PDHonline Course M207 (4 PDH)

HVAC - Overview of Space Heating Systems

Instructor: A. Bhatia, B.E.

2020

PDH Online | PDH Center

5272 Meadow Estates Drive
Fairfax, VA 22030-6658
Phone: 703-988-0088
www.PDHonline.com

An Approved Continuing Education Provider

HVAC - Overview of Space Heating Systems

Course Content

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, dependant 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 3°C below that at head level.
3) Airflow past the body is horizontal and at a velocity of 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 of between 40% to 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.

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

A = Square foot area of covering (sq-ft)

U = Conductivity value (Btu/hr-ft^2-°F)

T = Temperature difference (deg 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"); t*he 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 -** The U-values and indoor-outdoor temperature differential alone do not describe the extent of heat loss; the wind & infiltration has a great influence on the heat loss. 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 remember 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 * A * (Ti - Ta)

Where

1) Q = Total hourly rate of heat loss in Btu/hr

2) U = Heat transfer coefficient in Btu/hr-ft^2-°F; the value dependent on the materials of construction

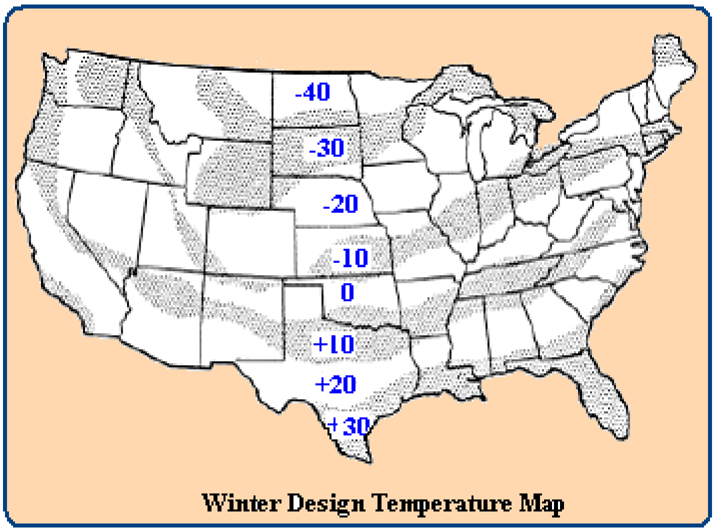
3) A = Area of exposed surface in ft^2; the value measured from building plan and elevation drawings

4) Ti = Inside design temperature in °F; the recommended value is 65°F

5) 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.



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 of materials. 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

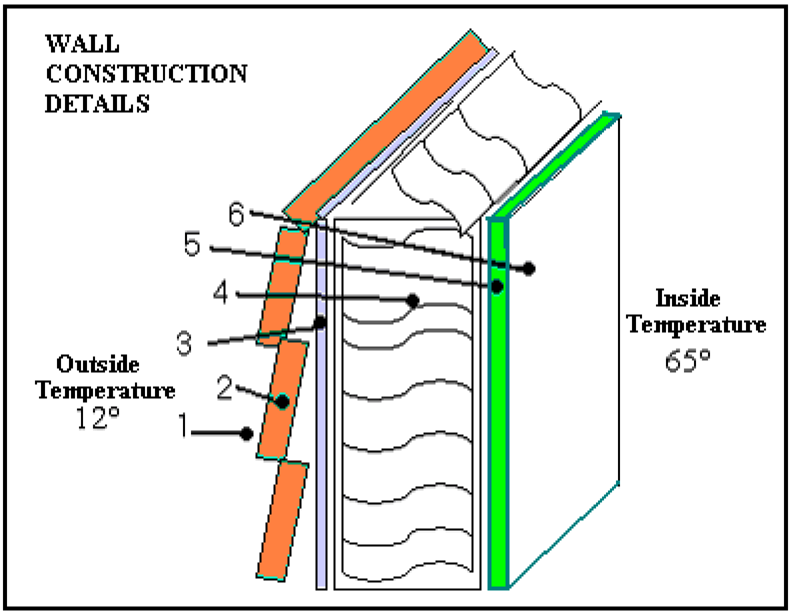
   $\sum R$ is the sum of the thermal resistances for each component used in the construction of the wall or roof section. The R-value of the single layer can be expressed as:

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

   Where

   1) C = layer conductance (Btu/hr sq-ft °F)
   2) K = layer conductivity (Btu in/hr sq-ft °F)
   3) l_t = thickness of layer (inches)

   As an example, consider a section of standard wall construction below:



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
4. Insulation (3-1/2" fiberglass) = 11.00
5. Gypsum board (1/2") = 0.45
6. Inside air film (still air) = 0.68

Adding the values gives a total resistance, $\sum R$ = 14.43 (hr-ft^2-°F / Btu) and therefore U-factor is determined by taking the reciprocal of the R-value i.e. $U = 1/\sum R = 1 / 14.43 = 0.07$ Btu / hr-ft^2-°F.

Here are a few of the most common covering materials and their associated "U" factors:

Material	"U" Value (Btu / hr-ft^2-°F)
Glass, single	1.13
Glass, double glazing	.70
Single film plastic	1.20
Double film plastic	.70
Corrugated FRP panels	1.20
Corrugated polycarbonate	1.20
Plastic structured sheet; 16 mm thick 8 mm thick 6 mm thick	 .58 .65 .72
Concrete block, 8 inch	.51

Heat loss from floors on slab

A substantial amount of heat energy is lost out of the perimeter of a space through the ground below the perimeter walls and ends. The slab heat loss is calculated by:

Q = F* P * (Ti-Tg)

Where:

1) F is the heat loss coefficient for the particular construction and is a function of the degree days of heating.
2) P is the perimeter of slab
3) Ti is the inside temperature
4) Tg is the ground temperature

Note that the heat loss from slab-on- grade foundations is a function of the slab perimeter rather than the floor area. For a concrete slab-on-grade floor, the thermal resistance to heat loss into the ground is close to an R-value of 10 hr-ft^2-°F/Btu (or F = 1 / 10 = 0.1 Btu/hr-ft^2-°F), and the ground temperature is fairly constant at about 45°F in the winter (65 - 45 = 20°F).

Perimetric heat loss is conductive heat loss that can be minimized by insulation below the frost line.

Infiltration and Ventilation Loss

The heat loss due to infiltration and controlled natural ventilation is divided into sensible and latent losses. Ventilation replenishes carbon dioxide, removes heat and assists in the control of humidity levels. Ventilation essentially provides the same benefit regardless of the season. Recommended summer ventilation rates vary but a common accepted rate is 8 cubic feet per minute (CFM) per square footage of floor space. Winter recommended ventilation rates are 1.5 CFM. The energy associated in raising the temperature of infiltrating or ventilating air up to indoor air temperature is the sensible heat loss, which is estimated by:

Q sensible = V * ρair * Cp * (Ti – To)

Where:

1) V = volumetric air flow rate
2) ρair is the density of the air
3) Cp = specific heat capacity of air at constant pressure
4) Ti = indoor air temperature
5) To = outdoor air temperature

The energy quantity associated with net loss of moisture from the space is latent heat loss which is given by:

Q latent = V * ρair * hfg * (Wi – Wo)

Where

1) V = volumetric air flow rate
2) ρair is the density of the air
3) Wi = humidity ratio of indoor air
4) Wo = humidity ratio of outdoor air
5) hfg = latent heat of evaporation at indoor air temperature

Air infiltration is treated the same way as ventilation. Some buildings have substantial air infiltration. This occurs when the structure (building envelope) is “leaky” and admits fresh air, which replaces heated inside air. For example spaces covered with lapped glass typically require more consideration of air infiltration when heat loss calculations are made. A very tight building will lose about 0.5 air changes per hour; an average building is about 1.0 air change per hour and a leaky older space can lose well over 2.0 air changes per hour.

Degree Days & Annual Heat Loss

The degree-day concept has traditionally been used to determine the coldness of a climate. For example, Pittsburgh, Columbus, Ohio, and Denver, Colorado, have comparable annual degree days (about 6000 DD/year). It can be expected that the same structure in all three locations would have about the same heating bill. Move the building to Great Falls, MT (7800 DD/year), it would have a higher heating bill; but in Albuquerque, NM, (4400 DD/year), it would have a relatively lower heating cost.

From the above data, we can make an educated guess about the annual heat loss. To determine the annual heat loss, divide the energy loss rate by the design temperature difference and then multiply it by 24 hours per day and the number of annual degree days (from the weather files of the location). For example, a house with a design heating load of 30,000 Btu/hr in Pittsburgh (outdoor design temperature of 4°F) will use:

[30,000 Btu/hr x 24 hr/day / (65-4) (°F)] x 6000 DD/yr = 71 million Btu/yr

---

Selecting Fuel and Heating System

Selecting the fuel and heating system best suited for your needs depends on many factors. These include: the cost and availability of the fuel or energy source; the type of appliance used to convert that fuel to heat and how the heat is distributed in your space; the cost to purchase, install, and maintain the heating appliance; the heating appliance's and heat delivery system's efficiency; and the environmental impacts associated with the heating fuel.

One somewhat simple way to evaluate heating options is to compare the cost of the fuel. To do that, you have to know the energy content of the fuel and the efficiency by which it is converted to useful heat.

Natural Gas: The heating capacity of gas heating appliances is measured in British thermal units per hour (Btu/h). (One Btu is equal to the amount of energy it takes to raise the temperature of one pound of water by 1 degree Fahrenheit.) Most gas heating appliances have heating capacities of between 40,000 and 150,000 Btu/h.

Consumption of natural gas is measured in cubic feet (ft^3). This is the amount that the gas meter registers and the amount that the gas utility records when a reading is taken. One cubic foot of natural gas contains about 1,007 Btu of energy.

Propane: Propane, or liquefied petroleum gas (LPG), can be used in many of the same types of equipment as natural gas. It is stored as a liquid in a tank, so it can be used anywhere, even in areas where natural gas hookups are not available. Consumption of propane is usually measured in gallons; propane has an energy content of about 92,700 Btu per gallon.

Fuel Oil: Several grades of fuel oil are produced by the petroleum industry, but only # 2 fuel oil is commonly used for space heating. The heating (bonnet) capacity of oil heating appliances is the steady-state heat output of the furnace, measured in Btu/h. Typical oil-fired central heating appliances have heating capacities of between 56,000 and 150,000 Btu/h. Oil use is generally billed by the gallon. One gallon of #2 fuel oil contains about 140,000 Btu of potential heat energy.

Electricity: The watt (W) is the basic unit of measurement of electric power. The heating capacity of electric systems is usually expressed in kilowatts (kW); 1 kW equals 1,000 W. A kilowatt-hour (kWh) is the amount of electrical energy supplied by 1 kW of power over a 1-hour period. Electric systems come in a wide range of capacities, generally from 10 kW to 50 kW.

When converted to heat in an electric resistance heating element, one kWh produces 3,413 Btu of heat.

Btu Content of Fuels

Since the actual heat content of different types of fuels varies, the approximate average values are often used. The table below provides a list of typical heating fuels and the Btu content in the units that they are typically sold in the United States. The figures below are for guidance only; commercial and industrial users should obtain more precise values from their fuel vendors.

Average Btu Content of Fuels	
Fuel Type	**No. of Btu/Unit**
#2 Fuel Oil	140,000/gallon
#6 Fuel Oil	150,500 /gallon
Diesel	137,750/gallon
Kerosene	134,000/gallon
Electricity	3,412/kWh
Natural Gas*	1,025,000/thousand cubic feet
Propane	91,330/gallon
Wood (air dried)*	20,000,000/cord or 8,000/pound
Pellets (for pellet stoves; premium)	16,500,000/ton
Kerosene	135,000/gallon
Coal	28,000,000/ton

*Natural gas is a mixture of several gases and can vary in composition from supplier to supplier. For this and other reasons it is often sold on the basis of "therms" (1 therm equals 100,000 Btu) rather than "per cubic foot".

*A cord of wood is a rough measuring unit; it is a stack of wood 4 feet high, 8 feet long, and 4 feet wide. A "good" cord of wood will be tightly packed. Pellet fuels are usually made from sawdust. The Btu content will therefore vary depending on the type of wood that the sawdust is from. Pellet fuels typically have a moisture content of around 10 percent.

Note that the energy content values may vary drastically, especially for wood and coal. As an energy system designer, you must learn the purchasing units associated with each energy source. Rounding things off can make it a little bit easier. For example, natural gas contains about 1000 Btu per cubic foot. So, one hundred cubic feet (CCF) contains about 100,000 Btu. A gallon of fuel oil delivers almost 100,000 Btu per gallon. Knowing the unit efficiency allows you to calculate the original content.

Heating Values - A More Detailed Discussion

The heating values provided in the table above are the "higher" or "gross" heating values of the fuels as estimated by the Energy Information Administration in the Annual Energy Review 2001. "Higher (or gross)" heating values are commonly used in energy calculations in the United States. "Net" or "lower" heating values may also be used. The difference between the two values is the amount of energy that is necessary to vaporize water that is contained in the fuel or created in the combustion process when hydrogen in the fuel is combined with oxygen to form water vapor. In general, this difference can range from as little as 2 percent to as much as 60 percent, depending on the hydrogen or moisture content of specific fuels. The heat energy contained in the water vapor is generally lost as the combustion gases leave the appliance vent or chimney. Some types of combustion appliances, however, such as high efficiency "condensing" forced-air furnaces, are able to capture much of the heat contained in the water vapor before it leaves the furnace vent (thus the term "condensing"). *Since electricity is not burned in a heating appliance, the two values are equal.*

Wood heating values can vary significantly. The most important factor affecting useful Btu content is the moisture content of the wood. Well-seasoned, air-dried wood will typically have a moisture content of around 20 percent (when compared to a "bone dry" sample of the wood). *A very rough approximation of the effect of moisture content on the heating value is for every percent increase in moisture content (relative to a bone-dry sample) there is a one percent decrease in heating value.*

How to equate the fuels based on heating values?

The average Btu content of fuel values make comparisons of fuel types possible. For example:

The heat content of one gallon of fuel oil roughly equals that of 41 kWh of electricity, 137 cubic feet of natural gas, 1.5 gallons of propane, 17.5 pounds of air-dried wood, 17 pounds of pellets, a gallon of kerosene, or 10 pounds of coal.

One million Btu is the heat equivalent of approximately 7 gallons of No. 2 heating oil or kerosene, 293 kWh of electricity, 976 cubic feet of natural gas, 11 gallons of propane, 125 pounds of air-dried wood, 121 pounds of pellets, or 71 pounds of coal.

The efficiency of the heating appliance is an important factor when determining the cost of a given amount of heat. In general, the efficiency is determined by measuring how well an appliance turns fuel into useful heat. (The condition of the heat distribution or delivery system also affects the overall system efficiency.) Many types of space heating appliances must meet minimum standards for efficiency developed by the U.S. Department of Energy. Table below provides average efficiencies for common heating appliances.

Estimated Average Fuel Conversion Efficiency of Common Heating Appliances

Fuel Type - Heating Equipment	Efficiency (%)
Coal (bituminous)	
Central heating, hand-fired	45.0
Central heating, stoker-fired	60.0
Water heating, pot stove (50 gal.)	14.5
Oil	
Cast iron head burner	60.0
Flame retention head burner	70 - 78
High static replacement burner	75 - 82
New standard furnace	78 - 86
Mid efficiency furnace	83 -89

High efficiency condensing furnace	85 - 95
Typical central heating	80 -85
Water heater (50 gal.)	60
Gas	
Conventional furnace	60.0
Vent damper with non-continuous pilot light	62 - 67
Mid efficiency furnace	78 -84
High efficiency condensing furnace	89 - 97
Typical central boiler	85.0
Minimum efficiency central furnace	78.0
Room heater, unvented [note 1]	99.0
Room heater, vented [note 1]	65.0
Water heater (50 gal.)	62.0
Electricity	
Baseboard, resistance	100
Central heating, electric furnace-forced air	100
Central heating, air source heat pump [note 2]	200+
Central heating, ground source heat pump [note 2]	300+
Wood & Pellets	
Franklin stoves	30.0 - 40.0
Stoves with circulating fans	40.0 - 70.0
Catalytic stoves	65.0 - 75.0
Pellet stoves	85.0 - 90.0

Note 1*: Most of the appliance efficiencies given in the table above roughly account for the net heating value fuels used in a vented appliance (i.e. one that has a chimney). An un-vented space heater, such as a kerosene heater or a natural gas fireplace insert, delivers nearly all of the heating value of a fuel to the space in which it is located. It also puts all the products of combustion including carbon dioxide, water vapor, and small amounts

of carbon monoxide, sulfur dioxide, and nitrous oxides into the room. These types of heating units generally require that a window be opened (slightly) for safe operation, which reduces their overall heating capability.

Note 2*: Heat pumps are measured by coefficient of performance (COP). A COP of 1.5 means that the equipment has an efficiency of 150%.It can be over 100% because heat pumps move heat from outside to inside, instead of creating it.

Comparing Fuel Costs

Comparing fuel costs is generally based on knowing two parameters viz. the efficiency of the appliance and the unit price of the fuel. Follow the steps below:

1) Convert the Btu content of the fuel per unit to millions of Btu by dividing the fuel's Btu content by 1,000,000. For example: 3,413 Btu/kWh (electricity) divided by 1,000,000 = 0.003413 millions Btu per unit.
2) Use the following equation to estimate energy cost:

   Energy cost ($ per million Btu) = Cost per unit of fuel ÷ [Fuel energy content (in millions Btu per unit) × Heating system efficiency (in decimal)]

The table below provides examples of heat cost tabulation for different fuels and heating equipment.

Heating Equipment	**Fuel**	**Fuel Cost (Note #1)**	**Fuel energy content (in millions Btu per unit)**	**Heating System Efficiency (Note #2)**	**Heat Cost in $ per million Btu (Note #3)**
Resistance Baseboard	Electric	$0.086 per kWh	0.003412	0.99	= $25.46
Heat Pump	Electric	$0.086 per kWh	0.003412	2	= $12.60
Medium Efficiency Furnace	Natural Gas	$9.96 per thousand cubic feet	1.03	0.90	= $10.74
Medium Efficiency Furnace	Fuel Oil	$1.25 per gallon	0.14	0.85	= $10.5
Medium Efficiency Furnace	Propane	$1.09 per gallon	0.0913	0.85	= $14.05

Note #1: The fuel costs used are the national annual average residential fuel prices in 2001 according to the Energy Information Administration (EIA), U.S. Department of Energy. Prices will vary by location and season.

Note #2: The system efficiencies used are assumed examples only.

Note #3: Energy cost ($ per million Btu) = Cost per unit of fuel ÷ [Fuel energy content (in millions Btu per unit) × Heating system efficiency (in decimal)]

Rule of Thumb Estimation of Annual Heating Cost

To convert Btu/yr values into dollars per year for the annual heating cost, we have to check how much energy costs. Again these values vary widely, depending on season, geographic location and type of fuel. This assumption is too general to use for making large economic decisions, but it is certainly easier than trying to keep up with these constantly changing values.

For simplicity, consider all energy will cost exactly $10 per million Btu. At today's energy prices, this average value is high for gas heat (by about a factor of 2), about right for fuel oil, and low for electric resistance heat (by about a factor of 2). The reason for this is that natural gas, for all practical purposes, is a raw commodity, while electricity is a value-added commodity. In other words, electricity is generated by raw commodities, including natural gas.

Even these prices vary substantially across the nation. Natural gas in New York sells for almost three times the price in Colorado and Louisiana. Electricity on Long Island costs almost ten times more than the price that Bonneville Power Administration gets for their hydroelectric power in Montana.

So in the Pittsburgh example we have discussed earlier using 71 million Btu/yr, we would calculate the heating cost to be 71 x $10 = $710 per year. But in reality the heating cost might range from under $350 for gas heat to over $1400 for electric resistance heat.

SECTION - 2 APPLICATION CONSIDERATIONS FOR VARIOUS SYSTEMS

There are almost endless variations and combinations that can be utilized to create the best system. Every type of heating equipment has its strength and limitations. Depending on the level of comfort and the operating costs, you'll need to choose the style of system that integrates best with your facility requirements. It's simply a matter of determining your requirements and researching the best options with expert design professionals.

In this section, we will examine

1) Heating System Choices
2) Factors influencing the choice of heating system
3) Heating Systems Ranking
4) System Design Decisions
    - Central or Zoned systems
    - Radiative or Convective heating systems
    - Type of Heating Equipments

Heating System Choices

There are numerous options on the choice of heating systems. A general understanding of heating equipment helps you make more informed decisions when discussing details with air conditioning and heating contractors.

Broadly, there are two types of heating equipment: one is combustion equipment and the other is electrical equipment.

1) In combustion equipment, heat is generated by the combustion of fuel in a furnace under careful air/fuel control and the heat of combustion is recovered in some form of integral heat exchanger.
2) In electric equipment, an electric resistance convert electricity to heat with almost 100 percent efficiency (but is still costly to operate-discussed later in section 5).

