Reviewing HVAC Designs for Compliance with ACCA Manual S

by Wes Davis

An approved code change to the 2009 *International Residential Code* (IRC) clarifies an existing requirement for sizing HVAC equipment: "Heating and cooling equipment shall be sized *in accordance with ACCA Manual S* based on building loads calculated in accordance with ACCA Manual J or other approved heating and cooling calculation methodologies" (emphasis added).

Air Conditioning Contractors of America (ACCA) Manual S, *Residential Heating and Cooling Equipment Selection,* provides clear instructions for interpreting and applying original equipment manufacturer (OEM) expanded performance data to select equipment that meets application requirements (heating, sensible cooling or latent cooling) for the applied design conditions used to calculate loads with ACCA Manual J, *Residential Load Calculation*. It also provides the methodology for identifying the blower airflow design value, in cubic feet per minute (cfm), which is subsequently used per IRC Section 1601.1 with ACCA Manual D, *Residential Duct Systems*, to calculate duct sizing.

In addition, Manual S sets equipment sizing limits, as summarized in Table 1. These sizing limits ensure

Table 1. Manual S equipment selection sizing limitations.

Equipment	Sizing Limitations	Reference (section)
Furnaces	100–140% of total heating load	2-2
boilers	100–140% of total heating load	2-2
air conditioners	115% of total cooling load*	3-4
heat pumps	115%[1] or 125%[2] of total cooling load*	4-4
supplemental heat (heat pumps)		
electric	based on equipment balance point	4-8
dual fuel	100–140% of total heating load	6-8
emergency heat (heat pumps)	based on local codes	4-9

1. Heat pumps in a cooling dominant climate are allowed to be 115% of the cooling level.
2. Heat pumps in a heating dominant climate are allowed to be 125% of the cooling level.

*The size of the cooling equipment must be based on the same temperature and humidity conditions that were used to calculate the Manual J loads.

that equipment capacities meet the minimum needs of occupants while preventing the problems associated with oversizing.[1]

How to Apply Manual S

Heating, Part One

Manual J heating load calculations produce values, in British thermal units per hour (BTU/h), for selecting HVAC equipment.

Take for example a home that requires a minimum of 56,000 Btu/h of heat to maintain an indoor temperature of 70°F when the outdoor temperature drops in the winter. Based on the sizing limitations (100%–140% of heating load), the furnace must have a capacity between 56,000 Btu/h and 78,400 Btu/h (140% x 56,000). Per the manufacturer's product data given in Figure 1, XYZ model FR 80-036—with an output capacity of 64,000 Btu/h—meets the requirement. Model FR 80-024 does not meet the minimum design temperature, while FR 125-036 has too much output capacity.

Cooling

The cooling loads given in Manual J for the example home are: total cooling = 30,000 Btu/h, sensible cooling = 22,000 Btu/h and latent cooling = 8,000 Btu/h. Based on the Manual S sizing limitations (100%—115% of the cooling load), the air conditioner must have a capacity between 30,000 Btu/h and 34,500 Btu/h (115% x 30,000).

Table 2. Manual D input for design air flow.

Mode of Operation	Requirement	Reference (section)
heating	temperature rise requirement	2-6
cooling	air flow associated with the selected equipment's capacity	3-11

Table 3. Example cooling design conditions.

Indoor Conditions			Outdoor Conditions
design temperature	relative design humidity	indoor wet-bulb temperature (at 75°F and 50% Rh)	design temperature
75°F	50% Rh	63°F wet-bulb	95°F

When selecting cooling equipment, it is necessary to know the design conditions used to calculate the cooling load. Unlike heating equipment, cooling equipment OEM data offers a range of performance at different outdoor and indoor conditions. The design conditions for the example home are given in Table 3.

