Comfort Heating: Introduction

Lessons 8 to 15

Lesson 8 Overview

In this assignment, we merge two phenomena already presented — how indoor humidity affects body evaporation heat loss and how humidity affects building components.

We go on to explain how to measure indoor humidity and how to add moisture using humidifiers or to dehumidify by means of Heat Recovery Ventilators (HRV's). In addition, for the first time, we'll talk about the effect of humidity on occupant health.

Now read Lesson 8 which begins on the next page.

Lesson 8: Humidity

A person breathes about 500 cubic feet of air each day. The condition of that air has a very decisive influence on occupant health and on worker performance in an office environment. Contaminants in indoor air may transmit illness. Indoor Air Quality (IAQ) is often defined as the *nature of air that affects the health and well being of occupants.*

Two of the traditional approaches to maintaining acceptable indoor air quality have been through proper humidity control and air filtration. This lesson deals with humidification --- your next lesson covers filtration.

In Lesson 3, we talked about the effects of humidity on the evaporation rate from the body and in Lesson 4 we talked about moisture migration and damage to building materials used in construction.

Often occupant comfort and the building itself are at odds regarding tolerable humidity levels. Let's build on what we already know about humidity.

What is Humidity?

Humidity is simply another word for the moisture in the form of an invisible vapor mixed with room air.

In everyday language, *air* is used to describe the vast volume of gases that envelops the earth. The earth's atmosphere is a mixture of many gases — principally nitrogen, oxygen, argon, carbon dioxide, water vapor, and small traces of neon, krypton, xenon, helium, and hydrogen. Fortunately, in HVAC we can neglect all of the rare gases, and the air to be processed is assumed to consist solely of oxygen, nitrogen, and *water vapor.*

Conveniently, oxygen and nitrogen are always found in the same proportions — 79% nitrogen and 21% oxygen by volume. So, we consider these two ingredients a single gas and call it *dry* air. However, the possible proportions of dry air and water vapor vary enormously.

For instance, the amount (in pounds) of water vapor may be as low as 0.000005 lb/lb of dry air during cold winter weather in Alaska, and it can exceed 0.02 lb/lb dry air in summer weather in many parts of the nation.

It is the study of the relationship between dry air and water vapor that is termed the science of *psychrometry.*

There are a number of specific relationships between moisture and air that are used in psychrometry. The two most common are *humidity ratio* and *relative* humidity.

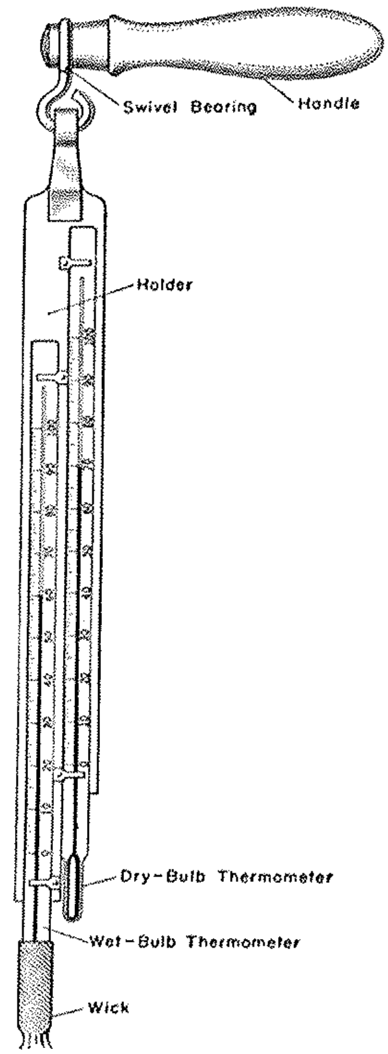
Humidity ratio is simply the *pounds* of water vapor contained in each pound of dry air, as we just demonstrated. (We also may use *grains* of moisture. 7,000 grains equals one pound.)

Relative humidity, although most familiar, is really somewhat more complex. It is a ratio of *pressures* rather than weight.

Relative humidity is expressed as a percent. The pressure exerted by the water vapor actually measured in a sample of air compared to the pressure of the water vapor that would exist if the air sample were completely saturated. That is, the air could not "hold" any more moisture.

Measuring Relative Humidity

A *hydrometer* is an instrument used to measure humidity. The particular type of hydrometer traditionally used by heating specialists to measure relative humidity is the *sling psychrometer.*



The traditional sling psychrometer consists of two mercury thermometers. These are known as *dry bulb* and *wet bulb* thermometers. The bulb of the wet bulb thermometer is covered with a wicking material that is soaked in water before it is used. Holding the psychrometer by the handle, one whirls it in the air several times and then quickly notes the temperature readings on both the wet and dry-bulb thermometers. Due to evaporation, the wet bulb thermometer reading will be *lower* than the dry bulb thermometer.

The *difference* between the two readings is known as wet bulb *depression.* The relative humidity may be obtained by referring these temperature readings to special tables or a special chart called a psychrometric chart.

For example, in the table on the next page, note that for a dry bulb temperature of 72° F and a wet bulb depression of 12 degrees, the relative humidity is 49%. Also, the greater the depression (difference), the lower the relative humidity.

Wet Bulb Depression º F	Dry Bulb Temperature 68	70	**72**	74
2	90	90	91	91
4	80	81	82	82
6	71	72	73	74
8	62	64	65	65
10	54	55	57	58
12	46	48	**49**	50
14	38	40	42	43
16	31	33	34	36

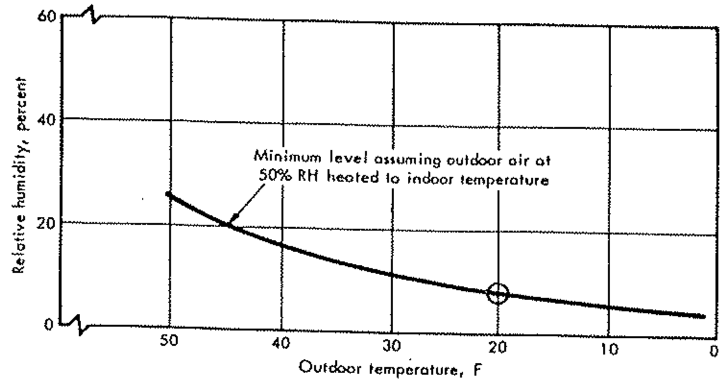
Many materials change in dimension with changes in humidity. Through a suitable linkage, this dimensional change can be used to cause a pointer to move across a dial calibrated to read in percent relative humidity. Materials often used are nylon, human hair, wood, and even paper. Electronic sensors are gaining in popularity because of cost and ease of use. Accuracy is generally comparable to the sling psychrometer; and in general, the higher the cost for the instrument, the greater the accuracy of the device. To be dependable, these devices should be recalibrated frequently.

How Much is Enough?

Suggestions are that relative humidity during the heating season in residences should be maintained somewhere around 35%. In order to maintain this humidity level during the heating season, it may be necessary to supply approximately ten gallons, or more, of water per day to the circulating air in the average house.

The actual amount of water necessary for comfort is dependent on the size of the house and construction. A tight, well built house with a vapor barrier will require less mechanical humidification than a home that is poorly constructed, with lots of air leakage around doors, windows, etc.

The following three graphs show important relationships between outdoor temperature and indoor humidity.



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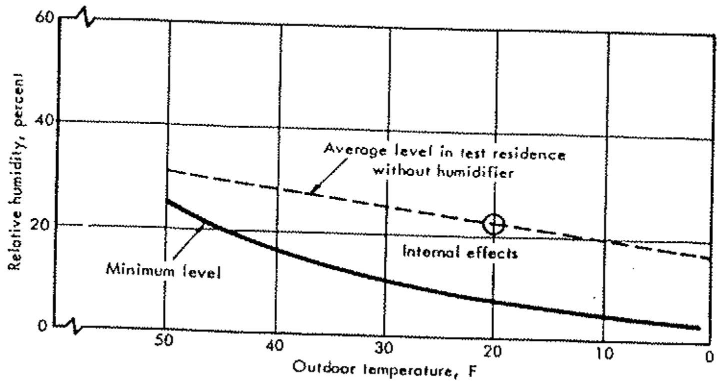
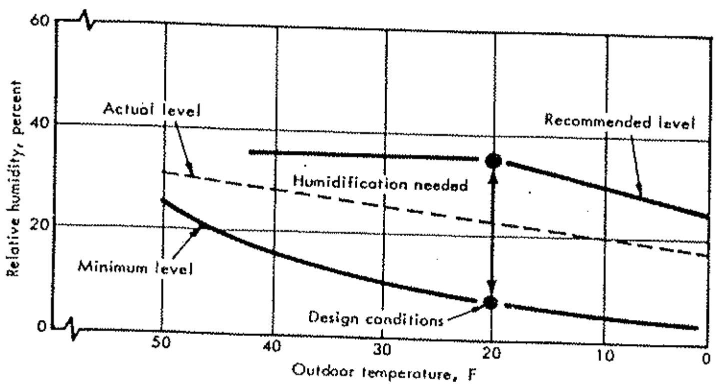
In graph 1, the curve shows the minimum indoor humidity for an unoccupied house, assuming outdoor air at 50%. RH is simply heated to room temperature. Note that at 20° outside (horizontal scale) the indoor RH is about 7%.



2

Occupant contributions, cooking, bathing, washing, etc. would tend to raise this "natural" indoor humidity level, as a family of four on average generates about 0.7 lb/hr. Graph 2 shows the internal effects from a family of four in a test house. Now, at 20°, the indoor RH is about 22%.



3

Graph 3 shows the recommend level of indoor humidity. The difference between the top curve and the dotted line is an indication of the need for additional humidity. This is representative of many residences in cold climates during the heating season.

Recent studies on the sensation of thermal comfort indicate that relative humidity can vary between 20 and 60% without many people noticing any change in comfort. This is for people relaxed or doing light reading, etc. and for normal room air temperatures.

As noted in Lesson 3 on comfort, the thermostat setting can be lowered if the humidity level is increased. But dramatic reductions in room temperature are not likely for many persons. For example, one study indicated that 50% RH at 73° F produced the same comfort sensation as 20% RH and 76° F.

This suggested an increase from 20% to 50% in RH could result in a 3° F decrease in room temperature without discomfort. Further studies indicate that only a 1° F reduction might be possible. Occupant age and health are obviously factors as well.

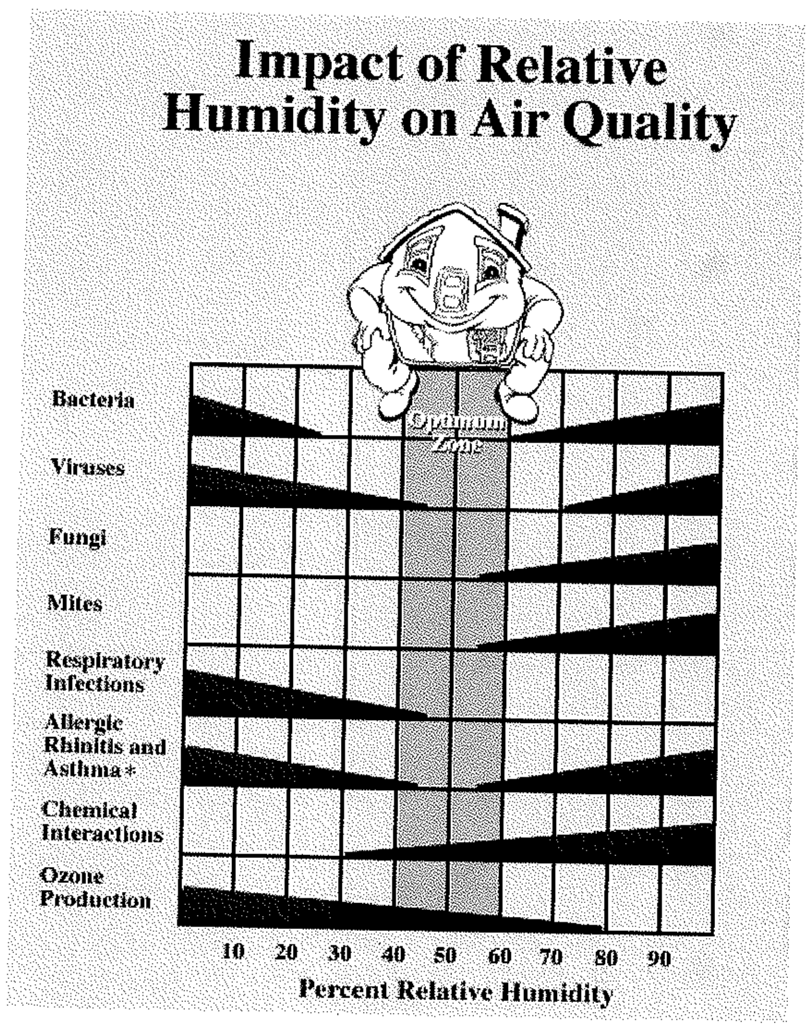
As a general rule, for winter *comfort,* it appears that indoor humidity should be kept above 20% RH.

Furnishings

In addition to human comfort, low humidity in winter can result in wood furnishings, floors, trim, etc. shrinking and cracking in the dry air. Consistent levels of humidity appear to be an important factor here, too. Exact values to maintain are uncertain but should approximate practical conditions, which might be around 35% RH.

Humidity also affects static electricity — those annoying electric "shocks" an occupant can experience after walking across a carpet and touching an object. Many materials require 45% RH or more to minimize electrostatic effects, but wool and some synthetic substances require still higher humidity levels.

Health



Medical authorities have demonstrated that humidity affects airborne infection. Maintaining 50% RH in nurseries has traditionally been recommended as one method to help prevent the spread of infection.

The effect of high humidity in a residential environment on winter "colds" and illness continues, but the chart above suggests that certain bacteria and viruses do not thrive in the 40% to 60% humidity range. Respiratory infections and allergies are also minimized in the same humidity range. Above 60% we can see that *mold growth* on damp wall and ceiling surfaces increases.

Humidity also affects *odors.* First it affects the sensitivity of the nose — raising humidity *decreases* sensitivity. Also, materials release and absorb odors according to humidity levels.

Keeping humidity level *constant* is preferable to one that fluctuates *(example: lingering odors after a party are often the result of a rise in indoor humidity during the night).*

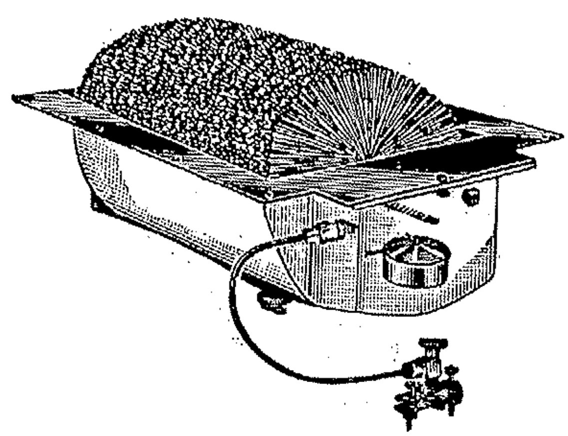
It could well be that more humidity is required for comfort and health than the typical *structure can tolerate.*
As is often observed, too much humidity will result in sweating windows, walls, and ceilings, which ultimately damages building materials.

The amount of humidity a building can tolerate relates to the quality of construction --- such factors as a lack of storm windows or insulated glass, insufficient wall/ ceiling insulation and lack of vapor barriers. Some houses cannot handle more than 30% relative humidity without condensation problems. And colder weather means even less tolerance. This table shows when condensation would likely appear on different types of windows as outdoor temperature changes.

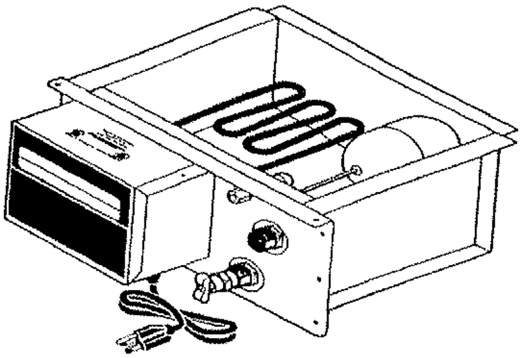
Window Type	**Indoor Relative Humidity, Percentage at which condensation will occur @ various outdoor temperatures.**			
	-20	-10	0	10
Single glass	3	7	8	12
Single glass plus removable wood storm sash	13	21	25	32
Double glass with ¼" sealed air space	24	28	34	40

Types of Humidifiers

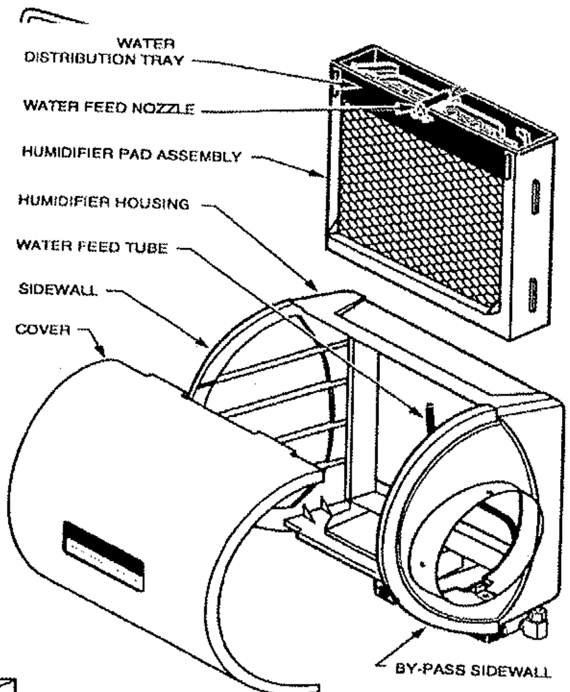
There are several kinds of furnace installed *central* humidifiers. Most residential type humidifiers can be grouped under three general categories: pan-type, wetted element, and atomizing. Within these families, there are a number of recognizable popular off-springs.



One of the earliest humidifiers was the basic open pan — a very low output device. The open pan could be fitted with water absorbent plates ("fins" to increase surface area) to increase output to about 2 gallons/day.



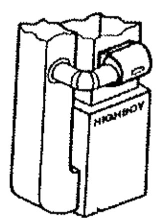
There's also a heated pan humidifier that uses external heat energy to "boil" the water in the pan to increase the evaporation rate to as much as 13 gallons/day.



A Typical Bypass Humidifier

The wetted element category includes all those humidifiers that circulate air through a fixed or rotating media saturated with water. This includes units with small fans, bypass designs that use furnace fan pressure to divert air through a bypass duct over the wet media, and also duct-type humidifiers that actually protrude into the main duct to expose a motor driven rotating wetted element to the supply air stream.

Under atomizing, there are direct spray nozzles — a solenoid operated valve with a spray head, or a centrifugal disc type that whirls to break up water into fine droplets for rapid evaporation.



Residential, small commercial, and light industrial humidifiers are covered by AHRI (Air Conditioning, Heating Refrigeration Institute) Standard 610. This voluntary standard establishes requirements for testing and rating central humidifiers, specifications, literature and advertising requirements, performance requirements, and conformance conditions.

Standard ratings of humidifiers under this standard are given in *gallons per day.* This standard permits the performance of humidifiers of participating manufacturers to be compared on an equitable basis.

Sizing

Sizing central humidifiers for residential and light commercial applications has generally been based on an individual's own rule of thumb method or a manufacturer's selection chart that is based on a basic formula published by ASHRAE. Essentially, the formula relates the air leakage rate of the building and the moisture difference between design indoor RH and the design outdoor RH.

Air change rates assumed in most sizing charts are 0.5 AC/hr for a tight modern house, 1.0 AC/hr for an average house and 2 AC/hr for a loose house.

A typical *outdoor* design condition might be 70% RH at 20° F and *indoors* at 35% at 70° F. For these conditions, this means that 2 grains of moisture must be added for each cubic foot of air that leaks into a building.

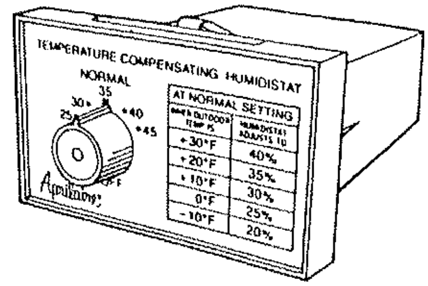
Indoor design could also be based on avoiding condensation on windows as discussed earlier. It's apparent that a home with just single glass cannot tolerate significant amounts of humidity in the winter in cold climates.

Sizing charts usually list the assumptions made in their development. This information should be reviewed carefully to assure the assumptions generally meet the application in question. Here's one example of a sizing table.

House Volume Ft^3	Outside Temperature	Relative Humidity %	Moisture Required (Gal/day) for:		
			Loose	Average	Tight
8,000	-10	20	10.0	5.0	2.5
	0	25	12.5	6.0	3.0
	10	30	14.0	7.0	3.5
	20	35	15.0	7.5	3.5
	30	35	12.0	6.0	3.0
10,000	-10	20	12.5	6.5	3.0
	0	25	15.5	7.5	4.0
	10	30	17.5	9.0	4.5
	20	35	18.5	9.5	4.5
	30	35	14.5	7.5	3.5
12,000	-10	20	15.5	7.5	4.0
	0	25	18.5	9.0	4.5
	10	30	21.0	10.5	5.5
	20	35	22.5	11.0	5.5
	30	35	17.5	9.0	4.5
14,000	-10	20	18.0	9.0	4.5
	0	25	21.5	11.0	5.5
	10	30	25.0	12.5	6.0
	20	35	26.0	13.0	6.5
	30	35	20.5	10.5	5.0

Note: Calculation base: 72° F indoor temperature, 70 % relative humidity outside. Higher indoor temperature requires more moisture to maintain same indoor relative humidity. Effects of internal moisture sources are not considered. Air leakage rates assumed to be 2 AC/hr for loose construction, 1 AC/hr for average construction and ½ AC/hr for tight construction. Moisture required expressed to nearest ½ gal/day.

Controls



A humidistat is a control which regulates operation of the humidifier and controls the relative humidity in the building. The humidistat is merely a wall-type hygrometer that may use a nylon ribbon to measure changes in humidity or electronic sensors. Changes in room humidity actuate a mechanism which controls the operation of the humidifier.

If excessive condensation appears on the exterior walls and windows, it may be necessary to lower the setting. If no condensation appears during a twenty-four hour period, the homeowner may want to raise the humidistat's setting.

Some controllers can *automatically* readjust their set-points based on increasing or decreasing outdoor temperature.

Maintenance Important

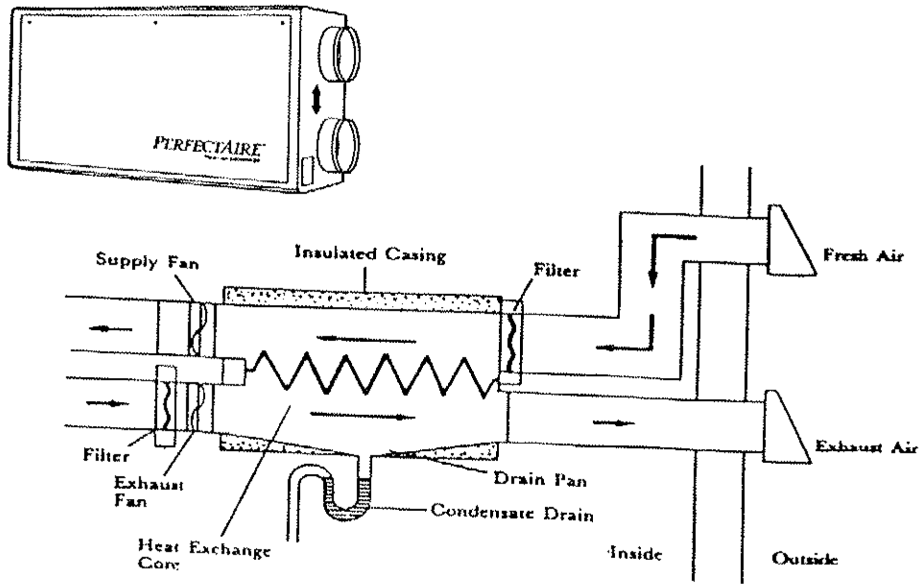
Because a humidifier is in continuous contact with water of varying quality, regular maintenance is essential to proper operation, long life, and, in some instances, good health. Water left standing in a humidifier — or any other container — can, under certain conditions, become a breeding ground for spores and other organisms that could possibly cause illness in some people.

In general, a humidifier should be drained monthly and cleaned using a vinegar solution; the water supply should be shut off when the unit is no longer required. And, of course, all manufacturer instructions should be read, understood, and followed.

Winter Dehumidification

While the common need in winter heating has traditionally been to add moisture to the indoor environment, there are some applications when moisture removal — dehumidification — is required.

As mentioned in previous lessons, the tightly constructed, super insulated home may experience excessive humidity due to a lack of natural infiltration into the structure. But even ordinary homes may, at times, experience too much humidity as a result of unusual activities of the occupants. The introduction of ventilation air is a practical way to reduce humidity to more acceptable levels. The Heat Recovery Ventilator (HRV) may be installed to minimize the expense of heating cold ventilation air.



Here's how it works:

The heat recovery device pulls stale, humid, warm air from the house and transfers the heat into the fresh cold air being pulled into the house. In the example above, the two air streams do not come into direct contact but are separated by the heat exchanger surfaces which can be made of thin sheets of plastic, treated paper, or metal. This type of unit is more suited to winter heating in cold climates than units which mix the air streams together.

As the moisture-laden exhaust air is cooled by the incoming cold air, the moisture condenses and is drained away (in cold climates this may require a defrost feature). The incoming air, low in moisture is warmed and introduced into the house — effectively reducing the humidity level inside.