These can be further broken down into central and large package heating equipment and portable heating equipment.

Factors Influencing the Choice of Heating System

Heating design is too often compromised by the first cost of equipment and the recurring fuel costs need for operation. The fuel price should not be the sole measure for selecting a heating system. The broad comparisons on the choice of a heating system is based on various system characteristics such as equipment efficiency, fuel source availability, required system capacity, fuel energy content in millions Btu per unit, environmental impact and heat response or recovery. Brief description of parameters that should be reviewed is discussed below:

1) ***Equipment costs*** not only vary between heating systems, but can also vary significantly within the same class of equipment depending on the size and efficiency. In many cases, the extra cost of more efficient models can be recovered in three to five years due to energy savings. Most experts agree that higher first costs are justified if the energy efficiency investments yield payback within five years. This means if you pay an extra $500 for a more efficient model, you should save $500 in energy costs within five years to make it worthwhile. This means approx 20% simple return on your investment. As utility costs increase, so will the return on your investment.
2) ***Price of fuel:*** This is not always easy to do without some help. You will need to know what your heating costs were for the last several years for the fuel you were using and compare that with the cost of the alternative fuel over the same period. Local consumer agencies should be able to help here. (Refer to discussion in section-1 on comparing the fuel costs).

3) ***Comfort:*** Comfort is defined by uniformity, heat response control and noise levels. A comfortable heating system may incorporate some radiant heating as well as convective. It may be difficult to obtain comfort levels if a purely radiant system is used (such as radiant panels) so a mixture of convective and radiant heating is desirable.

   - To maintain adequate comfort conditions a controllable heating system is necessary e.g. automatic thermostatic controls on oil or gas-fired system or electrical heating system. Note that a solid fuel system cannot be easily controlled.
   - Heat Response factor means how quickly the system will supply heat to the space. A heating system with a good "heat response" time brings a room up to the human comfort zone more quickly. A convective heater has much quicker heat response when compared to the radiant heaters.
   - If noise levels in a room such as a library are to be at a minimum then fan convectors is not a good option. Quieter form of heating options can be radiators, underfloor heating, natural convectors or a radiant ceiling.

4) ***Application & type of Building:*** There are many types of buildings each having different application. Here are few notes that require architect's or heating system designer's attention:

   - In some applications (e.g., theaters and churches) noise and vibration control are primary considerations.
   - In other buildings (refineries, chemicals or spray paint booths), explosion prevention may be the primary consideration.
   - In textile facilities fire is the major concern and in food facilities, the need for sanitary conditions can eliminate several options.
   - Hospitals require clean environment; thus filtered air heating may be necessary, usually in a full air conditioning system.
   - For warehouse radiant heating may be a suitable option since the air temperature need not be high.
   - Museums and Archive Stores require constant control of room temperature and humidity - air-conditioning may be necessary.
   - In some buildings it is difficult to run services through e.g. stone walls, solid concrete slabs, therefore electrical heating may be used.
   - In some buildings like nursery schools and nursing spaces, if radiators are utilised, it is advisable that low surface temperature radiators are used.
   - In wet areas like shower rooms and bathrooms underfloor heating has an advantage in that it keeps the floor dry.
   - Some buildings like churches may be intermittently used so electrical heating may not completely ruled out. High temperature roof mounted quartz electric heaters have been used in this type of building.
   - Schools have limited wall space so underfloor heating or low temperature ceiling heating is sometimes used.
   - In general, large areas benefit from the quick warm-up of air heating. In buildings with large occupancy a ventilation system may be necessary to provide adequate fresh air for occupants e.g. concert hall, auditoria. Ventilation systems with ductwork require ceiling void space.

5) ***Plant Space:*** Room for plant and equipment, storage space for fuel etc. are some of the considerations for selection of heating systems. While natural gas may be piped and electricity lines are fixed, space is required for storing the fuel oil and solid fuels. Decision needs to be made on putting the central heating unit in the basement (check if the unit is not prone to flooding) or rooftop unit (RTU) (if noise below is not an issue). Factory assembled RTU is

cheaper option, which provides better quality control, does not require valuable building floor space, and provides direct access to interior spaces via the ceiling plenum.

In very large facilities, all utility equipments such as air-conditioning plant, heating and cooling equipment, the emergency electrical generator, the fire safety systems, and often the electrical supply transformer and Motor Control Center (MCC) and Lighting Control Center (LCC) can be located in a remote mechanical room. This allows for better central management of the system operation, but is more expensive to build.

6) **Let Buildings:** Most landlords prefer the tenant to look after payment of their own heating bills. Individual meters for gas or electricity in a block of flats means that the tenants are responsible for the payment of bills. In a large office building with several tenants electrical or natural gas heating is easy to measure in zones. Hot water heating system is cumbersome to divide. In let buildings, some form of billing arrangement needs to be in place to charge tenants. This essentially requires study on the quality of available instrumentation, ease of measurement and reliability of readings.

7) ***Appearances:*** In some buildings, the designer may require the heating system to be totally hidden e.g. underfloor heating, heated ceiling or air heating. In some buildings the designer may wish to make a feature of the heating system or heat emitters e.g. warm air ductwork system painted a bright color or concealed in a reflected ceiling plan. In some areas like parametric lengths of building cast iron radiators may be the choice. For Rooftop units (RTUs) the designer need to integrate the unit into the architectural theme of the building so that it looks like it is supposed to be there, not just added as an after-thought!

8) **Efficiencies of heating equipment** are rated by different methods such as Heating System Performance Factor (HSPF) and Annual Fuel Utilization Efficiency (AFUE) or Thermal Efficiency/Combustion Efficiency Factor (E_t/E_c). In all cases, the higher is the rating number, the more efficient the unit.

The Federal Energy Agency requires all gas and oil fired furnaces be given operating efficiency ratings -- the annual fuel utilization efficiency (AFUE). For combustion furnaces such as gas or oil, an AFUE rating of 8.1 or higher is considered good.

For electric resistance heating though heat is generated almost at 100 percent efficiency, it is very costly on $ per Btu heat release compared to other options. This is because first we generate electricity by thermal energy at 35 to 50% efficiency and than using it again for heating. The high operating cost of electricity must be considered to get an accurate picture of the system economics.

An efficient method of using electric energy as heating source is the use heat pump. For air-to-air heat pumps (the heat exchanger is cooled or heated by air), a rating of 3.2 is considered good. For water-source heat pumps where the heat exchanger is heated or cooled by water, a rating of 3.8 is considered good. If rated by the HSPF method, 6.8 or better is considered good for heat pumps.

9) **Transport Media:** Another way of grouping heating systems is by the transport media used to get the heating energy to the distribution point. Heating fuels are normally handled in one of the following ways. Some fuels are stored or warehoused (such as fuel oil in a tank or coal in a bunker), while other fuels such as natural gas or electricity are point-of-use fuels. Point-of-use fuels are delivered through utility piping or wiring networks, and are metered and billed after consumption. Stored fuels are paid for when purchased. Stored fuel suppliers are not regulated as closely or carefully compared to point of-use fuel suppliers. As a result, prices for stored fuels tend to fluctuate more widely with market conditions. Point-of-use suppliers are normally regulated by state agencies and are restricted to rate schedules that tend to lag the market response of stored fuels. Electricity can be transported directly via wires.

10) ***Environmental impact*** factor considers air pollution and the best use of resources. The products of combustion of oil, coal and gas pollute the atmosphere.

- Coal is probably the worst offender since carbon dioxide contributes to the greenhouse effect and sulphur dioxide causes acid rain. Smoke causes urban smog and soot and ash add to the problem. Oil produces contaminants to a lesser extent and gas is probably the best of the three.

- Using electricity is of little benefit because power stations burn fuel to produce electricity. For example, to generate one kilowatt hour of electricity in a coal-fired plant will require burning one pound of coal. This produces about three pounds of carbon dioxide (a greenhouse gas) and four ounces of sulfur dioxide (contributes to acid rain).
- A totally 'green' source of heat may be solar energy if you live in an area with plenty of sunshine.

11) ***Safety:*** Ensure all apparatus is approved and meets standards and regulations. You should be aware of the following hazards when considering heating system:
    - Fires and burns caused by contact with or close proximity to the flame, heating element, or hot surface area.
    - Some open gas and coal fires and paraffin heaters have a poor safety record.
    - Fires and explosions caused by flammable fuels or defective wiring.
    - Indoor air pollution caused by improper venting or incomplete combustion of fuel-burning equipment.
    - Carbon monoxide poisoning caused by improper venting of fuel-burning equipment
12) **Security of Supply of Heat Source:** Some fuels at certain times may be liable to unsecured supply e.g. oil prices can fluctuate. It may be advisable to have a dual fuel system so that burners can easily be changed over to burn the cheaper or more readily available fuel.

    Alternative sources of energy are not always secure e.g. the wind doesn't always blow on a wind farm. The sun doesn’t always shine if the system relies on solar panels. A hybrid system is more secure or back-up boilers can be used.
13) **Fluctuating Heat Demand:** In some buildings the demand for heat fluctuates widely throughout the day. To meet this demand economically, a modular system such as multiple unit heaters or electrical units may be a good option. This means that the required number of boilers is automatically switched on to meet the demand.
14) **Industrial Waste Heat:** In some industrial units, heat is available from the process e.g. condensate, a by-product of steam or high temperature exhaust flue gases. Waste heat recovery equipment could be utilized to generate hot water or steam, which can be used to warm air in a heat exchanger. There are many ways in which waste heat can be utilized to pre-heat water or up-grade in heat pumps for further use in space heating.
15) **Maintenance:** Maintenance is very important with the heating systems because there are many pieces of equipment that can cause problems. With fuel fired equipment, the heat exchanger surfaces have to be cleaned and the burner has to be maintained and adjusted. In case of hot water system, the water quality needs to be assured to prevent scaling. The electrical system does not have such problems other than routine switchgear maintenance.
16) **Financial Rebates/Subsidies:** Some gas and electric utilities offer rebates or low interest loans if certain systems are installed. Electric utilities prefer high efficiency heat pumps using heat recovery units to improve water heating. Gas utilities prefer efficient combinations of gas space and water heating systems. If rebates or low interest loans are offered, it could make the "equipment cost" factor more favorable.

Heating Systems Ranking

The heating systems are ranked based on survey ratings from a group of design professionals, facility managers and contractors. In determining the overall rank of various systems, more weight is given to the "efficiency and fuel cost" factor.

1) Ranked first is the natural gas heating systems:

   Natural gas heating systems have high efficiencies and low fuel costs, low environmental impacts, quick heat response, moderate equipment costs and are relatively safe. It is clean burning, easy to use, and often the lowest cost per delivered energy. More efficient models have electronic ignition as opposed to pilot lights. Natural gas is the most popular heating source for locations where it is available.

2) Ranked second is the air to air heat pump systems:

Air to air heat pump systems are generally efficient to operate, but initial equipment cost is usually higher and heat response is slow. A heat recovery unit can be added to improve the performance of the water heater. Where resistance costs more than fuel fired systems on a Btu-for-Btu basis, heat pumps may be a more cost-effective alternative, especially where the heat pump can also provide space cooling, dehumidification, or recover building or waste-water waste heat.

3) Ranked third is the geothermal heat pump systems:

Water source or geothermal heat pump systems use a heat exchanger to recover heat from or release heat to ground water or earth. Systems using pumped well water may not be allowed in some water districts and may have scaling problems. The cost of these systems is generally highest, but comparable to natural gas in terms of efficiency and cost effectiveness to operate. Environmental impact is moderate; heat response is usually better than air to air heat pumps.

4) Ranked fourth is the fuel oil systems:

Fuel oil heating systems have moderately high efficiencies, moderate initial costs, relatively high environmental impact, and high heat recovery response. Fuel oil shares many of the same characteristics as gas, but requires on-site storage of fuel and a fuel unloading site.

5) Ranked fifth is the liquefied petroleum gas systems:

Liquid petroleum gas systems, such as propane and butane, have a moderately low initial cost, relatively high fuel cost, moderate environmental impact and high heat response. In general, the same technologies and comments apply to propane as to natural gas, with slight differences in the efficiencies. Propane has a lower hydrogen level than natural gas. About 3% less energy is tied up in the form of latent heat with propane systems than with natural gas. This means that conventional and mid-efficiency propane furnaces can be expected to be slightly more efficient than comparable natural gas units. On the other hand, propane's lower hydrogen content makes it more difficult to condense the combustion products, so that propane-fired condensing furnaces will be 2%-3% less efficient than the same unit fired with natural gas. While all current heating equipment has built-in safety features and are installed to rigid code requirements, LPG systems are less safe than others as this gas is heavier than air.

6) Ranked sixth is the wood stove systems:

Wood stove systems have a wide range of ratings depending on efficiency. Catalytic wood stoves with combustion efficiencies near 90 percent are considerably more expensive than standard wood stoves with combustion efficiencies of 20 to 40 percent. Handling wood and ashes is an inconvenience. Wood stoves have a high initial cost and, with the exception of catalytic stoves, the environmental impact is higher than gas, oil or heat pump heating systems. The heat response of wood stoves is moderate. Coal and wood-burning systems are only used in very large installations, where the lower fuel costs can justify the higher installation costs and higher operating costs.

7) Ranked seventh is the wood burning fireplaces:

Wood burning fireplaces have negative or very low efficiencies unless properly designed. The fireplaces are mainly used for aesthetics. Handling wood, disposing of ashes and increased risk of fire due to sparks and chimney fires are problem areas.

8) Ranked eighth is the electric resistance heating systems:

Electric resistance heating is costly to operate and has tremendous impact on environment. Though the electrical heating offer number of advantages to consumer such as they are cheap to buy, least expensive to install, 100% efficient i.e. all the energy is converted into heat, safer than fuel fired systems, a clean form of heating and easy to control with a thermostat but it has a set of problems. The environmental impact of using resistance heating is high and heat response is moderate. Since most electricity is produced from oil, gas, or coal generators that convert only about 30% of the fuel's energy into electricity and after accounting losses due to transmission & distribution, converting electricity back to heating doesn't make sense. The use of electric resistance heating should never be recommended as a policy measure.

Table below may serve as a decision-making guide.

Heating System	Equipment Cost	Efficiency & Fuel Cost	Environmental Impact	Heat Response	Overall Rank
Natural Gas	4	1-3	2	1	1
Heat Pump (Air to Air)	7	2-4	4	9	2
Heat Pump (Water Source, Geothermal)	10	1-3	4	6	3
Heating Oil	5	2-5	5	1	4
LPG (Propane/Butane)	4	8	4	1	5
Wood Stoves	4-8	2-6	2-4	4	6
Wood Fireplaces	7	5-10	6-10	5-8	7
Electric Resistance (Strip)	3	10	10	3	8
# Rating Scale: 1 = best value or condition; 10 = poorest value or condition					

Efficiency Terminology

When shopping for heating equipment, it is important that you understand the common terminology used to describe different types of equipment. There are several types of efficiency terms used when describing heating equipment. The most common terms used to describe heating equipment:

1) ***Combustion Efficiency:*** This term is the most basic description of efficiency. It denotes the percentage of fuel burned and turned into heating energy.

2) ***Thermal Efficiency:*** This term is a measurement of the actual amount of available energy that transfers into the heating medium. It is derived by operating a piece of equipment at a steady state and measuring how much fuel is used vs. how much useable heat comes out. It is most typically used in reference to boilers.

3) ***Distribution Efficiency:*** This is the measure of efficiency of how well the heating equipment actually delivers the heat energy (BTUs) to your space and structure. This expression addresses how energy is distributed and transferred to the objects requiring heat.

   Distribution efficiency is greatly affected by the system(s) you select, and how you utilize your equipment. Some examples:

   1) Forced hot air systems' distribution efficiency is largely dependent upon the means of air circulation used in the space.

   2) Infrared systems, properly installed, can transfer heating energy very well to crops without the necessity of air circulation.

   3) With hot water, distribution efficiency is affected tremendously if the supply and return lines are poorly installed or are not insulated.

   4) Some hot water systems deliver heat much more efficiently than others. Finned pipes heat faster than bare pipes.

   5) With hot water, a high efficiency distribution system coupled to a poor efficiency boiler may be better than a high efficiency boiler with poor efficiency distribution.

Look at all facets of heating system efficiency when making heating equipment purchases along with other selection factors. In the following sections we will discuss some design aspects of commercially installed Gas Fired Heating Systems, Hot Water Heating Systems and Electric Heating Systems in detail.

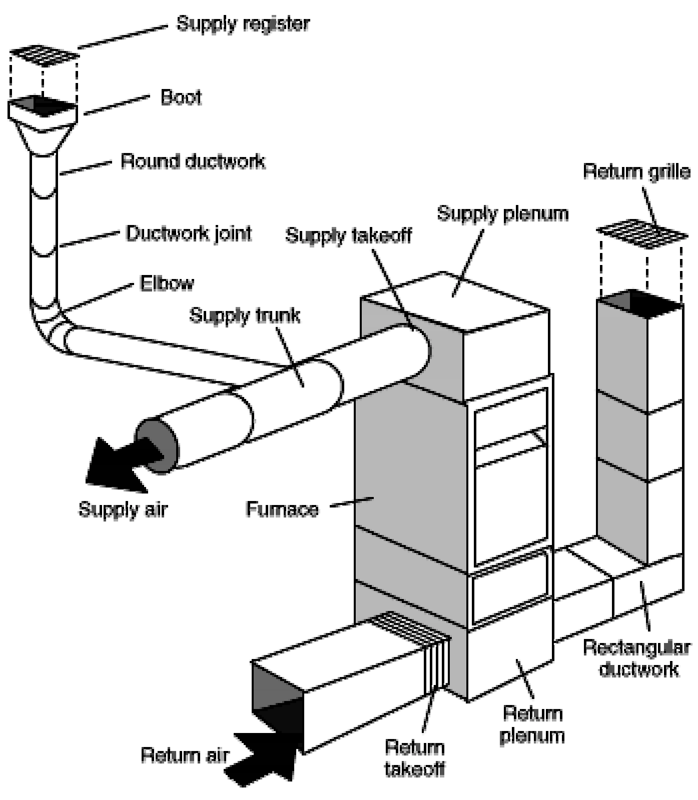
Central Heating Systems

Heating systems can be grouped into one of two categories: “central” and “zoned”.

A central heating system in commercial terminology refers to forced air systems using air handling units or hydronic (hot water) capable of heating most of your space at the one time. They consist of a heating unit, a distribution system, and controls, such as thermostats, that regulate the system. Unless fresh air is piped in from outside, the system will re-circulate 100% of the air. Properly installed, a warm air system becomes a loop by which air is drawn from the living space through return ducts to the furnace, heated, and sent back to the same space through supply ducts.

The advantages to this type of heating system are numerous. The air can be heated, cleaned, sterilized, humidified, or cooled (central air conditioning). If return air ducts are strategically located, this will reduce heat loss by recycling the warmest air back in to the system that collects at upper areas of the room.

Forced warm air systems have some disadvantages. Air coming from the heating registers sometimes feels cool (especially with certain heat pumps), even when it is warmer than the room temperature. There can also be short bursts of very hot air, especially with oversized units. Ductwork may transmit furnace noise and can circulate dust and odours throughout the indoor spaces. Ducts are also notoriously leaky, typically raising a space's heating costs by 20% to 30%.



Another form of central system is pipe system using multiple radiators. Instead of circulating warm air through a ductwork, hot water is circulated from boiler to the floor or ceiling mounted baseboard units.

Types of Central Heating System

The most economical and energy efficient central heating systems are either:

1) High efficiency, natural gas ducted heaters;
2) Natural gas hydronic systems;
3) Reversible-cycle heat pump air-conditioning system; or
4) Off-peak electric in-slab heating

When choosing gas systems, look for the energy rating label - the more stars you see, the better the performance, and the more money you'll save on your energy bill!

The table below compares various central heating systems per 1500 sq-ft space.

Central Heating System(1500 ft^2)	Description	Approx. purchase/install price	Annual Heating Costs (note 1)*
Ducted natural gas	Circulates warm air around the space.	\$4,000 - \$6,000	4-5 star rating: \$110-270 1-2 star rating: \$160-360
Reverse-cycle air conditioner	Circulates warm or cool air around the space.	\$8,000 - \$12,000	\$120-\$220
Hydronic Heating	Water is heated in a boiler (fuelled by natural gas, LPG, wood or off-peak tariff electricity) and circulated to radiator panels that heat the room.	\$5,000+	\$100-\$350(natural gas)
Electric in-slab	A concrete slab is heated by internal electric cables (or hot water pipes).	\$3 per ft^2	\$100-\$1352
Electric thin-film	Thin films installed in the ceiling wall panels or under floor coverings to give radiant heat.	\$3.5 per ft^2	\$150-\$2203

Note 1: Heater use for the winter quarter (90 days), for 8 hours per day, in an average temperature of 8 - 18°C

Zoned Systems

In contrast, zoned systems are designed to heat a zone, rather than a whole space. The space heaters are placed throughout the space, allowing you to adjust the temperatures in different area. Space heaters tend to be more economical than central heating simply because the units are smaller with lower running costs and these allow greater flexibility and individual control.

