The Pennsylvania Housing Research Center

Kitchen Ventilation Systems: Part 2
Providing Adequate Makeup Air

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INTRODUCTION

The first Builder Brief of this two-part series discussed the relationship between kitchen exhaust rates, house tightness, and house depressurization. That brief also provided an overview of the health and safety hazards associated with house depressurization and the presence of combustion appliances.

In this brief, we provide design guidance for introducing makeup air for a residential kitchen exhaust system using three common techniques: (1) engineered openings, (2) HVAC-integrated air systems, and (3) dedicated makeup air units. We will also discuss common design practices for meeting the interlocking and closure requirements of the 2009 International Residential Code (IRC) Section M1503.4.

PROPER RANGE EXHAUST SELECTION

The objective of a kitchen range exhaust system is to capture moisture and airborne contaminants created during cooking, and vent them to the outside. The selection of an exhaust system is largely dependent on the size and type of range, and its intended use. Wall mounted hoods are the most common exhaust system used in the residential kitchen; however, island canopy hoods and downdraft systems have risen in popularity in recent years.

The goal of an exhaust system specifier should be to provide an adequate, but not excessive, amount of exhaust without jeopardizing occupant safety or comfort. First, a homeowner or homebuyer should assess their cooking habits and select appliances based on need rather than a "bigger is better" mentality. Larger appliances demand more power and require larger exhaust systems leading to higher operation costs, and increased risk of house depressurization and associated hazards. In addition, every cubic foot of exhausted air is a cubic foot of makeup air that must be heated or cooled at the homeowner's expense.

The required exhaust rate for standard, low-powered, residential kitchen ranges is typically specified per linear foot of range. Table 1 shows recommended exhaust rate per linear foot (LF), according to the Home Ventilating Institute (HVI).

Table 1. HVI recommended and minimum ventilation rates for kitchen range hoods.

LOCATION	Rec. Vent. Rate per LF of Range	Min. Vent. Rate per LF of Range
Wall	100 CFM	40 CFM
Island	150 CFM	50 CFM

Kitchens that contain high-powered, commercial-style cooking equipment will require a higher exhaust rate. The installer should always check the equipment specifications for exhaust system recommendations. If no information is available, equipment should be classified by type, application and power consumption, and sized in accordance with the ASHRAE Handbook (HVAC Applications section), or other reputable source.

MAKEUP AIR REQUIREMENTS

Once the exhaust rate is specified, the designer can determine the need for makeup air. As discussed in Part 1 of this Builder Brief series, Section M1503.4 of the 2009 IRC requires makeup air at a rate roughly equal to the exhaust rate for systems capable of exceeding 400 CFM. That brief demonstrated that the 400 CFM threshold, although seemingly arbitrary, is appropriate for tight to moderately tight residential enclosures. Figure 4 in Part 1, shows that the potential for depressurization exists at almost any exhaust rate; therefore, it is prudent for a designer to conduct some type of risk assessment for all installations. See Part 1 of this Builder Brief series, or ASTM E1998, *Standard Guide for Assessing Depressurization Induced Backdrafting and Spillage from Vented Combustion Appliances*.

INTRODUCING MAKEUP AIR

Properly introducing makeup air is essential to ensuring a safe, comfortable, and efficient home. Improperly specified makeup air systems can lead to uncomfortable drafts, overstressed HVAC equipment, mold, and house depressurization. An ill-conceived exhaust and makeup air system design can be expensive as well as non-functional.

To maintain occupant comfort, most design guidance recommends providing a makeup air supply temperature within 10 degrees F of the room temperature. For example, if a house is maintained at 70 degrees F in the wintertime, the makeup air should be provided at a supply temperature of no less than 60 degrees F.

Design considerations for makeup air systems that exceed supply rates of 400 CFM are similar to that of a commercial kitchen or industrial exhaust system. Thus, it is highly recommended that a HVAC expert be involved in the design process. Significant quantities of makeup air will increase loads placed on the central HVAC system. The HVAC system or building enclosure will likely require modification to function efficiently with the newly introduced makeup air.

