EES 305 HVAC Spring 2007

COOLING

Homes are usually cooled with an electric air-conditioner. An AC uses electricity to pump heat out of a room to the outside.

QC = heat removed from the house
QH = heat dumped to the outside environment
E = energy supplied to the air conditioner

The efficiency of the AC unit may be expressed as a coefficient of performance (COP):

COP = QC (Btu) / E(Btu)

Another widely used measure of efficiency is the Seasonal Energy Efficiency Ratio (SEER):

SEER = seasonal average QC (Btu) / seasonal average E(Wh)

The older standard for AC units was SEER = 10 and the new standard is SEER = 13. The table below shows the relationship between SEER and the COP for these two standards.

SEER	10	13	Btu / Wh
COP	2.64	3.43	unitless

Example 1. A homeowner must remove 15 MBtu from his house in order to cool it during the cooling season. The SEER of his AC unit equals 10. How much electric energy is required to power this system for the cooling season?

E(Wh) = QC(Btu) / SEER = (15,000,000 / 10) Wh = 1,500,000 Wh = 1,500 kWh

Example 2. Suppose the homeowner in problem 1 replaces his cooling system with a new unit with SEER = 13. How much electric energy does he save by switching to this new unit?

E = (15,000,000 / 13) Wh = 1,154 kWh

Savings = 346 kWh

HEATING

A house may be heated with a furnace, a boiler, or a heat pump.

A **furnace** usually refers to a unit that burns natural gas or oil and produces forced hot air that is distributed through the house using a system of ducts.

A **boiler** usually refers to a unit that burns natural gas or oil and produces hot water that is distributed through radiators or used to heat the slab (radiant heat).

A furnace or a boiler converts the energy supplied (E) into thermal energy (QH) to heat the space. Some of the energy supplied is lost as waste heat (QC) to the environment.

The efficiency of these systems is usually expressed in terms of the Annual Fuel Utilization Efficiency (AFUE).

AFUE = QH / E

The national minimum AFUE for heaters is 78% and units with AFUE greater than 85% are available.

Example 3. A homeowner must add 30 MBtu of heat to her home during the heating season. The AFUE of her oil-fired boiler system equals 78%. How much oil energy is required to fuel this system for the heating season?

E(MBtu) = QH(MBtu) / AFUE = 30 MBtu / 0.78 = 38.5 MBtu

Example 4. Suppose the homeowner in problem 1 replaces her heating system with a new unit with AFUE = 0.95. How much oil energy does she save by switching to this new unit?

E(MBtu) = QH(MBtu) / AFUE = 30 MBtu / 0.95 = 31.6 MBtu

Savings = 6.9 MBtu

Heat pumps use energy more efficiently than boilers and furnaces.

Geothermal heat pumps (GHPs) are a relatively new technology that can save homeowners money. These ground-source heat pumps use the natural heat storage capacity of the earth or ground water to provide energy efficient heating and cooling. GHPs should not be confused with air-source heat pumps that rely on heated air.

Geothermal heat pumps use the relatively constant temperature of the ground or water several feet below the earth's surface as source of heating and cooling. Geothermal heat pumps are appropriate for retrofit or new homes, where both heating and cooling are desired. In addition to heating and cooling, geothermal heat pumps can provide domestic hot water. They can be used for virtually any size home or lot in any region of the U.S.

A geothermal heat pump system consists of indoor heat pump equipment, a ground loop, and a flow center to connect the indoor and outdoor equipment. The heat pump equipment works like a reversible refrigerator by removing heat from one location and depositing it in another location. The ground loop, which is invisible after installation, allows the exchange of heat between the earth and the heat pump.

Geothermal heat pumps can be open- or closed-loop. Open-loop systems draw well water for use as the heat source or heat sink, and after use, return the well water to a drainage field or another well. Closed-loop or earth-coupled systems use a water and antifreeze solution, circulated in a ground loop of pipe to extract heat from the earth.

Ground loops can be installed in a vertical well or a horizontal loop. Vertical wells are usually more expensive and used where space is limited. The length of loop pipe required will vary with soil type, loop configuration, and system capacity. Loop length can range from 250 to 1,000 feet per ton of capacity.