Electric baseboard heaters and radiant heating panels are examples of zoned heating.

Types of Zoned Space Heaters

The most economical space heaters in terms of running costs are either:

1) High efficiency (5-6 star rated) natural gas heaters;
2) High efficiency (3-6 star rated) reverse cycle air conditioners; or
3) Off-peak electric storage fan heaters

When choosing gas systems or reverse cycle zone air conditioners, look for the energy rating label - the more stars you see, the better the performance, and the more money you'll save on your energy bill!

The table below compares various space heaters per 600sq-ft space.

Space Heating System(600 sq-ft)	Description	Approx. purchase & install price	Annual Heating Costs (note-1)
Natural gas space heater	Produce convective and radiant heat or a combination of the two. Can be mounted on external walls or internal walls where a vertical flue can be a fitted. Rated for energy efficiency.	$600+	4-5 star rated: $70 - $125
Electric Storage fan heater(off-peak tariff)	Radiant/convection heaters which store off-peak electricity as heat in storage bricks. The fan helps distribute the heat and control the heat delivery and temperature.	$500+	$50 - $90
Reverse-cycle air conditioner (4 - 5 star rated)	Heat pump electric convection heaters, which extract heat from the outside air and deliver it into the space. Use a compressor and fan. Can also provide cooling. Rated for energy efficiency.	$800 - $5,000	$55 -$120
Electric space heater (continuous tariff)	Convection or radiant heaters which use 'general rate' electricity. Can be expensive to run, so should be limited to heating for short periods only (e.g. bedrooms)	$20+	$160 - $200
LPG space heater	Run on LPG. Produce convective and radiant heat or a combination of the two.	$600+	$100 - $300
Slow combustion wood heater	Convection or radiant heaters burning wood. Efficiency and performance depends on quality of wood and method of operation.	$800+	$85 - $110

Note 1: Heater use for the winter quarter (90 days), for 8 hours per day, in an average temperature of 8 to - 18°C

Central or Zoned System

The type that's best for you depends on the size of your facility, as well as the lifestyle. Central heating system heats all spaces served to the level required by those in use and is preferred for large facilities. In these cases, redundancy and backup capability is generally considered in the design. The overall efficiency of central system at peak loading is generally high compared to multiple zone space heaters.

Zoned heating is a plus, if majority of areas remain unoccupied and if the people preferences require different temperatures or they disagree about the most comfortable temperature. Smaller commercial buildings typically use packaged split or roof top equipment sized with this capability in mind. Redundancy is not factored into the design. If a unit fails, the presumption is that it will be repaired or replaced in short order. Most zone space heating systems permit room by room control and during off-load periods; they afford significant energy and cost savings, particularly when spaces are used only on an occasional basis. Time controls, personnel detection controls and other devices are normally integral to the unit.

As a general guideline, refer to the table below for a residential space:

If you need to heat….	Then…..
Only living zones	Use one or more high efficiency space heaters
Living areas for long periods, sleeping areas for short periods	Use high efficiency space heaters for living zones and electric 'spot' heaters for sleeping areas, or a zoned central heating system
Living and sleeping areas for long periods but at different times of the day	Use a zoned central heating system
Living and sleeping areas both for long periods at the same time	Use a zoned central heating system
Bathrooms/ensuites	Use radiant heaters e.g. strip heaters, infra-red lamps

Radiant Heating V/s Convective Heating

Most forms of space heating fall into either radiant or convective heating. Both these methods are effective in space heating and therefore it is important to understand the basic fundamentals.

1) ***Convective Heating:*** Convection utilizes air circulation to transfer heat. Convection heaters are appropriate if your rooms are insulated, well sealed against draughts and have average ceiling heights. They should be avoided in draughty rooms, rooms with high ceilings or areas with open stairwells. Convection involves two basic principles: a) Cold air displaces warm air; and b) warm air rises in the presence of cold air and is either free or forced type.

   - ***Free Convection systems*** rely on the buoyancy of heated air to provide circulation throughout the space. The most common examples are the steam radiator and the baseboard unit.
   - ***Forced Convection systems*** have a fan to force the air to circulate. Unit heaters and other fan/coil units are the common examples. These units allow the introduction of outside air and provide air filtration.

   To maximize efficient use of the heat energy, it is important to force the mixing and circulation of these warm air layers.

The Advantages of Convective Heating:

- Convectors are used to heat up spaces more quickly than radiators.
- The convective units ensure that warm air is evenly distributed throughout the structure.

The Principal Disadvantages:

- The air heaters attempt to heat the entire space including people, hardware and all of the air within the space.
- The high discharge air volumes can cause unwelcome draughts which may reduce the perceived heating effect.
- Because of their usual overhead location severe vertical temperature stratification can occur with ceiling temperatures as much as 30°C above floor temperature.

- High volume air movement can also cause dust problems which could affect product quality particularly in product coating operations.

2) ***Conduction:*** Conduction utilizes direct application of heat transfer to the space. Conduction of heat is generally a small proportion of the total heat output from equipment and is not useful heat transfer since most of the conducted heat ends up in ceiling voids or through external building fabrics as a heat loss.

3) ***Radiant Heating:*** Radiant heating systems utilize infra red radiation to heat objects, people and surfaces. Anyone who has warmed themselves by a hot wood stove or warmed their hands at a camp fire has experienced radiant heat. It is also demonstrated by standing in the sun on a winter's day; or walking near a brick wall that has been exposed to the sun during the day. In both examples, although the air may not be warm, you are able to feel the heat energy radiating from these surfaces.

   Radiant heat directly heats objects in the room, but does not directly warm the room air.

   Radiant heaters can be appropriate if your rooms have large open spaces or high ceilings, or are particularly draughty.

Advantages of Radiant Heating

- Heat can be applied only to the area required.
- No air movement is caused by the system itself, therefore unwelcome draughts are minimized and dust movement is reduced.
- Because of radiant heat transfer vertical temperature stratification is reduced.
- Lower operating costs should be achieved because of the localization of heating compared to convection systems.

Disadvantage of Radiant Heating

- An unobstructed space above floor level is necessary for an effective installation. The presence of ductwork, pipes, overheard conveyors and other equipment may sometimes limit full utilization of radiant heating.
- In certain applications where minimum ventilation rates is critical, a combination of convection heating (or the ventilation of intake air) and radiant heating is required.

Classification of Common Heat Emitters to Radiant & Convective Heating

Sno.	Emitter	Media	Heat Transfer
1.	Industrial Warm Air Heaters	air	Convective
2.	Unit Heaters	water	Convective
3.	Electrical Tubular Heating	direct	Mainly Convective
4.	Radiators	water	Mainly Convective
5.	Convectors	water	Mainly Convective
6.	Electrical Storage Heaters:	Direct	Mainly Convective
7.	Underfloor Heating: • Underfloor Heating • Electrical Underfloor Heating	 water direct	 Mainly Convective Mainly Convective

Sno.	Emitter	Media	Heat Transfer
8.	Skirting/Baseboard Heating	water	Mainly Convective
9.	Gas Radiant Heaters • Ceramic Gas Heaters • Gas Radiant Tubes	 Direct Direct	 Mainly Radiant Radiant
10.	Metal Radiant Panels Radiant Strips	water	Radiant
11.	Metal Radiant Ceilings	water	Radiant
12.	Electrical Radiant heaters • Infra-red heater • Quartz Lamp Heater • High Temperature Panels	Direct	Radiant

SECTION - 3 GAS & OIL FIRED SPACE HEATING SYSTEMS

Gas fired heating systems normally offer the most cost effective way to heat large buildings. Gas or fuel burning furnaces work on the same basic principle; the fuel is burned inside an enclosed metal container, generally referred to as a fire box and the exhaust gases are vented to the exterior of the building. The burning of the fuel warms the heat exchanger, which radiates the heat into the air in the living area. This heated air is circulated by gravity or pumped through the living area with a fan. Electric and oil fired heaters are sometimes useful for very specific space heating applications when gas is not available.

In this section, we will examine

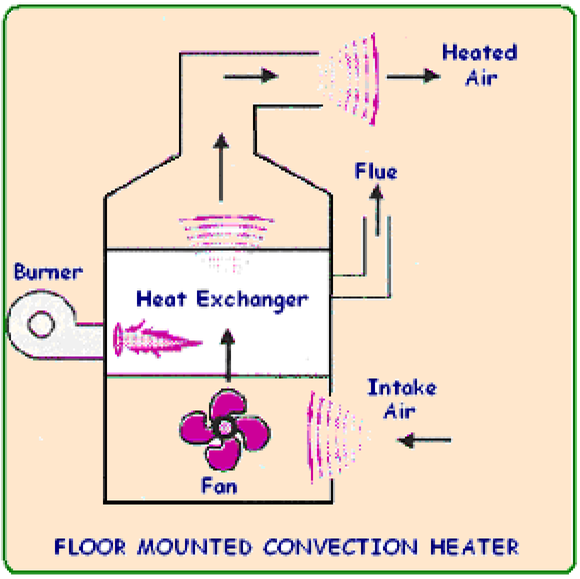
1) Codes & Standards
2) Classification & type of fired heating equipment
3) Furnace efficiencies
4) Combustion air requirements
5) Factors affecting combustion efficiency
6) Ventilation air requirements
7) Air Intake configurations
8) Rules for proper venting
9) Heating systems & indoor air quality
10) Installation, Operation & Maintenance guidelines

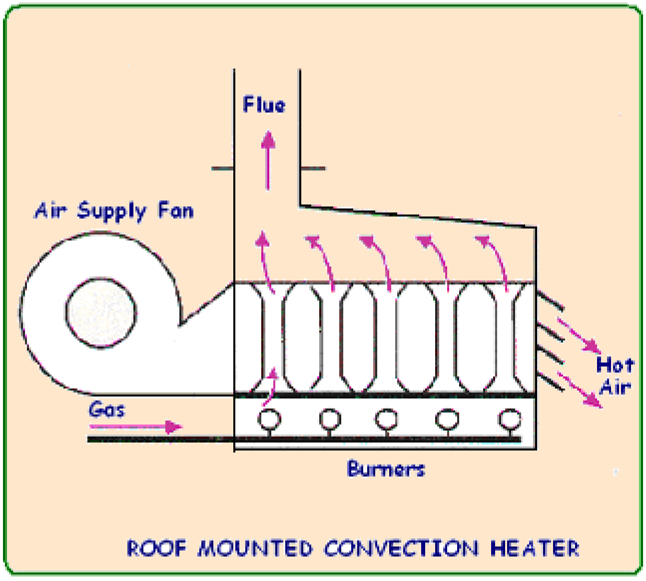
Codes & Standards

In US, installation of gas furnaces must conform to local building codes. In the absence of local codes, units must be installed according to the current National Fuel Gas Code (ANSI-Z223.1/NFPA 54). In Canada, installation must conform to current National Standard of Canada CSA-B149 Natural Gas and Propane Installation Codes, local plumbing or waste water codes and other applicable local codes. *Note that the codes are the mandatory requirements while standard are voluntary.*

Indirect-fired air heating system

The indirect fired air heating system uses a blower that delivers the warm air through a ductwork and enters the space through a diffusers or grilles. Heating is achieved indirectly by means of a burner firing into a heat exchanger with the space air blown over the heat exchanger. The products of combustion are vented out of the space. Two such systems are shown in the schematic below:





Thermal efficiency can be up to 70 to 80%, depending on the number of air turnovers per hour. Indoor air is circulated continuously through the system, so a furnace filter is used to contain dust, pollen and other airborne particles. These units can also be fitted with cooling coils for use in the summer.

When a furnace is installed in a basement it is considered an ***"Up flow" furnace***, meaning the cooler air is drawn at the base of the furnace, and the warm air exits out the top of the furnace. If a furnace is installed on the main floor of a space and the heat comes from floor registers, it is a ***"Down flow" furnace:*** In a down flow furnace, the cool air enters the furnace at the top and the warmed air exits at the bottom.

Direct-fired air heating system

Direct-fired air heating systems do not use a flue or heat exchanger. The gas is burned directly in the air stream being heated and the 100% of available heat is delivered to the heated space. Since, the products of combustion are also discharged into the space, stringent regulations apply to the design and operation of this type of heating system. The American National Standards Institute (ANSI) determines the US/Canadian standards for this equipment that sets safe maximum limits on the products of combustion (CO, CO_2 and NO_2). There are two types of direct fired air heating systems.

Blow-thru Heaters are essentially high temperature rise heaters, where burner is located downstream of the blower. This type of heater allows for the very high temperature rise to the tune of 160°F and therefore these achieve the highest Btu/CFM ratio, which means lower horsepower motors, less outside air and reduced energy costs. These are well suited for large facilities such as warehouse or industrial facilities.

Draw-thru heaters are essentially low temperature rise heaters which uses a draw-thru blower downstream the burner. It moves a large volume of warm air through a low temperature rise and provides constant air output. Generally these heaters are used as makeup air heaters for the facilities, which exhaust large volumes of air during the heating season.

As a rule of thumb a high temperature rise blow thru designs are best suited for space heating while low temperature rise draw thru designs are best suited for heating makeup air.

Gas & Oil Fired Furnaces – A Comparison

1) ***Conventional natural gas-fired*** warm-air furnace has a naturally aspirating burner, which means that air for combustion is drawn in from the surrounding area by the natural forces of hot air rising. The gas and air burn, forming combustion gases give up heat across a heat exchanger and are exhausted to the outside via a flue pipe and vent. A dilution device, known as a draft hood, isolates the burner from outside pressure fluctuations by pulling varying

quantities of heated air into the exhaust. A circulation fan passes indoor air from the return ducts over the furnace heat exchanger. The warmed air then flows into the ductwork for distribution around the indoor space. These older natural gas systems usually have seasonal efficiencies of about 60%.

A minor improvement in efficiency comes with adding a vent damper in the flue exhaust. By closing off the vent during the off cycle, the damper prevents some of the warm air from being drawn up the flue and lost to the outdoors. These furnaces usually have an electric or electronic ignition. Fuel savings are generally in the 3%-9% range, relative to a conventional furnace.

2) ***Conventional oil furnace*** is similar to a natural-gas furnace, but the dilution device is a barometric damper--a plate that acts as a valve on the side of the flue pipe. The damper isolates the burner from changes in pressure at the chimney exit by pulling varying quantities of heated room air into the exhaust. The quantity of air drawn through the barometric damper is much greater than the quantity required for combustion and can represent 10% to 15% of the total heat loss. The burner is a high-pressure gun type, with a blower fan to help mix the oil and air for good combustion. A conventional oil furnace with a cast-iron head burner has a seasonal efficiency about 60%. Replacing the conventional burner with a flame retention head burner will save 10%-15% on the fuel bill.

3) ***Mid-efficiency gas furnaces*** usually have a naturally aspirating burner like conventional units. They do not have a continuous pilot, however, and instead of a draft hood, they are equipped with a powered exhaust--usually a built-in induced draft fan. They save 15%-25% of the energy used by conventional gas furnaces.

   One word of caution: do not buy a mid-efficiency furnace that is more than 82% efficient. These systems often have condensation problems in the furnace or venting system. There is also some concern about the longevity of high temperature plastic pipe used to vent many of these mid-efficiency units. For higher efficiency, get a condensing furnace.

4) ***Mid-efficiency oil furnaces*** use a more efficient high-static retention burner. This type of furnace also features an improved low-mass combustion chamber (usually ceramic fiber) and passes the hot combustion gases through a superior heat exchanger that enables the circulating space air to extract more heat. The barometric damper, with its large requirement for air to dilute the combustion gases, has been eliminated in the most efficient of these designs. Benefits of a good mid-efficiency furnace are much lower combustion and dilution air requirements as well as more power to exhaust the combustion products (both advantages in new, tighter housing); a safety shutoff in case of draft problems; and a more effective venting system. Mid-efficiency oil furnaces can have seasonal efficiencies of 85%-89% and use 25%-30% less fuel than a conventional oil furnace producing the same amount of heat.

5) ***Gas condensing furnace*** condenses the water vapor produced in the combustion process and uses the heat from this condensation. An enlarged heat exchanger surface lowers the temperature of the exhaust gases, making the furnace more efficient. The exhaust gas temperature drops to the dew point of the water vapour in the gas, causing the vapour to condense to water and give up 970 Btu for every pound of water condensed. Natural gas can yield more than 1 gallon (8 lbs) of water per 100,000 Btu (one therm) burned, giving up about 7,760 Btu. Condensing furnaces achieve AFUE rating up to 96 percent. Because the flue gas temperature is low, plastic piping can be used for venting out the side wall of the building. Although a condensing unit costs more than a non-condensing unit, the condensing unit can save you money in fuel costs over the 15 to 20-year life of the unit. Condensing gas furnaces are the most energy efficient furnaces available, with seasonal efficiencies between 90% and 96%.

6) ***Oil condensing Furnace:*** While a natural-gas condensing furnace has a significant efficiency advantage over a mid-efficiency gas furnace, a “condensing oil furnace” is only marginally more efficient than a well-designed mid-efficiency oil furnace. Oil produces only half the water vapor of gas, and so has much less energy tied up in the form of latent heat; the furnace must work harder to condense less. In addition, the condensate is much more corrosive than with natural gas, so the condensing oil heat exchanger must be made of special materials. For these reasons, a mid-efficiency oil furnace is a better bet than a condensing oil furnace.

Classification of Furnaces

There are three types of furnaces: Single-Stage, Two-Stage, and Two-Stage Variable.

1) **Single-Stage:** Single stage implies the furnace control is simply on or off. Since every facility has a unique "heat load" which varies through out the day, the manufacturers wisely put options in the furnace fan speed. A single-stage furnace may have multiple speeds. If the heat load requires significantly less than the amount of heat that the furnace would provide - the furnace fan speed should be hard wired to its medium high option.
2) **Two-Stage:** Two-Stage furnaces were developed with comfort in mind. Here is how they function. When the thermostat activates the furnace, it comes on at 2/3 rd strength (burning gas at 65% of maximum). If, after 10 minutes of operation, the thermostat is still calling for heat - the furnace will switch to 100%. What that accomplishes is a uniform heating of entire space. If a furnace kicks on at full power and dumps hot air into the space to satisfy the thermostat - it will shut off leaving cool air still circulating the space; meaning that the furnace will have to kick in again. Two-Stage furnaces are more efficient and more effective at heating the space. Furnaces are like light bulbs, they operate better if they are turned on and left on. If you flick a light switch on and off, over and over - that bulb is toast. The same goes for furnaces. Running at 65% for 9 minutes is better than 100% for 3 minutes several times an hour. It uses less gas and is easier on the machine.
3) **Two-Stage Variable:** Two-Stage Variables were developed with the knowledge that subtle circulation of heated air is the most effective way to heat a space. The furnace part is the same as a Two-Stage; the difference is in the blower motor. In a Single-Stage, if you want your fan on for circulation, that fan is on high. It is the only option it has. Not only is that hard on the utility bill, but a fan on high means the warm air is moving fast, warm air moving fast is a cool breeze. In a Variable, the fan turns over slowly to maintain air circulation while being easy on the utility bill. By the way, most air cleaners and filtration devices are only active when the furnace blower is on. So the best way to utilize these accessories is to have a variable speed blower. By switching its blower fan from AC current to DC current, it only draws 1/10 the electricity.

Furnace Efficiencies

Furnaces are often classified according to efficiencies. You'll often hear furnaces being referred to as standard, mid and high efficient units. A standard furnace is one whose efficiency is below 70%, a mid efficient furnace is one whose efficiency is between 71% and 82% and a high efficient furnace is one with efficiency above 90%.

When a furnace is 80% efficient - it means that of the gas or fuel oil that is ignited to create heat - 80% of the heat energy is captured by your heating system. The remaining 20% escapes up the flue or emanates out the face of the furnace. For example, if the rating of old furnace is 100,000 BTU @ 60% efficiency, the effective heat delivery shall be 60,000 BTU and for new furnace of 80,000 BTU rating @ 80% efficiency, the effective heat delivery shall be 64,000 BTU of heat. So, a new 80% furnace should be smaller than your old one. But let's back up a bit to "heat load."

Let's say the heat load is 60000 BTU. An 80,000 @ 80% efficiency furnace provides 64,000 BTU. That is a good fit. It is a good idea to fudge a little on the side of enough heat. An 80,000 @ 90% efficiency furnace provides 72,000 BTU. That is overkill. The space will never reach optimal comfort because the heat will rise faster than it takes to cycle all of the cold air through the furnace. Your furnace would ""short cycle." That is bad. Over the long haul, a 90% efficient furnace will save you money on your utilities, but it might take 7 to 10 years. In either case, one size does not fit all.