Self-Check, Lesson 8 Quiz

You should have read all the material in Lesson 8 before attempting this review. Answer all the questions to the best of your ability before looking up the answers provided in the answer key.

Please indicate whether the following statements are true or false by drawing a circle around T (to indicate TRUE) or F (to indicate FALSE).

True False

1. T F The amount of water vapor in air does not vary substantially with the change in season or by geographic area In North America.

2. T F Relative humidity is the actual pounds of water vapor in room air compared to how much more the air could hold at saturation.

3. T F The difference between the dry bulb and wet bulb readings on a sling psychrometer is called wet bulb depression.

4. T F A house with a large infiltration rate will require a larger humidifier than a similar house with a low infiltration rate.

5. T F High indoor humidity is a major cause of static shock.

In the following multiple-choice questions, choose the phrase that <u>most</u> correctly completes the statement, and check the appropriate box for the corresponding letter in front of the phrase.

6. A family of four in the process of cooking, bathing, etc. would on average contribute about:

☐ A. 0.7 lb of moisture per hour. ☐ B. 0.7 gallons of moisture per day.
☐ C. 0.7 grains of moisture per hour. ☐ D. 0.7 grains of moisture per day.

7. For healthy persons under normal occupancy, raising the indoor humidity level from 20% to 50% RH would allow room temperature to be:

☐ A. lowered 5° to 6°for equal comfort. ☐ B. lowered l° to 3° for equal comfort.
☐ C. raised 3° to 5°for equal comfort. ☐ D. raised 1° to 3°for equal comfort.

8. For winter comfort, indoor humidity should not be maintained lower than:

☐ A. 60%. ☐ B. 35%.
☐ C. 20%. ☐ D. 7%.

9. Certain bacteria and viruses do not thrive in a humidity environment between:

☐ A. 10% to 20% RH. ☐ B. 20% to 40% RH.
☐ C. 40% to 60% RH. ☐ D. 60% to 80% RH.

10. The voluntary industry residential testing and performance humidifier standard is:

☐ A. Humidifier Institute Standard 500.
☐ B. Underwriters Laboratories Standard 550.
☐ C. Home Appliance Manufacturers Standard 600.
☐ D. Air-Conditioning, Heating & Refrigeration Institute Standard 610.

For the completion-type questions, fill in the blanks with the word (or words) that most accurately completes the thought.

Key Words

hydrometer	gallons	increase	hour	condensation
decrease	defrost	humidistat	pounds	day

11. A humidifier's output should be controlled by a/an ____________________.

12. An increase in wet bulb depression indicates a/an ____________ in indoor relative humidity.

13. One indication of maximum permissible indoor humidity level is when ______________ appears on windows.

14. Humidifier capacity is most often reported in ________________ per __________.

15. A Heat Recovery Ventilator may require a/an ______________ cycle to keep condensedmoisture in exhaust air draining.

Check Your Answers!

Now compare your answers with those given in the answer key at the back of this book. The answer key also directs you to a page in the lesson to review the text for any questions you may have missed.

When you are satisfied you understand the questions missed, proceed to your next assignment which starts on the next page.

Lesson 9 Overview

Filters used to enhance air quality seem a natural. The fact is, filters were first used to protect the heating equipment from dust buildup — not protect occupant health.

In this assignment, we'll define "dust and dirt" more precisely, we'll explain how filters work — that is, how they "capture" particles. Most importantly, we'll review how filters are tested and what arrestance and dust spot efficiency really mean.

Now read Lesson 9 which begins on the next page.

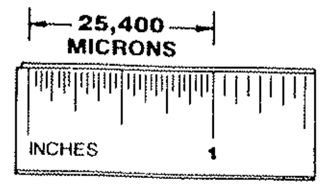
Lesson 9: Air Quality & Filters

Indoor air quality has become a concern and a focus of the heating industry.

To the layperson, the terms "dust and dirt" usually suffice to define the air contaminants removed by filters. The expert however, classifies contaminants more carefully. For our purposes consider these three classes:

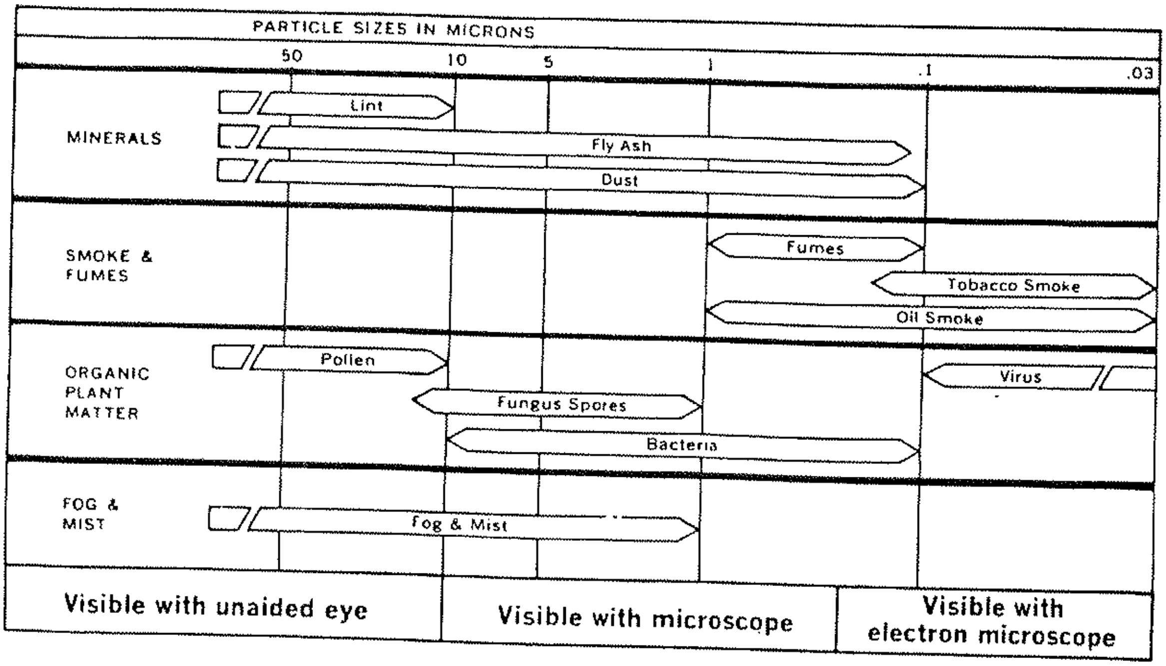
- *solid* particulate matter, such as dusts, fumes and smokes
- *liquid* particulates, such as mists, fogs and again smokes (smoke has both solid and liquid particulates)
- *vapors and gases*

Particle size is an important characteristic of solid and liquid contaminants, for the size usually dictates how readily the contaminant can be filtered and also how the particle will behave in air currents.



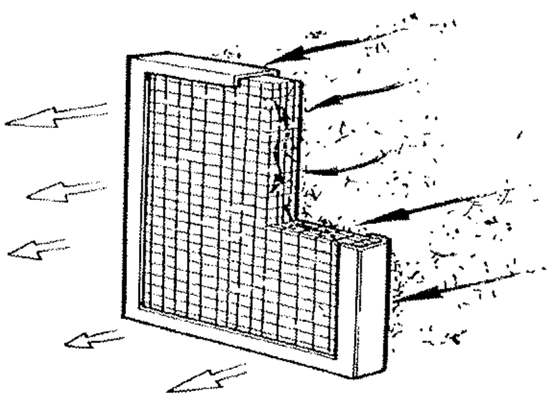
The diameter of a particulate is usually measured in *microns*. It takes 25,000 microns to equal 1 inch. The figure below shows the size of some of the more common contaminant particles.

Except under special lighting conditions, it is unlikely that particle sizes smaller than 10 microns would be visible to the unaided eye. It is also unlikely that particles larger than 10 microns would remain suspended in the relatively mild air currents found within a building. In other words, large, dense particles will settle to the floor or on other surfaces rather than be carried along in the moving stream and be delivered to a filter. And it is the small particles (2.5 microns and smaller) that stay suspended and can reach deep into our lungs and cause problems.



Notable note: Estimates are that up to 10% of particles by count or up to 90% by weight never reach a furnace filter because they do not remain suspended in room air for very long.

Air contaminants are generated by the normal processes of life --- manufacturing, agriculture, wear, and erosion.



Dust, for example, can originate from minerals such as rocks, metal, or sand; vegetables such as wood, grain, or pollen; and even animals --- wool, hair, silk, or feathers.

Airborne materials can originate in outside air and be brought indoors or be generated right inside a building from emissions or shedding of materials and, of course, combustion — cooking, heating and tobacco.

In comfort conditioning, we are specifically interested in minimizing dust, lint, pollen, harmful bioaerosols, and objectionable odors. For our purposes we can define each as follows:

Dust — any earthy material smaller than 100 microns in diameter.

Lint — string-like forms of dust originating from such things as wool, cotton, and man-made fibers.

Pollen — allergy particles originating from weeds, trees, flowers and other forms of vegetation.

Bioaerosols — minute living organisms (bacteria, viruses) some of which are dangerous to health (pollen and fungus spores are often included).

Odor — substance in vapor or gaseous state affecting olfactory sense.

Filtering Devices

An air cleaning device serves three important functions —

- protects heating and cooling equipment from dust build up
- cleans air by removing contaminants
- provides more healthful air by trapping airborne germs

It was the protection of equipment which probably prompted the first use of filters in duct systems.

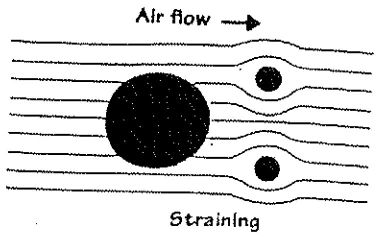
For example, if left unprotected, the wet surfaces of a cooling coil will soon accumulate sufficient dust to impede the air flow through the coil and also reduce the cooling capacity.

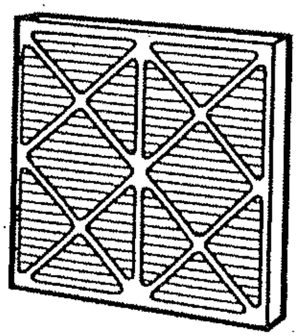
So, too, blowers will quickly accumulate dust which can reduce blower air delivery and increase fan power consumption. Protection of equipment is therefore vital to proper system performance and to maintain high operating efficiency.

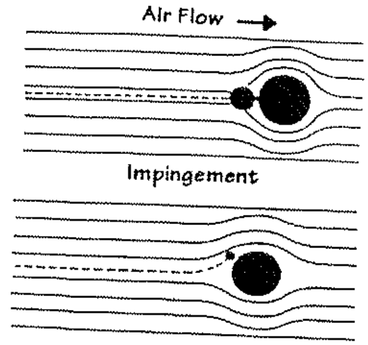
How Filters Work

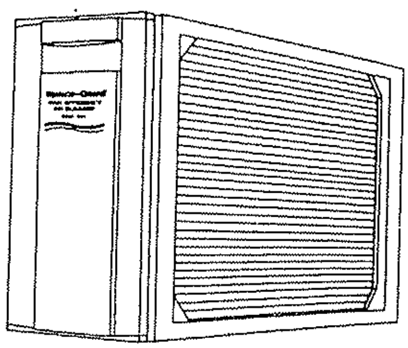
The theory of how filters "trap" particulates can delve deep into molecular physics. For our purpose, let's consider:

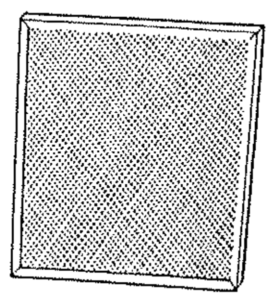
- Varying types screening
- Electrostatic effects
- Washing











By screening, we mean filtering the air through some sort of material, and there are two basic types --- dry and viscous impingement.

The dry filter strains the air of particulate matter as the air is passed through a *dense* material (like flour through a shifter).

Popular filter media are cellulose, glass cloth, cotton fabrics, and synthetic fibers. The porosity of the material obviously directly affects the minimum size of particle that can be captured. And the denser the material, the greater resistance to air flow. This means more work for the blower. Media is often pleated to provide an "extended" surface area.

Viscous impingement filters contain a relatively coarse mesh surface formed by steel shavings, spun glass, or animal hair. Tacky *oil* is coated over the surface to aid in dust collection (particles "crash" into the filter fibers.) Some types are permanent, washable, and can be recoated with the adhesive.

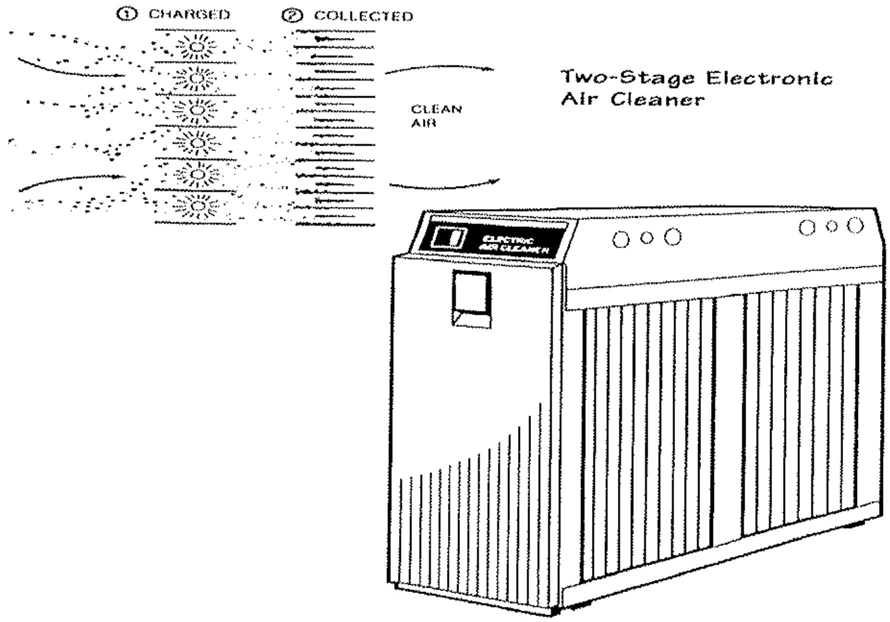
Static Cling

Electrostatic principles are employed to improve air cleaning efficiency in two ways:

1) by directly charging particles by passing them through an ionizer; and

2) by inducing a charge on the particles through the filter media itself

A two-stage electrostatic precipitator, commonly referred to as an *electronic air cleaner,* uses the direct charge approach. The particles first pass through an electric field of 6,000 to 12,000 volts DC, receive a charge, and are then attracted to flat plates that are also electrically charged.



In the second approach, inducing a charge is, in a sense, much like the old trick of rubbing a comb to produce a static electric charge and then attracting one's hair or piece of paper to the comb.

In an electrostatic filter, the media has a charge. Many dust and lint particles are attracted to the media, which aids in capturing the particles. The electric charge can be provided through a power source or by selecting certain media especially designed to develop a "natural" electrostatic charge — again, like the comb.

Air Washers

Air washers can remove certain contaminants and odors very effectively. Air is moved through a water spray in combination with a wetted surface where the air is scrubbed clean of contaminants.

Air washers today are generally used in only very large systems, owing to their bulky size and need for regular maintenance.

Controlling Odors

Odors are *not* particulate matter and cannot be filtered, but can be controlled by using ventilation air, adsorption filtering, or air washing, as just mentioned.

Odors are often controlled by the introduction of ventilation air and the exhausting of the stale air. Often this can be expensive where large volumes of ventilation air are required and where these quantities must be heated or cooled to room temperature.

Another method is by *adsorption* of the odor through the use of activated charcoal filters.

Adsorption is the adhesion, in very small layers, of gas molecules to the exposed surfaces of a solid. Porous charcoal (made from coconut shells) adsorbs large volumes of gases or vapors in relation to its own weight. When fully saturated, charcoal filters can be regenerated by heating to 1,000 degrees Fahrenheit.

The exact scientific process by which the odor molecules are contained and released is still not fully understood.

Filter Performance

One of the first filter testing procedures was the arrestance rating. Weight *arrestance* indicates the percentage of dust by *weight* the filter can remove. Back in the 1930s, it was intended to indicate how well a filter would keep dust from clogging up steam heating coils.

To perform the test, a known weight of carefully blended dust is introduced at a specified rate into a test chamber holding the filter to be evaluated. An absolute (ultra high efficiency) filter is located behind the test filter at the end of a test chamber. The absolute filter is weighed before and after the test, and the difference in this weight represents the dust which was not collected by the filter under test. For example, if 2 lb of dust was introduced and the absolute filter gained one pound, the test filter capture 1/2 or 50% of the dust by weight. Hence, it would have an arrestance of 50% for the test conducted.

This test can be repeated for various air flow rates and dust feed rates to establish an entire range of operating characteristics for the filter.

Particle Size a Factor

Since filters are not capable of collecting both large and small dust particles with identical ease, a weight test is not a true measure of filter performance in terms of size of particle removed. For example, a 10 micron particle has 1,000 times as much effect on the results of the weight arrestance test as a 1 micron particle. Yet the small particles can be the most troublesome in terms of soiling, streaking and entering our lungs.

To more fully credit a filter which removes small particles, another test, termed a *dust spot* efficiency test, is performed. For this test, air is sampled both upstream and downstream of the filter in a test chamber. An air sampler consists of a disk holding filter paper, and a nozzle for precisely measuring the air drawn through the sampler by a vacuum pump. After several minutes of blower operation, the filter paper in the sampler becomes soiled and a photometer measures the amount of light transmitted through the paper. The intensity of light is an index to the dust concentration on the paper.

Even with this test, larger particles still exercise a greater influence on the results than do smaller particles as they block out more light.

Obviously, if we counted every particle, each would contribute equal value toward the result of the filter efficiency test. Such a particle count test is used to evaluate filter performance in special cases such as pollen tests or where extremely hazardous dusts are involved. Microscopic counts of particles on slides upstream and downstream of the filter are used to determine the arrestance.

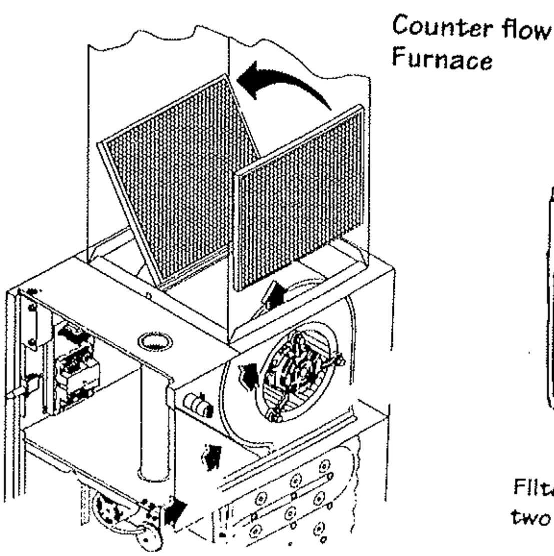
Performance Differs

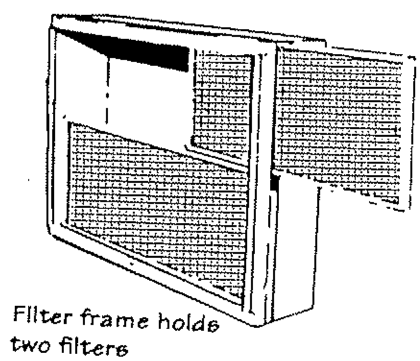
None of these filter tests precisely simulate the actual field performance of a filter, but they can indicate trends and provide a basis for a comparison between filters. Since each test is a measure of a slightly different characteristic, it is important to identify the performance of a filter in reference to the type of test. Thus, the statement that a filter has a "90 percent efficiency" is incomplete. We must know the type of test to which this value applies. The table below is one example of an engineer's attempt to relate filter performance to weight arrestance and dust spot efficiency tests.

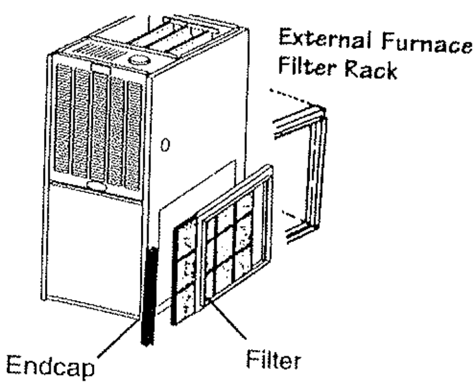
Filter Test		**Performance**			
Weight test arrestance (percent)	**Dust spot efficiency (percent)**	**Excellent**	**Good**	**Limited**	**Ineffective**
35-50	Up to 10	Protects equipment from lint			Smokes, fumes, dusts, pollens, staining particles
50-70	10-20	Lint		Ragweed pollen, dusts	Smokes, fumes, staining particles
70-85	20-25	Lint	Ragweed pollen, dusts		Smokes, fumes, staining particles
85-95	25-40	Lint, small dust particles	Smaller pollen	Some smokes and staining particles	Tobacco smoke
Over 95	35-60	Finer dusts and pollens	Smudge and staining particles	Fumes and some smokes	Tobacco smoke
	60-85	All pollens, major smudge and stain particles		Tobacco smoke, bacteria	

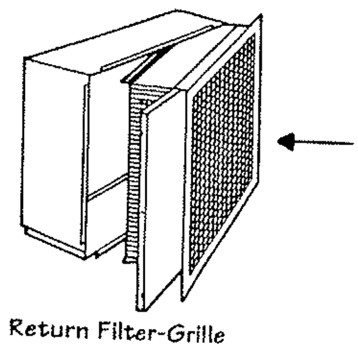
	85-99	Bacteria, smudge and stain particles, all pollens	Tobacco smoke		
	Over 99	Radioactive dusts, noxious dusts, all smokes and fumes, bacteria			

The racks or frames that hold filters in place also strongly influence field filtering performance. Filters in poorly fitted frames allow a large amount of air to bypass the filter and thus reduce efficiency and arrestance.









ASHRAE is introducing a new filter test using a new blend of dust with performance indicated by a Minimum Efficiency Reporting Value (MERV). MERV values range from 1 to 16 for general purpose ventilation — with the higher number indicating more effective filtration. One inch residential filters might typically be rated from 2 to 7 MERV. Electronic air cleaners are not rated by this test.

Filter Life

The dust *holding* capacity is also an important property of a filter since it is an index to filter service life before replacement or cleaning. It is defined as the weight of dust which the device will hold before the *pressure drop* through the filter exceeds a reasonable limit (set by manufacturer) or before arrestance drops to 85 percent or less of the maximum arrestance determined for a clean filter.

Germs Collect on Particles

Many diseases such as the common cold, influenza, and other ailments of a similar nature are usually spread by airborne germs rather than personal contact. Surprisingly, most germs are heavier than air, and they would precipitate if not for the suspended dust particles. Germs attach themselves to the dust particles and by such a mode are able to move about.

In general, then, high efficiency filters (both weight and dust spot tests) which very effectively remove dust particles indirectly remove bacteria attached to these particles. By cleaning the air of particles, we also reduce the germ count.

Self-Check, Lesson 9 Quiz

You should have read all the material in Lesson 9 before attempting this review. Answer all the questions to the best of your ability before looking up the answers provided in the Answer Key.

Please indicate whether the following statements are true or false by drawing a circle around T (to indicate TRUE) or F (to indicate FALSE).

True False

1. T F A micron is a class of particles that can only be filtered by means of an electronic air cleaner.

2. T F Filter life relates to how long a standard filter can be used before its media wears out.

3. T F Large, dense particles never stay suspended in room air long enough to be carried back to the air filter.

4. T F Pollen is string-like forms of dust originating from wool, cotton and man-made fibers.

5. T F Many germs attach themselves to dust particles and thus are able to be carried about in room air.

In the following multiple-choice questions, choose the phrase that <u>most</u> correctly completes the statement, and check the appropriate box for the corresponding letter in front of the phrase.

6. A viscous impingement filter is characterized by a:

- ☐ A. dense, pleated, filter media.
- ☐ B. coarse mesh surface coated with oil.
- ☐ C. media made of cellulose.
- ☐ D. media with a natural static charge.

7. Minute living organisms such as bacteria and viruses are collectively referred to as:

- ☐ A. contaminants.
- ☐ B. gases.
- ☐ C. fumes.
- ☐ D. bioaerosols.

8. Odors which affect our sense of smell are carried to the sensors in our nose in the:

- ☐ A. liquid state.
- ☐ B. vapor or gaseous state.
- ☐ C. solid particulate state.
- ☐ D. organic state.

9. The unaided eye can see particles larger than:

- ☐ A. 10 microns.
- ☐ B. 20 microns.
- ☐ C. 30 microns.
- ☐ D. 40 microns.

10. A new ASHRAE filter test using a special blend of dust reports performance in terms of:

- ☐ A. Dust Spot Efficiency Values.
- ☐ B. Arrestance Values.
- ☐ C. Micron Efficiency Values.
- ☐ D. Minimum Efficiency Reporting Values.

For the completion-type questions, fill in the blanks with the word (or words) that most accurately completes the thought.

Key Words

absorption	pressure	increase	hour	dust spot
arrestance	washing	frames	pounds	adsorption

11. Charcoal filters capture odor molecules by a process called ______________.

12. A filter test known as the __________________ test provides a indication of a filter's ability to capture small particles.

13. Particles can be removed from the air by screening, electrostatic effects and air __________.

14. Dust holding service life is determined when the filter ___________ drop exceeds a specified limit or arrestance drops to 85% of maximum value.

15. Poorly fitted filter _____________ are a significant cause of reduced filter performance in the field.

Check Your Answers!

Now compare your answers with those given in the answer key at the back of this book. The answer key also directs you to a page in the lesson to review the text for any questions you may have missed.

