Sizing and Startup Procedures for Cooling Systems

by

Armin Rudd

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Production homebuilder partners:

Pulte, Centex, Del Webb, KB, Artistic, T&C, Sturbridge

High performance building envelopes deserve high performance comfort conditioning systems.

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

Main Outline

- **Cooling system sizing procedures**
  - entire system and room-by-room flows
- **Duct and transfer air sizing procedures**
  - supply and return plenums
  - duct run-outs
  - transfer grilles and jump ducts
- **Refrigeration system set and startup procedures**
  - line-set install, connecting units, leak testing
  - evacuation, charging, checking charge and airflow

Cooling system sizing procedures: Entire system

- **Computerized ACCA Manual J approach**
  - Elite Software - RHVAC
  - Wrightsoft - Right J
  - others

  - need to handle especially carefully:
    - infiltration
    - ventilation
    - glazing, conversion of SHGC to SC $SHGC = 0.86\ SC$
    - temperature swing multiplier

Intermittent Ventilation Operation

- Sizing
  - intermittent flow equals constant flow reduced by low background infiltration amount when blower is not on, all divided by duty cycle fraction

$$\dot{Q}_{in} = \frac{(\dot{Q}_{co}) - (\frac{I}{60} V (1 - f))}{f}$$

Central-fan-integrated supply ventilation

Outside air duct (filtered) connected to return filter grille pan

October 2001

Cooling system sizing procedures: Entire system (cont.)

- Complete house model with front facing north, then rotate front of house to east, south, and west
- Size system to 100% of total load at worst orientation for subdivisions
- Choose equipment so that total cooling capacity matches the total cooling load at the outdoor design temperature
  - nominal ratings are for 95 F outdoor temperature
  - most unused latent capacity converts to sensible

Cooling system sizing procedures: Room-by-room air flow

- For any given subdivision model, average the computed cfm's for each room across all four cardinal orientations
    - This gives maximum flexibility to balance flows from the middle rather than the extremes
- Choose supply registers that have multiple adjustable curved blades in front to direct air flow, and flat blades with a single-lever control in back to balance flow

Duct sizing

- **Using the computerized ACCA Manual J approach, apply the following air velocity constraints to get appropriate duct sizing:**
  - **supply plenum: max 750 ft/min**
  - **supply run-outs: max 500 ft/min**
  - **return grille: max 350 ft/min (use 80% free area or actual)**
  - **return duct: max 500 ft/min**

$$A = \frac{\dot{Q}}{v ? f}$$

where : A = area, ft^2

$\dot{Q}$ = volumetric flow, ft^3/min

v = air speed, ft/min

f = free area fraction

Pulte Houston, Creek Bend, Manual J system sizing and duct sizing results

Plan 4244

	Orientation of Front of House									
	N	NE	E	SE	S	SW	W	NW	max	avg
	RHVAC program output									
Heating Load (kBtu/h)	27.9									**BSC**
Sensible Cooling Load (kBtu/h)	26.0		28.2		25.5		28.3			**Spec**
Latent Cooling Load (kBtu/h)	3.7		3.7		3.7		3.7			
Total Cooling Load (kBtu/h)	29.8		32.0		29.2		32.0		32.0	30.8	3.0 ton
Room Air Flow (cfm)										
Foyer	75		103		83		103		103	91	
Dining	75		112		86		112		112	96	
Kitchen	89		80		89		76		89	84	
Breakfast	128		123		122		118		128	123	
Great Room	165		215		143		215		215	185	
Master Bedrm	138		178		121		178		178	154	
Master Bath	39		22		39		27		39	32	
Master Closet	13		13		13		13		13	13	
Laundry	14		14		14		14		14	14	
Game Rm	58		75		63		75		75	68	
Bedrm 2	75		61		75		55		75	67	
Hall, 2nd	21		21		21		21		21	21	
Bath 2	35		49		29		49		49	41	
Bedrm 3	77		57		77		63		77	69	
Bedrm 4	75		56		75		62		75	67	
Bedrm 4 Closet	10		10		10		10		10	10	