AFUE Ratings (Efficiency)

The Federal Energy Agency requires all furnaces and boilers be given operating efficiency ratings -- the annual fuel utilization efficiency (AFUE). The AFUE tells how much heat the system extracts from the fuel it burns during a single heating season. The higher the AFUE, the more efficient is the equipment. The minimum efficiency standard for new furnaces is 78% AFUE. This factor includes on-and-off cycling, the energy embodied in combustion air, and jacket losses.

A high efficiency furnace or boiler has special efficiency features which raise the AFUE. These features may include electronic ignition, power draft system, improved burner, vent damper, high efficiency heat exchangers, and secondary heat exchangers in the highest efficiency models.

Combustion Air Requirements

All gas fired and oil fired equipment require a sufficient supply of oxygen to the burners in order to achieve efficient combustion. If sufficient combustion air is not available, the fuel cannot be properly burned and the furnace will operate inefficiently and unsafely. It will also cause excess water in the heat exchanger resulting in rusting and premature heat exchanger failure. Excessive exposure to contaminated combustion air will result in safety and performance related problems.

Two valuable tips which will insure proper gas fired combustion air are:

1) If louvers are used as a combustion air source, they must have one square inch of free area for each 1000 BTU burned. Note that the louver dimensions do not guarantee equivalent free space. Metal louvers normally provide 60% free space. Example: A 20” by 20” louver would have a free area of 240 sq-in (20 x 20 x.60)
2) If mechanical combustion air fans are used, provide 15 to 20 cu-ft of combustion air for each 1000 BTU burned.

Furnaces may draw the air they require for combustion from either inside the heated space or from outside. Sealed-combustion (direct vent) furnaces bring outside air into the burner and exhaust flue gases (combustion products) outside. They generally burn more efficiently and this arrangement virtually eliminates any risk that combustion gasses could leak into occupied space. It does, however, require some complicated installation techniques, so check the manufacturer's installation instructions carefully.

Combustion Efficiency

In order to understand the basics of combustion efficiency, the combustion process must be understood. Stable combustion conditions require three inputs: fuel, oxygen, and a source of ignition. If the combustibles themselves can provide this third element as they burn, the source of ignition can be turned off. The products of complete combustion are heat energy, carbon dioxide, water vapor, nitrogen, and other gases (excluding oxygen). In theory, there is a specific amount of oxygen that will completely burn a given amount of fuel. In practice, burning conditions are never ideal. Therefore, more air must be supplied to completely burn all fuel. The amount of air above the theoretical requirement is referred to as "excess air."

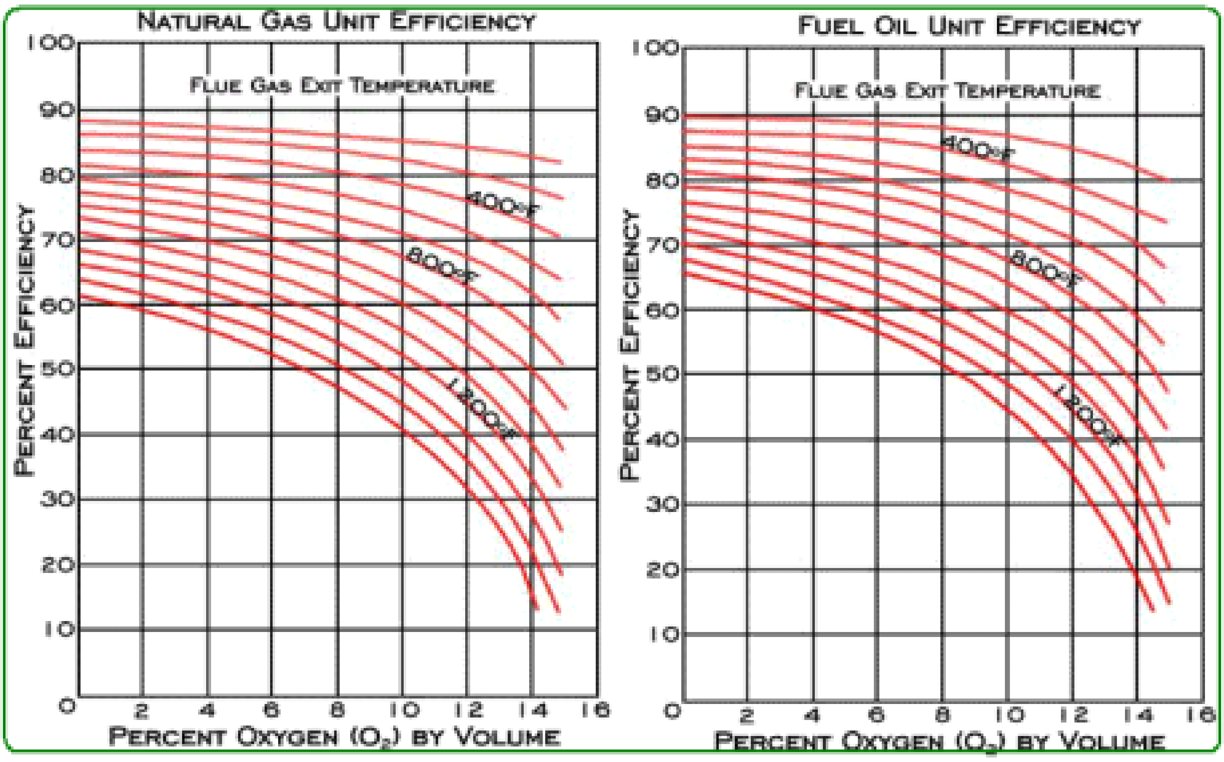
If an insufficient amount of air is supplied to the burners, unburned fuel, soot, smoke, and carbon monoxide are exhausted out the stack. This results in heat transfer surface fouling, pollution, lower combustion efficiency, flame instability (the flame blows out) and the potential for an explosion. To avoid these costly and unsafe conditions, furnaces are normally operated at an excess air level. This excess air level also provides operating protection from an insufficient oxygen condition caused by variations in fuel composition and "operating slop" in the fuel-air control system. Typical optimum values of excess air levels (and equivalent percentage of oxygen by volume) are shown in the table below:

Typical Optimum Excess Air Levels			
Fuel Type	**Firing Method**	**Optimum Excess Air**	**Equivalent Percent O_2 (by Volume)**
Natural Gas	-	5%- 10%	1% - 2%
Propane	-	5%- 10%	1% - 2%
Coke Oven Gas	-	5%- 10%	1% - 2%
No #2 Oil	Steam atomized	10%- 15%	2% - 3%

No #6 Oil	Steam atomized	10%- 15%	2% - 3.5%
Coal	Pulverized	15%- 20%	3% - 3.5%
Coal	Stoker	20%- 30%	3.5% - 5%

It is important to understand that "excess air" and "excess oxygen" is not the same. Because air is roughly 21% oxygen by volume, 50% excess air is approximately equal to 10.5% oxygen remaining in the exhaust stack.

While insufficient air to the burners can be dangerous, airflows in excess of those needed for stable flame propagation needlessly increase flue gas heat losses and consequently lower efficiency. Minimizing these losses monitoring for two variables: the percentage of O_2 (or CO_2), and the stack temperature. *Very high percent of O_2 in the flue stack means lower efficiency.* The percentage of O_2 (or CO_2) can be measured by using simple devices containing gas-absorbing analyzers.



These figures show the relationship between proper tune-up, proper heat transfer and efficiency.

As fuel is such a dominant cost factor, the boiler efficiency needs to be kept high to keep operating costs low. Decreases in efficiency over time can indicate the need for minor adjustments or repairs. In some cases, only control linkages, a fuel valve, or an air damper may need to be adjusted. In other cases, a worn burner tip or control cam may need replacing. High stack temperatures may also indicate the need for cleaning. In any situation, decreases in efficiency indicate the need for professional maintenance.

Ventilation Air Requirements

In addition to providing combustion air, fresh outdoor air for ventilation is required which dilutes contaminants in the indoor air. The requirements for providing air for combustion and ventilation depend largely on whether the furnace is installed in an unconfined* or a confined space.

Unless outside air is brought into the space for combustion, negative pressure (outside pressure is greater than inside pressure) will build to the point that a downdraft can occur in the furnace vent pipe or chimney. As a result, combustion gases enter the living space creating a potentially dangerous situation.

In the absence of local codes concerning air for combustion and ventilation, you must consider combustion air needs and requirements for exhaust vents and gas piping in accordance to the National Fuel Gas Code (ANSI- Z223.1/NFPA 54).

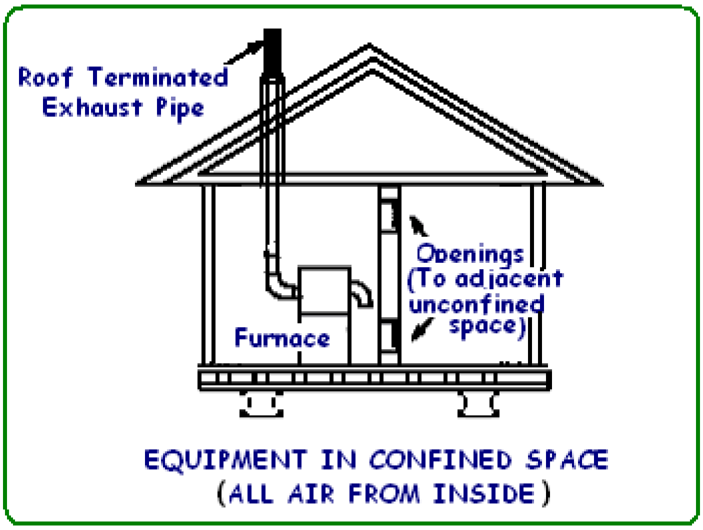
***Unconfined Space:** An unconfined space is an area such as a basement or large equipment room with a volume greater than 50 cubic feet (1.42 m^3) per 1,000 Btu (29 kW) per hour of the combined input rating of all appliances installed in that space.

This space also includes adjacent rooms which are not separated by a door. Though an area may appear to be unconfined, it might be necessary to bring in outdoor air for combustion, if the structure does not provide enough air by infiltration. If the furnace is located in a building of tight construction with weather stripping and caulking around the windows and doors, follow the procedures in the air from outside section (discussed below).

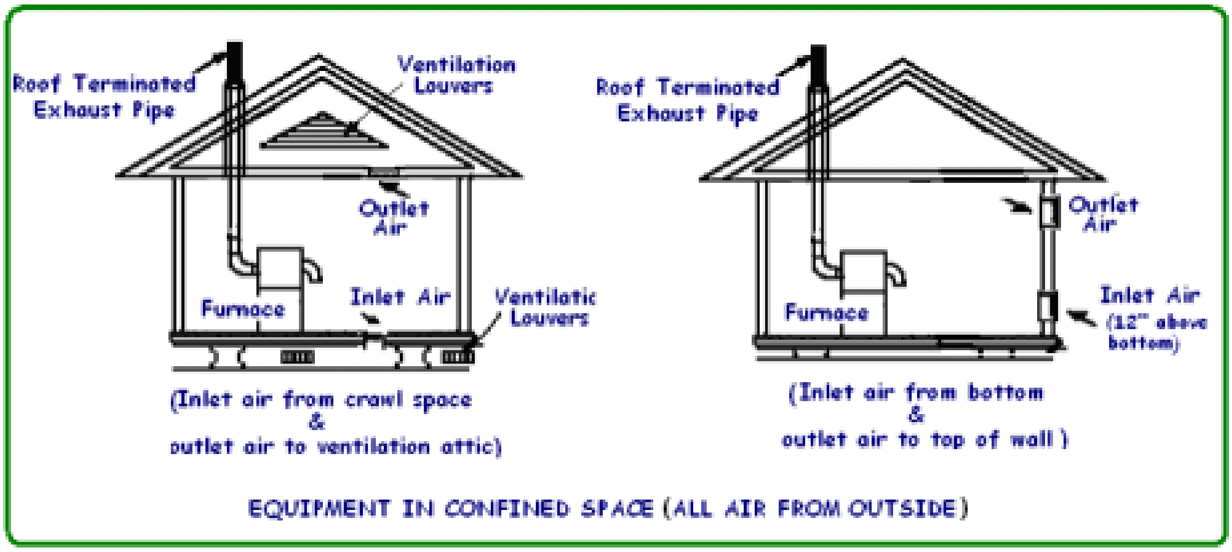
Confined Space: A confined space is an area with a volume less than 50 cubic feet (1.42 m^3) per 1,000 Btu (.29 kW) per hour of the combined input rating of all appliances installed in that space. This definition includes furnace closets or small equipment rooms.

Air Intake Configurations

1) **Air from Inside:** If the confined space that houses the furnace adjoins a space categorized as unconfined, the air can be brought in by providing two permanent openings between the two spaces. Each opening must have a minimum free area of 1 square inch (645 mm^2) per 1,000 Btu (29 kW) per hour of total input rating of all gas-fired equipment but not less than 100 square inches (64516 mm^2), each opening. One opening shall be within 12 inches (305 mm) of the top of the enclosure and one opening within 12 inches (305 mm) of the bottom.



2) **Air from Outside:** If air from outside is brought in for combustion and ventilation, the confined space shall be provided with two permanent openings. One opening shall be within 12" (305mm) of the top of the enclosure and one within 12" (305mm) of the bottom. These openings must communicate directly or by ducts with the outdoors or spaces (crawl or attic) that freely communicate with the outdoors or indirectly through vertical ducts. Each opening shall have a minimum free area of 1 square inch per 4,000 Btu (645mm2 per 1.17kW) per hour of total input rating of all equipment in the enclosure. When communicating with the outdoors through horizontal ducts, each opening shall have a minimum free area of 1 square inch per 2,000 Btu (645mm2 per .59kW) per total input rating of all equipment in the enclosure. Refer figures below:



If air from outside is brought in for combustion and ventilation, the confined space must have two permanent openings. When ducts are used, they shall be of the same cross-sectional area as the free area of the openings to which they connect. The minimum dimension of rectangular air ducts shall be no less than 3 inches (75 mm). In calculating free area, the blocking effect of louvers, grilles, or screens must be considered. If the design and free area of protective covering is not known for calculating the size opening required, it may be assumed that wood louvers will have 20 to 25 percent free area and metal louvers and grilles will have 60 to 75 percent free area. Louvers and grilles must be fixed in the open position or interlocked with the equipment so that they are opened automatically during equipment operation.

Venting Requirements

There are several rules to follow to assure proper venting of gravity vented equipment:

1) Keep vent runs as straight as possible with few turns or bends.

2) Never use a vent size smaller than the size recommended by the equipment manufacturer.

3) All vents must terminate with a proper wind proof vent cap

4) Limit horizontal vent runs to a maximum of 75% of the vertical run. Example, if the vertical run is 10 ft. The horizontal run must not exceed 7.5 ft.

5) Horizontal runs must be pitched with a minimum upward slope of .25 inch per foot of run

6) Vents must terminate a minimum of 2 1/2 ft above any obstructions within a 10 ft radius of the vent pipe.

7) Always provide a drip leg as near to the equipment as possible. This to prevent condensation of flue gases in the vent pipe from entering the equipment.

8) Keep combustible material 6 inches away from single wall vent pipe

9) *When venting into a common vent, the area of the common vent should be equal to or greater than the area of the largest vent plus 50% of the area of all additional vents*

10) When venting into a common vent, the individual vents should enter at different levels

Rules for Power Vents

The rules for power vented equipment generally are the same as gravity vented equipment with the following exceptions:

1) Approved power exhausted equipment may have its' vent system terminate horizontally out of a wall. A proper vent cap must still be installed.

2) Horizontal run lengths may exceed vertical run lengths. The combined total run length must not exceed the manufacturer's recommendations.

3) If elbows are used in the vent system you must attribute 6 ft. of equivalent length of run for each 90 degree elbow.

4) If a vent terminates horizontally out a wall make sure it does not terminate near an air inlet opening. A minimum of 3 ft. is recommended.

5) Make sure the horizontal vents are sufficiently high enough, or guarded so as to prevent accidental contact by people or equipment.

6) No common venting should be utilized.

Installation Guidelines

1) When the furnace is installed in an attic or other insulated space, keep insulation away from the furnace.
2) For installation in a residential garage, the furnace must be installed so that the burner(s) and the ignition source are located no less than 18" (457 mm) above the floor. The furnace must be located or protected to avoid physical damage by vehicles.
3) The furnace may be installed in alcoves, closets, attics, basements, garages, and utility rooms in the upflow position. When a furnace is installed in an attic, the passageway to and service area surrounding the equipment shall be floored.
4) The furnace shall not be installed directly on carpeting, tile, or other combustible material other than wood flooring.
5) Place the furnace as close to the center of the air distribution system as possible. The furnace should also be located close to the chimney or vent termination point
6) When the furnace is installed in non-direct vent* applications; do not block the furnace combustion air opening with clothing, boxes, doors, etc. Air is needed for proper combustion and safe unit operation.
7) When the furnace is installed in an unconditioned space, consider provisions required to prevent freezing of condensate drain system.
8) When this furnace is used with cooling units, it shall be installed in parallel with, or on the upstream side of cooling units to avoid condensation in the heating compartment.
9) The furnace must be installed so that its electrical components are protected from water. The furnace must be electrically grounded according to the current National Electric Code, ANSI/NFPA No. 70.

These instructions are intended as a general guide and do not supersede local codes in any way. Consult authorities having jurisdiction before installation. Typical commercial terminology is indicated below:

*In ***Direct Vent installations***, combustion air is taken from outdoors and flue gases are discharged outdoors.

*In ***Non-Direct Vent installations***, combustion air is taken from indoors and flue gases are discharged outdoors.

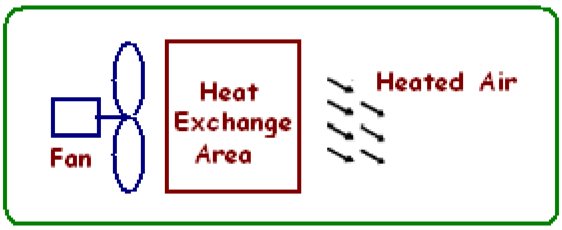
* In ***Un-vented installations***, combustion air is taken from indoors and the flue products are discharged into the space.

Unit Heaters

Unit Heaters are a proven method of heating small, open spaces. Multiple heaters are installed around the perimeter of a building to match heat losses. Advantages include redundancy in case one unit fails and intermittent fan operation that reduces electrical costs. The small unit heaters can be installed near the ceiling to get more floor space but due to limited air throw their efficiency decreases with increasing height above the floor. Initial installed cost is low for small facilities with a few unit heaters but can be very high for large buildings that require many heaters.

Unit heaters are the most commonly used form of heating due to the following reasons:

1) they provide the air circulation needed
2) they can be used in conjunction with ventilation systems
3) they are comparably the least expensive
4) they provide quick response to temperature changes
5) they are easy to install
6) they offer inexpensive expansion for additions
7) they can be used in conjunction with waste heat applications
8) they provide snow load protection which facilitates solar gain



Typical Unit Heater

1) ***Gas fired unit heaters:*** Gas fired unit heaters provide a reliable and energy efficient low cost heating system and are available for use with natural or propane gas. Gas fired unit heaters have evolved in three "generations".

    a. The initial design utilized a natural gravity vented system where the combustion air is taken from inside of space and has a flue pipe terminated above the ridge of the space.

    b. The second generation of gas fired space equipment answered the need for efficiency and is power vented. Modifications to the venting system increased the efficiency 20% by adding a fan unit that actively expels the products of combustion. This enhancement eliminates "thermal siphoning" of heated air out the flue pipe between heating cycles.

    c. The most recent generation is called the separated combustion style. They capitalize on the efficiency gained and increased longevity offered by utilizing air from outside the space for the combustion process. These products eliminate most of the concerns of combustion air quality and corrosion.

    Gas fired units heaters are available with propeller fan or blower wheel air delivery systems. Propeller fan gas unit heaters are most common. The propeller model is used to deliver the heated air directly to the space or in conjunction with a fan jet system. Blower units have the capability to be used in high static systems like large duct distribution systems.

2) ***Direct Un-vented gas fired unit heaters:*** Direct un-vented gas fired heaters do not vent hot flue products out of the space; instead, a direct fired heater expels all heated combustion products into the space. Products of combustion are carbon dioxide (CO_2), water (H_2O), and carbon monoxide (CO). Direct-fired heaters require intermittent ventilation to dilute their products of combustion. It is recommended that direct-fired heaters use outside air to optimize combustion.

3) ***Oil fired unit heaters:*** This style is utilized regionally. The northeast region of the U.S. utilizes oil fired equipment more than other areas. Oil fired equipment is available for suspended or floor mounted installation. Oil fired equipment normally requires more annual maintenance by a service company.