When you are satisfied you understand the questions missed, proceed to your next assignment which starts on the next page.

Lesson 10 Overview

"Set it and forget it" automatic heat is commonplace today because of the use of convenient fuels (gas and oil) and the development of sensitive electric and electronic control devices.

In this assignment, we will examine the complex world of controls and control circuits. We'll find out how the traditional thermostat works, the function of a relay, how to turn gas and oil burners on and off, what's unique to electric heat pumps and furnaces, and describe the basic ways to represent control diagrams.

Now read Lesson 10 which begins on the next page.

Lesson 10: Automatic Heat

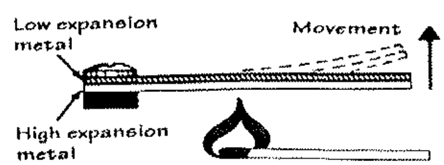
The invention and introduction of the electric *bimetal* thermostat to control heating systems occurred before the 20th century began, but even as late as 1920, draft dampers were still often mechanically (hand) controlled. The merits of battery powered vs. mechanically powered controls were regularly debated.

The early 1930s saw the simultaneous competitive eras of stoker-fed coal, gas, and oil-fired forced air heating. Converting to "automatic heat" utilizing electrified controls was a major industry promotional effort.

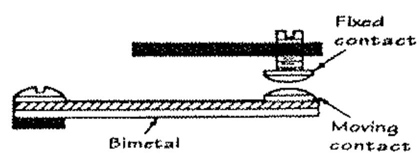
Unfortunately, all these developments came along just at the time of the Great Depression, when the luxury of costly automatic controls became impossible for most Americans. World War II quickly followed, and when U.S. industry had to shift to a war economy, the home front needs received second consideration. So, it really wasn't until after World War II that safe, completely unattended heating systems were made a *common* American reality.

Thermostatic Bimetals

Fundamentally, we want to control the *air* temperature in a room to keep people comfortable, so we need a device to *sense* changes in air temperature. The temperature-sensing element is the heart of the room thermostat and the thermostatic *bimetal* has been the sensor of choice in most room thermostats. However, the advent of the microprocessor "programmable" thermostat has become a strong competitor.



The thermostatic bimetal is composed of two or more metallic alloys which are bonded together. The metallic alloys selected have substantially *different* coefficient of expansions when exposed to heat. One metal will expand more rapidly than the other, forcing the bimetal to change shape when subjected to a change in room air temperature. We can use this *movement* to activate an electric circuit.



If an electric contact is fitted to the moving end of the bimetal and another contact fixed in place nearby, the bimetal becomes an automatic switch to turn on (or off) electric power to other devices (gas valve, for example) in response to the changes in room temperature.

Solid State Devices

The industry has introduced a large number of solid state components to replace certain electro-mechanical control devices like the bimetal thermostat. These devices can do many of the same functions as electro-mechanical components, but in addition, solid state devices can do some jobs that were previously impractical.

The term "solid state" is in comparison to the glass encased vacuum tube used in early radios and TV's. *Semiconductor* is perhaps the more appropriate electrical classification — components based on materials that are neither good conductors of electricity nor good insulators.

These devices can control electric current without any moving parts; they are small in size; light in weight. The transistor made from silicon is a typical solid state component.

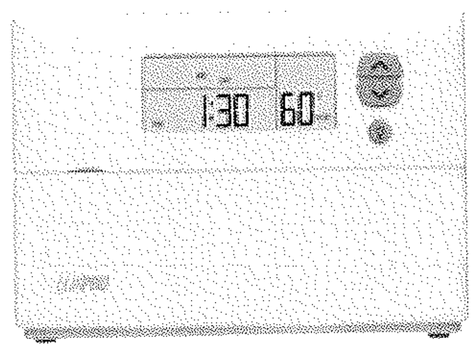
When thousands of transistors and other semiconductors are simultaneously formed on a small 1/4 inch square "chip" of material, the result is an Integrated Circuit (IC).

A *microprocessor* is a special IC that can process information — a kind of circuit "boss." A microprocessor can be programmed or given instructions to do specific tasks.

The most visible example of this latest technology is the electronic room thermostat. Clock thermostats with bimetals have been available for years. These setback thermostats could turn down the heat at night and bring it on in the morning. Today's programmable thermostat can provide four or more up or down cycles for 7 days, include vacation and skip commands, backlight control, filter change acknowledgement, adjust for weather, and much, much more.

Microprocessor-based controls can also provide a self-diagnosis of problems. Failure codes can be displayed that inform the service technician of where the trouble is — reducing service time and cost to the customer.

Thermostat Location



The thermostat should be located so that unique sources of heat such as the sun, lights, televisions, fireplaces, warm air direct from a nearby diffusers, etc., cannot affect its operation. In other words, the *room air* temperature is the only "heat" that should affect the thermostat.

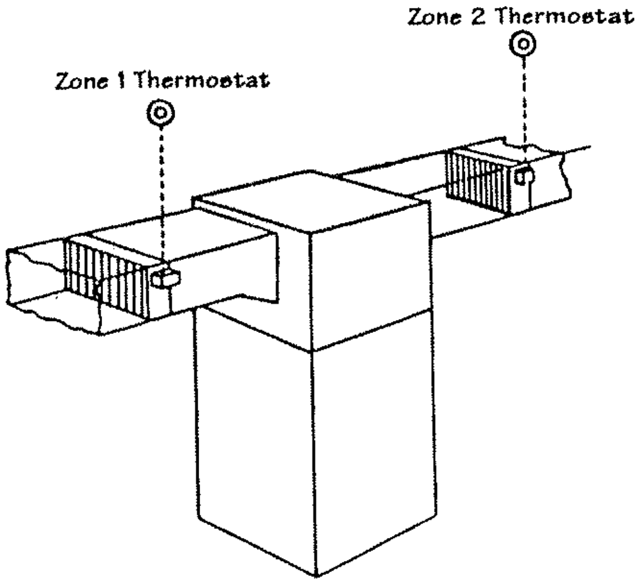
A typical location for a thermostat is on an *interior* wall of the living room or family room. Some are located in a common hallway. But wherever located, a single thermostat obviously cannot sense air temperatures in remote rooms.

Thermostat Controls Heating Unit

Ignoring for the moment the need for safety devices, the thermostat (bimetal or electronic) can be electrically connected to the gas valve, oil burner, electric heaters, or a heat pump compressor to turn on the heating unit and warm the building when the room air temperature decreases. Then, as room air becomes warmer, the thermostat will open the electrical circuit and shut the heating unit off.

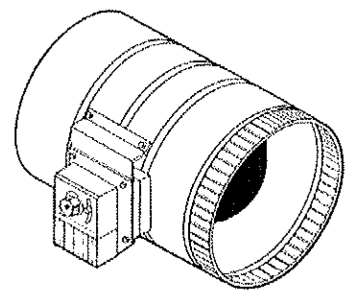
Zone Thermostats

As mentioned a moment ago, a single thermostat cannot sense "conditions" in remote sections of a building. In upgraded systems for large or multi-story homes, multiple thermostats are used to energize volume dampers in the duct system along with the heating unit.



A basic two-Zone system

A separate zone thermostat senses the need for heating one area of the building and opens a damper letting heated air circulate to the rooms in the zone. When the zone is satisfied, the thermostat shuts off the flow of air to the spaces. Each zone operates independently — opening and closing dampers and the heating unit as required.



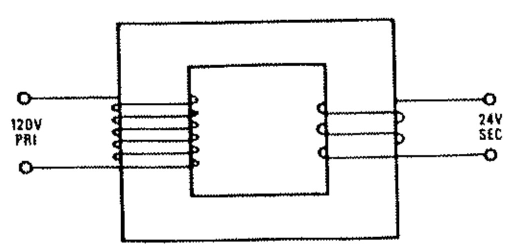
Zone damper in branch duct

The standard room thermostat is designed to operate in a *low voltage* electric circuit — typically 24 volts. Because of lower voltage and current, the thermostat can be made very sensitive to changes in air temperature. This assures good, even, control.

The Transformer

Homes and buildings are supplied "high" voltage electricity — 120 or 240 volts. To obtain the needed low voltage for a thermostat, a special device called a *transformer* is used. More specifically, a *step-down* transformer.

A step-down transformer consists of two *unconnected* coils of insulated wire wound around a common iron frame. The coil connected to the power supply is called the primary coil (PRI), and the coil which provides low voltage for the control circuit is called the secondary coil (SEC).

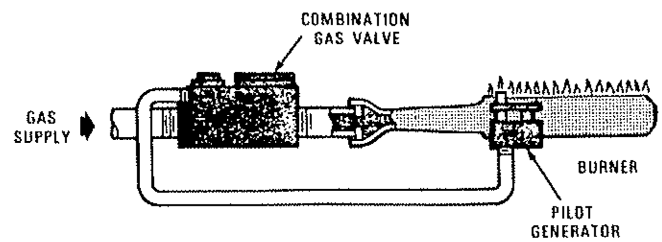


In a step-down transformer, the ratio of primary to secondary turns of wire wound around the iron frame determines the output voltage.

For instance, if there are five turns on the primary side for every turn wound on the secondary side, then the ratio of primary to secondary turns is 5:1, and the voltage measured on each side would be in the same proportion. If we applied 120 volts on the primary side, we would measure 1/5 or 24 volts on the secondary side. *(It is also possible to step-up the voltage using a transformer with more turns on the secondary than on the primary side. This would be a step-up transformer.)*

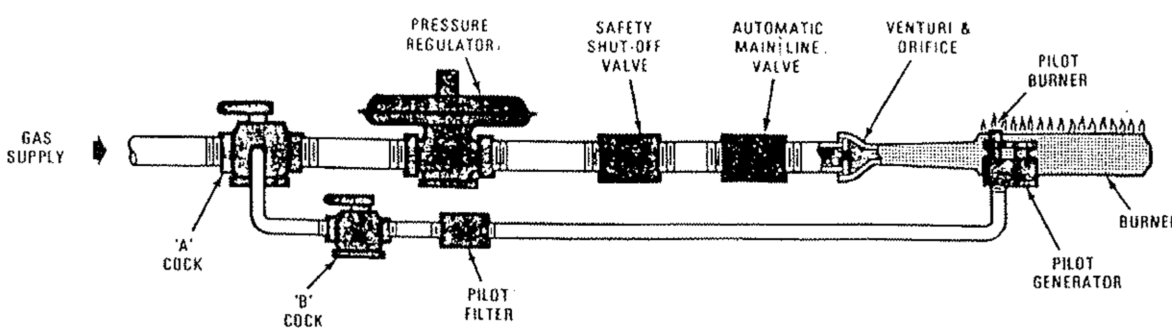
Gas Valve

Residential gas-fired systems installed today use *combination* valves. A combination gas valve performs four major functions: 1) manual shut-off, 2) safety shut-off, 3) pressure regulation, and 4) automatic on/off control of the burner.



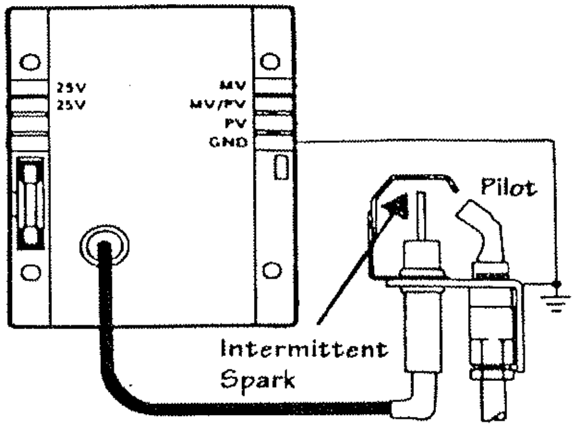
Before the advent of the combination gas control, four separate devices were used to provide the four functions mentioned above. Thus, in old systems, you'll likely find a manual shut-off valve, a pressure regulator, a main gas valve (controlled directly by thermostat), and a safety shut-off.

Old "gas train"



Safe Ignition

In the past, a continuous burning pilot light was the primary method to ignite a gas burner. A continuous burning pilot light obviously wastes gas — about 1 cubic foot of gas per hour — so manufacturers have introduced other gas ignition systems to help conserve fuel.



This spark ignition module (shown at left) lights the pilot, then the pilot lights the burner.

First there's the *intermittent pilot.* Upon a call for heat by the thermostat, an electric spark is used to light a pilot. The high voltage spark is produced using solid state electronics. The spark continues until the pilot flame is established and then it ceases.

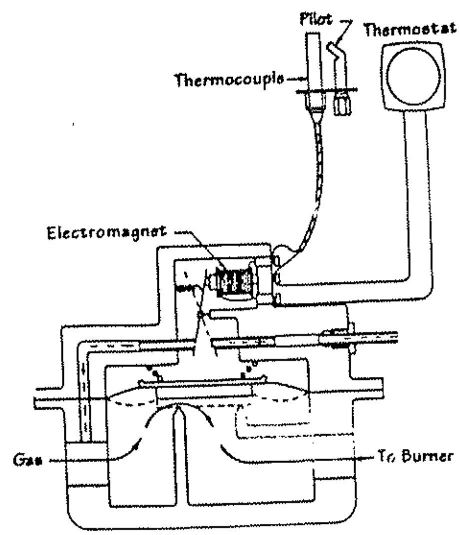
A direct spark igniter — where the spark directly lights the burner flame — is also available.

Another energy saving approach is the *hot surface igniter.* At a call for heat, a ceramic element is heated "cherry red" and ignites the fuel. The pilot light is totally eliminated.

These ignition systems include a sensor to signal a solid state control module that a flame has been successfully started. Without this message, the control module will close the gas valve and initiate a delay before a restart is attempted.

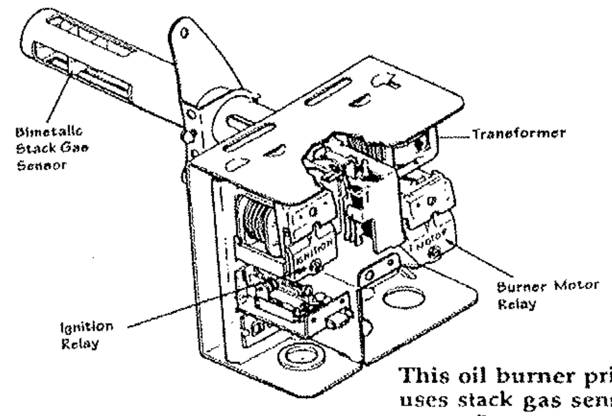
In the case of the traditional pilot light, the pilot flame also provides a source of heat for a safety shut-down device. Should the continuous burning pilot "go out", a safety shut-down prevents the main gas burner from opening on a call for heat.

The most common safety shutdown with a standing pilot is a heated *thermocouple,* although heated bellows and a bimetal switch have also been used.



The thermocouple is made of two unlike metals that, when heated by the burning pilot, generate a small amount of electricity. The electricity is used to hold an electromagnetic valve *open* inside the gas valve. In case of pilot failure, the thermocouple cools and stops the flow of current, and the gas valve is shut down.

An alternate approach is to have a thermocouple energize a switch that opens the thermostat circuit. With no signal from the thermostat, the gas valve closes.

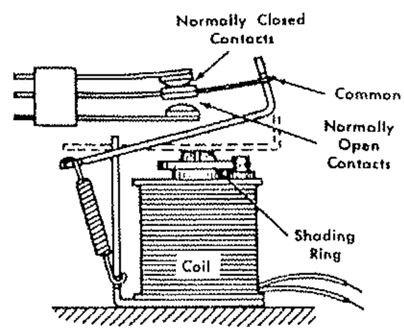


This oil burner primary uses stack gas sensor to prove flame.

Oil Burner Controls

An oil burner needs 120 volts to power both a fuel pump and a small blower. Very high voltage is required to produce a *spark* to ignite the oil/air mixture. A safety shut-down device is also required in case the oil fails to ignite or burn properly.

The oil burner *primary control* contains all the necessary devices to permit a low voltage thermostat to: 1) start and stop the oil burner motor; 2) initiate ignition of the burner; and 3) shut down the burner in case of ignition or flame failure.



Electromagnetic type relay.

Upon demand of the room thermostat, a *relay* inside the primary *closes* and starts the oil burner motor which drives the pump and the combustion air fan. Most primaries also contain a transformer to provide 24 volt power to the thermostat.

The *relay* is a switching device that permits a low voltage control such as a room thermostat to switch high voltage on and off.

Many relays operate on the *electromagnetic* principle. A small coil is energized by the low voltage circuit. This creates a magnetic pull on a high voltage switch which can be either opened or closed depending on the design (switch can be designed to be open or closed in the non-powered condition).

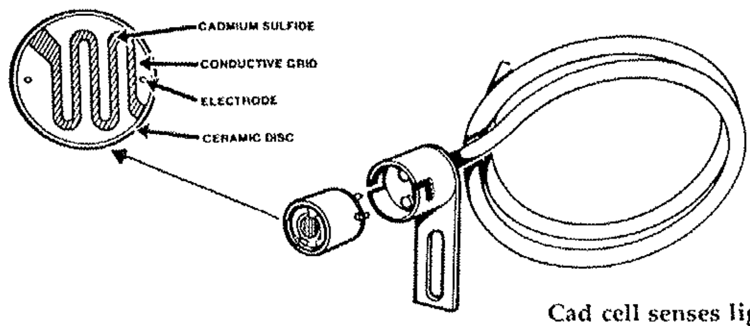
Some oil burner primaries contain a second *ignition relay* that closes with thermostat demand and provides power to a *step-up* ignition transformer to produce 10,000 volts for spark ignition. This second relay is featured in *intermittent ignition* primaries. After combustion is established the spark ceases.

Notable note: Another type of relay is the thermal relay. The thermal relay uses a resistance heater and a bimetal element instead of a magnetic coil. When the low voltage circuit is

energized, say by thermostat action, the low voltage heater warms the bimetal which warps and closes a switch on the high voltage side.

Safety Shutdown

Inside an oil burner primary, there is a race between the safety shutoff switch and the sensor used to detect a good flame. Unless the combustion detector deactivates the safety switch, the safety switch will interrupt the motor relay circuit and stop the burner.

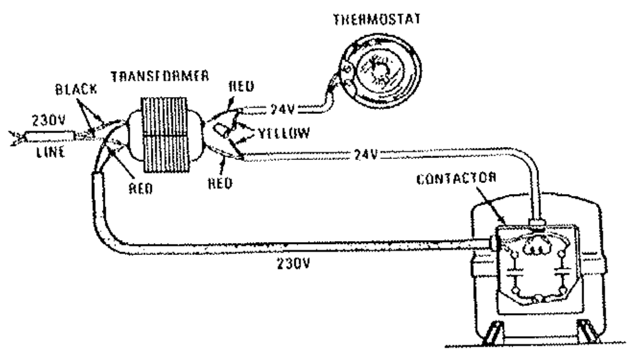


Cad cell senses light intensity to prove burner operation.

Common flame detectors are a temperature sensitive stack switch, combustion thermostat or a cadmium sulfide (cad) cell.

The stack switch senses the temperature of *the stack* gases leaving the equipment, the combustion thermostat reacts to the *radiant heat* of the burner flame, and the cad cell's electrical resistance changes with the intensity of the *light* emitted by the burner flame.

Through various circuit arrangements, including the use of solid state components, these various flame detectors are wired to deactivate the safety switch cut-out when a flame has been established.



Heat Pump

Heat pump compressors are started and stopped by the room thermostat through a *contactor.* This is simply a *heavy duty* relay.

Most heat pump thermostats are two-stage devices — two thermostats in one. The first stage closes the contactor to start the compressor; the second stage starts any auxiliary heat — electric heaters, oil gas or propane fired furnace — when the heat pump alone no longer supplies enough heat to warm the building. (There's more on heat pumps in Lesson 14.)

Many times, the second stage is connected through out-door thermostats if electric heaters are the auxiliary or supplemental heat. The outdoor thermostats close at preselected outdoor temperatures to engage increasing the amount of auxiliary heat supplied as outdoor conditions get colder. It is also possible to provide this stepwise heat input by sensing changes in the temperature of the supply air leaving the heat pump.

Heat Pump Safety

In series with the contactor on many units is an overload protector. This is a current and/or temperature sensitive switch that interrupts the power to the compressor if the compressor's motor windings get too hot or too much current is being drawn by the motor.

For additional "back-up", special pressure controls that sense refrigerant pressure in the refrigeration circuit may be added to shut off the compressor motor if pressure gets too high or even too low.

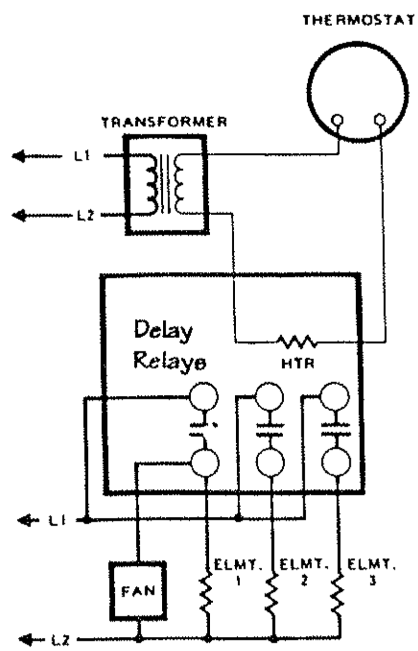
Electric Furnace

An electric furnace is fitted with several heating elements depending upon the Btu/h rating of the equipment. A somewhat different type of relay is used to permit the low voltage thermostat to control the power to the electric furnace.

Many electric furnaces are fitted with several *thermal* delay relays (TDR's). This relay uses a bimetal to switch the higher voltage load.

Their function is to energize furnace heating elements with brief delays between the added KW loads to minimize power surges in the house which could affect TV sets and other electric devices in the home.

With thermal relays, the room thermostat calls for heat by energizing the first thermal relay and the furnace blower. After a number of seconds, the relay closes and performs two functions: 1) it energizes the first heater; and 2) it energizes the second thermal relay. The second relay, after additional delay, closes and supplies power to the next electric element and the next relay and so forth.

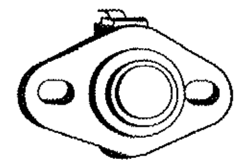


To improve comfort by minimizing temperature "swing" in room air temperature between furnace "cycles," an electric furnace can be wired to provide "staged" or modulated heat output. This can be accomplished using two-stage room thermostats, or outdoor thermostats. With two-stage room thermostats, the first stage brings on one portion of the furnace, and if additional heating is required, then the second stage brings on the remainder. Use of outdoor thermostats in series with the room thermostat is similar to that described for heat pump auxiliary heaters.

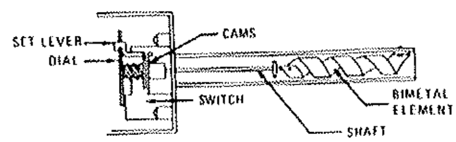
Each electric element in an electric furnace is fitted with a "fusible link" that melts and deenergizes the heater if excessive current or temperature occurs. Each heater is often separately fused as well.

Limit Controls

As we have learned, each type of equipment is fitted with specialized safety shut-off features appropriate to the type of fuel used, but furnaces are also fitted with safety shut-off controls called *limit switches. A* sensor often in the form of a snap-disc responds to excessive supply air temperature in the plenum and interrupts the power to the burner or electric heating element.

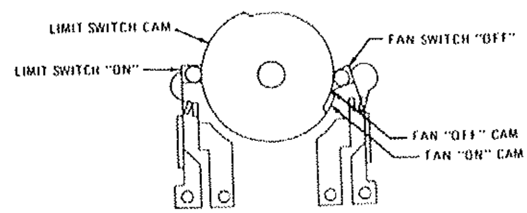


Disc type limit switch



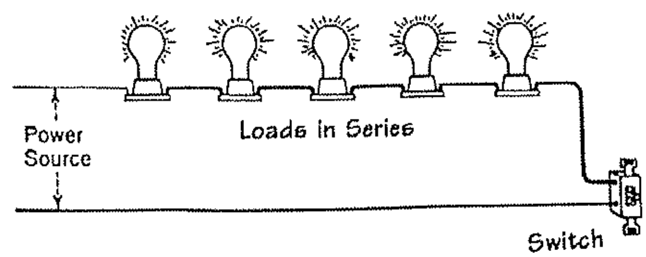
Fan Controls

To start and stop the furnace fan, a switch is used that reacts to the supply air temperature as it is being heated after the burner starts. At a preset air temperature, the switch closes and the fan is energized to circulate the heated air to each room.



Combination fan/limit control

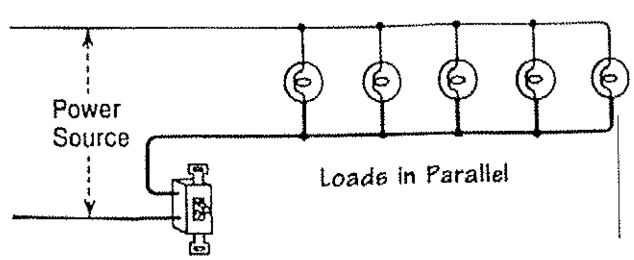
Many times the functions of both limit control and fan control are combined into one unit.



Control Circuits

Controls are joined together by wires to form complete electrical circuits.