Main supply trunk (minimum cross section): 18x16

Supply Duct Diameter (in)	RHVAC program output				BSC Spec
Foyer	1-6	1-7	1-6	1-7	1-7
Dining	1-6	1-7	1-6	1-7	1-7
Kitchen	1-6	1-6	1-6	1-6	1-6
Breakfast	1-7	1-7	1-7	1-7	1-7
Great Room	2-6	2-7	1-8	2-7	2-7
Master Bedrm	1-8	2-6	1-7	2-6	2-6
Master Bath	1-4	1-4	1-4	1-4	1-4
Master Closet	1-4	1-4	1-4	1-4	1-4
Laundry	1-4	1-4	1-4	1-4	1-4
Game Rm	1-5	1-6	1-5	1-6	1-6
Bedrm 2	1-6	1-5	1-6	1-5	1-6
Hall, 2nd	1-4	1-4	1-4	1-4	1-4
Bath 2	1-4	1-5	1-4	1-5	1-5
Bedrm 3	1-6	1-5	1-6	1-5	1-6
Bedrm 4	1-6	1-5	1-6	1-5	1-6
Bedrm 4 Closet	1-4	1-4	1-4	1-4	1-4

Transfer duct/grille sizing

- **Calculate free area required to get proper transfer air flow to avoid more than 3 Pa pressurization**

$$A = \frac{\dot{Q}}{1.07\sqrt{3}} = \frac{\dot{Q}}{1.853}$$

where: A = area in square inches

$\dot{Q}$ = air flow rate (ft^3/min)

- **For jump ducts, don't use less than 6" diameter, most master suites will need 10" to 12" diameter**

Pulte Houston, Creek Bend, Transfer Area and Jump Duct sizing results

Plan 4244

Air Transfer Free Area (in ^{2})

	Orientation of Front of House									
	N	NE	E	SE	S	SW	W	NW	max	avg
Foyer										
Dining										
Kitchen										
Breakfast										
Great Room										
Master Bedrm	87		99		77		102		102	91
Master Bath										
Master Closet										
Laundry										
Game Rm	15		24		18		24		24	21
Bedrm 2	24		17		24		14		24	20
Hall, 2nd										
Bath 2										
Bedrm 3	26		15		26		18		26	21
Bedrm 4	24		14		24		17		24	20
Bedrm 4 Closet										

Jump Duct Diameter (in)

										BSC Spec
Foyer										
Dining										
Kitchen										
Breakfast										
Great Room										
Master Bedrm	10		11		10		11		11	11	10
Master Bath										
Master Closet										
Laundry										
Game Rm	4		6		5		6		6	5	6
Bedrm 2	6		5		6		4		6	5	6
Hall, 2nd										
Bath 2										
Bedrm 3	6		4		6		5		6	5	6
Bedrm 4	6		4		6		5		6	5	6
Bedrm 4 Closet										

Refrigeration system set and startup procedures

1 **The refrigerant grade copper line set should not be left open to the atmosphere to collect contaminants. Cap it off at rough-in and fill with dry nitrogen to 125 psi.**

Refrigeration system set and startup procedures

1. The line set should not be left open to the atmosphere to collect contaminants. Cap it off at rough-in and fill with dry nitrogen to 125 psi.
2. Make sure a filter/dryer is installed in the liquid line (bi-directional for heat pumps)
3. Using a silver/phosphorus/copper alloy, with between 5% and 15% silver, braze refrigerant line set to the indoor and outdoor units with nitrogen flowing inside tube
4. Check quality of joints visually, then check for leaks by pressurizing the system with between 125 and 150 psi

Refrigeration system set and startup procedures, cont.

5 **Connect the manifold gauges, micron gauge, vacuum pump. Release the nitrogen charge and begin evacuation. A 2-stage pump is required.**

6 **Evacuate to 300 microns or less. Isolate the vacuum pump and observe pressure change on the micron gauge. If the micron gauge reading drifts above 700, run the vacuum pump for another 15 minutes and repeat the process.**