Safety

All unvented gas-fired space heaters (manufactured after 1983) should be equipped with an oxygen depletion sensor (ODS). An ODS detects a reduced level of oxygen in the area where the heater is operating and shuts off the heater before a hazardous level of carbon monoxide accumulates. These heaters also have labels that warn users about the hazards of carbon monoxide. Always have your gas heater and venting system professionally installed and inspected according to local codes.

Safety Warning: Unit heaters that vent products of combustion directly into the space structure should be used only in areas where adequate ventilation is available to avoid exposure to personnel from combustion byproducts such as carbon monoxide and ethylene.

Heating Systems & Indoor Air Quality

The 5 key principles to keep in mind when looking from the perspective of good indoor air quality:

1) The heat source should operate at a low temperature. Anything which is heated will release contaminants into the air. The higher the temperature of the heating source, the more it will cause dust and other particles hitting the surface to decompose, releasing even more contaminants into the air than those released when the dust is simply heated.

2) The emissions from burning fuels for heat are often a major source of pollution. System design will affect how much of this pollution is released into the living space.

3) The system should not distribute pollutants from one area of the building to another. Any system which distributes or allows movement of air from one part of a building to another will carry pollutants along with it, so that the air quality in the building will only be as good as that in the most contaminated room.

4) Heating surfaces must always remain free from pollutants. Due to the increased off-gassing of any heated surface, it is important that the finishes used on these areas be such that they will not become sources of pollution and also that these surfaces be kept free of dust and debris.

5) The energy source (i.e. fuel) should not be stored inside the building. Exposure to most commonly used energy sources is hazardous to sensitive individuals. This could be directly from the fuel itself or a "tag along" contaminant such as the moulds found on firewood.

Operation & Maintenance Guidelines

During the later part of the summer it is time to start up the heating system. This is the time to make some routine checks which are necessary to ensure that your heating equipment will be ready to function properly in the fall and winter.

1) Check equipment for physical damage. Check the sheet metal, fans and air movers, wiring, fuel piping and vent system.

2) Check for the cleanliness of the equipment's heat exchanger and burner.

3) Check the vent system. Sometimes birds will make nests in the vent system

4) Check to make sure no obstructions block the air intake or air discharge of the equipment.

5) Check lubrication of the motors on fans and pumps. With the power off check to see that the motor shafts turns freely.

6) Check the belt tension on equipment that utilizes a centrifugal blower system.

7) Check the heat exchanger of the equipment for any signs of cracks or corrosion. A flash light can be useful to check the inside and outside of the heat exchanger.

8) Check the heat exchanger of the equipment for signs of overheating. Metal that has been overheated will have a dark discoloring of the area overheated. Overheating could be the result of over-firing, improper venting, or inadequate combustion air.

9) Inspect the burner for general cleanliness. It is not uncommon to find that spiders or mice have nested in the control or burner area.

10) Check the control wiring to make sure the connections are tight.

11) Check to make sure the manual valves are opened.

12) If your space has an alarm system, make sure it is operational.

It is recommended that a record be kept of the date the heating equipment service was performed. It is also recommended that these same service checks be performed on a periodic basis throughout the heating season. By keeping a service record and updating it, it is less likely that this important maintenance will be overlooked.

SECTION - 4 HOT WATER HEATING SYSTEMS

Hot Water Heating (sometimes called hydronic heating) systems use water or a water-based solution as a medium to transport heat from a heat source to one or several heat emitters. The hot water then radiates heat and warms the air within the space. As the water circulates it begins to cool and is then circulated back to a boiler for reheating.

These systems are useful as centralized heating systems in large building complexes and can be designed as forced air or radiant heating systems. In a forced air application the heated water is passed through a coil (much like an automobile radiator) and a blower pushes (or pulls) the cool air across the coil. At the coil the air picks up the heat energy and the warm air is directed to the living area. In radiant systems the heated water is run through pipes in the floor (or walls) and the floor gets warm and the heat radiates into the living area. Both these design options require specific engineering knowledge and the installation is complex. However, the energy efficiency advantages and flexibility they offer and the potential to enhance evenness make them attractive alternative.

This section provides design and installation guidelines for both floor and space heating systems. The topics include:

1) What is hydronic heating and its benefits
2) Gravity circulation v/s forced circulation
3) Heat transfer to space – terminal units
4) Hot water system design – Primary elements
    - Sizing distribution system
    - Estimating water flow rate
    - Sizing supply piping
    - Piping configuration – direct v/s reverse return system
    - Sizing the circulator
5) Secondary components such as expansion tank, safety devices, instrumentation & control
6) Radiant floor heating system design

What is Hydronic heating?

Hydronic heating systems use hot water to move heat from where it is produced to where it is needed. Heat is absorbed by the water at a heat source, conveyed by the water through the distribution piping, and finally released into a heated space by room heat emitters (Refer fig.1 below). Hundreds of system configurations are possible, each capable of meeting the exact comfort requirements. For example, it's common for hydronic radiant heating to be used on the first floor of a house while the second floor rooms are heated using panel radiators or fin-tube baseboard. All these equipment do not use ducting.

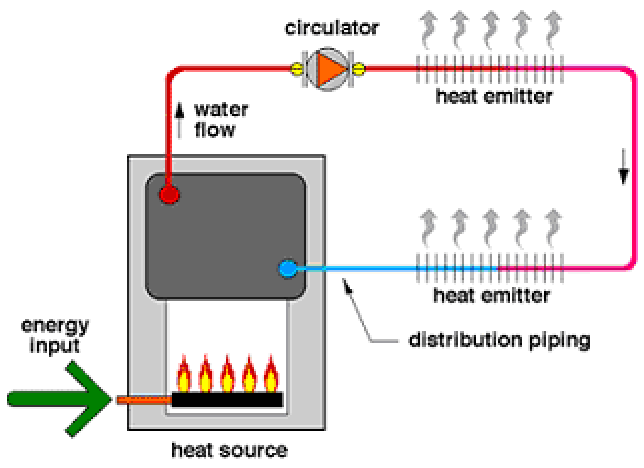


Fig-1
Hydronic Heating with Room Emitters

Alternatively, hydronic water system may use forced air handling units using blower, heating coil, and ducting to distribute heater air to various zones of the building. These systems are well suited for buildings where such a system already exists for cooling. The force air circulation system typically mixes 20% outside air with the space return air. In buildings where air cleanliness is imperative, the force air systems make use of appropriate air-filtering equipment to prevent ingress of dust indoors. In the regions where both cooling and heating is required, a forced air heating system is a sensible choice for cooling and heating, since the heating and cooling systems can share the ductwork and air handling unit. The air handling unit in such cases shall contain both the chilled water and hot water coil.

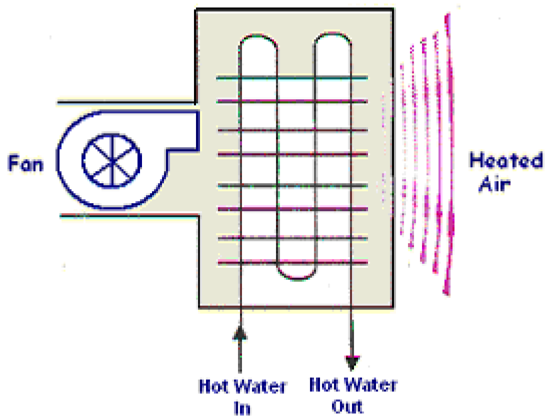


Fig-2
Hydronic Heating with Central Air-Handling Unit

Why Hydronic Heating?

1) Hydronic heating systems typically provide more even and steady heating than other systems. Even when the heat exchanger and boiler units are shut off, the system continues to emit heat until the circulating water cools. Some advantages of hydronic systems are the ability to regulate the temperature in each room and to use the same boiler for domestic hot water.

2) Hydronic heating is space efficient and the boiler unit can be located anywhere within the building as long as it is protected against freezing.

3) Hot water can be transported from a heat source to a space over great distances using insulated pipelines.

4) Hot water can be proportionately controlled to operate at various flow rates and temperatures – all from the same heat source.

5) When properly equipped, a hydronic heating system can also be used to heat domestic water for things like cooking, cleaning and bathing. Some heating systems can even be adapted to heat other structures such as greenhouses, garages, swimming pools and snow-melting systems in the driveway.

6) Exterior water heating and snow-melting systems use a heat exchanger placed between the boiler and a secondary fluid such as an anti-freeze solution.

7) A properly designed and installed hydronic system can operate with virtually undetectable sound levels in the occupied areas of a space.

8) *Noninvasive Installation:* It is often very difficult to conceal ducting out of sight within a typical house. The best that can be done in many cases is to encase the ducting in exposed soffits. Such situations often lead to compromises in duct sizing and / or placement. By comparison, hydronic heating systems are easily integrated into the structure of most small buildings without compromising their structure or the aesthetic character of the space. The underlying reason for this is the high heat capacity of water. A given volume of water can absorb almost 3500 times more heat as the same volume of air for the same temperature change. The volume of water that must be moved through a building to deliver a certain amount of heat is only about 0.03 percent that of air! This greatly reduces the size of the distribution "conduit". Here's an example of what that means: A 3/4-inch diameter tube can carry the same amount of heat as a 14" x 8" duct. Hydronic systems using small flexible tubing are much easier to retrofit into existing buildings than is ducting. The tubing can be routed through closed framing spaces much like electrical cable. Other benefit is that not only shall a ¾-inch diameter tube shall require considerably less material for insulation, the heat loss of the 14" x 8" inch duct is almost ten times greater than that of the 3/4 inch tube when insulated with the same material. For buildings where utility space is minimal, small wall-hung boilers can often be mounted in a closet. In many cases, these compact boilers supply the building's domestic hot water as well as its heat. The entire system might occupy less than ten square feet of floor area.

Disadvantages

The installed cost of hydronic systems is higher than that of direct fired forced-air systems, they can be slow to warm up, and there is no capability for central air conditioning, air filtering, or ventilation.

Unless your hydronic heating system also has a fan installed, it cannot provide the cooling, humidification, air filtration or forced air circulation that alternative heating systems can. In addition, excessive heat gains from sources such as sunlight can't be easily transferred to other areas within the home.

Another factor to consider when installing a hydronic heating system is its vulnerability to damaging impacts and leaks. The system will only function correctly if all piping is in full working order. If the piping becomes damaged, water leaks can rot the flooring and structure of the building.

Design Alternatives

Hot water heating system design can be either gravity heating systems or forced heating systems.

1) **Gravity Circulation:** In a hot water gravity heating system, the circulation of water is a result of the difference in density between the hot water in the supply line and the cold water in the return line. The hot water tends to flow upwards and cold water tends to flow downwards. The elevation of the supply and return lines are therefore important for proper functionality. Gravity systems have many disadvantages:

   - The low differential pressure in the system demands increased pipes and valves dimensions. They require very large diameter piping for supply and return mains.

- The gravity system will also have a relative low heating capacity because of low medium temperatures in the heating elements. The low temperature water provided a heat emission rate of only around 150 BTU's per square foot of radiation per hour. Consequently, radiators had to be large.

The gravity system is simple but limited to smaller systems.

---

2) **Forced Circulation:** In forced circulation system, a circulating booster pump is used to overcome the objections of the gravity systems while retaining all the advantages of heating with hot water. Water is circulated regardless of the temperature forces between hot and cold water. Forced circulation systems allowed design using higher water temperatures resulting in higher emission rates. A radiator of 60 square feet with an average water temperature of 170°F will emit heat at a rate of 150 BTU's per square foot per hour, or 9000 BTU's per hour. A radiator of 45 square feet with 197°F water will emit 200 BTU's per square foot per hour; producing the same 9000 BTU's per hour. It is not necessary to be careful with the piping elevations. The pipes, valves and heating elements, radiators and air heaters, can be downsized because of higher flow and higher mean temperatures.

   Forced circulation is in general the only practical alternative in bigger systems and are classified by pressure or piping scheme.

Type	Flow temperature (°C)	Temperature drop (°C)
Low Pressure Pumped Circulation	50 - 90	10 - 15
Low Pressure Gravity Circulation	90	20
Medium Pressure	90 - 120	15 -35
High Pressure	120 - 200	27 - 85

Heat transfer to Space

The design of hydronic heating systems is more complex than that of other heating systems and can be more expensive to install. Operating costs can be higher than for simpler systems unless good design, proper operation and maintenance of the system and all of its components are carried out regularly. A variety of heat distribution methods and equipment are available when choosing a hydronic heating system including:

1) ***Radiant Baseboards:*** Radiant baseboards transfer heat through radiation, making the rooms more comfortable and reducing stratification effects. They are positioned around the walls. Typically two pipes are run in these emitters to allow for supply and return connections at the same end. The disadvantage of using radiant baseboards is that the water temperature is the same for all baseboards.

2) ***Baseboard Convectors:*** Baseboard convectors transfer heat mainly through convection and consist of a length of pipe with attached "fins" that increase the surface area of the piping to improve heat transfer. These systems can be purchased with a sheet metal cover for use at a low level along a wall. Systems without a cover are usually concealed in an architectural enclosure or are recessed into floors where they won't be subject to damage or corrosion.

   Black steel pipe, finned-tube convectors, and fan-forced hot water unit heaters are the main types.

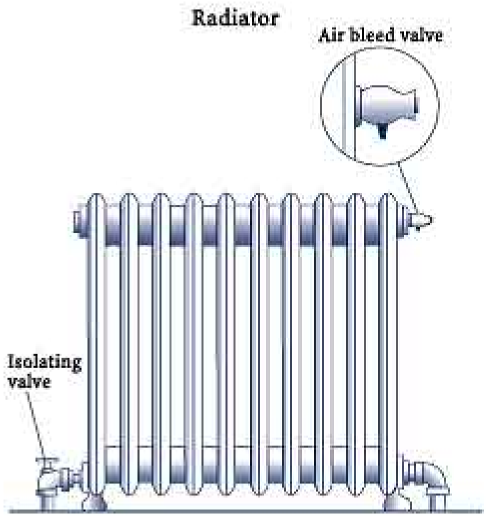
- ***Bare pipes:*** Perhaps the simplest means of transferring heat from hot water is through bare pipes of steel, black iron, copper, or aluminum. Black steel pipe is most commonly used; this is easy to clean, least affected by dust and not easily damaged. Galvanized pipe should not be used since the galvanizing restricts heat transfer. Black steel pipe is usually mounted under air inlets or on wall brackets at least one pipe diameter from the wall to permit free air circulation. Heat output for bare steel pipe, and the length of pipe needed can be determined from the standard tables or heating equipment vendor catalogues.
- ***Finned pipes:*** The addition of finned elements to the surface of a pipe enhances its ability to transfer heat by expanding the pipe's surface area. This reduces water volume to heat and less actual footage of piping is required to do the same work. There are many variations in the design of finned pipes. There are black pipes with steel fins attached, copper tubes with aluminum fins, and completely aluminum products. All of them seek to do the same job, enhance heating potential while minimizing footage and the water volume required.

  These are particularly suitable where there is not enough room for bare pipe. Where less heat is required, short sections of convector can be spaced along a wall. The main drawbacks to finned-tube systems are that they collect dust (reducing performance), require frequent cleaning and can easily be damaged. They are not recommended for dusty atmospheres.

3) **Cast-iron baseboard** systems include low-profile convector radiators that have lower heat output and substantially higher initial cost than baseboard convectors. These heating systems operate at the same temperatures as cast-iron radiators and can also overheat.
4) ***Fan Coils:*** Fan coils transfer heat mainly by forced convection. In a typical fan coil system the air in a room is drawn into the system and is heated over a heat exchanger, composed of hot-water finned-tube coils. The effectiveness of a fan coil to heat depends on the surface area, size of heat exchanger, spacing and thickness of coil fins, the number of tubes and the performance of the fan. The temperature of the entering water as well as the temperature of the entering air will also influence the heat capacity of the fan-coil.
   - The heat output of the fan coil is approximately proportional to the difference between the entering water temperature and the entering air temperature;
   - Increasing the rate of water flowing through the coil will increase the heating capacity of the fan coil;
   - The increase of the air flow rate flowing through the coil will also increase the heating capacity of the fan coil;
   - A fan coil unit running with lower water temperatures will have the same heat capacity of another similar heat coil with smaller coil surfaces and/or less tubes.

---

5) **Radiators:** These are large cast-iron heating units usually found in older buildings. They are designed to provide full heating capacity at a lower temperature than baseboard convectors. Caution should be used with these radiators as they can overheat.



6) ***Unit heaters:*** These are excellent for areas where a concentrated heat source is desired. They can also be incorporated with ventilation air ducts or other types of air circulation systems. In dusty buildings, these radiators should be inspected and cleaned regularly to maintain heating effectiveness. Hydronic unit heaters are often used as a way to supplement another hydronic heating system, like a heated slab floor system heating system. Hot water unit heaters are very reliable, inexpensive and very responsive to control inputs.
7) **Kick-space heaters** are designed to be installed horizontally under kitchen cabinets or bathroom vanities. Kick-space heaters are best suited to smaller rooms.
8) **Radiant floors** have hot water piping or tubing installed in or under the floor.

Hydronic Heating Equipment – Primary Elements

The basic hot water heating system consists of the following components:

Hot water heater or boiler; circulating pump; expansion tank; distribution piping; radiators in the space to be heated - black iron or steel pipe, finned-tube convectors, unit heaters or under-floor pipes; controls, valves, temperature and pressure gauges, air bleeding valve, pressure relief valve, and pres sure regulator.

1) **Boilers, or hot water generators,** don't actually boil the water but simply re-heat it (typically 140 - 180°F) prior to releasing it to the heat exchangers. Boilers are generally rated on input and/or output in British thermal units per hour (Btu/h) or in kilowatts. Boiler output should be adequate to offset building design heat loss, piping losses from exposure to unheated space and any additional heating needs such as swimming pools or hot tubs. These systems are often "closed" with virtually no fresh water makeup. Hot water boilers are often preferred because they normally do not need an operator or special water chemistry, and they run at higher fuel conversion efficiencies than steam generators.

   There are two basic boiler control strategies, variable temperature and constant temperature. Variable temperature control is used for systems that heat the living space. Constant temperature control is used when the system also heats domestic water, swimming pools or hot tubs.

   There are three different boiler types: gas-fired, oil-fired and electricity powered. Electricity powered boilers are difficult to find and, at this time, are more expensive to operate than either the gas-fired or oil-fired types. Gas and oil-fired boilers are rated through the Energy Star program. Boilers that meet or exceed an 85 percent efficiency rating are labelled as Energy Star compliant. For maximum energy efficiency, look for boilers displaying the Energy Star logo.
2) **Commercial Water Boilers:** Commercial water boilers for larger systems come in many shapes, sizes and construction methods and materials. The two basic boiler designs for buildings are fire-tube and water-tube.

In fire tube boilers, hot combustion gases pass through tubes submerged in water. These systems are simple and easy to construct and are generally used in low-pressure applications. The main components that make firetube boilers energy efficient is the four-pass design, the forced-draft design, the heating surface area and updraft construction.

- ***Four-pass design:*** The number of passes indicates the amount of time the flue gases pass through the tubes. It has been proven that the efficiency of the boiler is directly proportional to the number of passes. The four-pass design is based on the velocity of the gases being directly proportional to the ratio of the volume of the gases and the flow area. The flue gas has to maintain high flow velocity. The temperature of the exhaust gas is lower, leading to an increase of the overall efficiency of the boiler.
- ***Forced-draft design:*** The forced-draft design uses a fan to pressurize the combustion air before it is mixed with the fuel, which improves combustion. This design provides air in the required quantities and at the proper pressure, thus reducing excess air.
- ***Heating surface area:*** Heat transfer is fundamental for efficient and long lasting equipment. Packaged units can offer a heating surface area of 0.047 m^2/kW which helps increasing the life of the boiler, reduces maintenance requirements and increases the efficiency of the boiler.
- ***Updraft construction:*** Updraft construction involves placing the furnace at the lower end of the boiler and running the gases towards the higher end of the boiler. The furnace contains the hottest combustion gases and is designed with a significant clearance from the bottom shell to enable full fluid circulation in the system. Such a construction offers a safer operation and better combustion.

In water-tube boilers, the water is contained in tubes located inside a furnace and hot flue gases pass over the tubes, heating the water, and then exit out the stack. Small watertube boilers are usually available in packaged units while larger tubes are assembled in the field. Packaged watertube boilers, using oil or natural gas, have various designs and can have any capacity. They are usually categorized according to their burner, which can be an atmospheric burner (standing pilot of spark ignition) or a forced convection burner, which has a higher efficiency and better overall combustion.

For boilers to run at peak efficiency, operators must attend to boiler staging, water chemistry, pumping and boiler controls, boiler and pipe insulation, fuel-air mixtures, burn-to-load ratio, and stack temperatures.