Makeup air can be introduced in many ways with varying degrees of effectiveness. The two most common methods are engineered openings and mechanical systems. Engineered openings in the enclosure allow air to be drawn into the house as interior pressure becomes increasingly negative. The effects are hard to predict and highly dependent on the location of the opening and connectivity of rooms within the house. Mechanical systems introduce makeup air into the house by a fan, where it can be routed directly to the kitchen, or drawn into the central HVAC system and distributed throughout the house. When properly installed, a fan-assisted solution should eliminate any adverse pressure effects created by the exhaust system. Figure 1 illustrates the effects of both methods on building pressurization and the neutral pressure plane.

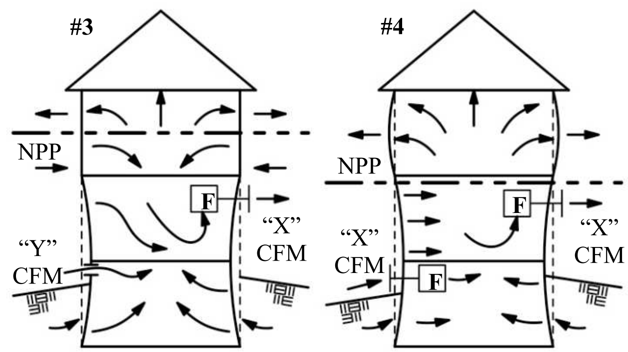

Figure 1. Comparison of air movement in a house with an engineered opening (Scenario #3) versus a house with fan-assisted a makeup air system (Scenario #4). In Scenario #3, the neutral pressure plane rises, and the level of house depressurization is less predictable. In Scenario #4, pressures in the house mirror those when no exhaust or makeup air systems are installed (natural conditions).

ENGINEERED OPENINGS

An engineered opening is an intentional opening placed in the enclosure for the purposes of transferring air between the interior and exterior of a building. An opening could be as simple as a hole placed through an exterior wall, or may include ductwork to a remote space such as the kitchen. Figure 1 shows a typical configuration for an engineered opening that supplies makeup air directly into the kitchen.

Providing one or more engineered openings in the enclosure is a simple and inexpensive technique to introduce makeup air. The effects are similar to that

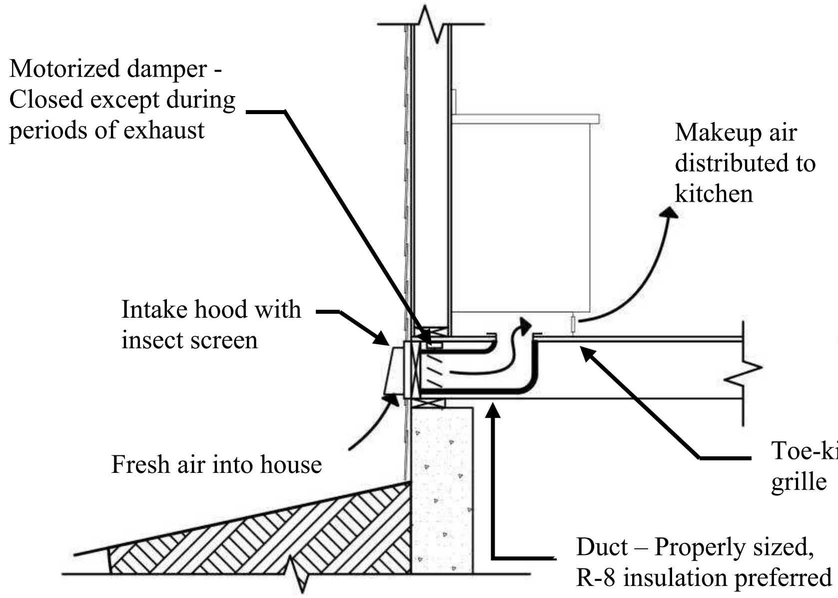

Figure 2. Typical engineered opening. The engineered opening in this diagram allows makeup air for a range hood to enter the house into the same room that the exhaust air leaves. This will help to alleviate negative pressure that may result from range hood operation.

of opening a door or window. Typically a damper is incorporated into the opening design to minimize heating and cooling costs and to ensure airflow only during times of depressurization or exhaust operation.

Airflow through engineered openings depends primarily on the area of the opening and pressure difference across the opening. The pressure differential depends on all the factors discussed in Part 1 of this series (wind, stack effect, and HVAC equipment). Table 2, which is derived from Equation 36 of Chapter 16 in the 2009 ASHRAE Handbook of Fundamentals, shows estimates of airflow through typical opening sizes (diameter) at various pressure differentials. Note that engineered openings only make sense for small amounts of makeup air. Pressures of 3 Pa or greater create a risk of backdrafting fireplaces and certain combustion appliances.