BOILING TEMPERATURES OF WATER AT CONVERTED PRESSURES

Temperature in °F.	Inches of Mercury	Pounds Sq. In. (Pressure)	Microns*
212°	29.92	14.696	759,968
205°	25.00	12.279	635,000
194°	20.69	10.162	525,526
176°	13.98	6.866	355,092
158°	9.20	4.519	233,680
140°	5.88	2.888	149,352
122°	3.64	1.788	92,456
104°	2.17	1.066	55,118
86°	1.25	.614	35,560
80°	1.00	.491	25,400
76°	.90	.442	22,860
72°	.80	.393	20,320
69°	.70	.344	17,780
64°	.60	.295	15,240
59°	.50	.246	12,700
53°	.40	.196	10,160
45°	.30	.147	7,620
32°	.18	.088	4,572
21°	.10	.049	2,540
6°	.05	.0245	1,270
—24°	.01	.0049	254
—35°	.005	.00245	127
—60°	.001	.00049	25.4
—70°	.0005	.00024	12.7
—90°	.0001	.000049	2.54

Remaining pressure in system in microns

1.000 inch = 25,400 microns = 2.540 CM = 25.40 MM
.100 inch = 2,540 microns = .254 CM = 2.54 MM
.039 inch = 1,000 microns = .100 CM = 1.00 MM

Refrigeration system set and startup procedures, cont.

7 **With the system in a vacuum, if the line set length is greater than the default length that the manufacturer pre-charged the condenser for, add refrigerant by weight to account for the actual line set according to the manufacturers specification for the tube diameter.**

- **A digital refrigerant scale with resolution of at least 1/2 ounce is required**

8 **Release the refrigerant charge from the condenser into the line set and evaporator**

Refrigeration system set and startup procedures, cont.

9 **If the line set length is less than the default length that the manufacturer pre-charged the condenser for, then remove refrigerant to account for the actual line set length according to the manufacturers specification.**

- **A digital refrigerant scale with resolution of at least 1/2 ounce is required**

10 **Start the system and run for at least 15 minutes**

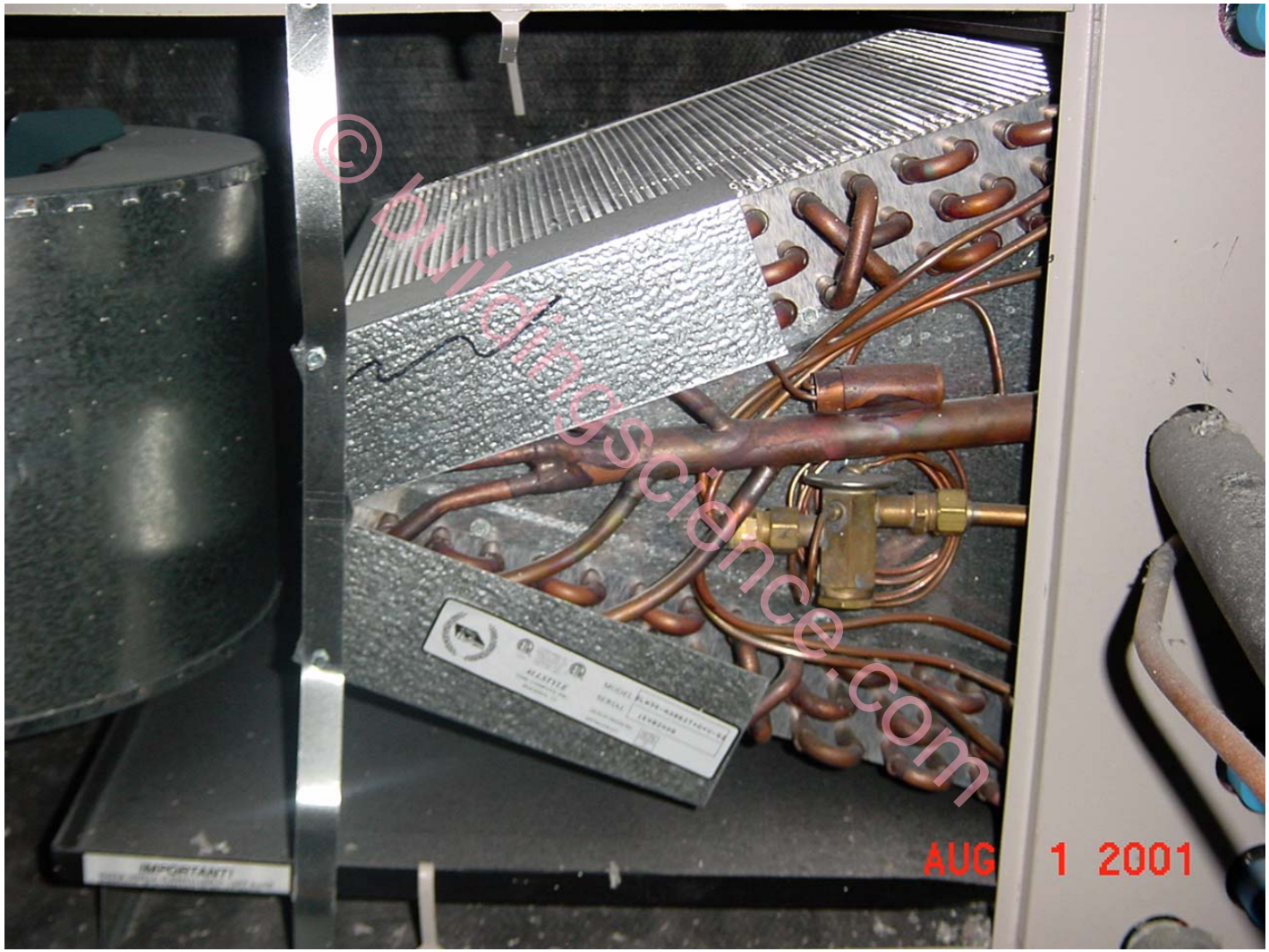
Refrigeration system set and startup procedures, cont.