3) **Circulator, or the circulating pump,** is an electrically driven pump that forces water through the boiler and/or the piping system. Some heating systems have more than one circulator in order to serve separate areas of the building. The circulator pump is selected for the flow rate and the head requirements. A pump must develop enough pressure to overcome the resistance (friction) created in the boiler, piping, fittings, heat distributing units and other parts of the system. When making your selection, do not add the static head pressure (due to the height of the system) to the head pressure rating of the circulator. The following facts may be noted:

   - Centrifugal pumps, in the form of wet rotor circulators or three-piece circulators, are most commonly used in hydronic heating systems.
   - There are four possible pump selections: a large and small pump, either of which can run in high or low speed. Obviously the large pump in high speed offers the maximum performance, but it would be both the most expensive to buy and the most expensive to run. The small pump in low speed is at the other extreme. Again we see the trade-off between initial cost and operating cost ("pay me now, or pay me later").

   Pumps can also be placed in parallel or in series. It is a good idea to use two pumps connected in parallel in case one should fail, or to have a spare on hand.

4) **Isolation Valves at all Zones or Flow Circuits** are often used as an alternative to having separate circulating pumps for each different zone in the building. Individual zone valves are electric and are controlled by their own thermostat so each zone or room in the home can be individually controlled for comfort and energy savings. Manually operated valves are sometimes needed to balance the system in multi-zoned installations, for system shut down, or if a thermostat fails. Valves can usually be one or two sizes smaller than the line they serve. If the

pipe is larger than the flow requires (as is often the case for bare pipe systems), know the flow rate and select a valve of the required capacity.

5) **Automatic Temperature Control and Zone Control:** These are desirable, using thermostatically controlled flow regulators. Automatic valves regulate the hot water circuit in each room or zone and are actuated by the thermostat for that room. The circulating pump usually runs continually and the valves open or close as required. Alternatively, the pump can be started by thermostat or aquastat, as one or more zones calls for heat. Three-speed pumps or pumps equipped with variable speed drive are also available, which increase or decrease the flow as needed.

6) **Relief Valve:** Every hot water boiler must have a safety relief valve that will keep the pressure at or below the boiler's working pressure. The A.S.M.E. (American Society of Mechanical Engineers) code states: "Every hot water heating boiler shall have at least one officially rated pressure relief valve set to relieve at or below the maximum allowable working pressure of the boiler. Relief valves shall be connected to the top of boilers with the spindle vertical if possible. No shutoff of any description shall be placed between the relief valve and the boiler, or on the discharge pipe between such valve and the atmosphere."

   The discharge of steam through a relief valve is an emergency condition and places a critical demand on the valve. Whenever the temperature of the water in the boiler is about 212°F or above, and the relief valve discharges, the sudden pressure drop causes the water to flash and to steam. The capacity of the relief valve must handle this. There is a vast difference between discharging water and discharging steam. A pound of water occupies 27.7 cubic inches of space. A pound of steam, at atmospheric pressure, occupies 26.8 cubic feet; over 1600 times more space than water! Thus, an A.S.M.E. relief valve is tested and rated on steam, even though it is a valve for a hot water boiler. The smallest pressure relief valve available is probably rated at 15,000 Btu/hr, which is also more than adequate.

7) **Low Water Cut-Off:** Most boiler manufacturers recommend putting low water cut-offs on hot water boilers. Many local codes will require this. Even though a boiler may be protected from exploding because it has an A.S.M.E. relief valve, dry firing can still ruin it. Most hot water boiler damage can be traced to low water conditions.

   There is a misconception that the pressure reducing fill valve will keep a system full under all circumstances. This is not true. To illustrate the problem, a typical system will have a pressure reducing fill valve set around 12 to 18 lbs and a relief valve set to open at 30 lbs and close at 26 lbs. Should the relief valve open to discharge water due to excess pressure, it is obvious the fill valve won't make up the water lost. Without make-up water replacing the loss through the relief valve, a low water condition can result. There are many other reasons a system can lose water so that a low water condition will result such as leaks in the boiler, piping, or through the pump seals. Carelessness, such as draining a boiler for repair and forgetting to refill the system is yet another common reason for a low water condition. A low water cut-off will save the boiler by not allowing the burner to come on until the low water condition is corrected.

   Under certain circumstances, a low water cut-off may not be enough protection. A fuel valve could stick open; contacts could weld closed due to an overload or short circuit making the low-water cut-off ineffective. The best recommendation to cover all installations is to use a combination water feeder and low water cut-off. The feeder portion is usually capable of feeding water into the boiler as fast as it can be discharged through the relief valve. While the feeder cut-off combination will add to the cost of an installation, when compared to the cost of replacing a boiler, it is "cheap" insurance. Remember, codes are minimum requirements, the "at least", that must be done. It is always good practice to exceed the code requirements, especially where safety is concerned.

8) **Expansion tanks** are used as a reservoir or overflow tank. Water expands about 4% as it heats from room temperature to near boiling. The expansion tank is an essential component of the hydronic heating system used to accommodate an increased volume of water in order to avoid damage and accidents due to high pressure. The expansion tank contains a quantity of air that is compressed as the volume of water rises in the system. In essence, the expansion tank performs two key functions: 1) Accept the extra water produced by heating the water in a sealed system and 2) Prevent the circulator from changing the static pressure in the sealed system. The three parameters to take into consideration when designing an expansion tank are

its location, its height and its volume. As a general rule, the expansion tank should also be located near the inlet port of the circulator and the volume of the tank should not be larger than the calculated volume value.

Expansion tanks are sized from the volume of water in the loop and the difference between the maximum and minimum operating temperatures. Generally the required volume is less than 10% of the system volume. System water volume and temperature determine tank size. The compression tank acts like a spring on the system, keeping pressure on it at all times.

- If the tank is too small, or becomes waterlogged, the relief valve will open when the boiler is heating and discharge water. When the heating cycle is over, the water will cool, system pressure will drop, and the feed valve will open and feed water until system pressure is back to "normal". On the next call for heat, the water will again expand, causing the relief valve to open. The cycle will repeat over and over until the too small tank is replaced, another expansion tank is added, or the waterlogged tank drained and properly refilled with the correct air and water charge.
- If the tank is too large, the system pressure increase may not be enough as the system heats up and approaches boiling, especially at the high point of the system where low static head exists. Proper compression tank sizing is very important for trouble-free system operation, whether it is a pre-charged tank with a bladder separating the water and air, or a standard expansion tank.

9) **Air elimination devices** should be installed at each high point in the hydronic system where air can gather. Trapped air must be expelled from the heating system to ensure optimum heating performance and to prevent noisy operation, blockage or even complete damage to the system.

Manual air vents at high points, automatic air vents, float-type air vents, air purgers and micro-bubble absorbers are used to solve the problem. There are two basic types of air vents; automatic and manual. Automatic air vents come in two styles. Float type and fiber disc type.

- Float vents have a float attached to a valve, all contained in a shell. When the shell is full of water, the float keeps the valve closed. When enough air accumulates in the shell, the float drops, opening the valve and air passes out until water again fills the shell, closing the valve.
- Fiber disk type automatic vents are physically very small, the same size as manual "loose key" or "coin" vents. They use special discs that swell when water touches them. As air accumulates and replaces the water around the discs, the discs dry out, shrink, and open a small vent port.
- The best air vents are the manual vents which require a small key to open or close them. These are just a small needle valve, metal to metal seat and are virtually indestructible and cheap. Their only drawback is that they must be manually opened and closed. Air vents for residential heating systems typically have a 1/8" NPT (National Pipe Thread) connection and require no further sizing.

10) **Heat transfer devices** such as radiators, convectors, fan-coil units and radiant floors transfer the heat from piped water to the living space.

11) **Heat exchangers** are the elements in the hydronic system that transfer heat to the piped water, or in the case of snow melting systems, the heat is transferred to an anti-freeze solution.

12) **Mixing valves** blend cooler return water with hot boiler water to obtain the desired thermostat temperature.

13) **Controls:** Standard low-voltage or newer programmable electronic thermostats can be used to provide temperature control for the hydronic system. Thermostats are usually connected to, and control, the zone valves. When the valve is fully open, an end switch on the zone valve turns the boiler and circulator on. Thermometers and pressure gauges are handy for balancing the system and also to monitor the efficiency of the system. Pressure gauge cocks and thermometer wells shall be installed at appropriate locations to make the routing checks.

14) **Pressure regulator:** The pressure regulator which is actually a pressure reducing valve must be provided on the cold water supply connection. It is used to fill the system initially and will add water when system pressure falls below the valve setting. The standard factory setting is

usually 12 lbs. This setting is the correct setting for a static height up to about 18 feet, good for most two-story buildings. For higher static heads, the valve can be adjusted up to 25 lbs. Most systems work best under a moderate pressure of about 15 PSI (100 kPa) for better circulation and to avoid vapor locks (just like automobile systems).

A 0-100 PSI pressure gage would be specified if the water tank is connected to the domestic water supply, since most city water systems operate in that range. If it is a stand-alone loop, specify a 0-30 PSI pressure gage, since residential heating equipment is generally required by ASME Pressure Vessel Code to operate in that range.

15) **Piping** materials for the hydronic system will vary depending on how the system is used and installed. Copper piping is typically used to distribute the hot water throughout the system, however, if the piping is embedded in concrete it may be made of iron, steel, synthetic rubber or plastic. Take changes in pipe size into account when choosing supports and planning layout. Provide sleeves or adequate clearance where pipes pass through walls or floors. Pipe supports should allow movement. Allow for expansion at the end of along pipe line or loop by stopping short of the end wall. For a 100°C change in temperature, steel expands 0.12% in length; various plastics expand 5 to 15 times as much.

16) **Draining and Venting:** Both are facilitated if heating lines slope uniformly to one end (or one point). Install drain cocks at the low points and air vents at the high points. One of each may be all that is required for simple systems; others may require several.

17) **Pipe insulation** is used to prevent heat loss and to ensure heat is delivered to the living space where it is required. Pipes running through unheated areas, such as crawlspaces, should be insulated with moulded fibreglass pipe insulation.

18) **Antifreeze and Corrosion Protection:** This protection is important. Antifreeze should be used if there is any danger of freezing. Use an ethylene glycol solution specially formulated for hot water heating systems. This contains corrosion inhibitors to maintain long-term performance of systems and components. Check the antifreeze solution every year, and add inhibitor if needed.

Sizing the Distribution Systems

Hot water heating systems have been traditionally designed for a supply temperature of 180 to 200°F with a 20°F temperature drop (delta T). Equipment manufacturer's selection data are normally indexed to these temperatures as are the practices of many design professionals.

Flow Rate: The required flow rate (in gallons per minute or GPM) is based on the quantity of energy that must be delivered. The volumetric flow rate in a heating system can be expressed by the basic equation:

$q = h / (cp * \rho * \Delta T)$

Where

q = volumetric flow rate, (gal/min)

h = heat flow rate, (Btu/h)

c_p = specific heat capacity, (Btu/lb F)

ρ = density, (lb/ft^3)

ΔT = temperature difference (°F)

The basic equation can be modified for the actual units - SI or imperial - and the liquids in use.

For water with temperature 60°F flow rate can be expressed as:

$q = h\ (7.48\ gal/ft^3) / ((1\ Btu/lb\ F)\ (62.34\ lb/ft^3)\ (60\ min/h)\ \Delta T)$ or

$q = h / (500 * \Delta T)$

Fluid Velocity: The acceptable range for water velocity in most applications is between three and seven feet per second (3-7 fps). Velocities lower than 3 fps represent large diameter pipe that is un-economical to install, and velocities higher than 7 fps represent too small pipe that will cause large pressure drops and un-economical sizing of circulator pump. Going outside of this acceptable design range can also cause problems with air entrapment in the water (if too slow) and pipe erosion and noise (if too fast).

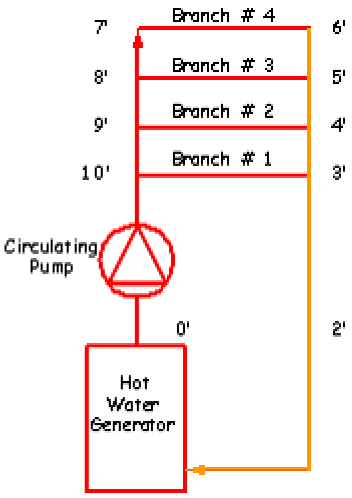
Pipe Size: The pipe size is determined from the standard selection charts based on equation q = A * V where A = area of the pipe, $\pi * d^2/4$ and V is velocity of flow in fps. When two parameters GPM and velocity range is fixed, the optimum pipe diameter can be selected. For example, if a system requires 90 GPM, we can select either 2-½" diameter pipe at 6 fps velocity or 3" diameter pipe at 4 fps both within the acceptable velocity range. Most flow rates will offer a choice between a couple of pipe diameters within the acceptable velocity range.

Distributing the hot water

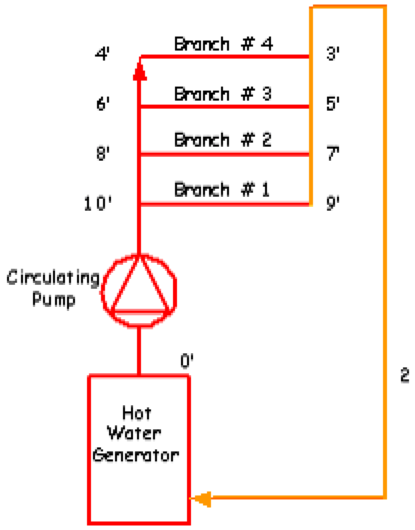
There are four basic piping systems used in hydronic heating systems to distribute heated water:

1) **One-pipe series loop systems** are the simplest version and use a single pipe that runs through a series of rooms. Heating devices are connected to the pipe wherever they are needed but no individual room control is possible within the loop. It is possible to divide this single loop into a series of zones using zone valves to control temperature within specific areas of the home. Each loop in a zone valve controlled loop should have shut-off and drain valves in the boiler room for isolation in the event of a system leak.
2) **One-pipe systems** with diverting tees is similar to the series loop system in that a single pipe is used but the heating units are installed in side circuits off the main pipe. In this system, a special pipe fitting is installed to force the heated water out of the main pipe to a heating device prior to returning the water back to the main pipe. In this system a thermostat control can be installed in each room, however, individual rooms may not reach the desired temperature setting due to water cooling along the way.
3) **Two-pipe direct return** has the fluid returned directly to the boiler by the shortest path. The hot water delivered to the first radiator is also the first to return to the boiler. This progresses through the circuit so that the last radiator is the last to return its cooler water to the boiler. With the direct return, units closest to the boiler tend to get too much flow and those on the end of the line get too little. There is a tendency for the radiators closest to the boiler to short-circuit the water so the units farther away do not get proper circulation. This system should be installed using balancing valves and carefully balanced.
4) **Two-pipe reverse return:** In a *reverse return* loop, the water in the return runs parallel with the supply pipe until the last coil has been supplied. In this system, the first radiator to be fed hot water has the longest return, and the last radiator to be fed has the shortest return. It is more expensive to install because more piping is required than the two pipe direct return system, but it functions much better because it results in more uniform or balanced flow as long as supply and return drops are the same size and length.

The concept of direct return v/s reverse return is further described below.



Normal Direct Return System



Reverse Return System

Case #1 – Direct Return System: Consider a system comprising of hot water generator, circulator and hot water distribution system serving 4 branches. As the water moves away from the circulator, the pressure differential across each circuit becomes less and less. On branch 1, the system has 10' of head pressure on the supply and 3' on the return side of the zone. That means there is a pressure differential of 7 ', and this 7' differential will cause a certain amount of flow to take place in that zone. At the farthest zone which has 7 ' of head pressure on the supply and 6 ' on the return side, only 1 ' of pressure differential exists across this zone. A difference in pressure is what causes water flow and greater the pressure differential, the greater shall be the flow rate. In the scheme above the farthest circuit might have 'no-flow or very scarce flow.

How do we solve this imbalance problem?

Case #2 (Reverse Return System): The reverse-return piping provides answer to this problem. Reverse-return maintain equal pressure drop throughout the entire piping system and ensures adequate flow to all the branch circuits. There is a bit more piping involved but maintaining water at every point makes it well worth installing.

Notice the length of circuit via branch 4 from pump discharge back to the hot water generator and via branch 1 is same resulting in somewhat equivalent pressure drop in both the circuits. Consider putting balancing valves on the return side of each circuit. By appropriate setting, the pressure drop in each circuit shall be the same. With equal pressure drops in each circuit, there is no "path of least resistance", and so there will be adequate flow in each circuit.

Note that the two pipe systems are more expensive than either of the one-pipe systems but water in each of the pipes travels shorter distances, returns to the boiler more quickly and allows greater heat control in individual rooms or zones.

Control Strategies

When a boiler is used for space heating, the simplest control strategy is to have the thermostat control the burner and circulator together. This easily adjusts the heat to your needs and provides the lowest operating costs. Programmable thermostats can be purchased and set up with the boiler and circulator to allow you to control the time and temperature settings of your heating system. A programmable thermostat is one of the most energy efficient items you can add to your heating system.

A second control strategy is to always keep the boiler hot and have the thermostat turn the circulator on and off. Operating costs for this strategy will be higher due to continual heat losses.

A third method of space heating is to adjust the boiler temperature to compensate for the temperature outside on the north side of the house. In this system, an externally mounted thermostat records outdoor temperatures and an internal thermostat adjusts interior zone valves to comfortable heating levels. This method is more energy efficient than the other temperature control strategies.

If your boiler is also used to heat domestic water it must be maintained at full temperature, even when living space heating isn't needed. This leads to increased operating costs from high stand-by heat losses. Separate water heating is recommended for energy efficiency.

Installation hints

1) Install a programmable thermostat with the heating system. Set it to turn heat down when your home is empty and to turn the heat up before you return home.
2) Install extra heating capacity in the bathroom, most people prefer a warmer bathroom.
3) Install a floor heater or recessed tube piping in front of glass patio doors to offset the chill caused by the large glass area. Allow at least 20 cm between the heater and the window.
4) Install a return air grille in the floor at the opposite side of the room from the heating device to improve cold air removal.
5) Clean heating devices regularly to remove dust and keep air circulating properly.
6) Install hot water to anti-freeze heat exchangers and piping systems under steps, sidewalks and driveways to melt snow and ice improving safety outside your home during winter.
7) As a minimum, bedrooms should be zoned separately from living and dining areas.
8) Rooms with southern exposure should be zoned separately from those with other exposures.
9) Radiant floors have lower water temperature requirements than convection units and these must be on separate zones.

System Startup

Most air problems can be eliminated by careful design, good maintenance, and proper initial startup of the system. The most often overlooked part of a forced hot water system is proper startup. Once a system has been installed, flushed, and filled to the proper static head, the boiler should be fired and slowly heated to at least 225°F water temperature and held there for about one-half hour. This will liberate the entrained air in the water and send it to the expansion tank. The hotter the water, the more air it will liberate. The circulating pump(s) should be off during this initial heating. Now, allow the boiler to cool to normal operating temperature and start all circulators and open all the zone valves, if used. Again, run the water temperature back up to at least 225°F and circulate all the water for 15 to 30 minutes. This will drive most of the air out of the fresh water, and as long as there are no leaks in the system, air problems will be prevented. Anytime the system is drained, say for some repairs, and re-filled, the startup procedure should be repeated.

HOT WATER RADIANT FLOOR HEATING

Radiant floor heating is accomplished by circulating hot water through lines of plastic pipe, either placed in sand below the floor, or right in the concrete itself. Most typically, a thermoplastic or synthetic rubber tube is used on 6”-12” centers, cast in the center or placed under the slab. Warm water is pumped through these tubes from manifolds placed at an accessible location, usually at one end of the space.

Radiant floors transfer heat through direct conduction, direct radiation and gentle convection. The combination of the three modes of heat transfer makes this one of the most comfortable systems. A hydronically heated slab floor provides very even temperatures and is the most popular and cost-effective systems for heating-dominated climates. An advantage to using this type of system is that it is very energy efficient. Radiant heat floors evenly heat rooms using lower water temperatures than other hydronic systems, thus reducing energy consumption. They offer benefits such as thermal comfort, energy efficiency, quietness, cleanliness, versatility, durability and minimized stratification effect. The main disadvantage is their slow response time compared to other hydronic systems.

Radiant floor systems can be installed in one of three ways:

- Slab-on-grade system
- Thin-slab system (lightweight concrete, gypsum under layment)
- Dry System (above deck system, below deck system)

Radiant Heating Design Principles

Systems are designed using the same principles outlined for hot water space heating. Unlike systems that heat air, a heated concrete slab floor should be controlled by monitoring the slab temperature directly. A heated concrete slab floor can usually provide 30- 50% of the total conductive heat loss of a space. Most often, another type of hot water system (bare pipes, finned pipes, unit heaters, or other system) is installed to supplement the floor system on cold nights.