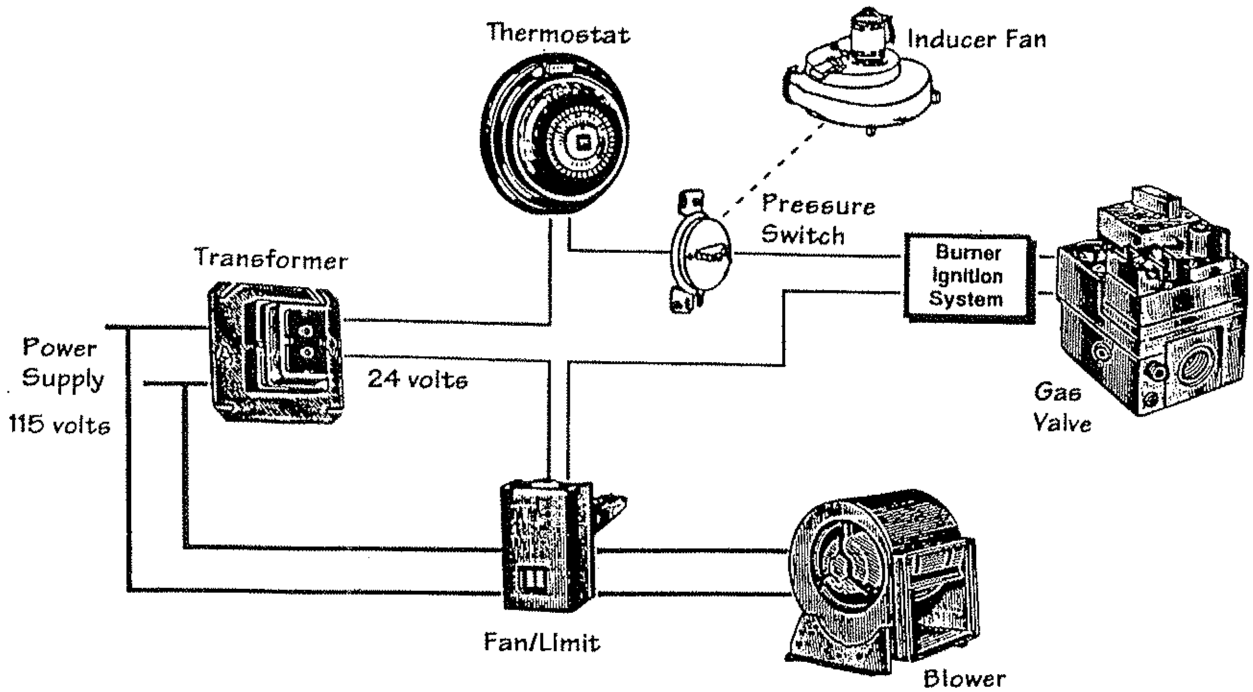
A *series* circuit indicates all devices are connected in a row, one-after-the-other, to provide just path for the current to flow.



A *parallel* circuit provides two or more paths for current to flow, and devices wired "in parallel" usually function independently from each other.

In practice, control circuits are very often compound circuits, a combination of both series and parallel connections.

Normal Operation



The figure above shows how a typical gas-fired furnace control system might be "wired" together. Let's consider a normal sequence of operation — ignoring for the moment the pressure switch and inducer fan which are featured in most mid-efficiency furnaces.

The room temperature drops below the set point of the thermostat; the thermostat contacts close and calls for heat; the main gas valve opens; and the gas burner(s) are ignited — by the standing pilot, spark or hot surface igniter.

Then, the fan control begins to sense the rising air temperature in the furnace plenum. When the air temperature reaches a preset value, say 130° F, and fan control starts the blower motor. Heated air is delivered to each space. When the room temperature exceeds the thermostat setting, the thermostat contacts open, and the main gas valve closes.

The furnace blower will continue to run until the plenum chamber cools below a preset value (perhaps 100° F) at which time the fan switch will open, and the blower motor stops.

Limit Protection

The above scenario represents normal operation. Suppose the furnace filter becomes very dirty and restricts the flow of air through the system. When the furnace starts, so little air is moving to carry away the heat that the temperature in the plenum will exceed the setting on the limit switch — which in our case is a part of the fan/limit control. This normally closed switch will open and interrupt the power to the main gas valve and shut down the furnace.

Most limits today automatically reset, but if fitted with a manual reset, the homeowner must press the reset button to start the system again. The reset feature forces the homeowner to inspect the furnace or at least be alerted to the fact that the equipment is cycling on limit.

Some older furnaces are fitted with a summer ventilation switch mounted in the furnace cabinet. Today, a fan switch on the thermostat offering "auto" or "on" operation is provided for user selection. This switch bypasses the function of the fan control, and the furnace blower will run continuously.

More Protection

Mid-efficiency furnaces include a *pressure switch* that senses the start of the combustion air fan before allowing the gas valve to open. It also monitors operation and shuts down the burner if the vent passage is blocked or the combustion air fan fails.

Some furnaces also feature a *flame roll-out protector* which is not shown in the previous illustration. Any rise in temperature in the burner compartment caused by flames backing out into the front of the furnace or other cause (such as the venting system being clogged) will open the switch and stop the flow of gas to the burner.

There is also a blower compartment *interlock switch* in the form of a button that rests on the access door to the filters and blower. If the door is removed, the button pops open and interrupts high voltage to the unit.

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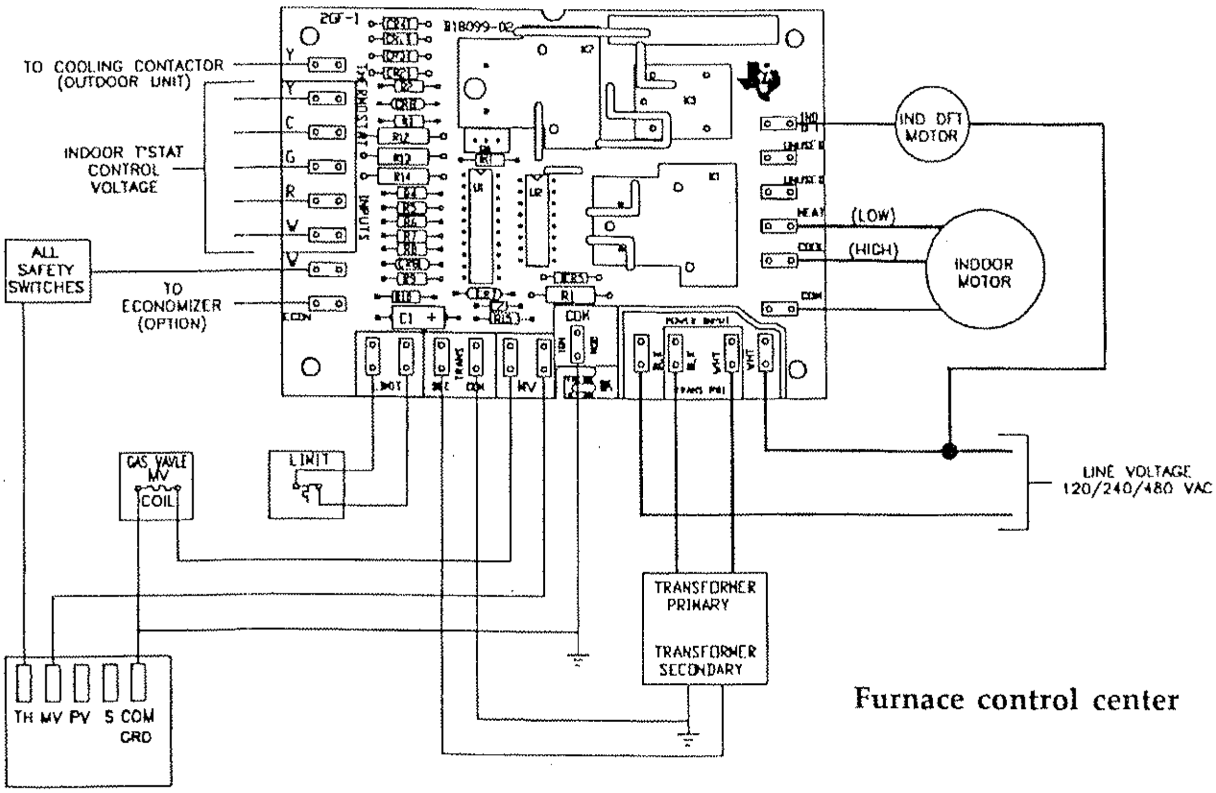


Furnace control center

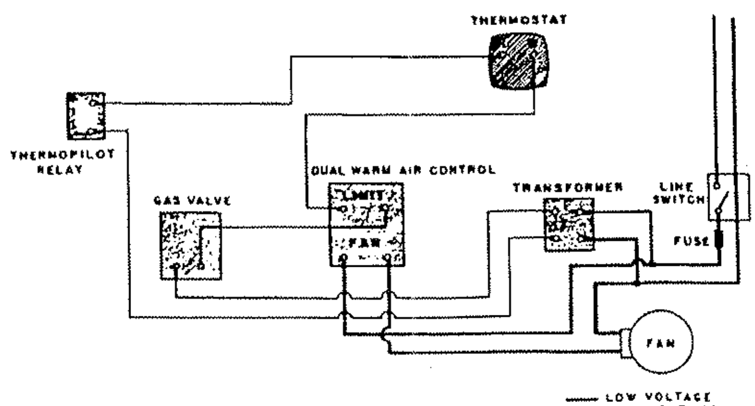
Other safety devices may be used by various manufacturers for specific product applications. In Canada, for example, a spill switch may be added to detect a downdraft at the vent connection for naturally vented furnace.

Modern furnaces may feature solid state "printed" circuit boards to consolidate control functions.

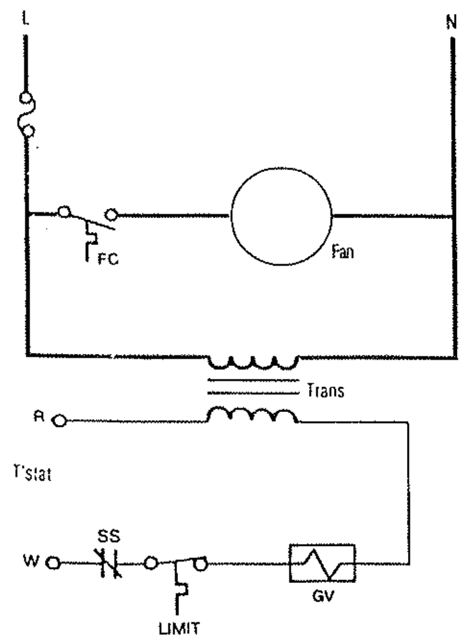
Wiring Diagrams

Equipment is shipped with wiring instructions. Often both a *connection* diagram and a *ladder* (or elementary) diagram are provided.

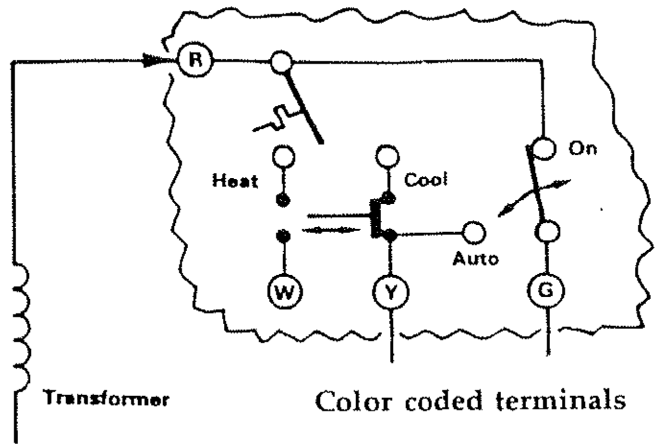
A connection diagram "pictures" as close as possible how components are wired together.



Connection diagram.



A ladder diagram is a *functional* arrangement using special "short hand" symbols to represent components.



Color coded terminals

Low voltage wiring is also color coded and terminals are numbered or lettered to conform with accepted industry practice. For example: Red (R) for power from transformer, White (W) for heating, Green (G) for fan, and Yellow (Y) for cooling.

Millivolt Systems

There is another type of control system, a self-generating control system, which does not depend on household electricity. It generates its own electrical current by using a special type of thermocouple and a pilot light. This thermocouple will supply enough current to operate the gas valve (self-generating controls are used only on gas-fired systems). With a self-generating control system, a gravity wall furnace will continue to operate even if there is a power failure in the home.

Self-Check, Lesson 10 Quiz

You should have read all the material in Lesson 10 before attempting this review. Answer all the questions to the best of your ability before looking up the answers provided in the answer key.

Please indicate whether the following statements are true or false by drawing a circle around T (to indicate TRUE) or F (to indicate FALSE).

True False

1. T F A bimetallic sensor moves in response to heat because the bonded alloys have different coefficient of expansions.

2. T F Semiconductor is a more accurate description of the popular term "solid state" device.

3. T F A popular location for a room thermostat is on an outside wall in or near the living room of the house.

4. T F A thermostat is classified as a safety device since it turns the heating equipment "on" and "off."

5. T F A standard low voltage room thermostat requires an electrical supply of 120 volts to operate a residential gas furnace.

In the following multiple-choice questions, choose the phrase that <u>most</u> correctly completes the statement, and check the appropriate box for the corresponding letter in front of the phrase.

6. An electronic "chip" containing many diodes, transistors, and other components is termed:

A. ☐ a miniaturized circuit.
B. ☐ a micro circuit.
C. ☐ an induced circuit.
D. ☐ an integrated circuit.

7. A step-down transformer is used in a control circuit to:

A. ☐ convert AC to PC power.
B. ☐ convert DC to AC power.
C. ☐ decrease voltage supply from 120 V to 24 V.
D. ☐ increase voltage supply from 120 V to 240 V.

8. A combination gas valve provides manual shut off, safety shutoff, pressure regulation, and:

A. ☐ on/off control of the burner.
B. ☐ burner ignition control.
C. ☐ burner orifice regulation.
D. ☐ rollout protection.

9. An oil burner primary control provides safety shutdown, spark ignition, and can start and stop:

A. ☐ the oil pump.
B. ☐ the combustion air blower.
C. ☐ the pump/ blower motor.
D. ☐ the furnace fan.

10. An air-to-air heat pump is most often controlled by:

A. ☐ a two-stage thermostat.
B. ☐ an electronic set back thermostat.
C. ☐ a line voltage thermostat.
D. ☐ a thermal type relay.

For the completion-type questions, fill in the blanks with the word (or words) that most accurately completes the thought.

Key Words

safety	pictorial	symmetrical	series	compound
parallel	ladder	operational	switchover	millivolt

11. A control circuit providing two or more paths for current to flow is called a/an __________ electrical circuit.

12. A control circuit where each device is wired one-after-the-other in a row is an example of a ______________ electrical circuit.

13. Most electrical circuits in furnaces are _____________ circuits meaning they are a combination of basic circuit configurations.

14. A furnace limit switch is an example of ____________ control.

15. Wiring instructions usually contain both a connection diagram and a/an ___________ diagram of the control devices and their functions.

Check Your Answers!

Now compare your answers with those given in the answer key at the back of this book. The answer key also directs you to a page in the lesson to review the text for any questions you may have missed.

When you are satisfied you understand the questions missed, proceed to your next assignment which starts on the next page.

Chapter 11 Overview

"Ordinances, codes and standards" — what's the difference? In this lesson, we will define each of these terms, provide a brief history of building codes, cover licensing, identify several of the principle safety standards organizations you'll encounter, as well as the "model" codes that local governments often adopt.

This lesson cannot be specific enough to cover detailed local code requirements for heating systems, so you should get a copy of applicable local requirements and learn what's required. Not knowing or ignoring local requirements can be costly in terms of job delays and changes, and may even involve fines.

Now read Lesson 11 which begins on the next page.

Lesson 11: What are Codes?

As with most products that affect the health and safety of the user, heating equipment and heating installations are governed by various ordinances, codes and standards. Let's define these terms by starting with an ordinance.

An **ordinance** is a law or regulation enacted by local, state or federal government bodies to protect public safety and health. An ordinance against smoking in buildings is a classic example.

Another fairly common ordinance for heating installers is a licensing ordinance. This would mean no person or perhaps no firm in a community can install, erect, alter or repair heating systems unless that person or employee of a firm is a license holder. Many times an examination is required before a license is issued. *(See Notable Note: Licensing)*

A **code** is a system of principles and rules that relate to one subject with the objective to control quality and performance. Size, illumination, and placement of exit signs is an example of a code — probably part of the larger building code.

Codes can be mandatory — incorporated into government ordinances, or simply a voluntary industry code for which participation is not a requirement. However, if one states conformance to a voluntary code, the code authority may be able to demand proof of conformance.

A **standard** is a level of competence established by a recognized group against which a given design, quality or performance can be measured. Duct fabrication materials, assembly, and erection details established by the Sheet Metal and Air-Conditioning Contractors Association is one example. This standard, as well as others, may be incorporated into a particular model mechanical code. A model code is simply a code prepared by a knowledgeable group which is presented as a useful example for others to adopt.

Notable Note: Licensing

***Licensing* is a process by which an agency of government grants permission to an individual to engage in a given occupation — heating service, for example — upon determining that the applicant has attained the minimal degree of competency required to ensure that the public health, safety and welfare will be reasonably well protected.**

Two regulatory approaches that are less restrictive are *registration* and *certification.* Registration may be invoked when the threat to life, health, safety and economic well being is relatively small and other forms of legal redress may be available to the public. Registration requires a person to file his or her name and address with a designated agency. This provides the public with a roster of practitioners.

Certification is a form of regulation that grants recognition to individuals who have met predetermined qualifications by a state agency. However, non certified individuals may in some instances offer similar services to the public as long as they do not describe themselves as being certified.

All three terms may present confusion as implemented by local laws (a registered nurse for example is really a licensed nurse) Also, non-government bodies also offer certification to practitioners who meet predetermined qualifications.

History

Fire has always been the most common form of disaster. Fire safety, together with structural reliability and the protection of human health, are the three fundamental objectives behind the origin of building codes and the institution of fire ordinances.

Perhaps the simplest code governing structural reliability was the Code of Hammurabi in Babylonia more than 2,000 years before the birth of Christ. It simply stated that the builder would be put to death if any of his buildings fell down due to faulty construction.

One of the first efforts to achieve fire safety was the set of ordinances to prevent the spread of fire between buildings laid down by England's King John after the great London fire in 1212.

In the United States, the *Common Council* was formed in the New York port area in 1675 to take up the already developing health problem regarding sewage and refuse disposal which led eventually into plumbing codes.

In the specific area of fire safety, little in truly scientific terms was accomplished until modern times. The Cleveland City Code of 1834 simply stated each building owner must provide at least one leather fire bucket — a form of fire fighting preparedness but surely not fire *prevention.*

But after the disastrous Chicago fire in 1871, and later the Baltimore (1904) and San Francisco (1906) fires, more emphasis began to be placed on fire prevention rather than just fire fighting. Both fire testing, research, and building code development accelerated.

Notable Note:
Get To Know These NFPA Standards

HVAC practitioners will find it convenient to have quick access to the following NFPA standards:

31 - Installation of Oil Burning Equipment
54 - National Fuel Gas Code
58 - Storage and Handling LP Gases

70 - National Electrical Code
70A - Electrical Code for One & Two Family Dwellings & Mobile Homes
90A - Installation of Air Conditioning and Ventilation Systems (non-residential)
90B - Installation of Warm Air Heating and Air Conditioning
96- Ventilation of Commercial Cooking Equipment
97- Standard Glossary of Terms Relating to Chimneys, Vents and Heat Producing Appliances
211 - Chimneys, Fireplaces, Vents and Solid Fuel Burning Appliances Systems

About halfway through the 19th century, *insurance* companies — interested in both fire prevention and in minimizing financial loss from fires — began forming service organizations. Factory Mutual (FM), formed in 1835, and the Board of Fire Underwriters, started in 1866 (later the American Insurance Association), are two examples. Their job: to gather and disseminate fire statistics and engineering data for policy holders. Much of what these groups learned and suggested became helpful to the public at large.

Underwriters Laboratories (UL), one of several important safety and testing laboratories in the United States, came into being when insurance underwriters in Chicago asked a young electrical expert to stay on after he had been helpful in stopping the many fires started by the Palace of Electricity display at the 1893 Columbian Exposition.

By 1896, the National Fire Protection Association (NFPA) was organized to promote the science and improve the methods of fire protection and prevention. Organizations such as insurance groups, engineering societies, trade associations as well as individuals such as consulting engineers, fire chiefs, arson inspectors, and anyone interested in fire safety make up NFPA's membership.

NFPA publishes material for public education and a professional journal for its members. NFPA is best known for its National Fire Codes including the National Electrical Code. The multivolume codes cover fire safety, standards on subjects ranging from the handling of flammable liquids to marinas and commercial and residential heating installations. Building Construction and Facilities is of particular interest to HVAC contractors.

A number of laboratories conduct fire testing research to provide the various fire protection interest groups — such as model code groups, associations, and consultants — with the necessary engineering data on fires. UL and FM, mentioned previously, are two well known examples, and there are specialized government laboratories and universities engaged in fire testing and research as well.

Notable Note: Fire Hazard vs. Fire Resistance

Underwriters Laboratories (UL), a laboratory engaged in testing for public safety, is one of several agencies that publish results of fire tests. UL's regularly published Building Materials List identifies products that have passed certain fire tests. Listing signifies that samples of the

product have been found acceptable by UL based on UL's established requirements. The value of a UL listing is dependent upon the confidence placed in UL by code authorities.

Building materials are classified in two ways — by fire hazard and by fire resistance (retarding) characteristics.

Fire *hazard* classification refers to the burning characteristics of *materials* — flame spread, fuel contributed ,and smoke developed. The comparative scale is based on the burning characteristics of red oak, which has been assigned an arbitrary value of 100 for all three characteristics, and asbestos cement board which has a value of 0 in all three categories.

(A sample that generates ½ the smoke of red oak would have a smoke developed rating of 50.)

Fire *resistance* classification applies to *structures* — columns, floors, walls, floor-ceiling assemblies — that are exposed during testing to a fire of controlled and repeatable intensity. Ratings are given in terms of hours of test endurance — 4 hr, 2 hr, 1 hr — until the collapse of the loaded structure or until the temperature rise across the structure exceeds an average of 250° F. (Limiting temperature rise is to prevent fire spread by heat conduction through the structure to combustible materials in contact on the other side.)

Thus, a particular ceiling tile material may have a fire hazard classification as follows: flame spread -1; smoke developed -10; and fuel contribution -15. When that tile is used in a complete assembly such as part of a T-bar ceiling, the entire assembly might have a 1 hr fire resistance rating.

Building codes make frequent reference to specific fire hazard and fire resistance requirements.

Who's the Boss?

Most states have a state *fire marshal* operating out of either a distinct department, or as a division of the state's department of public safety, police, or insurance.

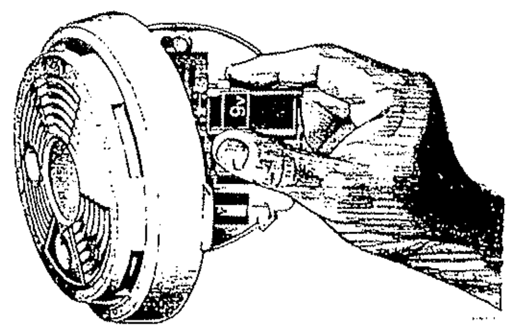
The state fire marshal enforces the state's fire protection code — covering the prevention of fires, storage and sale of explosives, alarm systems, fire escapes, and conducts arson investigations. The state fire marshal is the primary fire law *enforcement* officer. He is usually assisted by regional deputy marshals, as well as any local fire prevention bureaus that are established. The state fire marshal's office of California even has its own research laboratory.

On the local level, a municipality's building department and fire department share the responsibility of enforcing fire safety to the extent delegated by the state's fire marshal. Areas of responsibility very often overlap with final jurisdiction being established by convenience.

Generally a *building* department will be concerned with such things as lighting and ventilation, establishing fire zones, types of construction, loads and stress, chimneys and heating appliances, fire resistance requirements, plumbing, and the selection of fire extinguishing equipment.

A *fire* department will normally be concerned with the transportation of flammables, fireworks safety in lumber yards, dry cleaning establishments, and the *maintenance* of fire extinguishing equipment and exits.

A standard may be written for the desired performance of a smoke alarm. A model building code may make it a requirement that a smoke alarm that meets the standard be installed in all sleeping rooms of a motel. An ordinance passed by a legislative body makes the model code a law.



As a general rule, building code changes are seldom made retroactive, whereas a new fire protection code can be made to apply to existing as well as new facilities. Smoke alarms, for example, could be made a requirement for all buildings.

Code Groups:

International Code Council
500 New Jersey Ave. NW 6th Floor
Washington, DC 20001
(P) 1-888-422-7233
(F) 1-202-783-2348
www.iccsafe.org

NFPA
National Fire Protection Association
1 Battery march Park
Quincy, MA 02169-7471
(P) 1-800-347-3555
www.nfpa.org/

Model Codes Become One

Most existing building codes have been adaptations of one of three model codes. Model building codes include the *Basic Building Code,* prepared by the Building Officials Conference of America and widely adopted in the west; *Uniform Building Code,* prepared by the International Conference of Building Officials for the Midwest and East; and the *Standard Building Code* prepared by Southern Standard Building Code Congress International.

These model code groups are made up of governmental officials, such as fire marshals, building department staff, etc., — all with voting rights, plus non voting members, including architects, engineers, trade associations, and manufacturers.

In 1994, these building code organizations responded to a changing construction industry environment and formed the *International Code Council* (ICC) to write a unified set of regulatory documents for the U.S. and North America — a building code, mechanical code, plumbing code, and several others.

Individuals involved in the heating and cooling industry should have access to their local building, mechanical and energy codes. *"Install according to local code requirements"* is a familiar statement included in manufacturer installation instructions.

Self-Check, Lesson 11 Quiz

You should have read all the material in Lesson 11 before attempting this review. Answer all the questions to the best of your ability before looking up the answers provided in the Answer Key.

Please indicate whether the following statements are true or false by drawing a circle around T (to indicate TRUE) or F (to indicate FALSE).