11 Check for proper sub-cooling for TXV (thermal expansion valve) systems.

The required sub-cooling is specified by the manufacturer and is usually 5 - 15 F. It is not dependent on inside or outside environmental conditions.

Adjust refrigerant charge as necessary.

Thermal expansion valve (TXV) refrigerant metering device



Refrigeration system set and startup procedures, cont.

12 If indoor and outdoor environmental conditions are favorable, check for proper superheat for capillary tube and accurator/piston systems. Superheat is dependent on inside and outside environmental conditions.

If the target superheat is > 5 F, adjust refrigerant charge as necessary.

Table 1: Target Superheat (Suction Line Temperature - Evaporator Saturation Temperature)

Condenser Air Dry-Bulb Temperature (°F) ($T_{condenser, db}$)	Return Air Wet-Bulb Temperature (°F) ($T_{return, wb}$)																												
	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
55	8.8	10.1	11.5	12.8	14.2	15.6	17.1	18.5	20.0	21.5	23.1	24.6	26.2	27.8	29.4	31.0	32.4	33.8	35.1	36.4	37.7	39.0	40.2	41.5	42.7	43.9	45.0
56	8.6	9.9	11.2	12.6	14.0	15.4	16.8	18.2	19.7	21.2	22.7	24.2	25.7	27.3	28.9	30.5	31.8	33.2	34.6	35.9	37.2	38.5	39.7	41.0	42.2	43.4	44.6
57	8.3	9.6	11.0	12.3	13.7	15.1	16.5	17.9	19.4	20.8	22.3	23.8	25.3	26.8	28.3	29.9	31.3	32.6	34.0	35.3	36.7	38.0	39.2	40.5	41.7	43.0	44.2
58	7.9	9.3	10.6	12.0	13.4	14.8	16.2	17.6	19.0	20.4	21.9	23.3	24.8	26.3	27.8	29.3	30.7	32.1	33.5	34.8	36.1	37.5	38.7	40.0	41.3	42.5	43.7
59	7.5	8.9	10.2	11.6	13.0	14.4	15.8	17.2	18.6	20.0	21.4	22.9	24.3	25.7	27.2	28.7	30.1	31.5	32.9	34.3	35.6	36.9	38.3	39.5	40.8	42.1	43.3
60	7.0	8.4	9.8	11.2	12.6	14.0	15.4	16.8	18.2	19.6	21.0	22.4	23.8	25.2	26.6	28.1	29.6	31.0	32.4	33.7	35.1	36.4	37.8	39.1	40.4	41.6	42.9
61	6.5	7.9	9.3	10.7	12.1	13.5	14.9	16.3	17.7	19.1	20.5	21.9	23.3	24.7	26.1	27.5	29.0	30.4	31.8	33.2	34.6	35.9	37.3	38.6	39.9	41.2	42.4
62	6.0	7.4	8.8	10.2	11.7	13.1	14.5	15.9	17.3	18.7	20.1	21.4	22.8	24.2	25.5	27.0	28.4	29.9	31.3	32.7	34.1	35.4	36.8	38.1	39.4	40.7	42.0
63	5.3	6.8	8.3	9.7	11.1	12.6	14.0	15.4	16.8	18.2	19.6	20.9	22.3	23.6	25.0	26.4	27.8	29.3	30.7	32.2	33.6	34.9	36.3	37.7	39.0	40.3	41.6
64	-	6.1	7.6	9.1	10.6	12.0	13.5	14.9	16.3	17.7	19.0	20.4	21.7	23.1	24.4	25.8	27.3	28.7	30.2	31.6	33.0	34.4	35.8	37.2	38.5	39.9	41.2
65	-	5.4	7.0	8.5	10.0	11.5	12.9	14.3	15.8	17.1	18.5	19.9	21.2	22.5	23.8	25.2	26.7	28.2	29.7	31.1	32.5	33.9	35.3	36.7	38.1	39.4	40.8
66	-		6.3	7.8	9.3	10.8	12.3	13.8	15.2	16.6	18.0	19.3	20.7	22.0	23.2	24.6	26.1	27.6	29.1	30.6	32.0	33.4	34.9	36.3	37.6	39.0	40.4