Most of the equipment is the same: heater or boiler, circulating pump, expansion tank, valves and controls. The following comments are specific to floor heating:

Water temperature

For floor heat, hot water temperature can be much lower than for space heating; 100 -140°F rather than 190°F. The floor temperature of a large area is best controlled by regulating the water temperature, rather than by starting or stopping the flow. Control of small sections may be more precise and adjustable if line thermostats regulate flow to each section. Water temperature will be 50-60°F warmer than the floor when pipes are placed in the concrete and about 75°F warmer when they are in the sand below.

It is often useful to know the floor temperature. One way to do this is to make thermometer wells in the concrete. An ordinary thermometer (or electronic temperature probe) in contact with the floor can measure temperature directly. It works best if covered with small slab of foam insulation so it is kept at floor temperature. Cut a small groove in the insulation so if it's over the thermometer.

Piping

Usually, this is plastic. Polybutylene pipe made for hot water service is recommended. Higher strength 125 PSI (850 kPa) polyethylene can also be used, as well as soft copper tubing. Connections should be made outside the floor using double stainless steel clamps. Floor heat may require long runs of smaller pipe, thus pipe size must be adequate for the flow. For complete situations, get expert advice for checking flow and pressure loss, otherwise, the following is a safe guide for minimum pipe size, although larger pipe can be used:

Pipe Loop Lengths	Pipe Diameter
Up to100 ft	0.5”
Up to 200 ft	0.75”
Up to 325 ft	1.0”
Up to 500 ft	1.25”

Water flow should be higher than for space heat to keep the temperature more uniform. Use a temperature drop of 10-15°F for calculating flow rates.

Floor heat has a number of advantages:

1) Warm floor dries quickly

2) Snow and ice melt faster from vehicles
3) Heating is very uniform
4) Floor has high thermal mass, thus retains heat for a long time

It also has some disadvantages:

1) Relatively high cost compared to other methods
2) System can be damaged if the floor cracks
3) Slow to react to sudden changes in demand (large door opened, large cold machine brought in)
4) Not suitable for occasional use
5) By itself, may not maintain temperature during the coldest weather
6) The most serious drawback to floor heat is slow reaction time. You may find it necessary to have a supplementary space heater (separate unit heater or furnace), for quick response when cold-weather servicing is critical.

System Design

The best floor temperature is 77 - 86°F; warmer floors are uncomfortable and cooler ones are less effective. The amount of heat transferred from the concrete floor depends on both floor and the air temperatures. Heat input to the floor will depend on the inlet water temperature, pipe spacing and water flow, provided that the heating unit has enough capacity to keep up to the floor heat loss.

Heat output from floor to air is given by the following equation:

$h = 2.11 * (Tf - Ta)$

Where

h = heat output from the floor, Btu/sq-ft

Tf = floor slab temperature, °F

Ta = room air temperature, °F

For a floor at 86°F and air temperature of 58°F, heat output would be 2.11 x 28°F = 59 Btu/sq-ft. As the building cools below 58°F, the heat output will increase accordingly. Design for 60 Btu/sq-ft and size the heating unit slightly larger to account for system losses.

It is possible to get by with a smaller heating unit, down to about 50 Btu/sq-ft, if cooler floors are acceptable. This heat output will keep a reasonably well-insulated shop at 50 - 58°F but does not have extra capacity for reserve heat. It is not feasible, however, to obtain greater capacity from the floor system, since this would require a floor temperature too high for comfort. The system will have to be larger if auxiliary unit heaters are supplied from the same boiler system.

Water flow and pump capacity are calculated as outlined earlier; using equation

$q = h / (500 * \Delta T)$

Where

q = water flow rate (gal/min)

h = heat flow rate (Btu/h)

ΔT = temperature difference (°F)

The ΔT is usually taken as 9-16°F to maintain uniform conditions. Floor heating pipe is usually placed in loops running from a supply and back to a return header. Flow through each loop, for the purpose of checking pressure drop and sizing valves, is thus the total flow divided by the number of loops. Pipe may also be laid out in a continuous spiral around the building but this will require larger pipe owing to the longer loop length. The header system is normally of steel pipe, with T-fittings or nipples welded on for attaching the floor lines. The header should be sized for the total water flow in the system. Valves are recommended on each floor line to balance or control flow; one on the supply and another on the return are best in case one loop springs a leak.

Example:

Design a floor heating system for a room 32' x 50'. Floor area inside the foundation is about 30' x 48' = 1440 sq-ft. Calculate system size based on 70 Btu/sq-ft heat input.

Solution

Room floor area = 1440 sq-ft

1) Calculate system size based on 70 Btu/sq-ft heat input.

Total Heat input = 70 Btu/sq-ft x 1440 sq-ft = 100800 Btu (or ~ 30 kW capacity)

2) Determine flow rate for an inlet- outlet hot water temperature change of 10°F across the system

$q = h / (500 * \Delta T)$

$q = 96600 / (500 * 10)$

q = ~ 20 GPM

3) Determine number of loops and water quantity per loop

Each loop is about 100 ft (~2 x 48') long, thus ¾" pipe will be adequate (Note: double loops of 184 ft length could be run to reduce valves and connections).

Room width = 30 ft

Pipe spacing = 1.5 ft

Number of lines = 30 / 1.5 = 20

Therefore, use 20 lines or 10 loops

Water flow in each loop = 20/ 10 GPM = 2 GPM

4) Size the header system:

For a flow of 20 GPM, 2" (50 mm) pipe is more than adequate.

5) Estimate the volume of the system

1000 ft* of ¾" floor pipe x 0.025 gallons per ft = 25 gallons {Note *….100 ft loop x 10 loops; the ¾" pipe has a holding capacity of 0.0.25 gallons per ft of pipe}

60 ft* of 2" mm header x 0.16 gallons per ft = 9.6 gallons {Note*….2 x 30 ft of supply & return header; the 2" pipe has a holding capacity of 0.16 gallons per ft of pipe}

Boiler unit volume (estimated) = 5 gallons

Total = 39.6 gallon

Minimum expansion capacity required is 5% of 39.6 gallon = 1.98 gallon; obtain an expansion tank with at least 2 gallon net expansion capacity.

Heated Concrete Slab Floors Installation

Floor heating pipe may be laid either in sand layer below the concrete or directly in the concrete. The former is easier to do and safer from leaks caused by floor cracks. The latter is slightly more efficient. When concrete cures it shrinks, causing natural cracks to occur. Where pipe is placed in the floor, reinforcing is required to reduce cracking to small hairline cracks. This reinforcing can benefit any floor, but less is needed if control joints are part of the floor design (which cannot be done with in-floor pipes). To control cracking, the recommended cross-section area of reinforcing steel is 0.16% of the cross-section area of the floor slab. When selecting a heated concrete slab floor, it is important to consider many factors:

1) The tubing you use must last as long as the concrete itself, so make sure it has been developed for your specific purpose.

2) The type of concrete, and the way it is mixed will have a long term effect on the durability and usefulness of your floor.

3) Floor reinforcement: There are three basic methods used, re-bar, re-mesh, and “fiber-mesh”. The latter is an additive to the wet concrete and reportedly can offer the most integrity and longevity. Spend some time researching the best means of reinforcement for your project. Remember that you will need to secure your heating tubing to something and a reinforcement mesh might be the best choice.

4) Insulate! It cannot be stressed enough that a heated concrete slab floor should be insulated around the perimeter and as deep as the frost line in your area. Some reports indicate that up to 50% of your heat can be lost out the perimeter of a heated slab if no below grade insulation is installed. The best type of insulation to use is one of the extruded styrene boards, usually 1.5” - 2” inches thick.

5) Engineering: A good design and plumbing plan are the keys to a well designed heated concrete slab floor. A well designed system will include an appropriate boiler and pump sized to handle the load. Also important is a means of balancing the flow of hot water to achieve even floor temperatures.

The factors to take into consideration during the design of a radiant floor system are:

- dimensions of the space
- space heating loads
- ease of tube installation
- location of manifold stations
- position of control joints
- zoning of the spaces
- type of floor covering
- length of pipe circuits
- horizontal spacing between the tubes
- position of exterior walls
- possibility of driving fasteners in the floor

The following guidelines should be considered as well:

- the hottest fluid should be routed first along the exterior wall(s) of a room
- maximize straight runs and minimize bends and corners
- limit the length of the circuits with respect to the tubes
- design the circuit for room-by-room zoning
- limit the passage of pipes through control joints
- place the tubes according to the grid (slab-on-grade)
- avoid tube crossover
- avoid tube perforation

SECTION- 5 ELECTRICAL HEATING

Electric furnace using resistance heating converts nearly 100% of the energy in the electricity to heat. From energy management and environment conservation point of view, electric heating is not a recommended choice for heating. Since most electricity is produced from oil, gas, or coal generators that convert only about 30% of the fuel's energy into electricity and after accounting losses due to transmission & distribution, converting electricity back to heating doesn't make sense.

Electrical Resistance Space Heating Equipment

Electric resistance heat can be supplied by centralized forced-air furnaces or by zone heaters in each room, both of which can be composed of a variety of heater types.

Central Electric Furnace

In a central electric furnace, air is blown over electric heating coils and then distributed through the ductwork. This type of furnace is much simpler than a fuel-fired one, because no combustion air or exhaust is needed. These units therefore have an efficiency rating of 100%, meaning that all of the heat created goes into heating. However, this figure can be misleading. A lot of energy is lost producing and transporting electricity to the house, and it shows up on the energy bill. As with all forced-air systems, leaky ducts in a poor distribution system can lead to hefty additional heat losses. Electricity rates vary, but in most places a central electric furnace is the most expensive type of heating system to run.

Zone heaters distribute electric resistance heat more efficiently than electric furnaces because you set room temperatures according to occupancy. In addition, zone heaters have no ducts that can lose heat before it reaches the room. However, electric furnaces can accommodate central cooling easier than zone electric heating, because the air conditioner can share the furnace's ducts.

Typical zone electrical space heating equipment includes baseboard units, wall units, and unit heaters, portables, ceiling units, and insulated conductors embedded in ceiling or floor. Here are several options for electric resistance space heaters.

1) ***Baseboard Heaters:*** Sometimes called electric strip heaters, baseboard radiation is a fairly common heat source and heating system. Compact heating elements enclosed in protective and decorative linear housings are permanently installed along the lower part of one or more room walls -- near the intersection with the floor. Room air heated by the resistance element rises and is replaced by cooler room air, establishing a continuous convective flow of warm air while in operation.

   Although various control schemes are possible, baseboards are individually controlled. Electric baseboards are cheap to install but expensive to run, although if used to heat only occupied rooms, they can be less costly than a central electric furnace.

2) ***Wall Units:*** These heaters may be flush-mounted or recessed, and use a radiant or ceramic panel, heating coils, or other form of heating element. They come with or without a built-in fan and thermostat. These units are often used for spot heating in areas such as building entrances and where higher temperatures are needed.

3) ***Ceiling Units:*** These are similar to the wall units in type, but designed for ceiling installation. Units may include lighting devices (e.g., restrooms).

4) ***Deep Heat System:*** These systems are used in northern climates where it may be effective to bury electric heaters in a sand bed beneath the concrete floor of the warehouse, commercial space, or garage. These large thermal masses can often be heated during the off-peak period to provide economical space heat during occupied hours. Since most people are more comfortable when their feet are warm, these systems have also been reported to provide very pleasant work environments even in the most extreme of weather conditions.

5) ***Duct Insert Heater:*** Here heating elements inserted in the ducts of forced air heating systems, either at the fan location or near supply air outlets. Heaters may be step-controlled in accordance with amount of heat needed. Automatic safety cut-offs interrupt current on either over-temperature of unit or fan failure.

6) ***Heating Cable:*** These are insulated resistance heating elements manufactured in various lengths and wattage's and are suitable for installation in ceiling plaster or in/under concrete slabs. This method of heating evenly distributes the heat source and produces a low temperature radiant heat surface. This method has been used in large open buildings such as warehouses, garages, hangars, etc.

7) ***Unit Heaters:*** These heating elements are used with a fan or blower to force air into the conditioned space. Certain types are classified as heater-ventilators and perform the function of both controlled heating and ventilating. These units have been used primarily in schoolroom heating, but can be used for many commercial/industrial applications where ventilation is required.

8) **Electrical Tabular Heaters:** These are steel or aluminum tubes usually round or oval in section. They consist of an electrical heating element, which extends from end to end and is surrounded by air. The surface temperature is about 80°C. A single tube at 50mm diameter has an output of about 180 Watts per meter length and tubes may be mounted in banks, one above the other, for higher outputs. An electrical skirting heater with an output of 400 Watts per meter run is typical of some installations requiring background or low level heating. Tubular heaters are used in churches, under pews, in greenhouses, conservatories and foyers. They can be placed at the bottom of high windows to prevent downdraughts of cold air or be set to prevent frost in greenhouses or conservatories.

9) ***Radiant Heating:*** Instead of circulating heat by moving the air in the room, a radiant system heats objects including people. There are several types of electrical radiant heaters:

   - ***Infrared Radiant Heaters:*** These heaters generate infrared radiation, heating all objects in their "line of sight," or radiation path. The electrical elements used are similar to those fitted to luminous fires but, for a given rating, are commonly longer as shown below, and arranged to operate at about 900°C. Equipment is available with either metal sheath enclosed element, quartz tubes, and reflector lamps. They are all used with a directional reflector. Wall or ceiling models of these are suitable for kitchens and bathrooms, ratings are up to 3 kW. Infrared heating is used in areas where heating the entire space through convection would be difficult or expensive in comparison to keeping people comfortable such as warehouses, garages, etc.

   - ***Quartz Lamp Heater:*** The elements of this type of heater operate at about 2000oC and consist of a tungsten wire coil sealed within a quartz tube containing gas and a suitable halide rating of elements about 1.5kW. These are used in large spaces either where the requirement is intermittent or where only local areas require spot heating.

   - ***High Temperature Panels:*** These consist of either a vitreous enameled metal plate or a ceramic tile behind which a resistance element is mounted within a casing. Panels of this type operate at a temperature of about 250°C and have ratings in the range 750 W to 2 kW; they are normally used in washrooms in industrial situations. These low-density radiant heaters which can be mounted in wall or ceiling to provide spot heating.

Heat Pumps

Many forced-air systems use a heat pump instead of an electric furnace because of its high efficiency and capability to air-condition. A heat pump is an electrical device that functions by moving (or pumping) heat from one place to another. Like a standard air-conditioner, a heat pump takes heat from inside a building and dumps it outside. The difference is that a heat pump can be reversed to take heat from a heat source outside and pump it inside. Thus heat pump can be used for both summer cooling and winter heating cycles. Note the following facts:

1) In the heating mode, heat pumps are far more "efficient" at converting electricity into usable heat because the electricity is used to move heat, not to generate it.

2) Because they move heat rather than generating heat, heat pumps can provide up to 4 times the amount of energy they consume.

3) If you heat with electricity, a heat pump can trim the amount of electricity you use for heating by as much as 30% to 40%.

4) High-efficiency heat pumps also dehumidify better than standard central air conditioners, resulting in less energy usage and more cooling comfort in summer months.

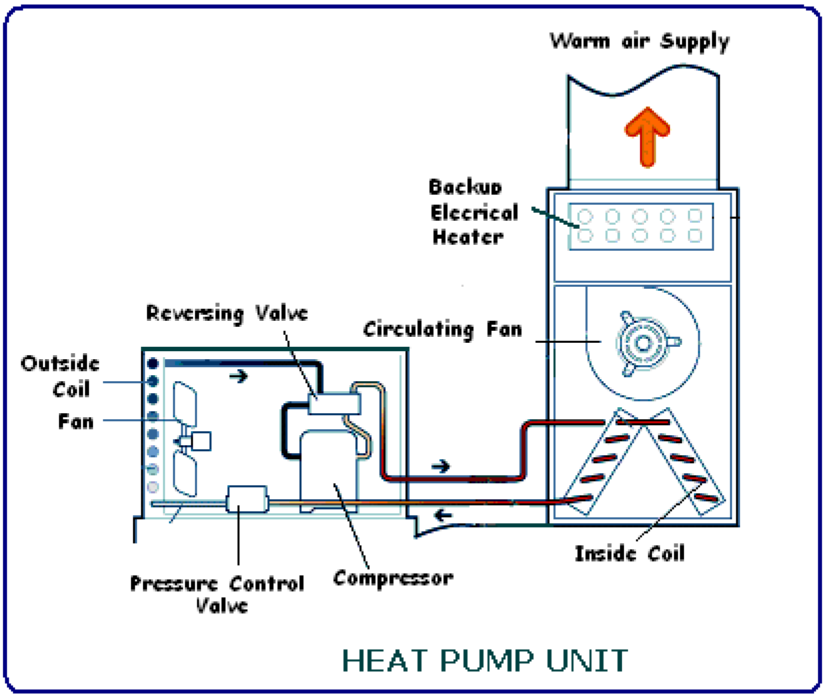
The heat pumps are divided into two major groups: air source (air-to-air) systems, which draw heat from the air, and ground source (earth energy) systems, which draw heat from the ground or underground water.

Air Source Heat Pump

The most common type of heat pump is the "air-source heat pump", which uses outside air as the heat source during the heating season and the heat sink during the air-conditioning season. A condenser absorbs heat from the outdoor air (even the coldest air contains some heat) and transfers it to an indoor heat exchanger inside the space. Indoor air is warmed in the heat exchanger and circulated throughout the space. During the summer, the process is reversed to cool and dehumidify the space.

Although air-source heat pumps can be used in nearly all parts of the United States, they do not perform well over extended periods of sub-freezing temperatures. In regions with sub-freezing winter temperatures, it may not be cost effective to meet all your heating needs with an air-source heat pump.

One of the biggest advantages of a heat pump is that it provides both heating and cooling capabilities in one unit. Electric heat pumps are usually supplemented with a backup system, such as electric heaters, radiant floor heaters or baseboard units (see below), in case of extended periods of extreme temperatures. Heat pump systems generally require larger duct sizes than other central heating systems. For proper heat pump operation, airflow should be 50 to 60 liters per second per kilowatt-hour or 400 to 500 cubic foot per minute per ton of cooling capacity.



Ground Source Heat Pump

Also known as a geothermal system, this type of heat pump uses underground loops to absorb heat from the earth or in other words transfer heat between your facility and the ground. Ground-source and water-source heat pumps work the same way, except that the heat source/sink is the groundwater or a body of surface water, such as a lake.

Ground-source heat pumps are complex. Basically, water or a non-toxic antifreeze-water mix is circulated through buried polyethylene or polybutylene piping, which then pumped through one of two heat exchangers in the heat pump. When used in the heating mode, this circulating water is pumped through the cold heat exchanger, where its heat is absorbed by evaporation of the refrigerant. The refrigerant is then pumped to the warm heat exchanger, where the refrigerant is condensed, releasing heat in the process. This sequence is reversed for operation in the cooling mode.

Although these cost more to install, these have low operating costs because they take advantage of relatively constant ground temperatures. However, the installation depends on the size of your lot, the subsoil and landscape. Ground-source or water-source heat pumps can be used in more extreme climatic conditions than air-source heat pumps, and customer satisfaction with the systems is very high.

The efficiency or coefficient of performance (COP) of ground-source heat pumps is significantly higher than that of air-source heat pumps because the heat source is warmer during the heating season and the heat sink is cooler during the cooling season. Ground-source heat pumps are environmentally attractive because they deliver so much heat or cooling energy per unit of electricity consumed. The COP is usually 3 or higher.

Heat Pump Efficiency

Heat pump efficiency is measured separately for the cooling and heating cycles. For cooling, the Seasonal Energy Efficiency Ratio (SEER) of an air source heat pump ranges from a minimum of 9 to a maximum of about 16. The Heating Seasonal Performance Factor (HSPF) for the same units ranges from a minimum of 5.9 to a maximum of 8.8. The SEER of a ground source heat pump ranges from 11 to 17, and the HSPF ranges from 8.3 to 11.6.

At the lower end of the product range, both air and ground source heat pumps have single-speed reciprocating compressors. Heat pumps with the highest SEERs and HSPFs invariably use variable or two-speed scroll compressors.

A building owner who has an electric furnace and wants to stay with electricity as an energy source may be able to reduce heating costs by up to 50% by converting to an air source heat pump and by 65% by converting to a ground source heat pump. Actual dollar savings will vary depending on factors such as local climate, the efficiency of the current heating system, the cost of electricity, the size and HSPF of the heat pump installed.

