1115	1040	950	850	725	575
		Med-Low	1250	1210	1160	1100	1040	965	885	790	670	520
070-08	Bottom or Side(s)	High	1030	1010	980	945	900	845	775	680	490	335
		Med-High	835	815	790	760	720	675	610	490	375	265
		Med-Low	725	700	675	645	600	555	475	390	300	—
070-12	Bottom or Side(s)	High	1425	1375	1320	1265	1200	1125	1035	940	830	685
		Med-High	1320	1280	1240	1205	1140	1075	995	905	790	620
		Med-Low	1200	1175	1145	1105	1050	990	920	840	725	555
070-16	Bottom or Side(s)	High	1805	1740	1670	1600	1530	1445	1360	1260	1180	1075
		Med-High	1630	1585	1530	1470	1405	1330	1255	1170	1080	990
		Med-Low	1460	1420	1385	1325	1280	1220	1155	1080	995	910
090-14	Bottom or Side(s)	High	1650	1600	1535	1465	1385	1285	1175	1055	895	645
		Med-High	1515	1485	1440	1380	1300	1220	1115	990	830	600
		Med-Low	1385	1360	1320	1260	1195	1120	1025	915	710	565
090-16	Bottom or Side(s)	High	2060	1985	1915	1820	1720	1610	1490	1340	1135	925
		Med-High	1790	1765	1715	1645	1560	1470	1345	1195	1010	820
		Med-Low	1505	1505	1480	1440	1375	1300	1190	1045	890	740
090-20	Bottom Only	High	2405	2310	2220	2130	2025	1920	1790	1660	1530	1350
		Med-High	2225	2155	2080	1995	1895	1785	1675	1565	1425	1260
		Med-Low	2020	1955	1880	1805	1730	1630	1535	1420	1275	1135
	Both Sides or 1 Side & Bottom	High	2530	2450	2365	2270	2165	2065	1940	1805	1670	1505
		Med-High	2285	2215	2150	2075	1985	1890	1780	1660	1525	1360
		Med-Low	1995	1945	1900	1840	1770	1665	1600	1480	1350	1180
	1 Side Only	High	2475	2395	2300	2200	2090	1985	1865	1730	1585	1425
		Med-High	2260	2190	2110	2035	1940	1845	1735	1620	1475	1325
		Med-Low	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

DETAILED COOLING CAPACITIES

24ABA4

EVAPORATOR AIR CFM	EWB	75 Total	75 Sens	75 KW**	85 Total	85 Sens	85 KW**	95 Total	95 Sens	95 KW**	105 Total	105 Sens	105 KW**	115 Total	115 Sens	115 KW**	125 Total	125 Sens	125 KW**
24ABA436A30 Outdoor Section With CAP**4221A** Indoor Section																			
1050	72	42.63	22.38	2.35	40.92	21.65	2.63	38.92	20.89	2.94	36.78	20.09	3.29	34.47	19.23	3.68	31.94	18.31	4.12
	67	38.83	27.27	2.35	37.06	26.52	2.63	35.20	25.74	2.94	33.22	24.93	3.29	31.08	24.06	3.68	28.75	23.12	4.12
	62	35.34	32.16	2.35	33.74	31.40	2.63	32.07	30.59	2.94	30.32	29.72	3.29	28.58	28.56	3.68	26.83	26.83	4.12
	57	34.25	34.25	2.35	32.98	32.98	2.63	31.63	31.63	2.94	30.17	30.17	3.29	28.58	28.58	3.68	26.83	26.83	4.12
1200	72	43.06	23.46	2.40	41.67	22.71	2.68	39.58	21.94	2.99	37.38	21.12	3.34	34.96	20.26	3.73	32.30	19.32	4.17
	67	39.58	28.97	2.40	37.74	28.21	2.68	35.85	27.42	2.99	33.76	26.59	3.34	31.55	25.71	3.73	29.14	24.76	4.17
	62	36.18	34.48	2.40	34.56	33.67	2.68	32.87	32.87	2.99	31.35	31.35	3.34	29.67	29.67	3.73	27.80	27.80	4.17
	57	35.72	35.72	2.40	34.36	34.38	2.68	32.91	32.91	2.99	31.36	31.36	3.34	29.67	29.67	3.73	27.80	27.80	4.17
1350	72	44.27	24.46	2.45	42.22	23.70	2.73	40.06	22.91	3.05	37.77	22.09	3.40	35.31	21.21	3.79	32.61	20.26	4.22
	67	40.14	30.57	2.45	38.24	29.80	2.73	36.25	29.01	3.04	34.15	28.17	3.39	31.80	27.28	3.78	29.44	26.29	4.22
	62	36.97	36.59	2.45	35.49	35.49	2.73	33.97	33.97	3.04	32.33	32.33	3.39	30.56	30.56	3.78	28.59	28.59	4.22
	57	36.94	36.94	2.45	35.50	35.50	2.73	33.97	33.97	3.04	32.34	32.34	3.39	30.56	30.56	3.78	28.60	28.60	4.22

Column groups: CONDENSER ENTERING AIR TEMPERATURES deg F (75, 85, 95, 105, 115, 125); each with Capacity MBtuh† (Total, Sens) and Total System KW**.