True False

1. T F A standard is a law or regulation enacted by a governmental body to protect public safety and health.
2. T F Securing a license to install, service or repair heating systems often involves taking a written test.
3. T F A code is a system of principles and rules that is intended to control the quality and performance of a particular subject.
4. T F A code can be a voluntary or mandatory effort incorporated into government regulations.
5. T F Insurance companies were an early source of safety testing.

In the following multiple-choice questions, choose the phrase that <u>most</u> correctly completes the statement, and check the appropriate box for the corresponding letter in front of the phrase.

6. The National Electrical Code is developed and published by:

☐ A. National Fire Protection Association. ☐ B. The Electric Council.
☐ C. Underwriters laboratories. ☐ D. Association of State Fire Marshals.

7. The National Fuel Gas Code is developed and published by:

☐ A. National Fire Protection Association.
☐ B. American Gas Association.
☐ C. Gas Appliance Manufacturers Association.
☐ D. Factory Mutual.

8. The regional building code groups of BOCA, ICBO and SBCCI joined forces to form a single building code organization called:

☐ A. International Conference of Building Officials.
☐ B. International Code Council.
☐ C. North American Council of Building Codes. ☐ D. Joint Task Force of Code Authorities.

9. CABO was a joint venture of the regional code groups to develop a national model:

☐ A. garden apartment building code.
☐ B. assisted living apartment code.
☐ C. one and two family dwelling code.
☐ D. urban renovation building code.

10. Duct construction manual of the Sheet Metal Contractors National Association is anexample of:

☐ A. a model code. ☐ B. a standard.
☐ C. an ordinance. ☐ D. a guide.

For the completion-type questions, fill in the blanks with the word (or words) that most accurately completes the thought.

Key Words

safety	permit	hazard	resistance	70-A
fire	90-B	registration	standard	building

11. A regulatory approach less restrictive than licensing is ____________________.

12. The installation of warm air heating and air conditioning systems is covered in NFPA___________.

13. The fire ____________ classification refers to the flame spread and smoke developed andother burning characteristics of materials.

14. A wall assembly could have a one hour fire _________________ rating.

15. Organizationally, the ________________ department of a city is concerned with fire zones,types of construction, heating appliance and fire resistance requirements.

Check Your Answers!

Now compare your answers with those given in the answer key at the back of this book. The answer key also directs you to a page in the lesson to review the text for any questions you may have missed.

Lesson 12 Overview

If installed improperly, the best made furnace or heat pump is a total waste. It will neither heat well nor operate economically. It may meet code and be safe, but the user will be unhappy.

As a follow-up to the lesson on codes, this assignment will cover the following:

- Problems posed by house style and construction.
- Basic requirements when installing equipment.
- Duct installation and gas lines.
- The need for combustion air for fuel-fired appliances.
- Venting fuel-fired appliances.
- System testing and balancing.

Lesson 12: Doing a Quality Installation

As we already know, heating installation requirements vary according to the nature of the building, type of distribution system needed and the type of heating unit selected. Also, local installation codes can and do vary.

In *Residential Comfort Systems Installation Standards* published by SMACNA, more than 20 different standards are referenced that relate to a proper heating installation.

Therefore, it is not possible to cover every aspect of a proper heating installation in this lesson. The intent here is to introduce general requirements and precautions and to stress the importance of a proper *safe* installation and the importance of balancing and adjusting a system for *comfort and economy.*

Building Styles

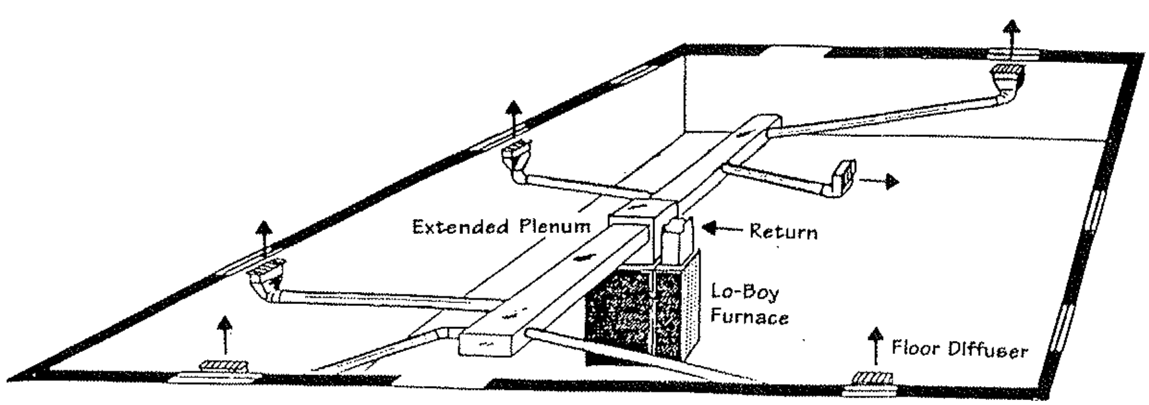
The architectural style of a building can pose unique heating installation and performance problems. One and two story homes pose distinct problems. Townhouses and condominiums are individually occupied structures, but share common walls. Apartments offer yet another example of special challenges to the heating specialist.

Let's discuss general building characteristics as they influence heating installation and performance problems.

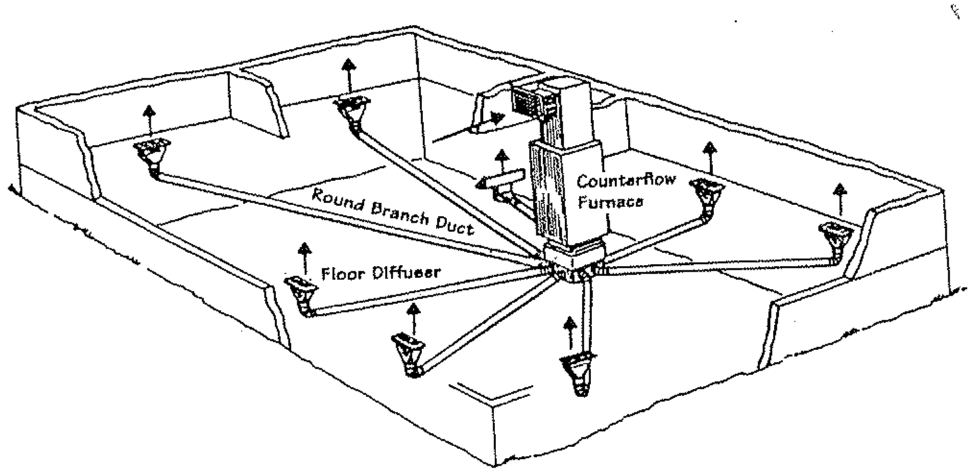
One-Floor Plan

It is comparatively easy to install a heating system for a single story "ranch" house over a full basement. There is usually more than adequate space for installation. This is equally true whether a heating system is being installed in a new house or modernized in an older house.

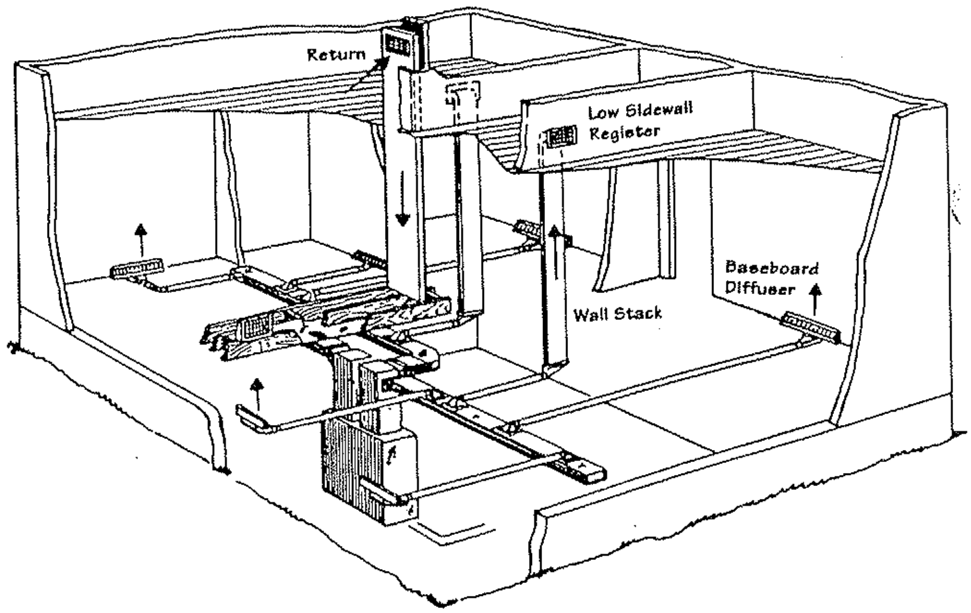
Ranches built over a crawl space or on a floor slab must allow space in a utility area or furnace "closet" for equipment. In some areas, attic and crawl space horizontal furnaces are popular.



One-story homes with a full basement present a minimum of installation problems.



A counterflow furnace is intended to simplify crawl space installations.



Two story homes can mean double trouble.

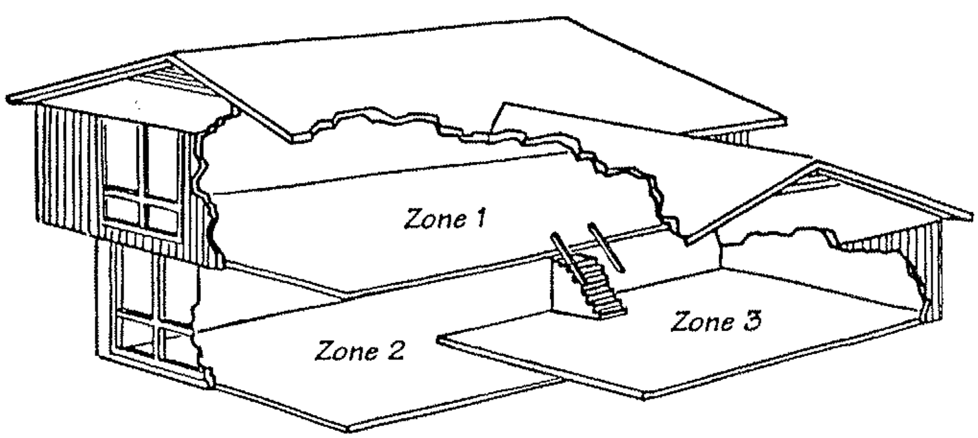
Exceptionally long ranch homes may pose air distribution problems to distant rooms especially when the heating equipment cannot be centrally located.

Two-Story Houses

A two-story house introduces new problems. Since the distribution system must be routed to the second floor, it is important to check that inside walls in the lower floors can carry wall stacks to suitable locations on the second floor. It is also necessary to check the electrical and plumbing systems in the house. You do not want to make the mistake of planning to use the same stud space that will be used by the electrician or plumber.
Sometimes, you may find that ductwork cannot be brought up to individual rooms on the second floor through downstairs partition walls. In this case, it may be necessary to run a central duct all the way to the attic with an overhead distribution system to upstairs rooms. If this is done, the ductwork through the attic must be sealed and well insulated. *(Ceiling diffusers are not ideal for heating in cold climates as we learned, but second-level rooms are often less difficult to heat, because these rooms are over heated spaces and have warm floors.)*

The open-plan split-level house may be the most difficult in which to install a heating system — especially when cathedral ceilings are part of the style. Rooms on three levels must be supplied heat. Ductwork may be difficult to route to reach some of these rooms; however, flexible duct may help. A split-level house calls for a great deal of cooperation between the builder, the HVAC contractor, and other trades.

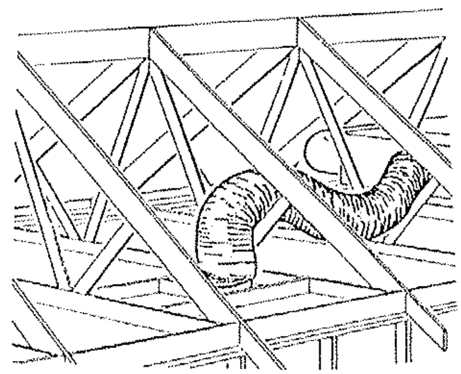
Often overlooked is the problem of heating rooms located *over* a garage or porch. It is best to consider that garage doors may be left open, which means that the space underneath the floor will often be at the current outside temperature. Therefore, it is essential that floors over garages or porches be heavily insulated. Any ductwork supplying these rooms must go through this cold space, so they should be well insulated whether they are supply or return ducts. The walls between an attached garage and the house should also be well insulated.



A split-level is a good candidate for zoning.

Some owners may wish to heat an attached garage. If heated by the central furnace, return air grilles should <u>not</u> be installed in the garage. This is to minimize drawing dangerous automobile exhaust into the warm air system of the residence. Local code requirements may require a *separate* heating unit to heat an attached garage.

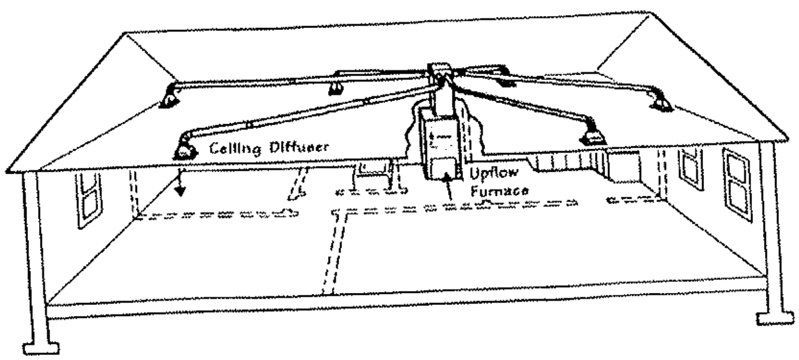
It may be desirable in a split-level, two story, and large ranch houses to divide the house into *zones* with an individual room thermostat for each zone. This can be accomplished using thermostatically controlled motorized dampers in the duct system or perhaps installing multiple furnaces. Two furnaces with smaller and simpler ductwork may sometimes be a better solution than a single furnace with a very complicated duct system and several zone dampers. In any case, zoning a home means a different approach to how the duct system is arrayed.



Flexible duct can reduce installation time but could add to the overall resistance to airflow. Be careful in its application and installation..

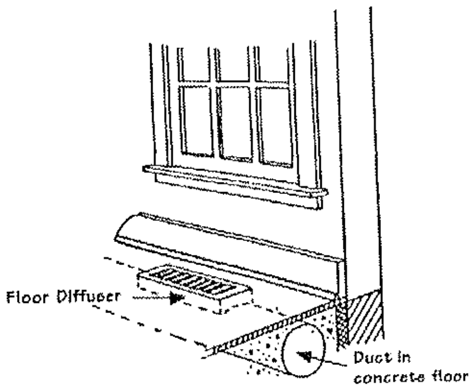
Floor Construction

The floor construction of the house is also an important factor when designing heating systems, as was pointed out in Lessons 4 and 5. Except in very mild climates, it is important to run supply ducts under the floor to maintain good comfort conditions. In the case of a concrete slab, ducts specially treated for in-slab installation must be used.



Overhead heat distribution is satisfactory in mild climates.

Apartments, townhouses, and other types of multiple occupancy buildings pose their own unique set of problems. Space for equipment and ductwork is often minimal. Noise is more often a nuisance since there are more units in proximity of one another. Ventilation of kitchen and laundry spaces is more critical too.



Left: In cold climates, floor slabs should be heated.

Corner units may have greater heating needs than housing units sandwiched between other heated spaces. Sizing of furnaces, locating ductwork and venting can be very challenging.

Be A Code Expert

Before proceeding with an actual installation, a designer/installer should be totally familiar with local code requirements and the *instructions* supplied by the manufacturers of the particular equipment and accessories being installed.
Many local heating ordinances will identify the load calculation, pipe, and duct sizing procedures that are acceptable. As a minimum, a local requirement will require that a room by room load calculation be made and submitted with a *permit* request to install the system.

In many cases, local requirements may also stipulate that only "approved" equipment be installed. This means that furnaces must have a label from some recognized testing or certification agency. For example: AGA for gas-furnaces, UL for oil, AHRI for heat pumps as was discussed in Lesson 6.

These standards also specify necessary *clearances from combustible* building surfaces that must be maintained for heating units. The manufacturer will also describe in their instructions the clearances required not only for fire safety, but to provide for *service access.* Manufacturer instructions must be thoroughly understood to avoid maintenance problems over the life of the equipment.

RECOMMENDED CLEARANCES TO COMBUSTIBLE MATERIALS FOR ALL UNITS	
REAR	0
FRONT	
Single Wall Vent	6" (150mm)
Type B-1 Double Wall Vent	3" (75mm)
For Service	30" (760mm)
ALL SIDES OF SUPPLY PLENUM	1" (25mm)
SIDES	0
VENT	
Single Wall Vent	6" (150mm)
Type B-1 Double Wall Vent	1" (25mm)
Thermoplastic Pipe	5" (125mm)
TOP OF FURNACE	6" (150mm)

Remember the serviceperson as well as safety requirements when positioning the equipment.

Installation of the heating unit will more than likely have to conform to the requirements listed in the National Fire Protection Association's (NFPA) Standard 90-A (for large buildings) and 90-B for residences. (Refer codes in Lesson 11.)

The equipment manufacturer will detail necessary assembly and fastening procedures to erect a unit and connect it to other components in the system. Manufacturer instructions will also provide equipment performance data and in many instances basic adjustment procedures.

Ductwork

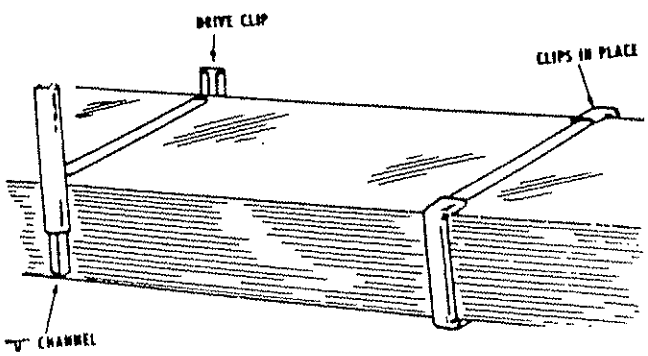
Duct material type and thickness (gauge in the case of metal duct) are usually based on recommendations found in NFPA 90-A and 90-B. For example: for a metal duct 14 inches wide or less, the standard states the duct must be made of 28 gauge for galvanized iron. Between 14 and 24 inches wide, 26 gauge is required. The recommendations in 90-A and 90-B, in turn, are based on UL duct material testing requirements.

For the actual construction and erection of ductwork, most code authorities specify "in accordance with the latest edition of the NAIMA or SMACNA Fibrous Glass Duct construction standards or the SMACNA low velocity duct construction standards (for metal)." These manuals show in great detail how to fabricate ductwork, join sections together and properly suspend the distribution system.

Assembly and installation practices today strongly emphasize the need to *seal the duct system* to conserve energy and minimize pressure unbalance within the building. Proper tape and mastic type to minimize air leaks can be applied.

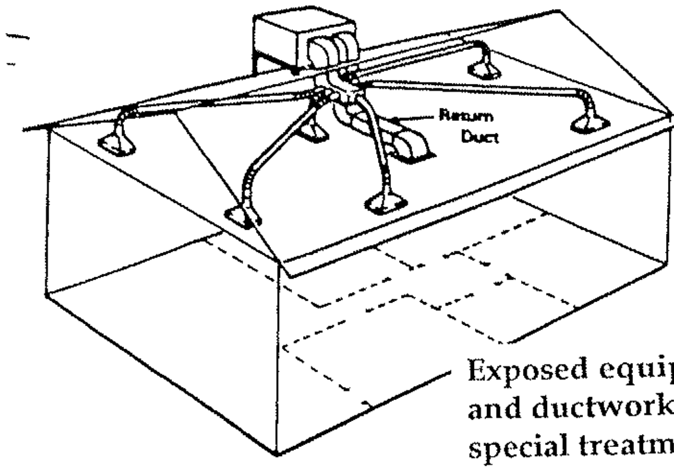
Supply ducts must be securely supported by metal hangers, straps, lugs, or brackets. Nails must not be driven through duct walls, and no unnecessary holes should be cut in the ductwork.

Joining metal duct sections using drive slip and plain "S" slip connectors usually meets most local requirements.



Duct materials and installation must meet code requirements.

A frequent requirement is that all ductwork exposed to outdoor weather must have 2 inches or more insulation applied. This may vary in some localities depending upon the severity of the weather. Ductwork which passes through unconditioned spaces (but not exposed directly to the weather) must also be insulated under most code requirements as noted in Lesson 7 on duct systems.



Exposed equipment and ductwork need special treatment.

Gas Lines

Gas-fired installations must meet requirements found in NFPAStandard 54 — the National Fuel Gas Code. This specifies gas pipe sizing to supply natural or LP gas to equipment. It also details how *combustion air* and ventilation must be provided to assure equipment receives adequate air for combustion and dilution venting. *(More on combustion air later.)*

Oil-fired equipment usually must meet the standards set forth in NFPA-31. As with gas, this standard specifies combustion air and ventilation requirements, oil storage tank construction, and installation as well as clearance requirements and pipe materials to use.

Unlike NFPA-54, the NFPA standard on oil does not list pipe sizing procedures. Most oil pump or oil burner manufacturers supply pipe sizing information for each model of pump. This information is usually included with the general instructions provided by the manufacturer of the furnace.

Chimney/Venting Systems

Vent and chimney requirements are also covered by code relative to materials, size of vent connectors, clearances, and general arrangements. Again, the manufacturer's instructions will provide the precise vent sizing requirement for specific models. This is based on tests for which the specific models have been approved for installation and safe operation.

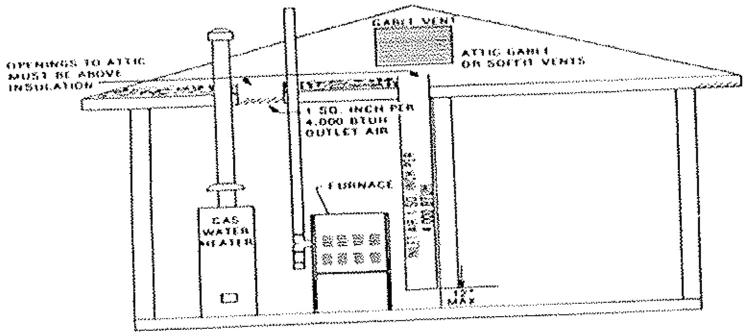
As discussed in Lesson 2, heat is produced most often by the burning of a fossil fuel. This requires the combination of the fuel with oxygen (air). For example: A 100,000 Btu furnace requires more than 1,000 cubic feet (per hour) of air to support combustion.

The burning process results in the production of heat, some light and waste gases — referred to as the products of combustion. Again, a typical 100,000 Btu/h furnace produces from 125 to 160 pounds of flue gases for each hour of operation.

Thus, a fossil-fuel furnace requires a supply of combustion air and a means to purge the living spaces of the products of combustion.

Combustion Air

NFPA standards describe methods to assure an adequate supply of combustion air for furnaces.



Furnaces installed in a full-size basement usually obtain sufficient combustion air from natural air leakage into the basement. When furnaces are installed in closets or small utility rooms, specific openings must be made to supply combustion air — especially true for tight modern homes and buildings.

Providing adequate combustion air must not be overlooked.

How can you anticipate that natural infiltration should be adequate? *By using the 1/20 rule.* For every cubic foot of space, you can install 20 Btus of heat. Thus, a 100,000 Btu/h furnace would need 5,000 cu ft of unconfined space about the size of a 2-1/2 car garage. Anything smaller would be considered a confined space and combustion air would have to be supplied to the furnace in accordance with NFPA Standards.

No furnace or water heater should be installed without a thorough understanding of local combustion air requirements.

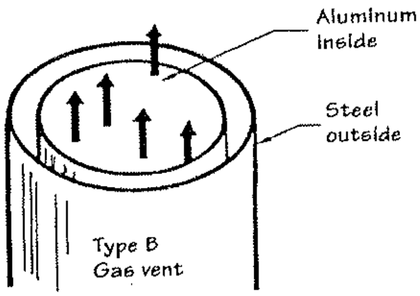
Purging Flue Gases

Combustion gases that could be harmful to a building's occupants are discharged to the out-ofdoors by means of a chimney or special venting system. A chimney is simply a vertical passageway to carry away the gases. It may be made of masonry or insulated metal.

In the past, many chimneys were constructed on-site. Today, factory-built chimneys are frequently used. These units are tested by Underwriters Laboratories and must be installed to precise specifications. Most factory-built *chimneys* are approved for use with all fuels — coal, wood, oil and gas.

Special venting systems have been developed for gas-fired furnaces to lower cost and improve safety and performance.

"B" vent systems are used with any gas furnace that does *not* produce a positive pressure in the vent system. These furnaces are called Category I furnaces.



A "B" vent consists of two concentric metal pipes. The inner pipe is aluminum and the outer pipe is made of galvanized steel. The air space between the two pipes acts as an insulator and permits close installation to combustible building materials. Joints need not be air tight. Standardized vent sizing tables are used for Category I furnaces and are a part of the installation instructions.

Furnaces that produce a positive pressure in the vent system are either Category III furnaces or Category IV *condensing* furnaces. Special materials, sizing information and air tight joints are required.

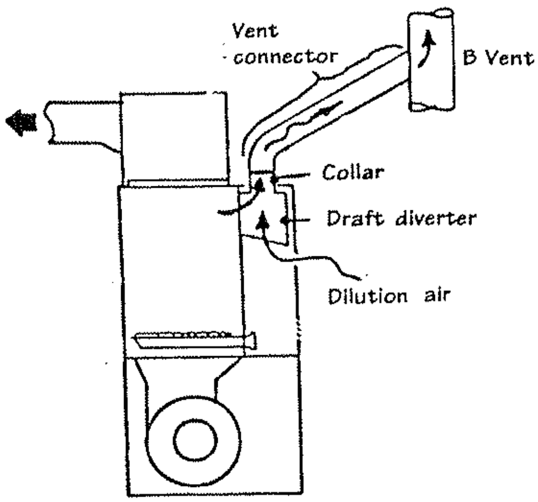
At one time, Category III furnaces were approved for use with special high temperature plastic. This is no longer the case. When vented horizontally, these furnaces may be connected to separate power vent units or special stainless steel vent systems. Condensation occurring in the vent system is of particular concern when venting this class of furnace.