Annexure # 1

Heating Equipment Characteristics

Equipment Type	Typical Available Output Ranges	Advantages	Disadvantages
Gas Furnaces	40000 to 150000 Btuh	• Burner relative quite • Warm comfortable heat delivered to spaces • Clean burning , minimal service • Available in upflow, downflow and horizontal configurations	• Use limited to availability of fuel • Flue required • Lower output unit (15000 to 30000 Btuh) compatible with actual requirements not readily available • Seasonal efficiency reduced by over sizing
Oil Furnaces	72800 to 168000 Btuh (0.65 to 1.5 gph nozzle size)	• Favourable alternative to electricity in colder climate • Warm comfortable heat delivered to spaces • Available in upflow, downflow and horizontal configurations	• Burner relatively noisy • Flue and storage tank required • Lower output unit (15000 to 30000 Btuh) compatible with actual requirements not readily available • Seasonal efficiency reduced by over sizing • Occasional service required to assure clean combustion
Electric Furnaces	17065 to 136520 Btuh (5 kW to 40 kW)	• Warm comfortable heat delivered to spaces • No flue required • Small space required • Same unit adaptable to upflow, downflow and horizontal configurations • Many sizes available in small increments (5 kW) allow close sizes to actual loads • Minimum service	• High operating costs in most areas
Heat Pump **(air to air)**	18000 to 60000 Btuh (1 ½ to 5 tons)	• No flue required • Small space required similar to electric furnace • Same unit often adaptable to upflow, downflow and horizontal configurations • Economical operation compared to electric resistance furnace • Use same equipment for both heating and cooling	• Low air temperature at registers • Higher air volume requires more critical duct design • Economical heating output limited to nominal tonnage of air-conditioner size • Least efficient when coldest outdoors • Less efficient for cooling than available high efficiency cooling only, condenser-coil

Equipment Type	Typical Available Output Ranges	Advantages	Disadvantages
			combinations • Servicing more sophisticate than furnace
Heat Pump **(water to air)**	18000 to 60000 Btuh (1 ½ to 5 tons)	• No flue required • Small space required similar to electric furnace • Same unit often adaptable to upflow, downflow and horizontal configurations • Extremely efficient in both heating and cooling modes	• Requires dependable ground water source within economical operating temperature range • Requires means of returning water to ground or other drainage • Potential freeze up problems in cooler climates • Installed costs higher dependent on the cost of obtaining ground water
Coal & Wood Furnace	80000 to 200000 Btuh	• Provide abundance of warm heat utilizing economical fuels • Ideal for retrofit in poorly insulated older homes • Coal furnace can burn coal, wood and even trash • Operation not dependent on electric supply, hence not affected by outages	• Economical use limited to availability of wood or coal • Requires large space for coal, wood storage and larger furnace • Requires frequent daily firing, coal handling and ash removal is messy and inconvenient • Difficult to accurately control temperature • Tends to overheat space during moderate weather

Annexure # 2

APPLICATION CONSIDERATIONS FOR VARIOUS SYSTEMS

A general guide to select an appropriate heating system for different buildings is presented below, based on experience. This can be amended judiciously for specific user's needs.

Heating/Cooling Systems and Buildings

BUILDING	HEATING SYSTEM / EMITTERS	HEATING MEDIA	COMMENTS
Hospital Ward	Full air conditioning central plant	Air	Used where air needs to be clean. Draughts of cool air may be a problem.
	Plenum heating	Air	Can be used if heat gains are minimal.
	Radiant ceiling	Water	Cleaner than radiators. High radiant temperatures may cause discomfort.
Hospital- **Operating Theater**	Full air conditioning central plant	Air	Clean air essential. Special high efficiency filters required.
	Chilled ceiling / beams.	Chilled water	Advantage no air – no bacteria. Condensation may be a problem.
Large Workshop, Industrial Building, Factory	Industrial warm air heaters	Oil/gas fired	Cheap to run. May be noisy. May use up floor space if floor mounted.
	Unit heaters	Steam, HTHW, MTHW, LTHW	A unit heater is simply a heat exchanger. Compact. May be noisy.
	Radiant tubes	Steam, HTHW, MTHW or direct gas fired.	No noise, especially if non-direct fired. Suitable for between isles heating.
	Radiant panels	Steam, HTHW, MTHW	Usually roof mounted. May be cheaper to operate than heating air.
Small Workshop, Garage	Industrial warm air heaters	Oil/gas fired	Cheap to run. May be noisy.
	Unit heaters	MTHW, LTHW	Compact. May be noisy.
	Fan convectors	MTHW, LTHW	Suitable for smaller workshops. There are various types.
Office Building, Public Building	Air conditioning central plant	Air	Prestigious offices. Inner city areas to reduce pollution.
	Fan coil units	Hot/chilled water	Not quiet running. Individual room control.

BUILDING	HEATING SYSTEM / EMITTERS	HEATING MEDIA	COMMENTS
	Room air conditioners/ cassette units	Hot/chilled water	Individual room control. May be ceiling mounted.
	Plenum heating	Air	Used in low heat gain areas. Cheaper than air conditioning.
	Radiators	LTHW	Require wall space. Easy to control.
	Natural convectors	LTHW	Require wall space. Quite bulky.
	Fan convectors	LTHW	May be noisy.
	Underfloor heating	LTHW	No floor space required. Heat output may not be sufficient
	Storage heaters	E7 electricity to air	Easy to charge occupier. Can be expensive to run.
Large Public Hall, Auditoria	Air conditioning central plant	Air	Calculate fresh air requirement. Air distribution is important.
	Plenum heating	Air	Cheaper than air conditioning.
Church, Library	Radiators	LTHW	High output usually required for large buildings.
	Underfloor heating	LTHW	If no wall space is available.
	Quartz lamp heaters	Electric quartz tube	Electric heating may be economical for occasional use.
	High temperature panels	Electric metal plate	Small heat emitters. Can be roof mounted.
	Low temperature panels	Electric elements in plate	Can be roof mounted.
	Skirting heating	Electric element	Low output. May be used with other systems.
	Tubular heaters	Electric element	Mounted at low level.
	Pipe coils	LTHW	Heaters under pews.
Department Store, Supermarket	Air conditioning central plant	Air	Large Prestigious store. Use in areas of high heat gain.

BUILDING	HEATING SYSTEM / EMITTERS	HEATING MEDIA	COMMENTS
	Room air conditioners/ cassette units	Hot/chilled water	Good control possibility. Compact.
	Plenum heating	Air	Used if heat gains are minimal.
	Radiators	LTHW	Use in small store.
	Fan convectors	LTHW	Use in small store. May be noisy.
School, College, University	Radiators	LTHW	Can be easily controlled with thermostatic valves.
	Radiators LST (Low Surface Temperature)	Warm water	In Nursery schools limit water temperature for safety.
	Radiant ceiling	Water	High radiant temperatures may cause discomfort. No wall space required
	Underfloor heating	LTHW	No wall space required. Comfortable floor.
	Warm air or air conditioning.	air	In larger areas e.g. lecture rooms.
Hotel	Radiators	LTHW	Easy room control. Bedrooms.
	Air conditioning central plant	Air	Lobby areas, large restaurants, banquet halls etc. Use in areas of high heat gain.
	Room air conditioners/ cassette units	Hot/chilled water	Good control possibility. Compact.
	Plenum heating	Air	Used if heat gains are minimal.
	Fan convectors	LTHW	Use in areas requiring quick heat up e.g. foyer. May be noisy.
	Natural convectors	Electric element	Possible key entry system which operates power to room.
House	Radiators	LTHW	Different types and materials. Efficient.
	Underfloor heating	LTHW	Invisible system.
	Air conditioner	Electrically operated refrigerant	Areas of high summertime temperatures. Use quieter systems.

BUILDING	HEATING SYSTEM / EMITTERS	HEATING MEDIA	COMMENTS
Apartment	Storage heaters	Electricity	Easier to charge client. Can be more expensive to run. Difficult to control.
	Underfloor heating	Electric cables	Expensive to run if not a suitable tariff. Invisible system.
	Underfloor heating	Water	Invisible system. Requires suitable floor with insulation.
	Radiators	LTHW gas-fired. Or oil-fired.	Natural gas easier to charge. Efficient.

LTHW – Low temperature hot water

MTHW – Medium temperature hot water

HTHW – High temperature hot water

Annexure # 3

ENERGY CONSERVATION & LOAD REDUCTION STRATEGIES

Heating requirements can be reduced through passive solar design and attention to tightening the building envelope. The following tips may be useful for energy conservation:

General Tips on Energy Conservation

1) Use a correctly sized heater for the space you are heating.
2) Heat only those areas in use at any one time.
3) The temperature of a heated room in winter should be between 64-68°F.
4) Don't overheat. Every one-degree increase in temperature is a 10% increase in heating bills and emissions.
5) Minimize heat loss through poor insulation by repairing faulty door seals, hanging curtains that sit close to the window frames and laying rugs on bare floors.
6) Frequent changes in thermostat settings will increase operating costs.
7) Always light gas heaters in accordance with manufacturer instructions, turning the setting down to a comfortable level after the burners are lit.
8) Keep all doors closed so that the warm air is restricted to the area requiring heating.
9) Ensure ceiling space above all heated areas is adequately insulated.
10) Install draught seals and weather stripping around doors and windows. Air leaks can account for 15-25% of heat loss from an uninsulated space and create uncomfortable draughts.
11) Protect your windows - up to 40% of total heat loss from a space occurs through uncovered windows. Close-fitting, heavy drapes or blinds, or double-glazed windows reduce heat loss.
12) Zone your space: being able to close off different areas of your space allows you to heat only those areas in use at any one time.
13) Open up curtains to north-facing windows on sunny winter days to let in the natural warmth.
14) Wear warmer clothing - it's free, easy and will let you turn down your heater just those few degrees more.
15) A wall-mounted heater is the safest to use in the bathroom. It should be mounted at least 1.4 meters above the floor, well away from water taps and shower outlets.
16) Don't leave the heater running on low overnight or while you are out.
17) Use a programmable thermostat. This simple, inexpensive device may provide better savings than any other efficiency measure.
18) Turn off pilot lights (if fitted) over summer.
19) Maintain your heating system according to the manufacturer's instructions.
20) On dark winter days, cover windows with close fitting, floor length heavy curtains - up to 30% of total heat loss from a home occurs through uncovered windows. Leaving curtains open can increase your heating bill by up to $80 per quarter for the average home!
21) On sunny winter days, open up the curtains to north-facing windows for free natural solar energy to warm your home.
22) Lower your thermostat setting at night and when there will be no one home for at least 4 hours; a 10° setback can give you significant savings. Setback thermostats save energy by automatically turning the thermostat down and up on a preset schedule.
23) Registers - Look for and correct the following conditions:
    - closed supply dampers
    - drapes, furniture or carpet obstructing the supply and/or return registers or grilles
    - leaks in warm air ducts and cold air returns

- dust plugging the supply and/or return registers or grilles
- high pile carpet blocking baseboard radiators at the bottom

Load Reduction Strategies

1) ***Weatherize your home:*** Insulation and air-sealing improvements to the shell of your building will always improve your comfort, regardless of the size and type of heating system installed. Weatherization may also allow the installation of a smaller, more economical heating system.
2) ***Doors and windows:*** Doors and windows should fit well and/or be draught-proofed. Keep doors and windows closed when the heating is on, but don't block ventilators or airbricks.
3) ***Curtains:*** Heavy curtains and/or thermal linings also help prevent heat loss. Open windows on the sunny side when the sun is up so that the sun can warm the rooms. Close all curtains when it gets dark. Do not have furniture close to or in front of radiators. If you have deep windowsills, curtains should sit neatly on top of them and not cover the radiator.
4) ***Filling in gaps between skirting boards and floor:*** Fill in any gaps between skirting boards and the floor. This can be done with wood molding or with one of the fillers.
5) ***Heat reflective foil behind radiators:*** Fit heat reflective foil behind radiators on outside walls to keep the heat inside your space, with the shiny side facing into the room.
6) ***Draught proofing:*** Draughts are one of the main reasons why spaces feel cold and cost a lot to heat. Draught strip windows, outside doors and the loft hatch and fill gaps in the ground floor floorboards and below the skirting board. Do not cover vents/air bricks
7) ***Roof insulation:*** As much as 20% of your energy bill can be saved by effective loft insulation. If you have a loft, it should have insulation at least 150 mm (6 in) thick to keep the heat in. If your insulation is 50 mm (2 in) thick or less, you may be eligible for a grant. Don't forget to insulate the loft hatch and pipes/tank in loft.
8) ***Cavity wall insulation:*** More heat is lost through the walls of an average uninsulated building than by any other route. Most spaces built since the early 1930's have cavity walls (two walls with a gap in between) which can be filled with insulating material. To install cavity wall insulation most people will need to employ a builder.
9) ***Solid wall insulation:*** Solid walls can be insulated but can be a problem to do. It may be worth doing a north facing wall or one that is exposed.
10) ***Internal insulation:*** Timber battens can be fixed to the wall in order that plasterboard, tongued and grooved boarding or a decorative wallboard can be attached. The timber bates are in filled with insulation such as mineral wool. Make sure a vapor barrier is installed to reduce the risk of interstitial condensation. Remember that internal solid wall insulation will reduce the room size by approximately 50 mm (2 in) along the side of the wall. Light switches, plugs, skirting boards will have to be removed and replaced. This measure is very disruptive if occupants are living in the property at the time of the work.
11) ***External insulation:*** It's a job for a specialist contractor and you can obtain details from the External Wall Insulation Association, a list of their members and descriptions of the systems they offer.
12) ***Floor insulation:*** As much as 10% can be lost through floorboards. If there is easy access to the joists under the floorboards, you can insulate from below by filling the spaces between the joists with mineral wool mat or expanded polystyrene boards.
13) ***Double glazing:*** Large windows cause heat loss; double-glazing could be an option. Even draught-proofed, single glazed windows allow a lot of heat to be lost (around 20% of the total heat loss). Heat loss through windows can be halved with double-glazing. Professionally fitted double-glazing can be expensive, but if you need new windows, having double-glazing fitted is the sensible thing to do as it makes rooms more comfortable. Put double-glazing in the rooms you use the most and on large windows first. Where double-glazing can halve the heat loss through windows, double-glazing with low emissivity glass can reduce it by a further 30%.

Annexure # 4

TYPICAL REQUIREMENTS & STANDARD SPECIFICATIONS FOR BOILER HYDRONIC SYSTEMS

(Per Canadian Codes)

These requirements apply to:

- Installations up to and including 400000 Btu/hr;
- Residential installations of three family or less housing; and
- Where the Boiler Safety Division will not be informed or required to inspect.

1.0 Owner and Operator Instruction

1.1 The installer shall be responsible to compile and provide to the owner and/or the operator all installation, operating and service instruction manuals and information.

1.2 The installer shall instruct the owner/operator on the use, maintenance and service requirements of the system and associated equipment as in the CSA B149.1 Natural Gas and Propane Installation code, "Responsibilities of the Installer".

2.0 General Requirements

2.1 All boilers shall be approved by a recognized Canadian certification agency and have all the required markings on the name/rating plate attached to the boiler.

2.2 Installations shall meet the requirements of the most recent version of the CSA B214 Installation Code for Hydronic Heating Systems.

2.3 Replacement boilers shall also meet these requirements.

2.4 Boiler controls and safeties can not be located or piped in such a way as to be isolated from the boiler by manual or automatic valves or controls.

2.5 All boilers shall have two limit controls. One shall act as an operating control and one shall act as a high limit safety control.

2.6 Pressure relief valves shall be installed with the discharge outlet facing down or horizontal and the discharge outlet piped down towards the floor. The ends of the discharge pipe shall not be threaded or provided with a fitting, which could allow the discharge pipe to be blocked or restricted.

3.0 Low Water Cut-off Requirements

3.1 Unless regulated by other jurisdictions, boilers installed with a heat distribution system at a level below the boiler shall be provided with an approved low water cut-off device.

3.2 Low water cut-off controls shall be installed as specified by the manufacturers certified installation instructions and shall be capable of shutting off the fuel supply to the burner(s).

3.3 Low water cut-off safety devices shall be installed and piped in the same manner as required by the Boiler and Pressure Vessels Act to allow for inspection and testing.

4.0 Boiler Installation and Operation

4.1 Boilers designed to have burner operation with no flow conditions present shall be installed as per the manufacturers certified installation instructions and any other requirements set forth by any national or local codes and jurisdictions.

4.2 Boilers sensitive to low return water temperatures shall be installed and controlled in such a way as to maintain the minimum return water temperature during normal operation as required by the manufacturer. Owners and/or operators shall be instructed of any minimum return water temperature requirements.

4.3 Boiler installations shall include a minimum of two thermometers located to accurately sense the water temperature inside (or leaving) the boiler and the return water temperature entering the boiler. Installations shall have a minimum of one pressure gauge located at or on the boiler.

5.0 Coil and Fin Tube Boilers

5.1 When used in residential applications and in heating applications of three family and less housing:

- The heating system shall be installed in such a manner that the boiler has constant flow conditions when in use.
- The boiler shall be equipped with a flow switch installed so that with reduced or no flow, the burner must shut off.
- The boiler shall be equipped with two limit controls. One to act as an operating (primary) control and the second shall act as a high limit (secondary) control. Both of which must shut down the fuel supply to the burner when the respective set point has been reached.

5.2 When used in commercial applications or residential applications of more than three families:

- The heating system shall be installed in such a manner that the boiler has constant flow conditions when in use.
- In accordance with the Boiler Safety Division a flow switch shall be installed. The flow switch must be capable of being tested in service. When flow is reduced or stopped, the burner must shut off.
- The boiler shall be equipped with two limit controls. One to act as an operating (primary) control and the second shall act as a high limit (secondary) control. Both of which must shut down the fuel supply to the burner when the respective set point has been reached.

6.0 <u>Hydronic Boilers Other Than Fin Tube (Cast Iron Sectional etc)</u>

6.1 When used in residential applications and in heating applications of three family and less housing:

- The boiler shall be equipped with two limit controls. One to act as an operating (primary) control and the second shall act as a high limit (secondary) control. Both of which must shut down the fuel supply to the burner when the respective set point has been reached.

6.2 When used in commercial applications or residential applications of more than three families:

- The boiler shall be equipped with two limit controls. One to act as an operating (primary) control and the second shall act as a high limit (secondary) control. Both of which must shut down the fuel supply to the burner when the respective set point has been reached.

In accordance with the Boiler Safety Division:

- Boilers with inputs of 400,000 Btu/hr or less shall have either a flow switch or a low water cut-off safety device installed.
- Boilers with inputs over 400,000 Btu/hr shall have a low water cut-off device installed.
- Both safety controls would be acceptable.
- The flow switch must be capable of being tested in service and when flow is reduced or stopped, it must shut down the flow of fuel to the burner.

7.0 <u>Steam Boilers and Replacement Steam Boilers</u>

7.1 Steam boilers shall be installed as required by the manufacturer's certified installation instructions and to the requirements of all authorities having jurisdiction. They shall include all specified controls, safeties and related components.

7.2 Steam boilers shall have a minimum of one operating pressure control and one high limit pressure control approved for use on steam boilers.

8.0 <u>Recommended Installation Guidelines</u>

8.1 Hydronic heating systems must be design approved by an engineer or a qualified hydronic heating design specialist. A qualified hydronic heating design specialist may be an individual or company that can provide verification of successfully completing technical training in hydronic heating system design.

8.2 Heating systems must be constructed with consideration to indoor design temperatures, outdoor design temperatures, and minimum ventilation requirements and shall be in accordance with all national and local codes and jurisdictions.

8.3 Minimum return water temperatures to boilers must be maintained and identified in the owner's operating instructions.

8.4 When outdoor temperature compensation is used, boiler minimum return water temperatures must be considered.

8.5 In multiple boiler installations, the method of installation of the boilers must allow for recommended design flow through all boilers using piping design, pumping methods or balancing devices.

8.6 Use design approved valves for flow balancing. (Ball and gate valves are not approved for flow regulation.)

8.7 Installations with continuous flow conditions may require a pressure relief bypass valve or a piping arrangement to provide adequate flow if the system flow conditions can drop to 30% or less of design flow conditions. The pressure relief bypass valve or piping arrangement must be sized to suit the needs of the system.

8.8 Boilers sensitive to high or low flow conditions shall be installed as required by the manufacturers certified installation instructions.

8.9 The maximum operating pressure of a boiler must be at least 10 psi below the relief valve discharge pressure.

8.10 It is not recommended to pipe a relief valve discharge to the outdoors, pipe vertical above the outlet of the relief valve or pipe through a wall to another room. The discharge must be no more than 12” or less than 1” above the floor. The distance above the floor must be at least twice the diameter of the discharge pipe.

8.11 Any secondary heating loops isolated from the primary loop by means of a heat exchanger must have a separate expansion compensator, relief valve, thermometers, pressure gauges and controls as required by design, manufacturer's installation instructions and good piping practices.

8.12 Steam boiler replacements with units of a smaller water storage capacity must give consideration to the needs of a condensate receiving/holding tank to prevent the system from flooding the boiler or cycle on the low water cut-off.

8.13 Automatic feed water supply systems must comply with local or provincial plumbing codes.

8.14 Ventilation requirements as indicated in the National Building Code must be met.

8.15 When heat exchangers are used for secondary heating loops or when heat exchangers are used to heat domestic (potable) water, the installer must ensure the heat exchanger(s) is approved to suit the needs of the installation. The installation must meet the requirements of all national and local codes as well as the requirements of all jurisdictions having authority.