Geothermal heating can be more efficient than electric resistance heating. These systems are also typically more efficient than gas or oil-fired heating systems. They are more energy efficient than air-source heat pumps because they draw heat from, or release heat to, the earth, which has moderate temperatures year round, rather than to the air (which is generally colder in winter and warmer in summer than the earth, resulting in less effective heat.

Heat pumps are basically air-conditioners run in a heating mode:

QC = heat removed from the environment
QH = heat transferred into the house
E = energy supplied to the heat pump

The efficiency of the heat pump may be expressed as a coefficient of performance (COP):

COP = QH (Btu) / E(Btu)

Another widely used measure of efficiency is the ***Heating Season Performance*** Factor (HSPF):

HSPF = seasonal average QH (Btu) / seasonal average E(Wh)

The older standard for heat pumps was HSPF = 7.0 and the new standard is HSPF = 7.7.

Example 5. A homeowner requires 30 MBtu to heat her home during the heating season. The HSPF of her heat pump equals 7.0. How much electric energy is required to power this system for the heating season?

E = QH(Btu) / HSPF = (30,000,000 / 7.0) Wh = 4,300,000 Wh = 4,300 kWh

This electric energy value can be converted to MBTU by multiplying by 3413 Btu/kWh:

E = 4,300 * 3,413 Btu = 14.6 MBtu (Note: COP = 30/14.6 = 2.05)

Example 6. Suppose the homeowner in problem 5 replaces her heating system with a new unit with HSPF = 7.7. How much electric energy does she save by switching to this new unit?

E = QH(Btu) / HSPF = (30,000,000 / 7.7) Wh = 3,900,000 Wh = 3,900 kWh

This electric energy value can be converted to MBTU by multiplying by 3413 Btu/kWh:

E = 3,900 * 3,413 Btu = 13.3 MBtu (Note: COP = 30/14.6 = 2.26)

Energy savings = 400 kWh or 1.3 Mbtu

Rule of Thumb Sizing Methods

Residential Heating System Sizing.

Choose the best description of the construction for the building you intend to heat.

A. No insulation in walls, ceilings, or floors. No storm windows installed. Air leakage around loose fitting windows and doors. Construction typically found in garages, sheds, recreational dwellings or storage buildings. For this type of building, use multiplier factors **90** to **110**.

B. Construction typically found in older homes and better quality garages, sheds, recreational dwellings or storage buildings. Walls and ceilings are insulated to R-11 but there is no insulation in the floors. Doors are of standard construction; not insulated. Windows are ordinary single pane; not thermal double pane nor storm windows. However, the fit of the doors and windows is good enough that they do not allow noticeable air leakage. For this type of building, use multiplier factors **50** to **85**.

C. Newer standard construction for homes, offices and stores. Walls insulated to R-19. Ceilings insulated to R-30. Weather stripping on all doors and windows. Thermal double pane windows or storm windows fit tightly. For this type of building, use multiplier factors **29** to 35

D. Buildings that claim to be super-insulated or Energy-Star. Walls insulated to R-24. Ceilings insulated to R-40. Weather stripping on all doors and windows. Thermal double pane or storm windows fit tightly. Tyvek or similar vapor barrier was taped and sealed carefully during construction. For this type of building, use multiplier factors **20** to **25**.

Multiply your building's square footage by each of the multiplier factors. This will give you two numbers which signify the Btu-per-hour (Btu/Hr) output range of a furnace for that size and type of house. Pick a furnace with a Btu/Hr output rating in the lower part of the range if your building is in a warm climate. Choosing a furnace with a Btu/Hr output rating in the higher part of the range would be appropriate if your building is in a colder climate.

Residential Air Conditioning Sizing: A simple rule of thumb for relatively cool climates such as the Northeastern United States: one ton per 500 to 1000 sq.ft.

Heating Load Method

Calculate the heating load under **design conditions**:

$$\textbf{Rate (Btu/hour)} = (A_{walls}/R_{walls} + A_{windows}/R_{windows} + A_{ceiling}/R_{ceiling} + 0.018 * V_{interior} * K) * (T_i - T_o)$$

This method is included on the Excel Spreadsheet.

Units: One Ton = 12 MBH = 12,000 Btu/h