Figures 2 and 3 provide OEM expanded performance data for two air conditioners: a 2.5-ton capacity model and a 3.0-ton capacity model. Manufacturers may present this data in a different format, but all should include airflow, entering air wet-bulb temperature,[2] outdoor temperature, and cooling capacities (usually, total and sensible capacities). Note that a slightly different approach is employed when using Manual S to verify cooling equipment selection than to select the equipment. Verification begins by considering the outdoor air temperature and indoor wet-bulb temperature.

The 2.5-ton air conditioner seems like a natural choice for a home with a 30,000 Btu/h cooling load because a 2.5-ton unit has a nominal capacity of 30,000 Btu/h. However, the OEM data for XYZ model AC-30 reveals that the unit does not meet the Manual S total cooling capacity requirement at the design 95°F outdoor temperature and 63°F entering wet-bulb temperature. In contrast, according to the OEM data, XYZ model AC-36 has enough total cooling capacity (31,510 Btu/h) without exceeding the 115-percent limit (34,500 Btu/h). The system's sensible cooling capacity (23,000 Btu/h) also meets the sensible cooling load (22,000 Btu/h) and the latent capacity (total capacity – sensible capacity = latent capacity 8,510 Btu/h) meets the latent load (8,000 Btu/h).

Another critical design element is the volume of air that must flow over the indoor air conditioner coil to achieve the required cooling capacities.[3] The furnace manufacturer will provide blower performance data indicating the air flow that the unit can deliver at different levels of resistance. Referring to the fan performance data given in Figure 4 for XYZ model FR 80-036 (1,035 cfm at 0.60 inches water column [iwc], interpolated to 1,050 cfm at 0.58 iwc), the furnace can deliver the airflow required per ACCA Manual D.

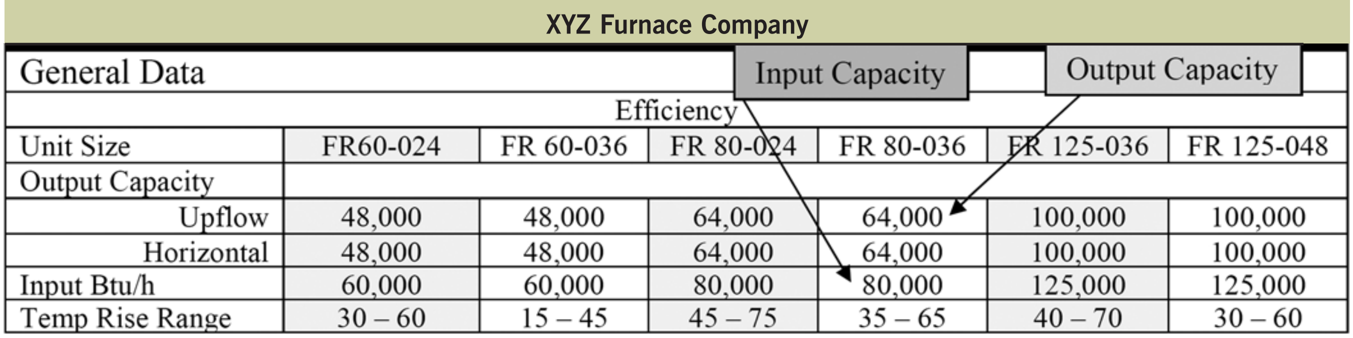
Heating, Part Two

Given the duct design value of 1,050 cfm, the final hurdle is to determine if the unit selection meets the furnace requirements for temperature rise. Referring back to Figure 1, the XYZ model FR 80-036 furnace has an OEM

Sensible and Latent Loads

There are two aspects to the consideration of cooling load: sensible and latent loads. The sensible load is the heat that is measured by a thermometer or a thermostat. This is the "dry" heat one consciously feels. The latent load is the heat associated with airborne moisture as measured by a hygrometer or humidistat.

When you enter a home whose thermostat shows a cool temperature but which has high latent heat—or relative humidity—the initial feeling is comfort. But as your body adjusts to the temperature you begin to feel sticky, clammy and uncomfortable. You may even feel warm again. This is why two homes with the same thermostat setting can feel very different.