Category IV condensing gas furnaces may use Polyvinyl Chloride (PVC) plastic for venting systems that will not exceed about 140° F, while Chlorinated Polyvinyl Chloride (CPVC) plastic may be necessary for furnace venting gases at 180° F.

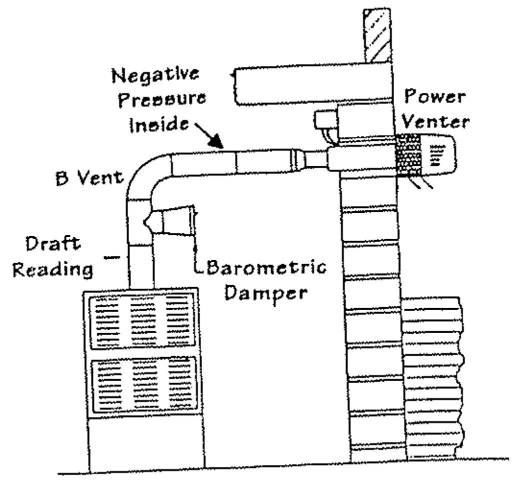
All joints must be sealed since the pressure inside the vent is greater than outside and vent gases could escape.

Special Draft Devices

The draft, or upward push of a chimney or venting system, varies with temperature and wind conditions. If extremes of draft were permitted to occur, it could affect the combustion process in the equipment. To minimize the effect of varying draft on the performance of equipment, a couple of special devices are used.



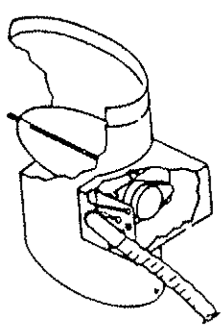
Until the advent of the vent fan-assisted furnace, the typical gas-fired furnace used atmospheric type burners and was fitted with a draft hood (sometimes called a draft diverter). The hood permits additional air from the basement, or utility room to enter the flue passage of the vent and join the combustion gasses, thereby diluting the effect of increasing draft. The additional air is referred to as "dilution air." The combustion chamber of the furnace is in a sense "uncoupled" and unaffected by any excessive draft that may occur.



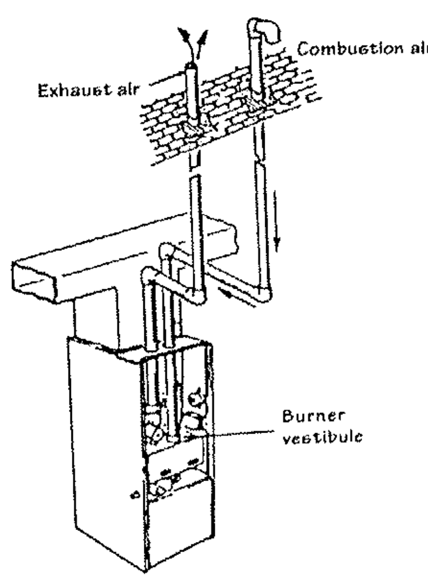
The draft hood also prevents downdrafts from affecting the performance of the equipment. The vent hood is usually made part of the furnace but in some instances a separate vent hood may be fitted to the appliance.

An oil-fired (and coal) furnace is usually equipped with a barometric draft control to regulate the draft just above the combustion chamber. Some large power gas burners may also use a barometric damper in lieu of a draft hood in a vent system.

Vent Damper



Vent dampers are automatic devices installed after a draft diverter in the furnace venting system. The damper closes the vent passage during the *off* cycle of the equipment. This device minimizes the loss of theat up the flue during the furnace off cycle and improves the overall operating efficiency of a standard draft hood furnace. Power vented furnaces do not use vent dampers.



Sealed Combustion

Some gas-fired furnaces (and even space heaters) employ sealed combustion. All combustion air is drawn from outside the building. These units are not fitted with a draft hood and are "air-isolated" from the space they are installed.
Furnaces are power vented.

In addition to the venting of combustion products found in the NFPA standards, NFPA Standard-211 covers chimney construction, fireplaces and venting systems.

Electric Equipment

The installation of electric furnaces and heat pump systems are covered in NFPA 90-A and 90-B, but additional requirements are detailed in NFPA 70 or 70A — the *National Electrical Code.*

Quite obviously, the electric code establishes minimum requirements for wiring the furnace or heat pump. As with piping fuel to fossil-fired furnaces, electric furnaces and heat pumps must have adequately sized electrical conductors to provide adequate electrical energy to the equipment. Procedures to provide this energy safely are detailed in the electric code.

Generally, one or more fused disconnect switches are required at the equipment. The number required depends upon the electrical rating of the furnace. Most furnaces will also provide a ground connection since the electric code requires that circuits to the furnace be *grounded.*

Power to the compressor in outdoor sections must also be fitted with an adjacent fused disconnect switch.

No Temporary Heat

A furnace should not be fired as a temporary heater for buildings under construction. Construction dust, construction chemicals, and low ambient air temperatures through the heat exchanger all may cause serious damage to the equipment. Manufacturers usually void any warranty when equipment is operated under these conditions.

Inspection

Designers of heating systems and field supervisors of heating installations must be familiar with local requirements which are generally based on the national standards just reviewed. In some instances, these individuals must be licensed to design and install systems. Many times, licensing is achieved through a written examination supervised by a heating "board" established by local ordinance. (See previous lesson on codes.)

Many localities also use "heating inspectors" to visit each installation, and they must "approve" the installation. If the installation does not meet local requirements, the designer/installer will be compelled to make changes before receiving approval.

System Adjustments

After completing an installation, the heating system must be tested, adjusted, and balanced.

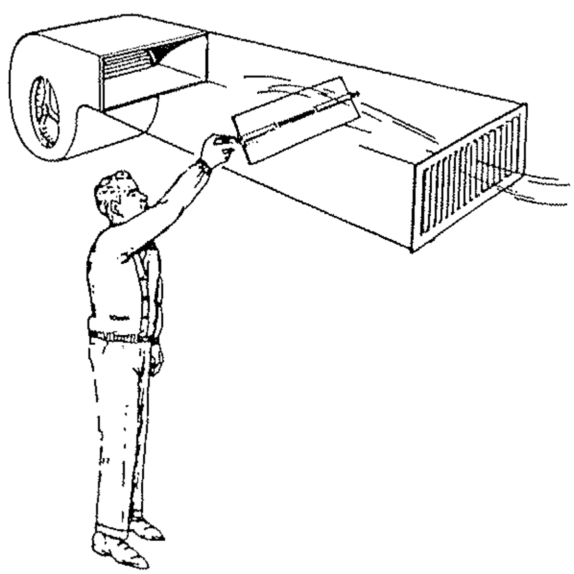
In the case of fossil-fuel fired equipment, a combustion test should be made. This consists of measuring carbon dioxide, oxygen, excess air, and carbon monoxide levels in the flue gases along with the temperature of these gases. With these two measurements, the combustion efficiency of the gas or oil burner can be determined.

Adjustments to combustion air supply, fuel input rate, and gas manifold pressure may be required to provide high efficiency operation.
Oversized equipment can be detrimental to operating efficiency. Ideally, the heating output of the equipment installed should match the calculated heat loss. Equipment that is more than *40 percent* oversized should not be selected whenever possible. Besides improving operating efficiency, comfort conditions under part load can be improved when equipment is properly sized.

On the other hand, if night setback thermostat operation is anticipated, over sizing does *shorten* the recovery time required to go from the night setting of say 62° to 72° for the morning. This could be very important at near design weather conditions. Occupants certainly do not want to wait hours for the house to get warm.

Balancing

Ideally, a properly designed air distribution system would be self-balancing. That is, the actual air flow rates to each space would be precisely as calculated. Because of necessary design assumptions and the use of available duct sizes, each system must be "fine tuned" to provide uniform temperatures in the building.



Balancing the system is nothing more than reducing the volume of air from one room that is overheating, and forcing it to another room that needs additional heat. This is accomplished by moving a volume damper installed in each branch run or (less desirable) by the volume damper right at the supply outlet. Because of this need to balance a system, volume dampers should be placed in all of the branch runs of the heating system.

Adjusting the total air flow through the system and to each heated space is important for good comfort.

There are two basic approaches to balancing a forced air system.

In large commercial systems, the air flow discharging out each register is measured using any number of different types of air flow and air velocity instruments.

The measured air flow is then compared to the design values, and air volume dampers are adjusted to increase or decrease the air flow accordingly.

Measuring air velocity (and volume) is one way to balance a system.

Accurately measuring air discharging from an outlet is difficult and time consuming. Also, changes to one register can affect air leaving another which requires a systematic approach to balancing a large system. Certified balancing contractors and technicians are often called upon to balance large systems. Personnel attend special schools to learn how to balance and are certified when they complete their training.
For small systems, no attempt is usually made to measure the air flow from each individual outlet. The system is balanced by simply measuring the *air temperature* in each space and then adjusting the air flow up or down to bring all spaces to within one or two degrees of the thermostat setting.

To measure the temperature simultaneously in each space, accurate thermometers are usually placed in the center of the space at table height. Balancing is normally undertaken on overcast days to minimize any effect of the sun, and also when the space is unoccupied or there is minimum internal occupancy load.

Once the system is balanced, the total system air flow is measured and adjusted by speeding up or slowing down the blower to comply with the *temperature rise* specified for the heating equipment. This is the difference between the return air entering the unit and the supply air leaving.

Continuous Circulation

Building heat loss is always occurring in cold weather. When the furnace blower is operated intermittently, exposed windows, walls and ceilings will cool the air in the room. This cooled air moves to the floor and builds up a layer of cold air. As we learned, this is called stratification or the stagnant layer. When the blower is started after being off for a long period of time, the cool air moves across the floor creating a very noticeable draft.

When the blower is operated continuously, you have the advantage of moving air throughout the building. This assists in maintaining a closer room-to-room temperature balance and smaller temperature gradients from floor to ceiling.

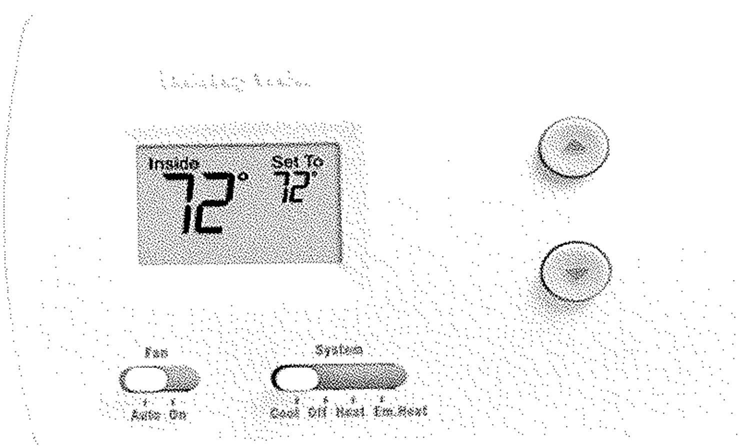
While it is difficult to measure, studies indicated a trade off between increased electrical consumption to operate a standard blower continuously (or near continuously) and the reduced fuel required to heat the building because of more uniform temperatures in the structure. (Lower temperatures near the ceiling, for example, reduce the heat loss through the ceiling.)

Others contend there may not be an equal trade off, and operating a blower continuously will cost the owner more money. This does not include the possibility that more frequent *on/off* cycles may reduce the expected useful life of a standard motor.

In any event, costs involved are likely to be small compared to the improved comfort provided by continuous blower operation. Furthermore, the performance of accessories such as a humidifier and high efficiency filters would also be affected by intermittent blower operation.

Continuous blower operation can be accomplished in a number of ways.

For those fan controls that are field adjustable, an *off* setting near 80° F is suggested. With this setting, or near this value, the blower will operate intermittently in very mild weather, but as the weather becomes colder, continuous or near continuous operation will occur. This is assuming that equipment is not seriously oversized and air flow in the system is not excessive.



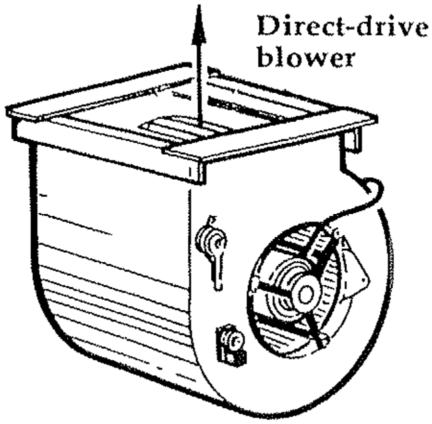
As we learned in the lesson "Automatic Heat," it is possible to install a thermostat with a fan switch option which allows the operator to choose continuous or intermittent fan operation. This is almost universally used for all heating units including electric furnaces and heat pumps.

Deluxe models of some heating units feature automatic *variable speed* motors that in effect provide continuous blower operation.

System CFM

While much more critical for cooling, the amount of air being circulated is a factor in heating as well. Too little air and people will complain about "being stuffy"; too much air and complaints about drafts will be heard.

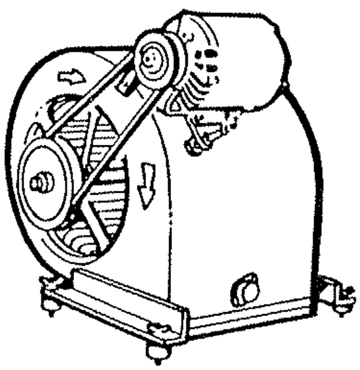
Heat pumps in particular are sensitive to air flow. Equipment is usually certified to operate between a *maximum and minimum* air flow rate.



Almost all residential equipment today features direct-drive blowers. The electric motor is directly connected to the rotating wheel of the blower.

Notable Note: There is a relationship between heat input and air temperature rise through the equipment. By measuring the air temperatures entering and leaving the equipment and knowing the heat input it is possible to determine the system airflow rate.

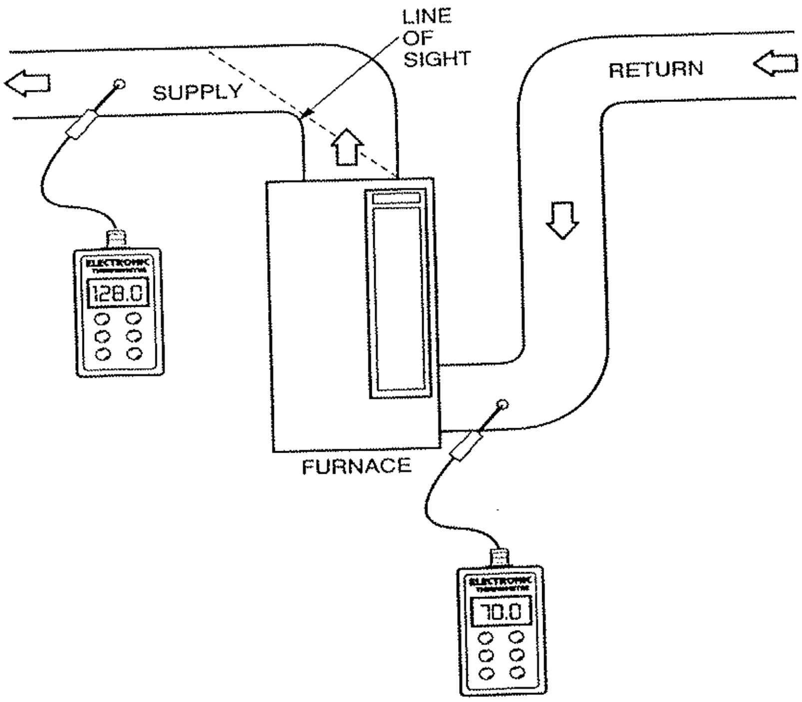
You may encounter on some older units and large commercial size equipment belt-driven blowers. The electric motor transmits power through a "V" belt to the rotating wheel of the blower.



Here's how total system air flow can be adjusted:

For direct drive blowers, *speed taps* are usually provided. By connecting electric power to the appropriate motor tap, blower motor speed can be increased or decreased. This of course increases or decreases the blower CFM.

Belt driven blowers can be speeded up or slowed down by making changes to the motor *pulley size.* If you had equal size pulleys on motor and blower, then they would run at the same speed. This is usually not done as the motor would not create enough torque to get the blower started.



Typically, the pulley on the motor is increased in size, either by an adjustable pulley or replacing the existing pulley with a larger one.

Temperature rise through the furnace varies with the system air flow rate.

Self-Check, Lesson 12 Quiz

You should have read all the material in Lesson 12 before attempting this review. Answer all the questions to the best of your ability before looking up the answers provided in the Answer Key.

Please indicate whether the following statements are true or false by drawing a circle around T (to indicate TRUE) or F (to indicate FALSE).

True False

1. T F Counterflow furnaces are intended for application in a single story ranch house with a full basement.
2. T F Routing ductwork to upper floors in two story homes requires advance planning and coordination with other trades.
3. T F A multi-level home cannot be zoned for heating.
4. T F Rooms located over a porch or garage pose no special heating problems.
5. T F Apartments are frequently short on space for equipment and ductwork.

In the following multiple-choice questions, choose the phrase that <u>most</u> correctly completes the statement, and check the appropriate box for the corresponding letter in front of the phrase.

6. To minimize pressure unbalance in a building and conserve energy, duct systems should be:

☐ A. insulated on the outside.
☐ B. insulated on the inside.
☐ C. sealed to minimize air leaks.
☐ D. oversize slightly to reduce fan pressure.

7. An unconfined space for a furnace installation is defined as meeting this requirement, providing:

☐ A. one cu ft of space per 20 Btu/h installed capacity.
☐ B. one sq ft of space per 20 Btu/h Installed capacity.
☐ C. 20 cu ft of space per Btu/h installed capacity.
☐ D. 20 sq ft of space per Btu/h installed capacity.

8. A double wall vent system limited to venting negative pressure Category I gas furnaces is a:

- ☐ A. type W vent system.
- ☐ B. type L vent system.
- ☐ C. type G vent system.
- ☐ D. type B vent system.

9. Adjusting the air flow to each room is the installation/startup procedure referred to as:

- ☐ A. damper tuning.
- ☐ B. fine tuning.
- ☐ C. system balancing.
- ☐ D. system zoning.

10. The supply air temperature rise through a furnace is dependent on:

- ☐ A. the thermostat setting.
- ☐ B. intermittent fan operation.
- ☐ C. continuous fan operation.
- ☐ D. system air flow rate.

For the completion-type questions, fill in the blanks with the word (or words) that most accurately completes the thought.

Key Words

servicing	regulated	hazard	approved	cleaning
smooth	air-tight	temporary	standard	combustion

11. Local building departments may stipulate that only AGA/UL or AHRI ____________ equipment can be installed in their jurisdictions.

12. Furnace placement must meet code clearances from combustible materials and allow adequate room for _______________.

13. Furnaces installed in closets must be provided with openings to supply adequate _______________ air.

14. Condensing furnaces must be vented through a system with __________ connections.

15. Because of the dangers of dust, corrosive construction chemicals and low ambient temperatures, furnaces should not be used for ____________ heat during building construction.

Check Your Answers!

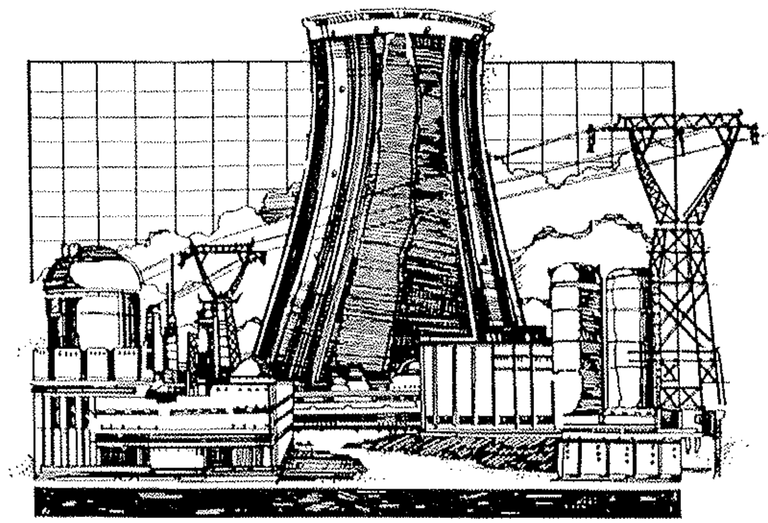
Lesson 13 Overview

There is a great deal of competition among energy providers. Heat with oil, no gas, or better yet, clean electric heat! However, rarely does the small building user or HVAC person really get to choose. Often, it's simply what's available or a project may be sold as an all-electric community as decided by others. One may have a choice of a piece of equipment, say, a gas furnace over a heat pump, an electric air conditioner over a gas air conditioner. Sometimes there's a choice of oil over LP or natural gas, but usually the major decision on energy on energy has already been made.

In this lesson, we intend to talk about energy choices, energy characteristics, and a little bit about energy costs.

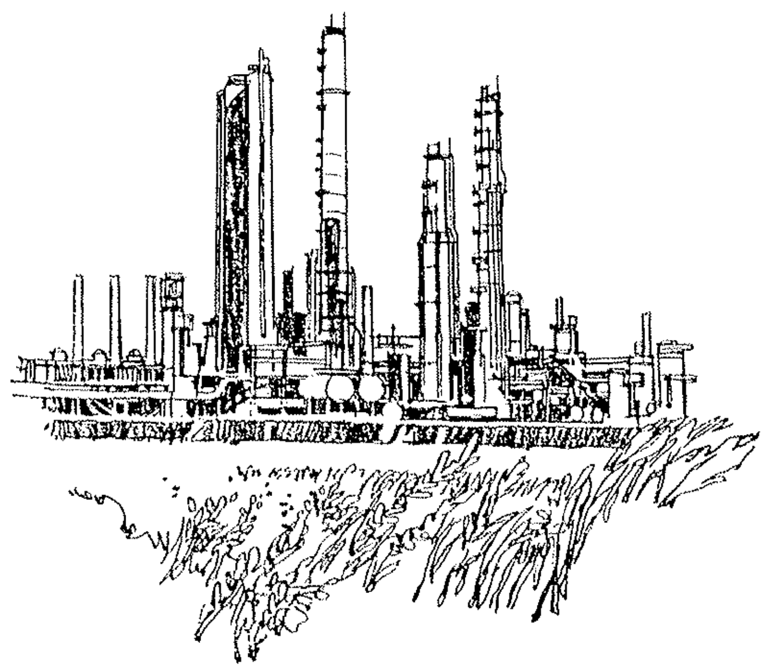
Now read Lesson 13 which begins on the next page.

Lesson 13: Energy Choices



The types of energy used to provide comfort heating include gas (natural and liquefied petroleum gases), oil, but also electricity and to a lesser extent even kerosene, coal and wood. While the HVAC person has little direct influence on the choice of fuels, it is useful to have an overview of fuel characteristics and selection criteria.

Electricity competes with gas and oil for building energy market share.



Fuel Considerations

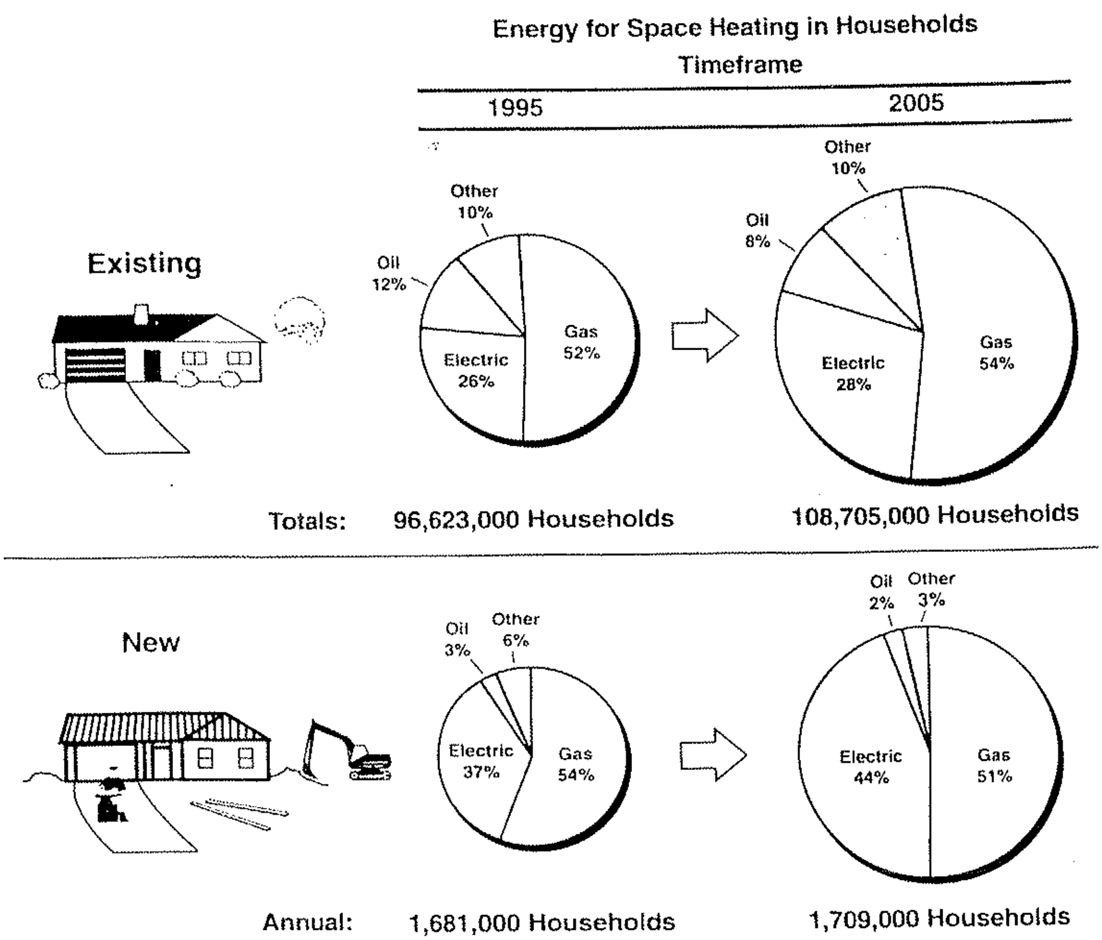
Selection of a fuel depends on many factors. However, in most localities, selection generally is between two or possibly three fuels ---- gas, oil, or electricity. Very often, the choice may not be an option for the end user, but a decision of the builder.

