

UNDERSTANDING HVAC SYSTEM DESIGN ISSUES¹

When designing a comfort system, it is not adequate to merely produce a heat loss and heat gain estimate. Much more is involved in the proper design and installation of a comfort system. Heat loss and heat gain estimates are part of a design procedure that flows from system selection decisions, the actual load calculations, to equipment selection procedures, to placement and selection of air distribution hardware, to duct routing and airway sizing.

Documents such as ACCA *Manual RS* provide valuable information about zoning, system concepts, equipment capability and design procedures. It is strongly recommended that system designers be familiar with the material in Manual RS.

Manual J or equivalent load calculations affect every aspect of the system design procedure. The calculations must be as accurate as possible.

- Equipment capacity that matches the size of the applied heating and cooling loads will deliver comfort, efficiency and reliability over the entire range of operating conditions.
- Heating and cooling loads determine the total air delivery requirement (blower CFM) and the air flow requirement for each room (room CFM). This airflow information is then used to select supply air outlets and to size the duct runs.
- Load information also is used to estimate purchased energy requirements and to estimate annual operating cost. In this regard, the energy and operating cost estimates will only be as accurate as the load estimate.
- The design concept must be suitable for the application:
 - Contemporary architecture tends to produce dwellings that require a zoned system and/or variable capacity equipment.
 - Custom homes that feature a large amount of architectural glass that provides a panoramic view or architectural theme may not have internal shade, or the shading device may be completely open when the room is occupied. In such cases, the performance of the glass (U-value and solar heat gain coefficient) has a significant effect on comfort, equipment size and energy use. If there is a large amount of South glass, cooling may be required during cold weather. These dwellings must be carefully zoned and may require year-around cooling.
 - People may be uncomfortable when bathed by sunlight pouring through a window. During cold nights or cold overcast days, radiation from the occupant's skin to cold glass surfaces may cause discomfort
- External overhangs or some type of internal shading device are desirable because they provide comfort for the occupants (overhangs provide shade without interfering with the view).

¹ Information provided by the Air Conditioning Contractors of America (ACCA).

Manual S (or equivalent) and Manufacturer's Data to Select Equipment

In general, the effective capacity of heating and cooling equipment shall, as closely as possible, match the load when the equipment is subjected to design conditions. For instance, *Manual S* explains how to use *Manual J* output and manufacturer performance data to obtain this result. *Manual S* also provides guidelines pertaining to the acceptable amount of excess capacity and manipulating heat pump balance points.

ACCA Manual T (or equivalent) and Manufacturer's Data to Select Supply Outlets and Return Grilles

Supply outlets (grilles and registers) shall be the appropriate style and size for the application and shall be in an appropriate location for the application.

- Supply outlets shall not produce objectionable noise. Design guides and manufacturers' information establish limits for face velocity.
- Supply outlets shall provide the appropriate throw for the installed location. Floor outlets shall throw the supply air to the ceiling; ceiling outlets shall throw the supply air to the wall, etc. Size depends on product performance, the supply CFM value and the face velocity limitation.
- Never blow supply air directly into the occupied zone. Occupants will complain about drafts.
- Floor outlets that blow air straight up the exposed wall are best for cold-climate heating; and if properly selected, adequate for cooling.
- Ceiling outlets are best for cooling, but will not warm slab or exposed floors during the winter.
- If high sidewall outlets are used for cooling, supply air shall not drop into the occupied zone during cooling. These devices will not warm slab or exposed floors during the winter.
- The relation between supply CFM, throw, face velocity and drop is established by manufacturer performance data. Performance is very sensitive to size and devices that appear to be generally similar can have substantially different performance characteristics.
- A low resistance return path shall be provided for every room that receives supply air - a wall opening with no door, a transfer grille or a ducted return. Door undercuts are not acceptable).
- Return grilles shall be the correct size for the grille flow rate. Filter grilles have a lower face velocity than plain grilles.
- The location of the return grille does not affect room air patterns which are controlled by the supply outlets and will not have a significant affect on pockets of stagnate air. Low returns do "pull" warm air down to the floor and high returns do not "pull" cool air up into the occupied zone.

Manual D (or equivalent) to Size the Duct Runs

The resistance (inches water gauge of static pressure) of the longest circulation path (longest supply run plus longest return run) shall be compatible with the performance of the blower that is supplied with the heating-cooling equipment. Airway sizes that are compatible with the blower performance shall be increased if airflow velocity creates a potential noise problem. All systems shall have adequate provision for balancing airflow.