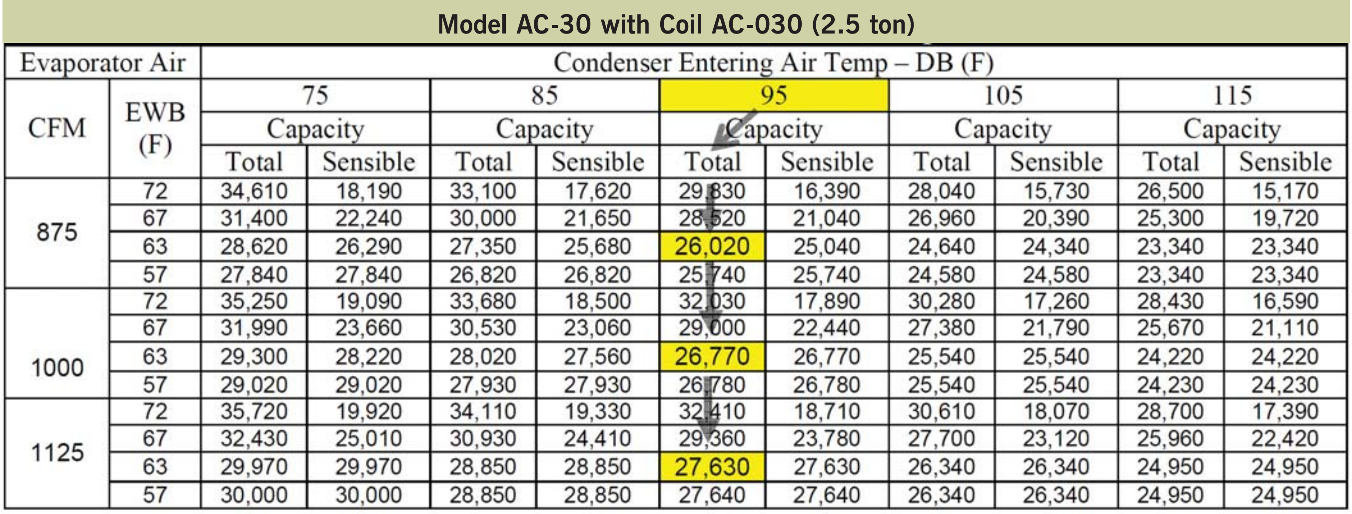
XYZ Furnace Company

General Data

Efficiency

Unit Size	FR60-024	FR 60-036	FR 80-024	FR 80-036	FR 125-036	FR 125-048
Output Capacity						
Upflow	48,000	48,000	64,000	64,000	100,000	100,000
Horizontal	48,000	48,000	64,000	64,000	100,000	100,000
Input Btu/h	60,000	60,000	80,000	80,000	125,000	125,000
Temp Rise Range	30 – 60	15 – 45	45 – 75	35 – 65	40 – 70	30 – 60