Table 2. Airflow through an engineered opening.

Pressure (Pa)	Airflow (CFM) Based on Opening Size				
	4 in	6 in	8 in	10 in	12 in
1	14	30	54	84	122
2	**19**	**43**	**76**	**119**	**172**
3	23	53	94	146	211
4	27	61	108	169	243
5	30	68	121	189	272
6	33	74	132	207	298
7	36	80	143	223	322
8	38	86	153	239	344
9	41	91	162	253	365
10	43	96	171	267	384

For example, say a homeowner wants to install an 800 CFM Kitchen exhaust fan in a house that contains a masonry fireplace with no outdoor intake. The HVAC professional calls for a blower door test, which results in an air tightness level of 2,500 CFM at 50 Pa. The HVAC professional specifies a single 10” makeup air duct routed directly to the kitchen area. Would this installation be adequate?

Part 1 of this series demonstrated the pressure differential between inside and outside of the house should be kept below 3 Pa to avoid dangerous backdrafting of combustion appliances. According to Table 2, a 10-inch opening can only supply 119

CFM of makeup air at a pressure of 2 Pa. Clearly the opening is inadequate to provide the required 800 CFM of makeup air while maintaining safe pressure levels.

Even if air infiltration through the building enclosure is included in the analysis, this installation falls short. Interpreting Figure 4 from Part 1 of this series in a slightly different way, it can be determined that infiltration could provide about 300 CFM of makeup air while maintaining a safe pressure of 2 Pa. Adding the makeup air from infiltration to that of the engineered opening results in a total makeup air of 419 CFM. This is significantly lower than the exhaust rate of the fan; thus, the 10” opening will not be able to maintain a safe pressure difference between the inside and the outside of the home.

Pros of engineered openings:

- Relatively inexpensive.
- Air can be directly introduced to the space where it is needed.
- Little strain on HVAC systems. Air has the opportunity to mix and temper with interior air before returning to central HVAC equipment.

Cons of engineered openings:

- Additional load on central HVAC equipment.
- Varying degrees of effectiveness, depending on placement of the opening.
- Could introduce drafts, if misplaced.
- Limited to lower exhaust rate applications.

HVAC-INTEGRATED MAKEUP AIR SYSTEMS

Another way to add makeup air to a house is to add unconditioned outside air directly to the central air handler. For this method, unconditioned makeup air is typically added upstream of the air handler, where it can mix with return air and become tempered before reaching the central conditioning unit. The central conditioning unit then filters, conditions, and distributes makeup air throughout the house along with the return air.

The makeup air is mechanically drawn in by the air handler through an opening provided in the enclosure. An HVAC technician balances the flow rate of the incoming fresh air to the desired rate. When the range hood is not in operation, the opening is typically closed automatically by a motorized damper that is interlocked with the range hood on/off switch. Figure 3 illustrates an example of this configuration.

This technique is popular for adding small quantities of ventilation air to houses. The central air handler provides adequate mixing of the fresh air with the return air, and evenly distributes it to all connected rooms of the house. The even distribution of the air supply helps to alleviate pressure imbalances throughout the house.

Most HVAC equipment manufacturers specify minimum and maximum return air temperatures (commonly 60 degrees F and 85 degrees F, respectively). Return air temperatures outside of this range may result in premature failure of heat exchangers, motors, and controls. Excessively high or low entering air temperatures will also negatively impact equipment efficiency. For these reasons, an HVAC designer must be careful that the rate of makeup air does not significantly affect the temperature of the air entering the air handler.

ACCA Manual S, *Residential Equipment Selection*, contains a threshold of 10 percent for the rate of outdoor air entering DX-type cooling equipment. Makeup air quantities of less than 10 percent of system design air flow will normally not significantly increase risks to HVAC equipment. For example, if the design airflow is 1500 CFM, then it will usually be safe to add 150 CFM of unconditioned makeup air to the central air handler. When adding quantities of outdoor air in excess of 10 percent, the entering air conditions (temperature and relative humidity) are altered to the point where a more detailed design should be considered.