Essential considerations are obviously availability and dependability of supply, convenience in handling of the fuel, and the monthly cost. Is there a need for a back-up or emergency energy source (consider the needs of a hospital or nursing home)?

Local ordinances or zoning regulations may prohibit the use of certain fuels. Once coal was "king" of the fuels. Now in most areas ,smoke abatement ordinances rule out the use of coal for home heating, and require higher grades of coal and supervised automatic fuel burning equipment for other large applications.

Another example; many wood stoves may not meet local emission restrictions in several states.

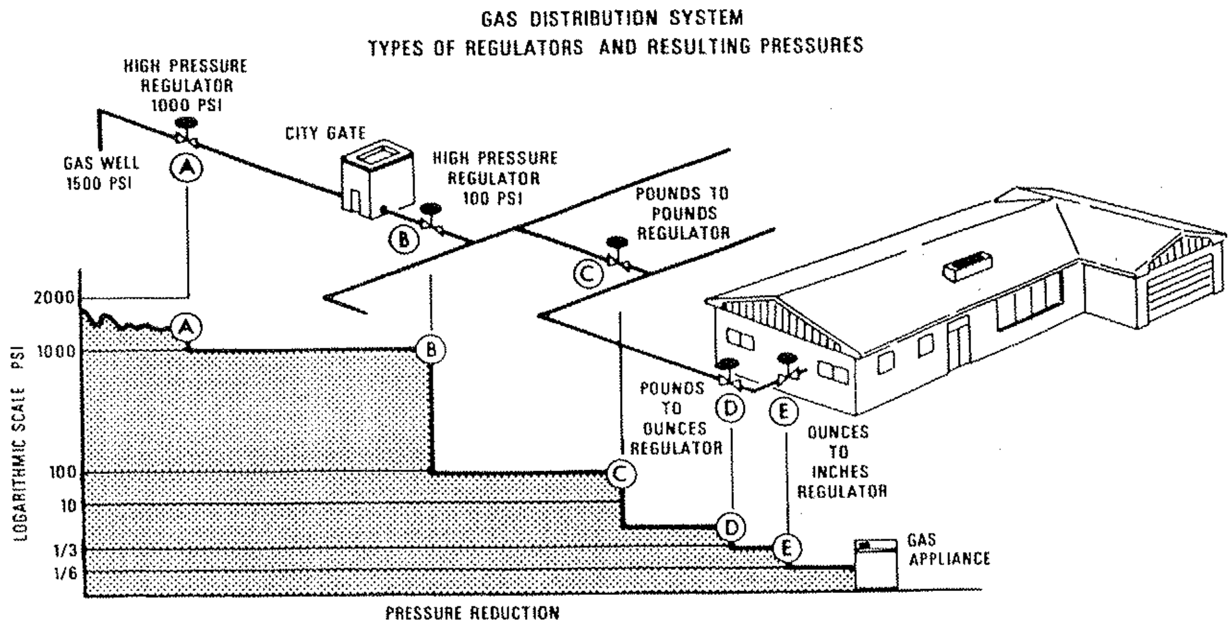
Natural Gas



Gas continues as the predominate energy sources for residential buildings.

The most popular fuel used today is *natural gas*. It is used in far more new installations than any other fuel -- around 75%. Natural gas fuels 51% of all existing heating systems in the U.S. In Canada, nearly 46% use piped gas as a main heating fuel.

A vast network of gas pipelines reaches a large part of North America. These pipes bring natural gas from the gas fields and often store it underground locations conveniently located to the gas markets. In many parts of the country, natural gas is a competitively priced fuel to burn. Furnaces and boilers which use gas are generally lower priced than equipment using other fuels. The efficiency of gas burning equipment is high, and no fuel storage facilities are required on the premises.



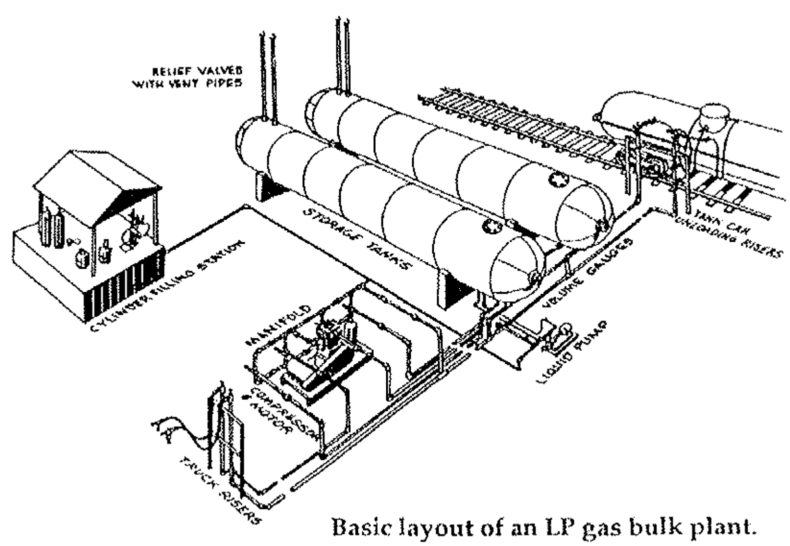
Gas distribution begins in the pipeline at about 1,000 psi (A) and ends up just several pounds at (D) and around 3.5 inches of water column at the furnace. 3.5 inches of water column equals 0.125 psi or 1/8th of a pound per square inch.

Other Gases

Manufactured gas has been used in some populated areas where natural gas was not initially available. Manufactured gas may be made from coal, or it may be converted from fuel oil. Manufactured gas was usually more expensive than natural gas and had a lower heat content. Nevertheless, it was a popular alternative at one time where natural gas was not available. In some places, manufactured and natural gas were mixed together to form a highly satisfactory fuel.

Beyond Gas Mains

In many rural areas where natural gas lines do not exist, liquefied petroleum (LP) or bottled gas is used. About 6 million homes used "bottled" gas as a main heating fuel. LP gas may be either a propane or butane based gas. In cold climates, *propane* is used because butane will not vaporize at temperatures below freezing at atmospheric pressure.



Basic layout of an LP gas bulk plant.

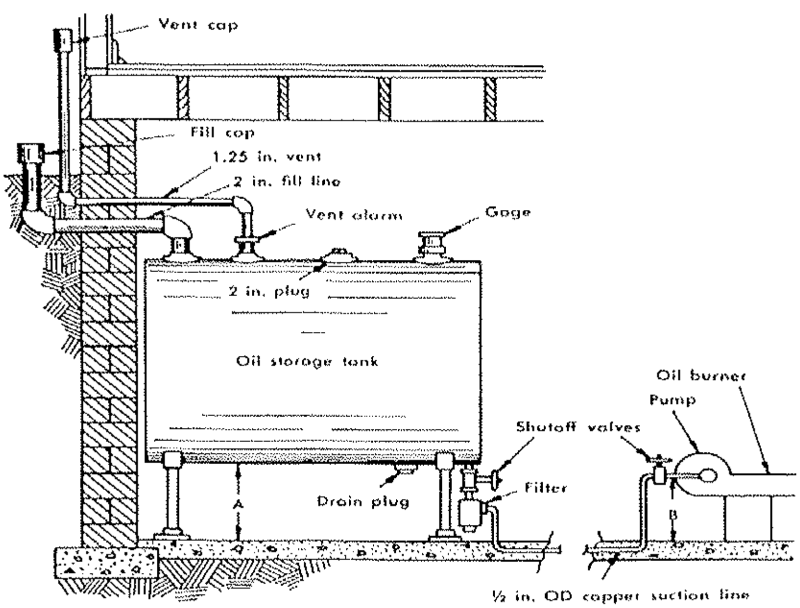
It is necessary to store LP gas in tanks located out-of-doors, usually right on the premises, above or below ground. There are pressure tanks which hold a combination of liquid and vapor. LP gas is *heavier* than air and safety and installation requirements must take this characteristic into account.

Gas fired heating equipment may be converted rather easily to use natural or LP gas. Liquefied petroleum gases are usually more expensive than natural gas and have higher heat contents than natural gas. (More on this later.)

Fuel Oil

In the Northeastern part of the U.S., fuel oil is popular for residential heating. About 38% of homes in this area use oil as compared to 4% to 6% in other areas. Oil equipment is generally more costly than gas, and it also requires fuel storage equipment on site which adds to installation expense. Many people burn oil because natural gas was not available or its cost was not competitive at the time their heating systems were installed.

It is difficult to determine the financial savings, if any, for a heating system replacement or conversion to another fuel. Conversion and operating costs must be carefully considered as well as personal preferences. Still, nearly 200,000 conversions to natural gas are reported each year - about 33% of which are replacing *electric* resistance heat systems.



UL approved 275 gallon oil tanks may be installed in basements. Local codes may allow two to be combined.

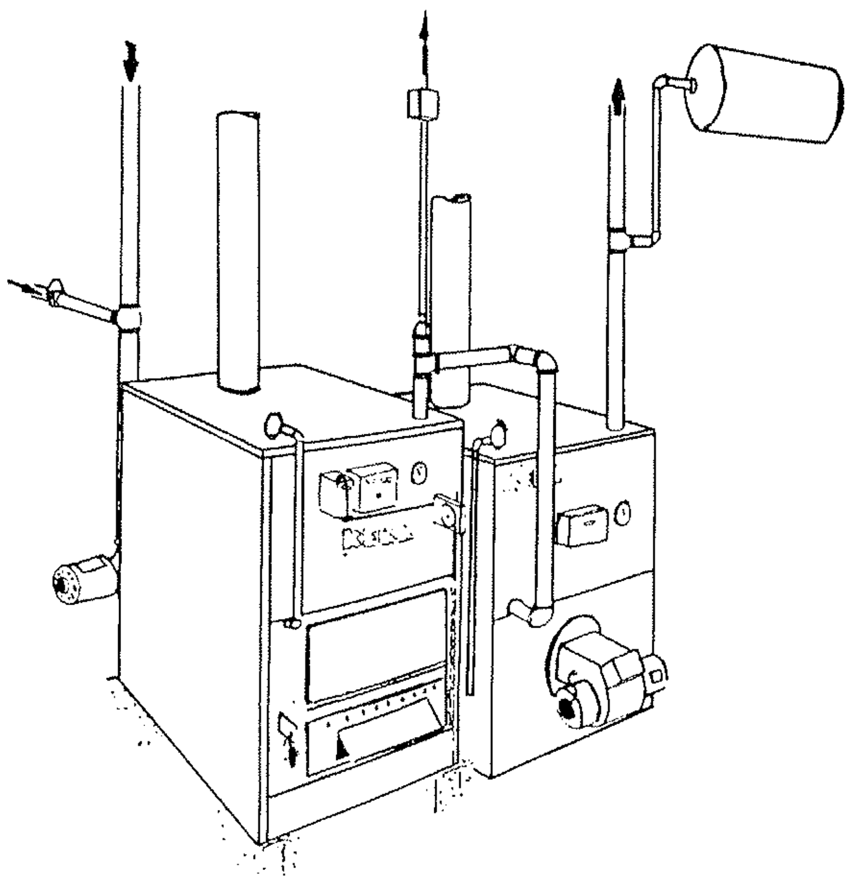
Oil may be more economical to burn than liquefied petroleum gases in some markets. Despite strong marketing efforts, oil usage for residential heating is on a gradual decline, but currently 14 million homes heat with oil.

Solid Fuels

Except in a few spot areas, solid fuels such as coal and wood are not important residential heating fuels. The fuel burning equipment for solid fuels is generally more expensive than gas or oil-fired equipment and requires much more user attention.

Coal lost its economical advantage to residential homeowners following World War II. Even with the use of automatic fuel burning equipment such as a stoker, coal is not as clean or convenient as gas or oil. Coal can, however, be an economical source of heat in areas close to the fuel supply and to large industrial users in many areas of the country. Fewer than 300,000 homes use coal today as a main house heating fuel.

Dual Fuel Systems



Dual-fuel equipment or a solid fuel add-on may be desirable in a rural area.

Urban homeowners converted their coal burning furnaces to gas or oil heating systems way back in the 1950s. Now, there has been some renewed interest in coal and wood-fired furnaces. In selected instances dual-fuel fired equipment may be a good solution. A typical dual-fuel furnace might be a gas or oil-fired unit with provisions for a secondary wood or coal combustion chamber. The wood or coal is the basic heat supply and the gas or oil burner is turned on when the solid fuel has been depleted or cannot satisfy the heating demand. Another option is to place a separate wood burning unit in parallel with the gas or oil unit. Houses in rural areas may be candidates for such a system.

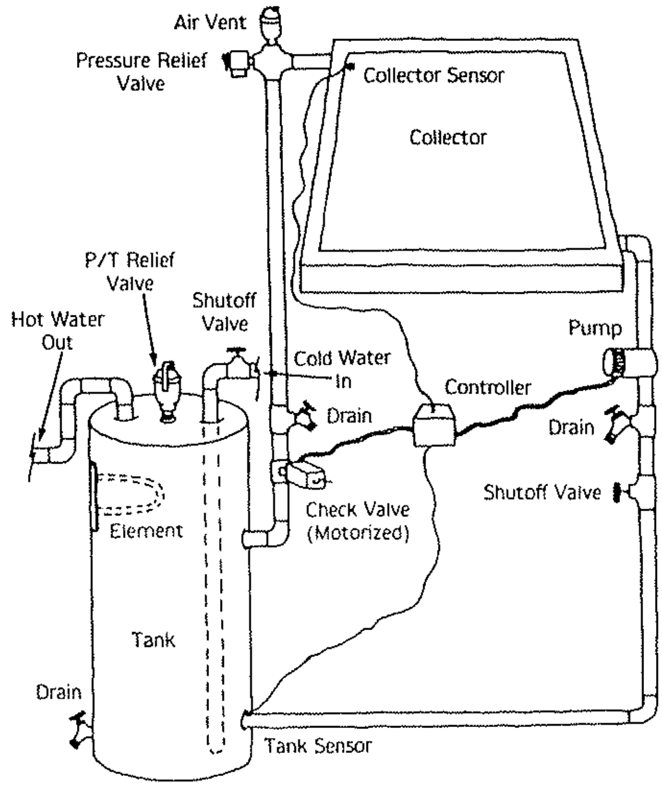
Electric Heat

Electricity has become an important means of heating residences. This is particularly true in those parts of the country where homes are extremely well insulated and power rates make electric space heating feasible. Over 25 million housing units feature electric heat.

Electric heating usually means a heat pump (see next lesson), which in cold climates is supplemented by electrical resistance heating or even a gas-furnace. Direct resistance heating in the form of baseboard convectors, ceiling panels, or electric furnaces may also be employed, but may not be competitive on operating costs when compared to a heat pump. Another plus to a heat pump is that it also provides central air conditioning.

With electricity, there is no fuel storage required, and it lends itself to completely automatic control just as gas or fuel oil. Marketing all-electric homes is practiced by many electric utilities.

Solar Energy



Because of both rising fuel costs and fossil fuel uncertainties back in the 1970s, there was great interest in using solar energy to supply at least part of the heat energy needed for space heating. A variety of systems were tested.

Many solar-assisted heating systems used *flat plate* collectors to capture heat from the sun and then deliver the heat by circulating water or air for eventual use in conjunction with a conventional heating system.

The *flat plate* collector consists of a blackened absorber plate which is heated by the sun's rays. The absorber plate is contained near the bottom of an insulated frame with one or two glass (or plastic) covers on top. The absorber plate temperature may average around 150° F for both water and air collectors on sunny days.

Heat collected can be directed right to the rooms to be heated, or alternately to a heat *storage* unit for later use at night or on cloudy days.

In liquid systems, large water tanks are most often used for storage, while rock storage bins are used in air systems.

Savings of from 50 to 70% in annual energy usage were demonstrated in favorable geographic areas (lots of sun, small heating loads).

There is an upturn in the installation and application of solar assisted heating systems in today's marketplace. Great strides have been currently made in solar products and application techniques. This segment of the industry will continue to grow as years go by.

High first costs have generally limited solar assisted heating to domestic water heating rather than whole house heating *(60,000 say it is their main house heating fuel, while 150,000 say they use solar for supplemental heat).*

Solar assisted domestic water heating systems usually forgo any storage capability to reduce complexity and cost.

A typical domestic water panel might be 3 feet by 7 feet. Any number of collector panels can be assembled in an "array" to provide various outputs.
More recent research has focused on solar photovoltaic (PV) panels. The solar cells convert solar energy directly into electricity. The cells are interconnected with the local utility grid. When a heat pump (or house electric service) requires more electricity then the cells produce, it is purchased from the utility; when demand is less, excess is sent to the utility. An experimental house in Florida required 400 square feet of PV panels.

The future trend in choice of "fuels" will be strongly influenced by political decisions - energy deregulation, clean air laws and the need for national energy reserves perhaps to a far greater degree than consumer, builder, or developer prefers. Energy conservation continues to be a national and world issue.

Heat Energy in Fuels

Natural gas is nearly odorless and colorless and is obtained from natural gas wells or in the upper portions of some oil wells.

The heating value of natural gas is normally given in terms of gas volume. Natural gas when burned will produce from 900 to 1,200 Btu/cu ft. The most common heating value is 1,000 or 1,050 Btus per cubic foot.

LP or liquefied petroleum gas is normally obtained as a byproduct of oil refinery operations. Propane, used extensively in cold climates, has a heating value of about 2,500 Btu/ cubic foot. Since propane is often *sold* by the gallon, it is useful at times to know that there are 92,000 Btus in each gallon.

Butane is another common LP gas. It has a heating value of 3,200 Btu/ cu ft. Butane liquid turns into a gas at much higher temperatures than propane (32° F at atmospheric pressure) ,so it is *not* a convenient heating fuel in cold regions of North America.

Heating oils are graded 1 through 6 according to their characteristics. A number 2 fuel oil which is most commonly used in residential type heating has a heat content that might range from 137,000 to 141,800 Btu/gallon.

The heat content of coal also varies with the type of coal. Classifying coals is not a scientifically exact exercise. Most listings of coals are according to tradition and may be quite arbitrary.

Most commonly used heating coals will provide about 11,000 to 14,000 Btus per pound.

Wood, as a fuel, will provide about 8,600 Btus per pound with zero moisture content. As the moisture content goes up, the heating value goes down.

Electricity as a fuel for space heating provides 3,413 Btu/h for each kilowatt consumed. (*A heat pump may under some circumstances provide 4 to 7 times as many Btus per kW consumed.)*

What about the sun as a fuel? How much energy is there for comfort heating? Just outside the Earth's atmosphere, the sun radiates about 429 Btus per hour per sq ft of surface normal to the sun. This is *the solar constant.* Typically, the maximum intensity on the Earth's surface might be 300 Btu/h-per sq ft.
Over the entire day, in winter, in northern climates, there might be from 1,500 to 1,800 Btus of energy available per sq ft per day.

Efficiently using this low density energy is still a challenge.

Cost of Fuel

Since wood is sold by the cord, coal by the ton, oil and LP gas by the gallon, and gas by the 100 cu ft (CCF), it is not easy to compare costs. Fuel costs also represent energy *sold,* not utilized, so efficiency is a consideration.

The table below is one example of an elementary attempt to compare fuels based on the cost of a *therm* of utilized heat. A therm, in turn, is simply 100,000 Btus. In the table, we see that a therm of utilized heat provided by natural gas selling at 80.00 cents a therm costs $0.89 as compared to $1.89 for oil selling for $2.25 a gallon.

To construct this table, we assumed a fixed or average sale price, while energy is often sold on a sliding scale - especially natural gas and electricity. You pay more for the first units consumed than charged for the next, and the next, etc. on a monthly basis. There are also other billing charges that are part of the utility invoice - service fees, "shipping" charges and taxes. A simple analysis, therefore, may not be highly accurate.

A **therm is 100,000 Btu. Table compares example cost of fuel as purchased, then cost based on heat (therm) actually produced to warm the building.**

Fuel Type	Sale Unit	Heating Value	Price/Sale Unit	System Efficiency	Cost/Therm Utilized
Nat gas	therm	100,000 Btu/therm	80.00¢therm	90%	$0.89
Oil	gallon	140,000 Btu/gal	$2.25/gal	85%	$1.89
LP gas	gallon	92,000 Btu/gal	$2.25/gal	90%	$2.71
Electricity*	Kwh	3,413 Btu/Kwh	8.24¢/Kwh	100%	$2.41
Coal	ton	27 million Btu/ton	$182/ton	65%	$1.04
Wood	cord	22 million Btu/cord	$90/cord	50%	$0.82

* Resistance heating systems, not heat pump

Self-Check, Lesson 13 Quiz

You should have read all the material in Lesson 13 before attempting this review. Answer all the questions to the best of your ability before looking up the answers provided in the Answer Key.

Please indicate whether the following statements are true or false by drawing a circle around T (to indicate TRUE) or F (to indicate FALSE).

True False

1. T F Natural gas is the predominate heating energy source for residential buildings.

2. T F Solid fuels often cannot be burned because of local emission restrictions.

3. T F LP gas is lighter than air and safety controls and installation procedures must include protection over this characteristic.

4. T F Natural gas furnaces cannot be converted to operate on (propane) gas.

5. T F Oil-fired equipment is less expensive than gas-fired units of the same size.

In the following multiple-choice questions, choose the phrase that <u>most</u> correctly completes the statement, and check the appropriate box for the corresponding letter in front of the phrase.

6. The current estimate of the number of homes, heated by oil is:

☐ A. 10 million. ☐ B. 14 million.
☐ C. 22 million. ☐ D. 44 million.

7. The most popular form of electric house heating is:

☐ A. resistance baseboard units. ☐ B. electric ceiling panel systems.
☐ C. electric space heaters. ☐ D. heat pump system.

8. Flat plate solar heating panels are most often used to supply heat for:

☐ A. domestic hot water. ☐ B. whole house heating without storage.
☐ C. whole house heating with storage. ☐ D. swimming pools.

9. The solar constant or the solar energy measured just outside the earth's atmosphere is:

☐ A. 300 Btu/hr sq ft at 12:00 noon. ☐ B. 300 Btu/hr sq mile at dawn.

☐ C. 429 Btu/hr sq ft normal to the sun. ☐ D. 429 Btu/hr sq ft per day.

10. The most common grade of fuel oil used for comfort heating is number:

☐ A. 2 fuel oil. ☐ B. 3 fuel oil.

☐ C. 4 fuel oil. ☐ D. 5 fuel oil.

For the completion-type questions, fill in the blanks with the word (or words) that most accurately completes the thought.

Key Words

propane	3,413	2,500	therm	natural gas	92,000
butane	6,280	100 cu ft	standard	137,000	8,700

11. Natural gas is sold by the CCF which is a/an ________________.

12. A/an ______________ is defined as 100,000 Btu.

13. LP gas has a heating value averaging about __________ Btu/cu. ft.

14. A one kilowatt heater would produce ____________ Btu/h of heat.

15. Because ____________ will not vaporize at temperatures below freezing at atmosphericpressure, ______________ is used as the LP gas in cold climates to avoid using energy to heat the liquid fuel in the storage tanks.

Check Your Answers!

Now compare your answers with those given in the answer key at the back of this book. The answer key also directs you to a page in the lesson to review the text for any questions you may have missed.

Lesson 14 Overview

Not surprising, there are other types of central heating besides a gas or oil-fired furnace connected to an air distribution system. And we are not talking about the various types of inspace equipment mentioned in Lesson 6.

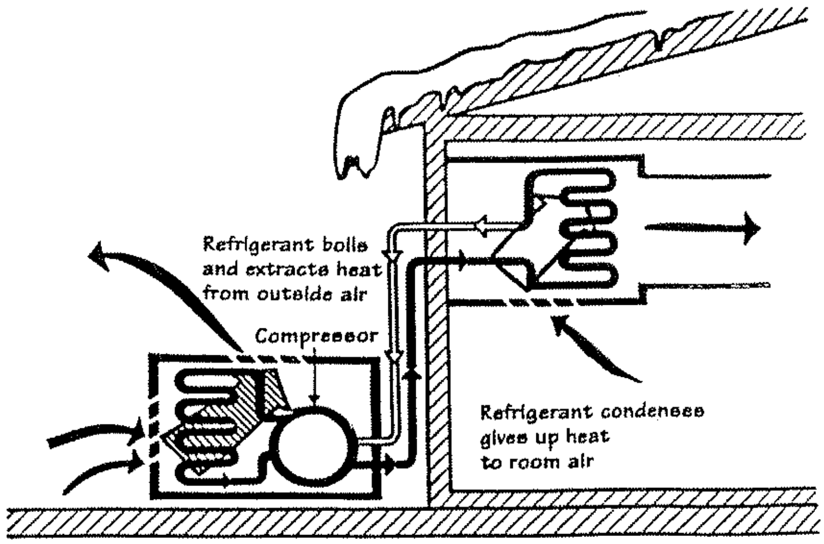
The first alternative to a ducted furnace system is a ducted heat pump system. A totally different approach is hot water heating --- called hydronic heating. Heat pumps and hydronics are the focus of this lesson.