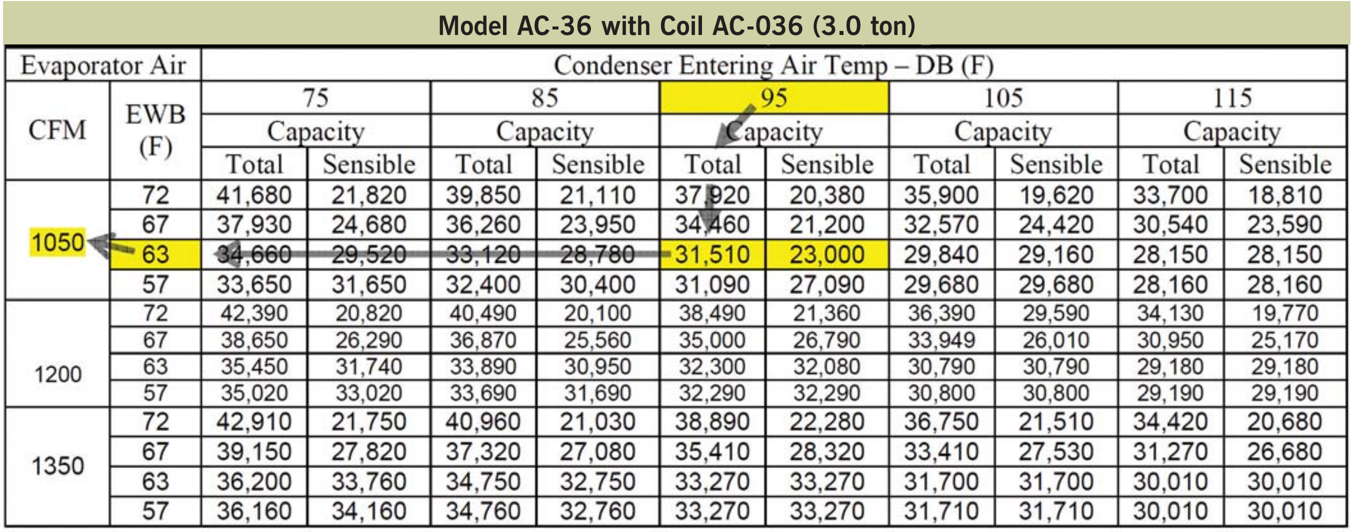
Figure 1. Furnace product data for XYZ 3.0-ton air conditioners.



Model AC-30 with Coil AC-030 (2.5 ton)

Evaporator Air		Condenser Entering Air Temp – DB (F)									
CFM	EWB (F)	75		85		95		105		115	
		Capacity		Capacity		Capacity		Capacity		Capacity	
		Total	Sensible	Total	Sensible	Total	Sensible	Total	Sensible	Total	Sensible
875	72	34,610	18,190	33,100	17,620	29,830	16,390	28,040	15,730	26,500	15,170
	67	31,400	22,240	30,000	21,650	28,520	21,040	26,960	20,390	25,300	19,720
	63	28,620	26,290	27,350	25,680	26,020	25,040	24,640	24,340	23,340	23,340
	57	27,840	27,840	26,820	26,820	25,740	25,740	24,580	24,580	23,340	23,340
1000	72	35,250	19,090	33,680	18,500	32,030	17,890	30,280	17,260	28,430	16,590
	67	31,990	23,660	30,530	23,060	29,000	22,440	27,380	21,790	25,670	21,110
	63	29,300	28,220	28,020	27,560	26,770	26,770	25,540	25,540	24,220	24,220
	57	29,020	29,020	27,930	27,930	26,780	26,780	25,540	25,540	24,230	24,230
1125	72	35,720	19,920	34,110	19,330	32,410	18,710	30,610	18,070	28,700	17,390
	67	32,430	25,010	30,930	24,410	29,360	23,780	27,700	23,120	25,960	22,420
	63	29,970	29,970	28,850	28,850	27,630	27,630	26,340	26,340	24,950	24,950
	57	30,000	30,000	28,850	28,850	27,640	27,640	26,340	26,340	24,950	24,950

Figure 2. OEM performance data for XYZ AC-30 2.5-ton air conditioner.