67	-	-	5.5	7.1	8.7	10.2	11.7	13.2	14.6	16.0	17.4	18.8	20.1	21.4	22.7	24.1	25.6	27.1	28.6	30.1	31.5	33.0	34.4	35.8	37.2	38.6	39.9
68	-	-	-	6.3	8.0	9.5	11.1	12.6	14.0	15.5	16.8	18.2	19.5	20.8	22.1	23.5	25.0	26.5	28.0	29.5	31.0	32.5	33.9	35.3	36.8	38.1	39.5
69	-	-	-	5.5	7.2	8.8	10.4	11.9	13.4	14.8	16.3	17.6	19.0	20.3	21.5	22.9	24.4	26.0	27.5	29.0	30.5	32.0	33.4	34.9	36.3	37.7	39.1
70	-	-	-	-	6.4	8.1	9.7	11.2	12.7	14.2	15.7	17.0	18.4	19.7	20.9	22.3	23.9	25.4	27.0	28.5	30.0	31.5	33.0	34.4	35.9	37.3	38.7
71	-	-	-	-	5.6	7.3	8.9	10.5	12.1	13.6	15.0	16.4	17.8	19.1	20.3	21.7	23.3	24.9	26.4	28.0	29.5	31.0	32.5	34.0	35.4	36.9	38.3
72	-	-	-	-	-	6.4	8.1	9.8	11.4	12.9	14.4	15.8	17.2	18.5	19.7	21.2	22.8	24.3	25.9	27.4	29.0	30.5	32.0	33.5	35.0	36.5	37.9
73	-	-	-	-	-	5.6	7.3	9.0	10.7	12.2	13.7	15.2	16.6	17.9	19.2	20.6	22.2	23.8	25.4	26.9	28.5	30.0	31.5	33.1	34.6	36.0	37.5
74	-	-	-	-	-	-	6.5	8.2	9.9	11.5	13.1	14.5	15.9	17.3	18.6	20.0	21.6	23.2	24.8	26.4	28.0	29.5	31.1	32.6	34.1	35.6	37.1
75	-	-	-	-	-	-	5.6	7.4	9.2	10.8	12.4	13.9	15.3	16.7	18.0	19.4	21.1	22.7	24.3	25.9	27.5	29.1	30.6	32.2	33.7	35.2	36.7
76	-	-	-	-	-	-	-	6.6	8.4	10.1	11.7	13.2	14.7	16.1	17.4	18.9	20.5	22.1	23.8	25.4	27.0	28.6	30.1	31.7	33.3	34.8	36.3
77	-	-	-	-	-	-	-	5.7	7.5	9.3	11.0	12.5	14.0	15.4	16.8	18.3	20.0	21.6	23.2	24.9	26.5	28.1	29.7	31.3	32.8	34.4	36.0
78	-	-	-	-	-	-	-	-	6.7	8.5	10.2	11.8	13.4	14.8	16.2	17.7	19.4	21.1	22.7	24.4	26.0	27.6	29.2	30.8	32.4	34.0	35.6
79	-	-	-	-	-	-	-	-	5.9	7.7	9.5	11.1	12.7	14.2	15.6	17.1	18.8	20.5	22.2	23.8	25.5	27.1	28.8	30.4	32.0	33.6	35.2
80	-	-	-	-	-	-	-	-	-	6.9	8.7	10.4	12.0	13.5	15.0	16.6	18.3	20.0	21.7	23.3	25.0	26.7	28.3	29.9	31.6	33.2	34.8
81	-	-	-	-	-	-	-	-	-	6.0	7.9	9.7	11.3	12.9	14.3	16.0	17.7	19.4	21.1	22.8	24.5	26.2	27.9	29.5	31.2	32.8	34.4
82	-	-	-	-	-	-	-	-	-	5.2	7.1	8.9	10.6	12.2	13.7	15.4	17.2	18.9	20.6	22.3	24.0	25.7	27.4	29.1	30.7	32.4	34.0
83	-	-	-	-	-	-	-	-	-	-	6.3	8.2	9.9	11.6	13.1	14.9	16.6	18.4	20.1	21.8	23.5	25.2	26.9	28.6	30.3	32.0	33.7
84	-	-	-	-	-	-	-	-	-	-	5.5	7.4	9.2	10.9	12.5	14.3	16.1	17.8	19.6	21.3	23.0	24.8	26.5	28.2	29.9	31.6	33.3
85	-	-	-	-	-	-	-	-	-	-	-	6.6	8.5	10.3	11.9	13.7	15.5	17.3	19.0	20.8	22.6	24.3	26.0	27.8	29.5	31.2	32.9
86	-	-	-	-	-	-	-	-	-	-	-	5.8	7.8	9.6	11.3	13.2	15.0	16.7	18.5	20.3	22.1	23.8	25.6	27.3	29.1	30.8	32.6
87	-	-	-	-	-	-	-	-	-	-	-	5.0	7.0	8.9	10.6	12.6	14.4	16.2	18.0	19.8	21.6	23.4	25.1	26.9	28.7	30.4	32.2
88	-	-	-	-	-	-	-	-	-	-	-	-	6.3	8.2	10.0	12.0	13.9	15.7	17.5	19.3	21.1	22.9	24.7	26.5	28.3	30.1	31.8
89	-	-	-	-	-	-	-	-	-	-	-	-	5.5	7.5	9.4	11.5	13.3	15.1	17.0	18.8	20.6	22.4	24.3	26.1	27.9	29.7	31.5
90	-	-	-	-	-	-	-	-	-	-	-	-	-	6.8	8.8	10.9	12.8	14.6	16.5	18.3	20.1	22.0	23.8	25.6	27.5	29.3	31.1