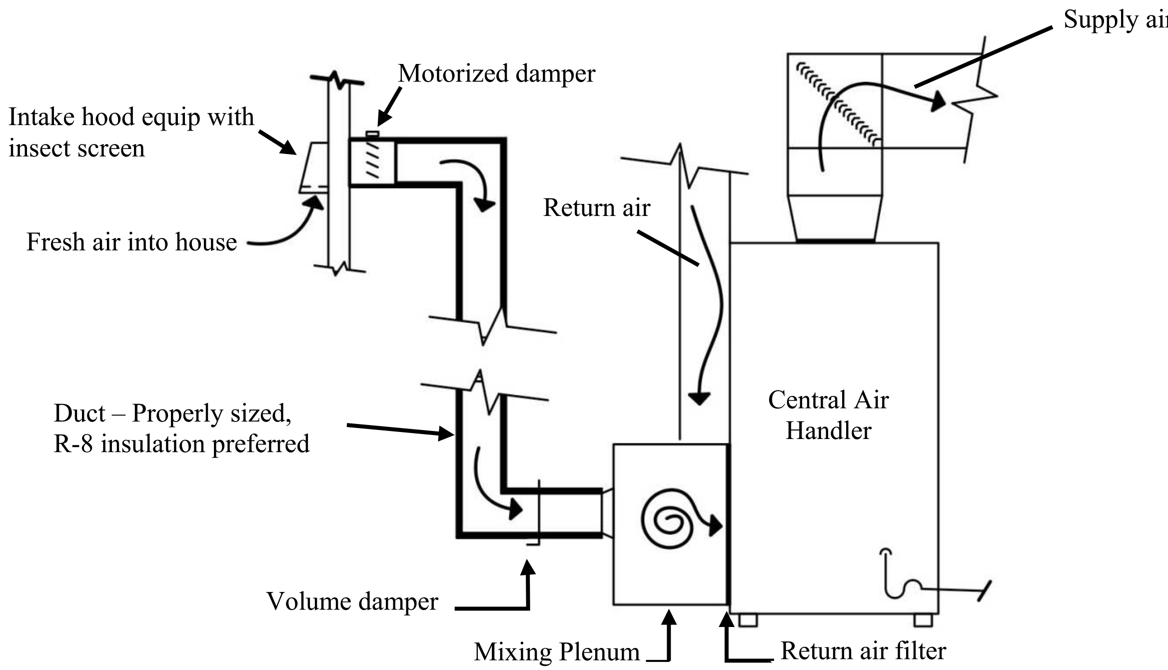

Figure 3. Typical HVAC-integrated makeup air system. When the motorized damper is open, air enters through an opening, which is ducted to the central air handler.

Finally, as with any exhaust system, heating and cooling loads will be increased commensurate with the exhaust rate. Without additional heating and cooling capacity, occupants may experience temporary discomfort during, and for a brief period after, range hood operation. The ventilation loads could be met by increasing the capacity of the central HVAC system, but it is likely that this would lead to equipment that is oversized for the vast majority of its operating time.

Pros of HVAC-Integrated Air Systems:

- Relatively inexpensive.
- Air is conditioned and filtered by HVAC unit.
- Air is evenly distributed throughout house.

Cons of HVAC-Integrated Air Systems:

- Additional load to central HVAC equipment.
- Only limited quantities can be introduced to the central HVAC without requiring additional design assistance and equipment capacity.
- Difficulty meeting peak heating/cooling loads without over-sizing central HVAC equipment.

MAKEUP AIR LOADS

To illustrate the magnitude of the additional loads from a 400 CFM exhaust fan, an example calculation for a house located in State College is shown below. The calculation methodology and design conditions are taken from ACCA Manual J.

Example:

$\text{Load (H)} = 1.1 \times CFM_{vent} \times (T_{room} - T_{vent}) \times ACF$
$\text{Load (CS)} = 1.1 \times CFM_{vent} \times (T_{vent} - T_{room}) \times ACF$
$\text{Load (CL)} = 0.68 \times CFM_{vent} \times (GR_{vent} - GR_{room}) \times ACF$

Load (H) = Sensible Heating load (Btu/h)
Load (CS) = Sensible Cooling load (Btu/h)
Load (CL) = Latent Cooling load (Btu/h)
CFM_{vent} = Ventilation rate (or makeup air rate)
T_{room} = Indoor design temperature
T_{vent} = Outdoor design temperature
ACF = Altitude correction factor (assume 0.97)
GR_{vent} = Moisture content ventilation air (Grains)
GR_{room} = Moisture content room (Grains)