Model AC-36 with Coil AC-036 (3.0 ton)

Evaporator Air		Condenser Entering Air Temp – DB (F)									
CFM	EWB (F)	75		85		95		105		115	
		Capacity		Capacity		Capacity		Capacity		Capacity	
		Total	Sensible	Total	Sensible	Total	Sensible	Total	Sensible	Total	Sensible
1050	72	41,680	21,820	39,850	21,110	37,920	20,380	35,900	19,620	33,700	18,810
	67	37,930	24,680	36,260	23,950	34,460	21,200	32,570	24,420	30,540	23,590
	63	34,660	29,520	33,120	28,780	31,510	23,000	29,840	29,160	28,150	28,150
	57	33,650	31,650	32,400	30,400	31,090	27,090	29,680	29,680	28,160	28,160
1200	72	42,390	20,820	40,490	20,100	38,490	21,360	36,390	29,590	34,130	19,770
	67	38,650	26,290	36,870	25,560	35,000	26,790	33,949	26,010	30,950	25,170
	63	35,450	31,740	33,890	30,950	32,300	32,080	30,790	30,790	29,180	29,180
	57	35,020	33,020	33,690	31,690	32,290	32,290	30,800	30,800	29,190	29,190
1350	72	42,910	21,750	40,960	21,030	38,890	22,280	36,750	21,510	34,420	20,680
	67	39,150	27,820	37,320	27,080	35,410	28,320	33,410	27,530	31,270	26,680
	63	36,200	33,760	34,750	32,750	33,270	33,270	31,700	31,700	30,010	30,010
	57	36,160	34,160	34,760	32,760	33,270	33,270	31,710	31,710	30,010	30,010

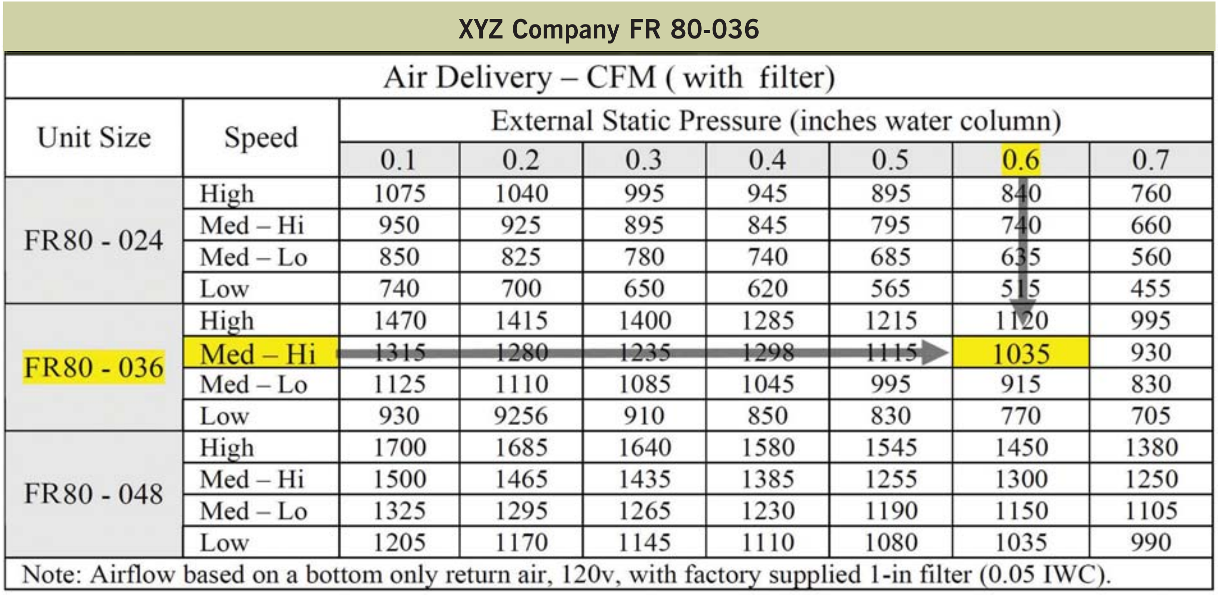
Figure 3. OEM performance data for XYZ AC-36 3.0-ton air conditioner.

design temperature rise range of 35°F–65°F.