Refrigeration system set and startup procedures, cont.

13 Check for proper temperature drop across the evaporator coil (varies with return air dry bulb and wet bulb temperature, usually 15 - 25 F).

Check static pressures in the supply and return plenums (max 125 Pa differential across blower).

Correct for any airflow problems/restrictions as necessary.

Refrigeration system set and startup procedures, cont.

According to the best engineering data available, the performance loss using a TXV metering device is about 5% if the refrigerant charge is off by plus or minus 20%.

The performance loss using a fixed metering device (capillary tube or accurator) is about 15% to 20% if the refrigerant charge is off by plus or minus 20%.

Therefore, TXV systems are best, however, by following the installation procedure listed above, the refrigerant charge should be within about 5% every time, limiting the performance loss to about 5%.

Additional Resources

- "Just the facts," Thermal Engineering Company, Toledo, OH
- "Fundamentals of dehydrating a refrigerant system," Robinair Manufacturing Corp., Montpelier, OH
- "Influence of the expansion device on air-conditioner system performance characteristics under a range of charging conditions," Farzad and O'Neal, ASHRAE Transactions 1993, V. 99, Pt. 1.
- "Residential cooling load calculation methods analysis," Proctor Engineering Group.
- "Soldering and brazing copper tube," Copper Development Association Inc.
- "Three refrigerant states," Wheeler, Contracting Business, Dec 1989.
- "Split system space cooling refrigerant charge and air flow measurement," California Energy Commission, Contractor's Report, #P 400-01-014, http://www.energy.ca.gov/reports.