Load (H)=1.1 x 400CFM x (70 – 7) x 0.97=26,888 Btu/h
26,888 Btu/h x 0.293 = 7,878Watt-hours = 7.9 kWh
26,888 Btu/h /12,000 = **2.24 tons**

Load (CS)=1.1 x 400CFM x (87-70) x 0.97=7,256 Btu/h
7,256 Btu/h x 0.293 = 2,126 Watt-hours = 2.1 kWh
7,256 Btu/h / 12,000 = **0.60 tons**

Load(CL)=0.68 x 400CFM x (26gr) x 0.97=6,860 Btu/h
6,860 Btu/h x 0.293 = 2,009 Watt-hours = 2.0 kWh
6,860 Btu/h / 12,000 = **0.57 tons**

SUPPLEMENTARY MAKEUP AIR CONDITIONING EQUIPMENT

If a large amount of makeup air is required, a homeowner will be better served by a stand-alone makeup air conditioning system. Adding separate conditioning units will prevent overloading of the central HVAC unit, while allowing it to function at peak efficiency, and eliminate any discomfort that might arise from introducing unconditioned air to the living space.

The example from the previous section shows that supplementary HVAC equipment will be helpful. A heating unit would be desirable to condition the extra 2.24 tons of heating load, and a dehumidifier would remove most if not all of the 0.57 tons of latent cooling load during times of exhaust operation. The small sensible cooling load could most likely be incorporated into the central HVAC unit, without fear of over sizing. Figure 4 illustrates a central air handler with a makeup air heating unit and dehumidifier installed.

Heating make up air can be accomplished with any of the traditional methods of heating air (i.e. combustion equipment, DX or hot water coils, or electric resistance coils). Particular attention must be paid to temperature rise limitations and any adverse effects that the entering unconditioned air might have on the equipment. ACCA Manuals CS, and P are helpful references for equipment selection.

One of the least design-intensive and easiest (but not always the cheapest) ways of heating make up air is to purchase a proprietary residential makeup air unit.