Air temperature rise through the furnace depends on the rate of flow through the heat exchanger. If the air flow is outside of the temperature rise range, the equipment may cycle off at safety limits, suffer damage or possibly even create an unsafe condition. Incorrect air flow can cause too much temperature rise (slow-moving air may allow the heat exchanger to become too hot, which can result in warping or cracking of the metal heat exchanger) or too little temperature rise (fast-moving air may cause condensation in the metal heat exchanger, which can result in the production of an acid that can harm or penetrate the heat exchanger).

AHRI Versus OEM Expanded Performance Data

Manufacturers of heating and cooling equipment are responsible for testing and certifying the performance of their products. The Air Conditioning, Heating and Refrigeration Institute (AHRI) produces standards for rating such equipment, but data published in AHRI product directories should not be used because the test conditions simulate a very small geographic area in the U.S. As such, AHRI directories should only be used to compare equipment efficiency ratings—OEM expanded performance data should be used to select properly sized equipment.



XYZ Company FR 80-036

Air Delivery – CFM (with filter)

Unit Size	Speed	External Static Pressure (inches water column)						
		0.1	0.2	0.3	0.4	0.5	0.6	0.7
FR80 - 024	High	1075	1040	995	945	895	840	760
	Med – Hi	950	925	895	845	795	740	660
	Med – Lo	850	825	780	740	685	635	560
	Low	740	700	650	620	565	515	455
FR80 - 036	High	1470	1415	1400	1285	1215	1120	995
	Med – Hi	1315	1280	1235	1298	1115	1035	930
	Med – Lo	1125	1110	1085	1045	995	915	830
	Low	930	9256	910	850	830	770	705
FR80 - 048	High	1700	1685	1640	1580	1545	1450	1380
	Med – Hi	1500	1465	1435	1385	1255	1300	1250
	Med – Lo	1325	1295	1265	1230	1190	1150	1105
	Low	1205	1170	1145	1110	1080	1035	990

Note: Airflow based on a bottom only return air, 120v, with factory supplied 1-in filter (0.05 IWC).

Figure 4. Fan performance data.

An air flow rate is acceptable if it yields a temperature rise within the range prescribed by the equipment manufaturer. In our example, 1,050 cfm equates to an acceptable (35°F–65°F) furnace temperature rise of approximately 55°F:

$$\Delta T = Btu/h^{4} \div (CFM \times 1.1 \times ACF)$$

$$55.4°F = 64{,}000 \div (1{,}050 \times 1.1 \times 1.0)$$

where:

ΔT = temperature difference in the air between the inlet and outlet of the furnace or cooling coil

Btu/h = thermal output capacity of the furnace or cooling system

CFM = volume of air, in cubic feet per minute, moved through the furnace by the blower assembly

1.1 = a physical air constant (derived from the laws of physics)

ACF = altitude correction factor; 1.0 at sea level

Conclusion

This article serves to demonstrate the value of the adopted code revision in ensuring that appropriate load calculations are used as the basis for HVAC equipment selection: one more way that First Preventers can protect the health and safety of building occupants across the country. ◆

Notes

1. Oversizing can lead to health issues associated with excessive humidity; higher costs for equipment and installation labor and materials; greater energy consumption; and more wear and tear on equipment.
2. This considers both the temperature and moisture content of the air.
3. When the blower moves 1,050 cfm over the XYZ model AC-36 indoor air conditioner coil, it delivers the required cooling capacity. If the airflow value changes, the equipment capacity and performance also change.
4. In this case, the actual furnace output capacity of 64,000 Btu/h is used, not the 56,000 Btu/h design capacity from the load calculation.

WES DAVIS *is Manager of Technical Services for the Air Conditioning Contractors of America (ACCA), in which capacity he develops HVAC-oriented technical documents, delivers educational presentations and provides technical support to ACCA members.*

He is the author of Bob's House*, a step-by-step case study in the proper design of a residential HVAC system; serves on several industry technical committees; and coordinated the development of ACCA's* Quality Maintenance Standard *and* Quality Installation Verification Protocols.