HVAC - Space Heating Systems

An Online Continuing Education Course for Engineers

Course Number: HV-6012

Credit: 6 Hours / 6 PDH / 6 CPD

HVAC - SPACE HEATING SYSTEMS

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Maintaining comfort is not a matter of supplying heat to the body. Instead, it's a matter of controlling how the body loses heat. "Thermal comfort" is a measure of a person's satisfaction with his or her surroundings, and is achieved when a desirable heat balance between the body and surroundings are met. Since there is no single ideal comfort point for any group of people, a range of values are described as the ideal thermal zone. These conditions are:

1. Air temperatures between 60-72°F, dependent upon the type of activity being carried out, age of occupants and the level and quality of clothing;
2. Air temperature at feet level, not greater than 5.4°F below that at head level;
3. Airflow past the body is horizontal and at velocity ranging between 40 and 50 feet per minute. A variable air velocity is preferable to a constant one;
4. Room surface temperatures not above the air temperatures;
5. Relative humidity between 40%- 60%.

The heating system design can have lot of options; the three main considerations in the selection of a heating system are: 1) low installation cost, 2) low operating and maintenance cost, and 3) adequate control of space conditions.

In this course, we will categorize heating systems in several ways. First we will consider where the primary energy comes from. Then we will compare the various options and discuss the variety of ways used to deliver heat within the space and finally, some general guidelines on the energy conservation and application strategies for various buildings. The course is divided in six sections:

Section # 1	The Basics of Heat Loss
Section # 2	Application Considerations – Fuel Choices
Section # 3	Types of Heating Systems
Section # 4	Gas & Oil Fired Space Heating Systems
Section # 5	Hot Water Heating Systems
Section # 6	Electrical Heating Systems
Annexure # 1	Industry Standards & Codes
Annexure # 2	Heating Equipment Characteristics
Annexure # 3	Application Considerations for various systems
Annexure # 4	Energy Conservation & Load Reduction Strategies

The course reviews the above criteria in detail and is followed by course summary and multiple – choice quiz at the end.

SECTION 1 THE BASICS OF HEAT LOSS

In this section, we will examine

1. How heat loss occurs?
2. How to size the heating system?
3. How to extrapolate your heat loss results into an annual energy usage rate?
4. How to estimate the annual cost of heating?
5. Basis of selecting appropriate heating source.

How Heat Loss Occurs?

Heat loss occurs from a building envelope whenever the interior temperature exceeds the exterior temperature. The rate at which it occurs is affected primarily by the efficiency of the covering materials (glazing, roof, side walls, doors, window frames and end walls). Heat loss is typically expressed in terms of total British Thermal Units per Hour (BTU/h) and is given by:

$Q = A \times U \times \Delta T$

Where:

- Q = heat loss, BTUH or BTU/hr
- A = area of the surface, square feet
- U = heat transfer coefficient, BTUH per sq ft per °F
- ΔT = temperature difference between inside and outside, °F

For example: 10 sq. ft. of single glass with U value of 1.13, an inside temperature of 70°F and an outside temperature of 0° would have 791 BTU/h heat loss: A (10) x U (1.13) x ΔT (70 - 0) = 791 BTU/h.

The most commonly discussed parameters and the factors affecting heat loss are conduction, temperature and infiltration.

1. ***Conduction*** is heat flow through a material from hot to cold. The materials used in the construction of building determine the level of conductivity. Insulating the building structure slows the flow of heat. R-value is a measure of insulation; *the larger the R-value, the lesser is the heat loss.* "U" factor is the inverse of "R" factor, ("U" = 1 / "R"); *the lower the "U" factor, the less ability of the material to transfer heat, therefore, the lower the heat loss.*
2. ***Temperature*** difference between the inside and outside of the building is the primary cause of heat loss in the winter months. The greater this difference, the higher the rate of heat loss. Since most buildings are controlled to a constant inside temperature by the occupants, higher heat loss occurs when it is colder outside.
3. ***Wind* and infiltration –** Heat loss from a building can also occur through infiltration--the leakage of air into a building through cracks, poorly fitted windows and doors, chimneys and other breaks in the continuity of the enclosure.

High winds can occur on the cold nights and when they do, heat loss can be higher because of air scrubbing the outside of the space covering. Winds can also force their way through cracks in the structure, causing infiltration and drafts. In fact, the studies indicate that up to one-third of the annual heating energy goes to heat this moving infiltration air. Shrubs and windbreaks to keep the high winds from impacting the walls will help reduce this energy loss.

Heating System Sizing

The first step in designing heating system is finding out how much heat is needed. The heating load of a space depend on climate, size, and style of building; insulation levels; air tightness; amount of useful solar energy through windows; amount of heat given off by lights and appliances; thermostat setting; and other operational factors. Together, these factors determine how much heat must be put into the space by the heating system over the annual heating season. This number, usually expressed as BTU per year, can be estimated by a heat loss calculation. The overall heat loss from buildings is divided into three groups:

1. The heat transmission losses through the confining walls, floor, ceiling, glass, or other surfaces
2. Perimetric heat loss through floor slab and
3. The infiltration losses through cracks and openings, or heat required to warm outdoor air used for ventilation.

