



## **HVAC Systems**

### **Introduction**

This factsheet presents information on heating, ventilating, and air conditioning (HVAC) systems. It includes information on their basic function, designing and sizing, efficiencies of the most common system types, and installation and maintenance requirements. This factsheet addresses multifamily installations but the information is applicable to all residential systems.

HVAC systems should provide comfort as efficiently as possible. Space conditioning accounts for between 30% and 60% of the total standard energy budget for low-rise multifamily units in the climate zones that make up the San Francisco Bay Area (CEC Low-Rise Multifamily Building New Construction Characteristics Study, July, 2000).

Advances in technology have led to much higher equipment efficiencies with better comfort control compared to available technology even a decade ago. Beginning in January 2006, Title 24 will require residential air conditioning equipment to have a minimum SEER (Seasonal Energy Efficiency Ratio) of 13 and most heating equipment must have a higher AFUE (Annual Fuel Utilization Efficiency) than previously allowed.

However, choosing high efficiency equipment is only one step in achieving an efficient system. Equipment sizing, system design and installation will all determine the overall efficiency and performance of an HVAC system, and how well the system is maintained will determine how quickly that efficiency degrades.

### **Green Building Benefits**

Properly designed and installed HVAC systems reap multiple benefits for occupants, building owners, contractors, and the environment.

- Efficient, properly designed and sized HVAC equipment increases comfort and reduces energy costs for residents, reduces complaints for building owners and benefits the environment through reduced green house gas emissions.
- Considering the entire building design when designing HVAC systems allows easier

installation and maintenance, reduces resistance to airflow, and increases efficiency.

- Well sealed duct systems and proper filtration improve indoor air quality.
- Sealed and balanced systems improve air quality and safety by reducing the possibility of backdrafting.

### **System Design**

Title 24 requires that heating and cooling loads be calculated but does not always ensure that systems be sized to meet the load calculations. Mechanical contractors often prefer to oversize the equipment to reduce the possibility of complaints and callbacks. This “fudge factor” often covers up poor installation practices. Oversizing also leads to increased cycling, which results in higher energy use, decreased equipment life, and reduced comfort. The building owner or their representative should contractually require that HVAC systems be sized according to the heating and cooling load calculations.

The most commonly used tool for sizing residential HVAC systems is ACCA (Air Conditioning Contractors of America) Manual J. Manual J calculates the heating and cooling loads of a building by taking into account the local climate, building envelope, orientation, and internal loads. It is a simplified method based on ASHRAE (American Society of Heating, and Air Conditioning Engineers) calculations. Manual J works well for single family homes but has limitations in calculating loads for multifamily buildings. Its main limitation is that Manual J cannot account for load diversity in multifamily buildings, i.e. Manual J assumes that all apartments experience peak cooling and heating loads at the same time of day, regardless of each apartment’s solar exposure. This causes it to exaggerate building loads. More sophisticated (and complex) software such as Trane Trace, Carrier HAP and others can provide more accurate load calculations for multifamily buildings.

Forced air systems require ductwork, which presents other challenges for construction professionals. Ductwork design affects all aspects of comfort and energy usage. Every turn in a duct increases air resistance, causing the supply air fan to work harder. In many cases, resistance is so great due to poorly designed ductwork that the fan is unable to provide sufficient air to heat/cool the space, reducing comfort. Careful planning is required, with the

designer and HVAC professional working together, to plan duct runs with as few turns as possible. Ductwork types must also be factored into design to ensure sufficient airflow. While metal ductwork has a higher initial cost than flexible ductwork, it also has only one third the resistance to airflow compared to the more commonly used flexduct and it lasts the life of the building. Duct systems should be sized using ACCA Manual D, also available for download from ACCA.

The 2005 Building Energy Efficiency Standards (Title 24) establishes strict minimum standards for duct sealing and insulation in Section 4.4 of the *Residential Compliance Manual*. Owners, builders, and designers should be familiar with these standards and the possible trade-offs due to location of the ducts and placement of building insulation.

Duct leakage testing is required for prescriptive compliance methods but not for performance-based compliance. Even if not required, duct leakage testing should be performed to ensure that the installation was done properly and none of the other trades has damaged the ducts after installation.

### Efficiency

Choosing equipment with high efficiencies is the last (but very important) step in ensuring high system efficiency. Residential air conditioning systems are typically rated by their Seasonal Energy Efficiency Ratio (SEER). This is a measure of how much cooling a system provides over an entire cooling season compared to the amount of energy it consumes. Higher SEERs mean more cooling is provided with less energy, and indicate a higher efficiency. As of January 23, 2006 Title 24 requires a minimum 13 SEER for split systems with single phase power.

Heating systems vary widely, but common systems include furnaces, boilers, electric resistance and heat pumps. The efficiency of furnaces and gas-fired boilers is measured by the Annual Fuel Utilization Efficiency (AFUE), a measure of the system’s overall seasonal performance. As of January 23, 2005 Title 24 requires furnaces to have a 78% minimum AFUE and boilers to have at least an 80% AFUE. Newer condensing furnaces burn at such high efficiency that they condense water from the exhaust flue and typically have 90%+ AFUE ratings. While these systems cost more up front, reduced operating costs can make them a wise choice in heating climates.