- The length of the longest circulation path and the available static pressure determine the friction rate used for airway sizing.
- The length of the circulation path includes the straight runs and the equivalent length of the fittings along the path. One fitting can add from 5 feet to more than 60 feet to the length of the path.
- External static pressure is determined from the equipment manufacturer's blower performance data, preferably for medium-speed operation.
- The available static pressure equals the external static pressure minus the pressure drop through all the air-side devices in the circulation path. Refer to blower table footnotes and manufacturer pressure drop data for devices that were not in place when blower performance was laboratory-tested by the equipment manufacturer.
- Accessory or after-market filters (or any device) that produce a substantial increase in system resistance shall not be installed if the blower cannot accommodate the increased resistance by speed change. An arbitrary increase in system resistance may cause low airflow to rooms, a high temperature rise across a furnace heat exchanger, or low suction pressure at the cooling coil.
- The room heat loss and heat gain estimate (*Manual J or equivalent*) and the heating and cooling factors (*Manual D or equivalent*) determine the design value for room airflow.
- Airway size is determined by sectional flow rate and the design friction rate value.
- The friction chart or duct slide rule used for airway sizing shall be technically correct for the type of duct material.
- Airway velocities shall not exceed specified design limits.
- Branch (runout) ducts shall be equipped with a hand damper (for balancing).

Related Comfort Conditioning System Design Considerations:

Impacts of Incorrectly Sized Heating and Cooling Equipment

- The obvious problem with significantly undersized equipment is that it will not maintain the desired set-point temperature when a passing weather system imposes a design load on the heating and cooling equipment. However, slightly undersized cooling equipment -- by a margin of 10 percent or less -- may actually provide more comfort at a lower cost.
- Oversized equipment causes short-cycles, marginalizes part-load temperature control, creates pockets of stagnate air (unless the blower operates continuously) and degrades humidity control during the cooling season (more information on this subject is provided below). Oversized equipment also requires larger duct runs, increases installed cost, increases operating cost, increases the installed load on the utility grid and causes unnecessary stress on the machinery.

Humidity Control During the Cooling Season:

- Sensible and latent cooling loads are imposed on dwellings located in climates that have a substantial amount of moisture in the outdoor air during the cooling season (wet-coil climates). When the summer design condition occurs, properly sized equipment will operate continuously or almost continuously, both loads will

be completely neutralized, and the occupants will be comfortable. But, the design condition only occurs for a few dozen hours per season.

- Reduced latent capacity at part load will cause the indoor humidity to drift above the design value, which is acceptable, providing the relative humidity stays below 60 percent. The possibility for experiencing comfort problems at part load conditions is minimized by observing the following guidelines:
 - Use outdoor design conditions recommended by design manual, providing a code or regulation does not specify a different set of conditions.
 - Use the default indoor design conditions recommended by design manual, unless a code or regulation specifies a different set of conditions.
- Some climates are too dry to produce a latent load on the indoor coil. In this case, the indoor humidity depends on the moisture content of the outdoor air, the infiltration rate and the amount of moisture generated by the occupants. If the outdoor air is very dry, these factors will combine to produce an indoor relative humidity that is less than 50 percent and it could even be lower than 40 percent. But, if the relative humidity stays above 30 percent, the indoor air condition will be in the comfort zone.

Humidity Control During the Heating Season

During the heating season, very cold weather can produce discomfort. Dry-air causes a sensation of coolness, a desire to increase the thermostat set point, problems with static electricity and dry sinuses. Adding a humidifier to the heating system moderates these problems, but if a humidifier is installed, it must not produce a visible or concealed condensation problem. (See the unabridged version of *Manual J* for more information on this subject).

Part Load Days More Important than Design Load Days

As a group, homeowners are overly concerned with extreme weather conditions that occur for a few hours per season and uninformed about the significance of the part-load conditions that occur for thousands of hours per season. This lack of understanding pressures contractors to install oversized equipment. This results in systems that are more expensive to install, less efficient, less comfortable for a majority of the season and less reliable. In addition, the oversized equipment produces an unnecessary load on the electric and gas distribution systems. The solution to this problem is consumer education. Section 10-4 of *Manual RS* provides more information on this subject.