Heat loss estimation shall be made on the worst scenario. The important points to note are:

a. The heat loss calculations are made on most unfavorable but economical combination of temperature and wind speed.
b. Credit for the heat of people present in the building is normally not taken since the building could be unoccupied.
c. Internal heat gain from lighting and appliances is usually neglected.
d. Inside design temperature for most commercial and residential spaces is 65°F.

Heat Loss from Building Envelope (wall, roof, glazing etc)

The hourly rate of heat loss from the building envelope is given by equation:

$Q = U \times A \times (Ti - Ta)$

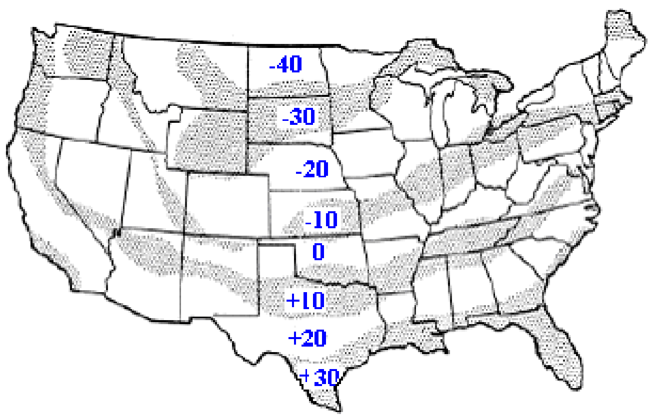
Where

- Q = total hourly rate of heat loss in BTUH
- A = area of the surface, square feet; the value measured from building plan and elevation drawings
- U = heat transfer coefficient, BTUH per sq ft per °F; ; the value dependent on the thickness and materials of construction

- Ti = inside design temperature in °F; the recommended value is 65°F
- To = outside design temperature in °F; look up for geographical location and refer ASHRAE handbook

Let's examine each one of these terms, starting at the bottom.

1) *The outside design temperature (To):* First step is to obtain data on the local micro climate of the region. This information is available from ASHRAE Handbook of Fundamentals or from the local airport database. As a basis for design, the most unfavorable but economical combination of temperature and wind speed is chosen. *Use of 99% values is recommended, which suggest that the outdoor temperature is equal to or lower than design data 1% of the time.* For example, the Pittsburgh, PA, 99% design temperature is 4°F. Only one percent of the hours in a typical heating season (about 30 hour's total) fall at or below that temperature. Since most of these hours are during the night-time when most people are sleeping and because these extremes are buffered by the large storage mass of the building, these cooler periods usually go unnoticed. For general reference, the map below shows the lowest outside temperatures.



Winter Design Temperature Map

2) The *inside design temperature (Ti)* is traditionally taken as 65°F, because most buildings have people, lights, and equipment that will reduce the occupied heating requirement in comparison to the unoccupied winter night loads. But there are numerous exceptions such as warehouses and hospitals.
3) The *net area (A)* of each building section is determined from the drawings (in new construction) or from field measurements (in retrofit situations). In addition to the areas of the four walls, floor, and ceiling, we must also consider heat loss from doors and windows. Finally, we will need to determine the volume of the building as an easy way to estimate the rate of infiltration into the building measured in air changes per hour.
4) The *heat transfer coefficient (U-factor)* is a measure of the rate of heat loss or gain through construction materials and depends on the thickness and the nature of the material. This rate is the U-Factor (heat transmission coefficient) of a material. It

indicates how many BTUs will flow through a material having a one-square-foot surface in one hour for each degree of temperature difference between inside and outside. The lower the U-factor, the greater the material's resistance to heat flow and the better is the insulating value. U-value is the inverse of R-value (hr sq-ft °F /BTU).

Mathematically, the U-value of a construction consisting of several layers can be expressed as

$U = 1 / \sum R$

Where

- $\sum R$ is the sum of the thermal resistances for each component used in the construction of the wall or roof section. The R-value of the single layer can be expressed as:

  $R = 1 / C = 1 / K\, l_t$

Where

- C =
- K =
- l_t = t

As an examp ... low:

To view the remainder of the course material and to take the quiz for PDH credit, you must purchase the course.

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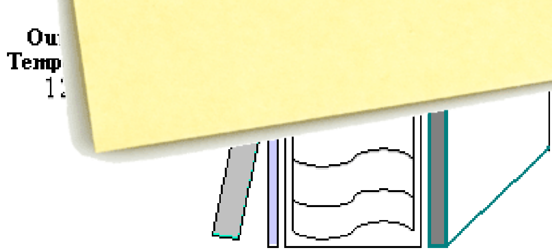

Wall Construction Details

There are 6 components contributing to the R-value

1. Outside Air Film (15 mph) = 0.17
2. Wood siding (1/2 x 8") = 0.81
3. Sheathing (1/2" regular) = 1.32