Multipliers for determining the performance with other indoor sections

Cooling Indoor Model	Capacity	Power	Furnace Model
*CAP**4221A**	1.00	1.00	
CAP**3614A**	0.98	0.98	
CAP**3617A**	0.99	0.99	
CAP**3621A**	0.99	0.99	
CAP**4224A**	1.00	1.00	
CNPF*3618A**	0.99	0.99	
CNPH*3617A**	0.99	0.99	
CNPH*4221A**	1.00	1.00	
CNPV*3617A**	0.99	0.99	

Carrier	model
indoor furnace	58STA070-1216
outdoor condenser	24ABA430A300
cooling coil	CNPHP3017A

Detailed cooling capaciti es

		Sensible cooling capacity (kBtu/h) at condenser entering temp (F)			apply 0.99 coil correcti on factor	Final Sensible Capacity [1]adjust from 80 F indoors to 75 F indoors	BSC sens load calc	over/under	
		table	design	table				(kBtu/h)	(%)
cfm	ewb	95	97	105					
1050	67	20.87	20.74	20.23	20.53	16.56	20.001	-3.44	-17.2
1050	62	24.87	24.73	24.19	24.49	20.51			
1200	67	22.25	22.12	21.61	21.90	18.42			
1200	62	26.73	26.49	25.55	26.23	22.75			

[1]Note from Carrier literature:

Sensible capaciti es shown [in Detailed Cooling Capaciti es] are based on 80_F (27_C) entering air at the indoor coil. For sensible capaciti es at other than 80_F (27_C), deduct 835 Btuh (245 kW) per 1000 CFM (480 L/S) of indoor coil air for each degree below 80_F (27_C), or add 835 Btuh (245 kW) per 1000 CFM (480 L/S) of indoor coil air per degree above 80_F (27_C)

24ABA4
CHARGING SUBCOOLING (TXV--TYPE EXPANSION DEVICE)

UNIT SIZE---SERIES	REQUIRED SUBCOOLING (F)
18---30	10
24---30	11
30---30	8
36---30	10
42---30	12
48---30	9
60---30	9

Table 2: Target Temperature Split (Return Dry-Bulb – Supply Dry-Bulb)

Return Air Dry-Bulb (ºF) ($T_{return, db}$) \ Return Air Wet-Bulb (ºF) ($T_{return, wb}$)	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
70	20.9	20.7	20.6	20.4	20.1	19.9	19.5	19.1	18.7	18.2	17.7	17.2	16.5	15.9	15.2	14.4	13.7	12.8	11.9	11.0	10.0	9.0	7.9	6.8	5.7	4.5	3.2
71	21.4	21.3	21.1	20.9	20.7	20.4	20.1	19.7	19.3	18.8	18.3	17.7	17.1	16.4	15.7	15.0	14.2	13.4	12.5	11.5	10.6	9.5	8.5	7.4	6.2	5.0	3.8
72	21.9	21.8	21.7	21.5	21.2	20.9	20.6	20.2	19.8	19.3	18.8	18.2	17.6	17.0	16.3	15.5	14.7	13.9	13.0	12.1	11.1	10.1	9.0	7.9	6.8	5.6	4.3
73	22.5	22.4	22.2	22.0	21.8	21.5	21.2	20.8	20.3	19.9	19.4	18.8	18.2	17.5	16.8	16.1	15.3	14.4	13.6	12.6	11.7	10.6	9.6	8.5	7.3	6.1	4.8
74	23.0	22.9	22.8	22.6	22.3	22.0	21.7	21.3	20.9	20.4	19.9	19.3	18.7	18.1	17.4	16.6	15.8	15.0	14.1	13.2	12.2	11.2	10.1	9.0	7.8	6.6	5.4
75	23.6	23.5	23.3	23.1	22.9	22.6	22.2	21.9	21.4	21.0	20.4	19.9	19.3	18.6	17.9	17.2	16.4	15.5	14.7	13.7	12.7	11.7	10.7	9.5	8.4	7.2	5.9
76	24.1	24.0	23.9	23.7	23.4	23.1	22.8	22.4	22.0	21.5	21.0	20.4	19.8	19.2	18.5	17.7	16.9	16.1	15.2	14.3	13.3	12.3	11.2	10.1	8.9	7.7	6.5
77	-	24.6	24.4	24.2	24.0	23.7	23.3	22.9	22.5	22.0	21.5	21.0	20.4	19.7	19.0	18.3	17.5	16.6	15.7	14.8	13.8	12.8	11.7	10.6	9.5	8.3	7.0
78	-	-	-	24.7	24.5	24.2	23.9	23.5	23.1	22.6	22.1	21.5	20.9	20.2	19.5	18.8	18.0	17.2	16.3	15.4	14.4	13.4	12.3	11.2	10.0	8.8	7.6
79	-	-	-	-	-	24.8	24.4	24.0	23.6	23.1	22.6	22.1	21.4	20.8	20.1	19.3	18.5	17.7	16.8	15.9	14.9	13.9	12.8	11.7	10.6	9.4	8.1
80	-	-	-	-	-	-	25.0	24.6	24.2	23.7	23.2	22.6	22.0	21.3	20.6	19.9	19.1	18.3	17.4	16.4	15.5	14.4	13.4	12.3	11.1	9.9	8.7
81	-	-	-	-	-	-	-	25.1	24.7	24.2	23.7	23.1	22.5	21.9	21.2	20.4	19.6	18.8	17.9	17.0	16.0	15.0	13.9	12.8	11.7	10.4	9.2
82	-	-	-	-	-	-	-	-	25.2	24.8	24.2	23.7	23.1	22.4	21.7	21.0	20.2	19.3	18.5	17.5	16.6	15.5	14.5	13.4	12.2	11.0	9.7
83	-	-	-	-	-	-	-	-	-	25.3	24.8	24.2	23.6	23.0	22.3	21.5	20.7	19.9	19.0	18.1	17.1	16.1	15.0	13.9	12.7	11.5	10.3
84	-	-	-	-	-	-	-	-	-	25.9	25.3	24.8	24.2	23.5	22.8	22.1	21.3	20.4	19.5	18.6	17.6	16.6	15.6	14.4	13.3	12.1	10.8

source: California Energy Commission report 2001

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