Heat pumps are an excellent choice for heating, particularly when gas is unavailable or expensive.

These systems provide both cooling in the summer months and heating in the winter months. In the winter, they provide heat by “pumping” it from the outdoors to the indoor space, which is many times more efficient than creating the heat. While the cooling performance of these systems is rated in SEER just like air conditioners, the heating performance is rated by the Heating Seasonal Performance Factor (HSPF). Similar to SEER, this is a measure of a system’s heating output over a season compared to the energy used to provide that amount of heating. Title 24 requires a minimum 6.8 HSPF, while highly efficient heat pumps achieve ratings around 9.0 HSPF.

Electric resistance heating is usually the lowest first cost option for heating and always the highest operating cost. By comparison, electric resistance heating is typically several times more costly to operate than either a heat pump or gas-fired heating. Paybacks in heating climates can easily be less than five years when comparing a heat pump to electric resistance heating and frequently under three years.

### Minimum Equipment Efficiency

System Type	Rating	Required
Air Conditioners	SEER	13
Furnaces	AFUE	78% - 80%
Heat Pumps	HSPF	6.8

### Installation & Testing

Even the most efficiently designed and specified HVAC system will perform poorly if improperly installed. Testing the HVAC system is the only way to ensure the system operates as intended. Duct blower tests are the only sufficient method for determining that the air delivery system was properly sealed during installation. This testing procedure identifies the percent leakage in a ductwork system. Properly sealed systems should not exceed 6 percent leakage. If more than 6 percent leakage is found during testing, installers should locate the leaks and seal them, testing again to ensure compliance.

Air flow testing measures the airflow exiting each register. These airflows should closely match the airflows specified by the designers. Incorrect airflows can be corrected by adjusting dampers installed at the start collars of each duct run until correct airflow is measured in all registers.

Refrigerant charge testing should be required to ensure that the refrigerant in split AC systems is at

proper levels. If the charge is not correct, the system will not perform at stated efficiencies.

Finally, a backdraft test will determine if pressure imbalances have resulted in negative space pressures, which will cause exhaust gasses from gas-burning appliances to travel back into the conditioned space instead of letting them exhaust out of the flue. This is a critical safety test. If the test results show that the system depressurizes the unit enough to cause backdrafting, immediate action must be taken to restore pressure balance.

**Recommended Performance Tests**

Test	Desired Outcome
Duct Blaster	Little or no duct leakage
Air Flow	Air flow at each register matches design air flow to each room
Refrigerant Charge	AC system has correct refrigerant charge
Backdraft	Depressurization does not draw exhaust gases back into living spaces

**Filtration**

Air filters are the primary line of defense for the coil. Insufficient filtration leads to dirty coils, which decrease efficiency and comfort while increasing the likelihood of air quality problems. Filter efficiency is found by the Minimum Efficiency Reporting Value (MERV), which is a scale from 0 to 20. A higher MERV rating means the filter will remove smaller particles from the airstream. Pleated media filters with a MERV rating between 6 and 12 should adequately protect the coil and provide indoor air quality benefits. While older panel fiberglass filters are less expensive to buy, they waste money in the long run because dirt and contaminants can easily

**Disclaimer**

Development of this case study was funded by California ratepayers under the auspices of the California Public Utilities Commission (Commission). It does not necessarily represent the view of the Commission, its employees, or the State of California. The Green Affordable Housing Coalition, the Commission, the State of California, its employees, contractors, and subcontractors make no warranty, express or implied, and assume no legal liability for the information in this report, nor does any party represent that the use of this information will not infringe upon privately owned rights. This report has not been approved or disapproved by the Commission, nor has the Commission passed upon the accuracy of adequacy of the information in this report. Contents are provided for general education and informational purposes only. The actual suitability and applicability of this information for a given use depends upon a host of project-specific considerations. The Green Affordable Housing Coalition strongly encourages the reader to consult with a construction professional and/or product supplier before applying any of this information to a specific use or purpose.

pass through, quickly clogging air coils and increasing energy usage. Filters with MERV ratings higher than 12 should only be installed when the ventilation system has been designed to accommodate the more restrictive air flow. For more information, see the Green Affordable Housing Coalition’s “Air Filters” fact sheet.

**Maintenance**

Maintenance is the final piece of an efficient HVAC system. Improper maintenance leads to degradation of efficiency, equipment life, air quality and comfort.

Biannual maintenance by a qualified technician is needed to keep the system operating as intended. Many service companies offer prepaid contracts which reduce costs while ensuring the system receives the proper maintenance. Common problems which can be detected during routine inspection include improper refrigerant charge, clogged coils, dirty filters, and clogged condensate lines.

**For more information**

- [www.ACCA.org](http://www.ACCA.org) Manuals J & D
- [Energy Efficient Builders Association](http://www.energycollaboration.com) Builders Guide for Hot-Dry & Mixed Dry Climates
- <http://www.energy.ca.gov/title24/> California Building Energy Standards
- [www.buildingscience.com](http://www.buildingscience.com) Building Science Corp. provides many factsheets and studies on building design and HVAC
- For more information about the Coalition, visit [www.greenaffordablehousing.org](http://www.greenaffordablehousing.org) or call Bruce Mast at 510-271-4785.