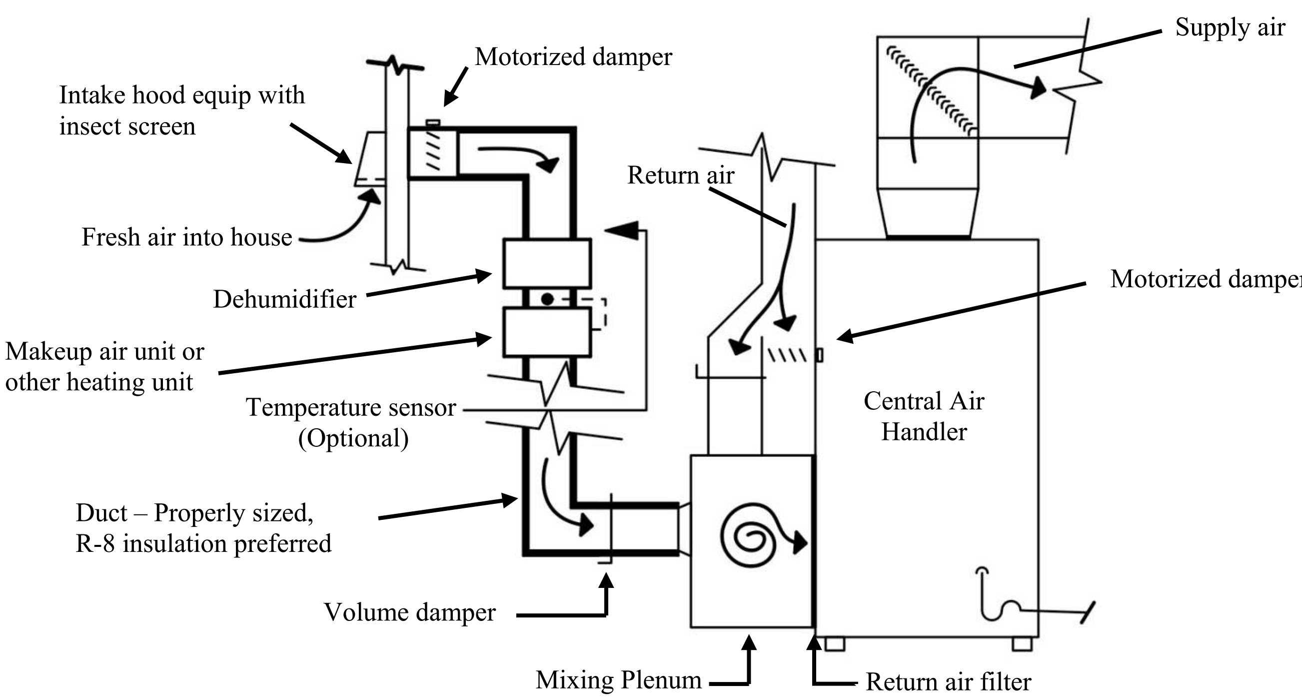

Figure 4. Typical residential makeup air unit. This installation is similar to the HVAC-integrated system, but includes a dedicated heating unit and dehumidifier to temper the makeup air.

There is a variety of companies providing these units, and many provide kits that include motorized dampers, fans, and electrical interlocking components. The equipment cost depends on what is included in the kit, with typical packages ranging from $1,000 to $2,500.

Pros of supplementary makeup air equipment:

- Makeup air can usually be added to central HVAC in greater amounts.
- Elimination of occupant discomfort.
- Easy to size and install.
- Minimal additional load on central HVAC equipment.

Cons of supplementary makeup air equipment:

- Expensive.
- Additional electrical operation cost.

INTERLOCKING AND CLOSURE

In order to minimize energy costs, outdoor air should only be introduced when the kitchen exhaust system is in operation. IRC Section M1503.4 requires that, "Makeup air systems be equipped with a means of closure and shall be automatically controlled to start and operate simultaneously with the exhaust system".

The means of closure for the three examples in this document is a motorized damper. The damper is intended to prevent any outdoor air from entering the house when the exhaust system is not in operation. The automatic control can be accomplished with an electrical circuit involving a current-sensing relay. Current-sensing relays are readily available from HVAC suppliers, and are typically used as a control element in many humidification circuits.

The current-sensing relay senses when the exhaust fan is operating. It allows a 24V signal to pass through and open the motorized damper, allowing makeup air to flow (Figure 5). When the fan is turned off, the circuit is closed and the signal is removed from the damper, causing it to return to its closed position.

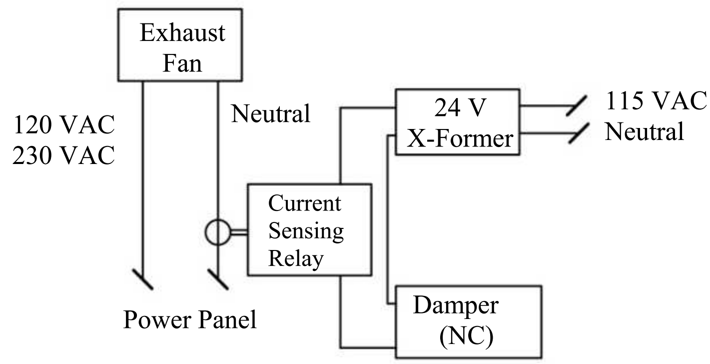

Figure 5. Typical electric schematic for an exhaust system interlocking circuit.

CONCLUSIONS

Makeup air for large range hoods is important to ensure occupant health and safety in any house with open combustion equipment, or an attached garage. Negative pressures created by exhaust systems may lead to backdrafting of appliances or air infiltration from hazardous sources.

Designing a system to provide an adequate amount of makeup air, while maintaining occupant comfort, can be a challenge. First, a contractor or homeowner should assess whether commercial-style cooking appliances are appropriate to meet the homeowner's needs. If a large range and range hood are desired, the contractor must introduce sufficient makeup air to meet code and avoid potentially dangerous pressure imbalances in the house. This brief helps contractors and installers understand the limitations, drawbacks, and benefits of three common approaches to providing makeup air.

RESOURCES

1. ASHRAE Handbook – Fundamentals (2009), American Society of Heating, Refrigeration and Air-Conditioning Engineers
2. Home Ventilation Institute, www.hvi.org
3. Rutkowski, Hank, *Manual CS, Commercial Applications, Systems and Equipment*, Air Conditioning Contractors of America (ACCA)
4. Rutkowski, Hank, *Manual J, Residential Load Calculation*, Eighth Edition, Air Conditioning Contractors of America (ACCA)
5. Rutkowski, Hank, *Manual P, Psychometrics Theory and Applications*, Air Conditioning Contractors of America (ACCA)
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