Now read Lesson 14 which begins on the next page.

Lesson 14: Other Systems

The Heat Pump

In the previous description of warm air heating equipment, a fuel was burned to produce heat, or electricity was converted to heat by means of resistance heating elements. Actually, the second most popular method of providing ducted air heating (after a gas furnace) is by means of the air-to-air heat pump. More than 11 million homes are heated (and cooled) by heat pumps.



An air-to-air heat pump is a popular second choice to provide central warm air heating and cooling in new construction.

Heat is produced using a refrigeration cycle. In this approach, a fluid (the refrigerant) ---

- boils in coils located outdoors to extract heat from outside air; then refrigerant gas is
- compressed to a higher pressure and temperature; and then
- condensed in an indoor coil which gives up heat to the circulating room air.

The air source heat pump produces a great deal of heat for the electric energy consumed. As an example: one kW of electricity --- consumed in an electric heater --- provides 3,413 Btu of heat. One kW of electricity driving a heat pump can result in as many as 6,826 to 17,065 Btus being delivered for heating. Btu/h output is dependent upon outdoor temperature. This obviously means a cost saving to the homeowner.

The ratio of the heat output divided by the kilowatt hours used to produce the heat over a winter is called the Heating Seasonal Performance Factor (HSPF) of the heat pump unit. Normally, heat pumps HSPF range is from 6.5 to just over 10.0 Btu/h per watt.

For an air-to-air heat pump, as the outdoor air gets colder, the "efficiency" of the heat pump decreases. The compressor has to work harder to extract more heat from colder and colder air. You won't get 6,826 Btu/h for each kW as suggested. The HSPF goes down, capacity falls off and energy costs go up.
At some outdoor temperature, the heat pump's output may be just enough to satisfy the building's heat loss. This is the "balance point." Below this temperature, supplemental heat -- either electric heaters, gas, or oil furnace must be turned on to make up the difference in Btu/h capacity.

A heat pump can also be designed to extract heat from water, say from an open well or from the earth itself through water coils buried in the ground. In either case, heat is extracted, and pumped by the compressor into a coil, which gives up the heat to the circulating room air.

Earth-coupled (geothermal) and water-source heat pump systems provide a more consistent heat output and consistent HSPF than do air-to-air heat pumps. This means lower annual operating costs. On the other hand, installed costs are higher for the geothermal systems.

The air distribution side of a heat pump system is essentially the same as for a furnace, with the exception of the supply air temperature. The discharge temperature leaving a heat pump is usually less than for a gas or oil-fired furnace. This may require a higher system CFM and perhaps a larger main duct or more branch runs. However, if cooling is part of the furnace system, which is usually the case, then the air distribution system will probably be the same size for both types of equipment.

Hydronic Heating

A *hydronic* heating system circulates a hot fluid to distribute the heat "generated" in a *boiler* to each room.

Hot Water System ---

The most common hydronic system uses hot water flowing through copper pipes to distribute heat. These pipes connect a boiler (or a domestic water heater) to radiators, convectors, or other suitable water-to-air heat exchangers located in each room.

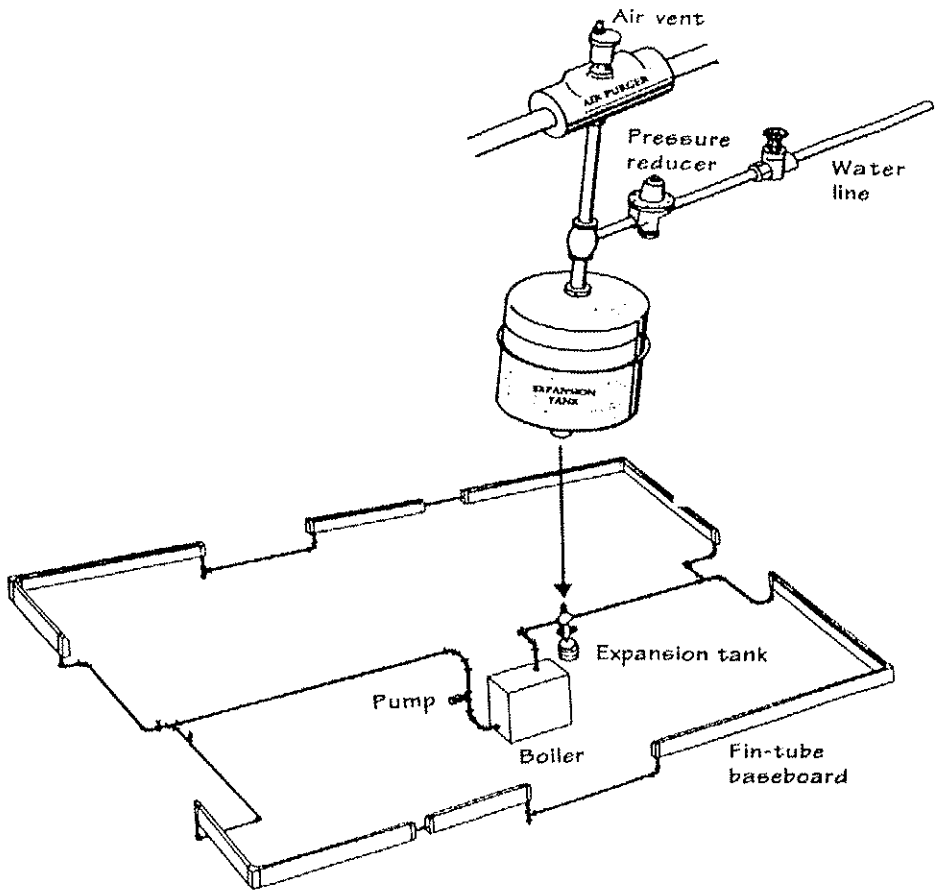
Hot water heating also began as a gravity system. In a gravity hot water system, the heat exchangers (radiators) in the room must be located at a higher level than the boiler. The water heated by the boiler will rise through the pipes to the radiators and then flow back to the boiler as it becomes cooler. Circulation through the pipes dependeds on the small force produced by the difference in density of the water due to the difference in temperature between the supply and return pipes. Consequently, the pipes had to be large in diameter to assure low resistance and an adequate flow of water.

Forced Hot Water ---

In the modern forced hot water system, a pump is used to circulate the water from the boiler through the radiators and then back to the boiler. This serves the same purpose as a blower on a forced warm air heating system. A circulating pump permits faster and more efficient circulation of water and also permits smaller sized pipes to be used. Copper tubing as small as ¾" inside diameter may be used (there is even some use of ½" tubing) in place of the old standard 3 inch or larger piping. The pump also eliminates the necessity of always having the radiators positioned higher than the boiler.

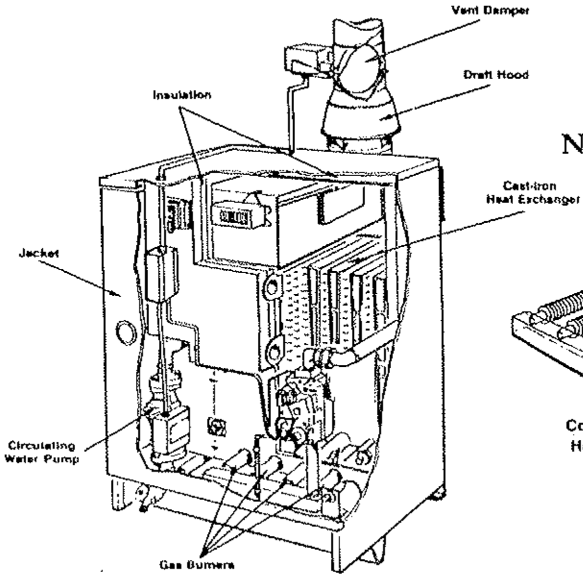
Boilers ---

The ordinary homeowner quite often considers a furnace and a boiler as the same device. A boiler is in reality quite different from a furnace.

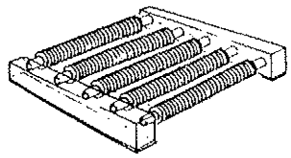


A furnace is designed to heat air effectively; boilers are designed to heat water. Where a furnace uses a blower to move air over the heat exchanger, a boiler is equipped with a pump to circulate water through channels that are heated by hot combustion gases from burning gas or oil.

A common configuration for a hydronic heating system a is two-circuit, series loop baseboard system arrangement. Note the use of a closed expansion tank system used to control pressure due to changes in water column as it is heated.



Natural Draft Boiler



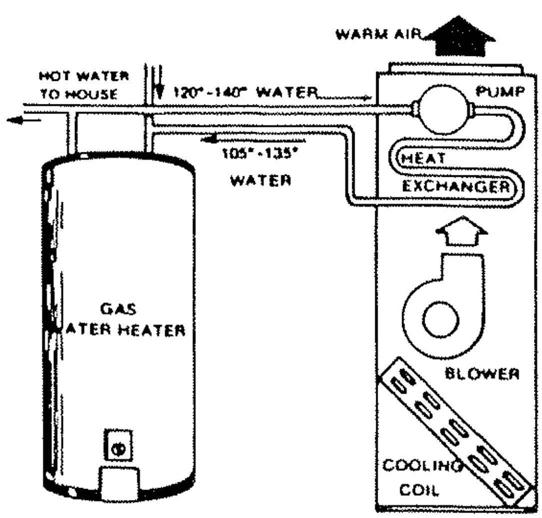
Copper Fin-Tube Heat Exchanger

Most small boilers feature cast iron heat exchangers. Steel or copper fin-tube heat exchangers are used in alternate designs. They are lighter and store less water than cast iron units. While most boilers use natural draft, some boilers are marketed with mechanical draft combustion systems.

A boiler with an IBR (Institute of Boilers and Radiators Manufacturers) or SBI emblem indicates that the boiler has been tested in conformance with the testing code of the Hydronics Institute, a division of the Gas Appliance Manufacturers Association (Now the American Heating Refrigeration Institute). Boilers must also meet the construction code of the American Society of Mechanical Engineers (ASME).

Boiler ratings include input, and both net output and DOE heating capacity ratings. Boilers are usually selected based on their **net rating** for residential work.

The difference between net and DOE heating capacity is simply a built-in allowance for piping losses (much like ductwork heat loss) and a pickup factor.



For appliances with moderate heat loads, slightly oversized water heaters can be used to provide heat for both space heating and water.

A third component in a hot water heating system is an *expansion tank*. The expansion tank accommodates the change in water volume after it has been heated. This prevents excessive pressure build up in the system.

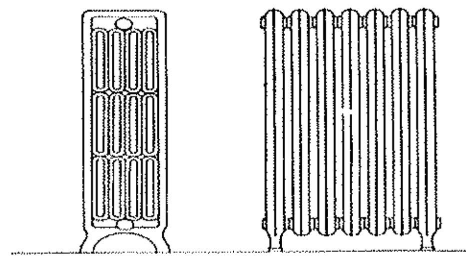
An open (to the atmosphere) expansion tank used in old gravity systems must be located above the highest point of the system, usually in the attic.

A modern closed tank operates with a cushion of air that changes volume. A closed tank may be located at any point, either above or below other parts of the heating system, but is usually placed at the boiler discharge line. At this location, it can be made an effective part of an air removal system since this is the hottest point in the system.

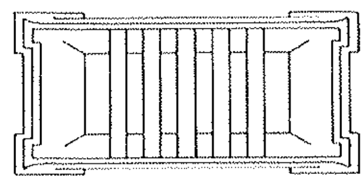
Air trapped in a hot water system can become very noisy and impede system operation. When heated, air in the water percolates, separates from the water, and can be readily purged.

Steam Systems ---

It has been a number of years since steam heating systems have been installed in residential applications. However, many of these systems can still be found in older structures. Steam heating systems have a boiler which generates steam. This steam is conveyed to the structure to the radiators under pressure. In the radiators, the steam condenses back into water as it gives up its heat to room air. The condensate (liquid water) is then returned to the boiler.



Small tube radiator (above), wall radiator (below).



The steam pressure may be above atmospheric pressure, or the system may operate in a vacuum with steam temperatures at temperatures below 212° F --- the boiling point of water at atmospheric pressure.

Steam heating systems may have installation economies over hot water heating systems in industrial buildings where steam is required for other processes.

Radiators ---

Radiators are heat exchanger units used in steam and hot water heating systems to deliver heat to the room. One or more units may be installed in each room of a building.

The term radiator refers to a heat exchanger that emits a large part of its heat to a room by radiation. Traditionally, this meant a cast iron floor standing radiator, but small tube and European tubular steel and flat panel units are also included.

An exposed radiator emits roughly half of its heat by radiation --- the rest by convection air currents.

The amount varies with the size and number of radiator sections. In general, a thin radiator, such as a wall radiator, emits a greater part of its heat by radiation than does a thick radiator.

When a radiator is enclosed or shielded, the proportion of heat emitted by radiation is reduced. The balance of the emission occurs by convection as the air contacts the hot surface. This heated air rises and circulates and mixes with room air.

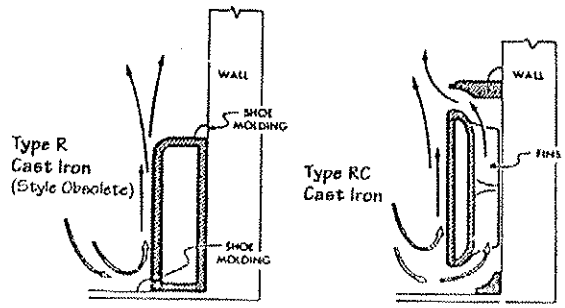
The color of the radiator has no significant effect on performance, unless the radiator is painted with a metallic paint such as a bright aluminum.

Baseboard ---

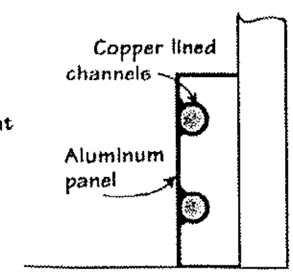
Baseboard units about 8 inches high may be installed along a wall in place of wood baseboard trim. Several types have been developed --- radiant cast iron, radiant aluminum with copper water pipe in back, radiant-convector cast iron or steel, and finned (copper) tube baseboard. The radiant-convector cast iron baseboard has fins on the back surface through which the room air passes. Thus, radiant heat is emitted from the front surface and convection heat by the air passing through the fins on the back surface.

Fin-tube baseboard is primarily a convection heating device with the highest Btu/h output per foot of length of all the baseboard types.

Baseboard



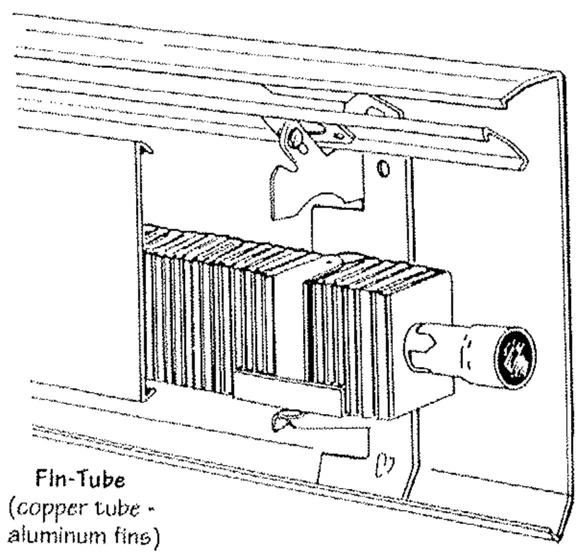
Convectors---



The term convectors refer to a unit which emits a large proportion of its heat by convection. These are finned heating elements enclosed in metal casings of various heights and depths. These cabinets can be fully exposed in the room, partially recessed, or fully recessed in the wall.

Convectors transmit only a small proportion of their heat capacity by radiation. Room air enters an opening at the bottom of the enclosure, and passes through the fins, and enters the room from an opening at the top of the enclosure.

The heat emission rate is influenced by the vertical distance between the heating element and outlet grille at the top of the convector cabinet which produces a "chimney" effect to increase air flow over the heating element.



Fin-Tube
(copper tube - aluminum fins)

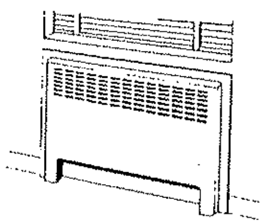
Panel Heating ---

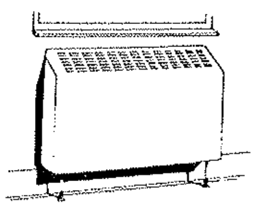
Radiant heating, or more correctly, panel heating, is a method of space heating that employs large heated surfaces of a room. These panels operate at relatively low surface temperatures from 80° to 125° F.

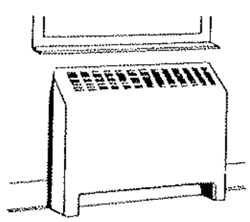
The heating elements usually consist of warm water piping, or occasionally low temperature electrical resistance elements, embedded in, or located directly behind ceiling, wall, or floor surfaces.

Even though called radiant heating, a great deal of heating is still achieved through convection transfer between the warm panel and room air currents.

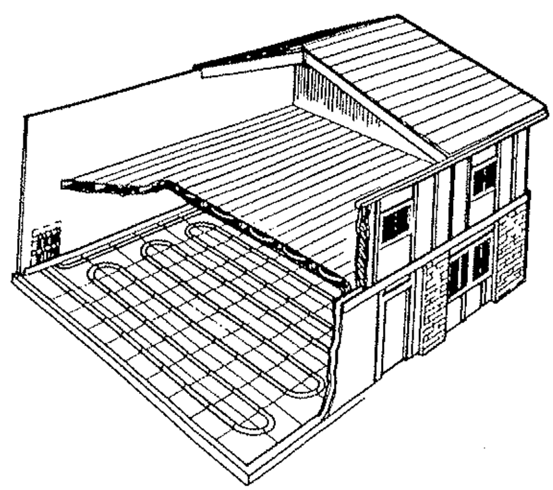
In addition to heating occupied spaces, panel systems can be used to heat sidewalks and driveways to melt snow and eliminate the formation of ice and snow during the winter months.


Semi Recessed


Wall Hung


Standing

Convectors


Floor panel system

Self-Check, Lesson 14 Quiz

You should have read all the material in Lesson 14 before attempting this review. Answer all the questions to the best of your ability before looking up the answers provided in the Answer Key.

Please indicate whether the following statements are true or false by drawing a circle around T (to indicate TRUE) or F (to indicate FALSE).

True False

1. T F A water source heat pump is second only to the gas furnace in popularity as equipment choice for central warm air heating.

2. T F A heat pump is more economical to operate than straight electric resistance heating.

3. T F The Btu/h capacity of an air-to-air heat pump decreases as the outdoor temperature rises.

4. T F The supply air temperature leaving an air-to-air heat pump is lower than that supplied by a conventional gas furnace.

5. T F Earth coupled heat pump systems have lower first costs than air-to-air heat pump installations

In the following multiple-choice questions, choose the phrase that <u>most</u> correctly completes the statement, and check the appropriate box for the corresponding letter in front of the phrase.

6. Water moves through a forced hot water system by means of:

A. ☐ gravity.
B. ☐ thermal expansion.
C. ☐ a circulator or pump.
D. ☐ the TD between room air and water.

7. The closed expansion tank is placed in a hydronic heating system to:

A. ☐ control the expansion of the piping.
B. ☐ control the water pressure in the system.
C. ☐ reduce the amount of water circulated.
D. ☐ reduce the size of the pipe.

8. The most common type of US manufactured atmospheric boiler features a:

A. ☐ copper fin heat exchanger.
B. ☐ steel heat exchanger.
C. ☐ cast iron heat exchanger.
D. ☐ brass plated loop exchanger.

9. In residential work, boiler sizing is based on the unit's:

A. ☐ net Btu/h input.
B. ☐ net Btu/h rating.
C. ☐ DOE heating capacity.
D. ☐ gross Btu/h input.

10. A radiant panel heating system transfers heat into a room by:

A. ☐ radiation.
B. ☐ convection.
C. ☐ radiation and convection.
D. ☐ convection and evaporation.

For the completion-type question, fill in the blanks with the word (or words) that most accurately completes the thought.

Key Words

Fin-tube	6.5 to 10	convector	180 to 212	10 to 14
80 to 125	panel	crossover	balance	R-C cast iron

11. The outdoor temperature when the Btu/h output of the air-to-air heat pump just meets the Btu/h heat loss of the structure is called the __________ point.

12. Heating Seasonal Performance Factors (HSPF) for air-to-air heat pumps range from _______ to _______ Btu/h per watt.

13. The baseboard unit with the highest Btu/h rating per foot is the _____________ baseboard.

14. In addition to space heating, ____________ systems can be used to heat driveways and walkways to melt snow.

15. Ceilings and floors used in radiant heating operate at surface temperatures between ________ to ________° F.

Check Your Answers!

Lesson 15 Overview

There really isn't any secret process to be good at service and repair. But, does experience ever help!

Having said that, there are two very basic things one needs to do to be successful in the service and troubleshooting side of the technology.

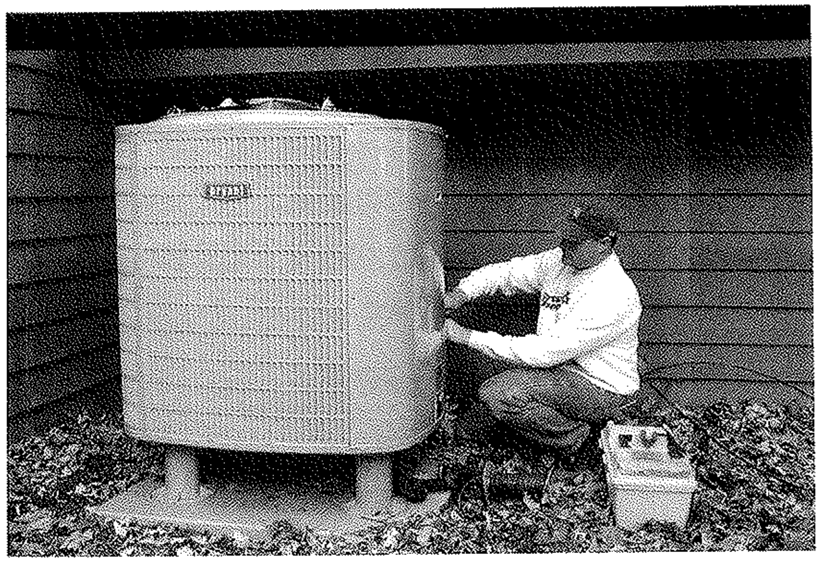
Number one --- study and use the servicing information supplied by the manufacturers of the equipment and controls.

Number two --- understand and apply the basic heating principles as described in this course.

In this your last assignment, we discuss the underlying causes of heating system failures by establishing four basic cause categories:

1. Part failure.
2. Improper adjustment.
3. Poor installation.
4. Poor design.

Lesson 15: Troubleshooting Heating Complaints



Good design, good installation, and good service --- all three are necessary to meet customer needs and assure customer satisfaction.

A basic understanding of the theory behind troubleshooting heating complaints is valuable to any heating industry person whether or not one may be directly involved with customer service or not.

There are three kinds of service performed on a heating/cooling system. First is the installation start-up, during which the system becomes operational and is tuned for optimum efficiency. (See Lesson 12 on balancing.)

The second phase of servicing must be done safely. When working around heating/cooling systems, care must be taken to guard against burns and electrical shock.

Regular Maintenance

The quality of service can make the difference between success and failure in the HVAC business. The customer expects not only a good installation, but also prompt and efficient service in the event of trouble.

Some new construction contractors identify service as a problem rather than a potential profit center. Very often these firms cover one year warranty service and let other firm *be in the service business.*

On the other hand, many successful contractors sell their customers on the practical aspects of annual maintenance contracts. This means inspection of the heating equipment often before the start of the winter season and in the spring before the start of the cooling season to insure that the system is in good working order. This will reduce the probability of an emergency service call in the middle of the hottest or coldest season.

A good service operation is also an important conduit to the replacement and modernization business.

Troubleshooting - the 3rd Phase

There is no substitute for experience when it comes to efficient servicing. No text could possibly cover all service problems. Obviously, the importance of understanding and using detailed service instructions provided by the manufacturer of specific makes and models of equipment and controls cannot be overemphasized.

Unless an individual is an extremely experienced serviceperson, the basic approach to troubleshooting has simply got to be by means of a process of elimination. Start off by *listening* carefully to the complaint and the symptoms as described by the user.

Avoid guesswork. Instead, rely on a systematic approach to the problem. Of course, not all guesswork can be avoided. The so-called "educated guess" of an experienced service technician can often save time and money. Past experience greatly assists the organized troubleshooting approach.

When a heating system fails to perform properly, the underlying cause will usually fall into one of four categories:

- Part failure
- Improper adjustments
- Poor installations
- Poor design

A part failure is, perhaps, the easiest malfunction to correct since, once detected, a simple replacement puts the system back into satisfactory operation. Many part failures are quite obvious; for example, a broken belt, a worn out bearing, or an open circuit breaker. Some, however, require considerable skill to detect. In between, there are failures such as a leaking pipe joint, a burned-out motor capacitor, or a defective control. Following a process of elimination procedure may be necessary in order to pin-point the *root cause* of these problems.

Parts fail for several reasons, all of which can be summarized as follows: (1) defective in manufacture, (2) subject to conditions beyond their rated capacity, (3) not properly maintained, and (4) worn out from usage.

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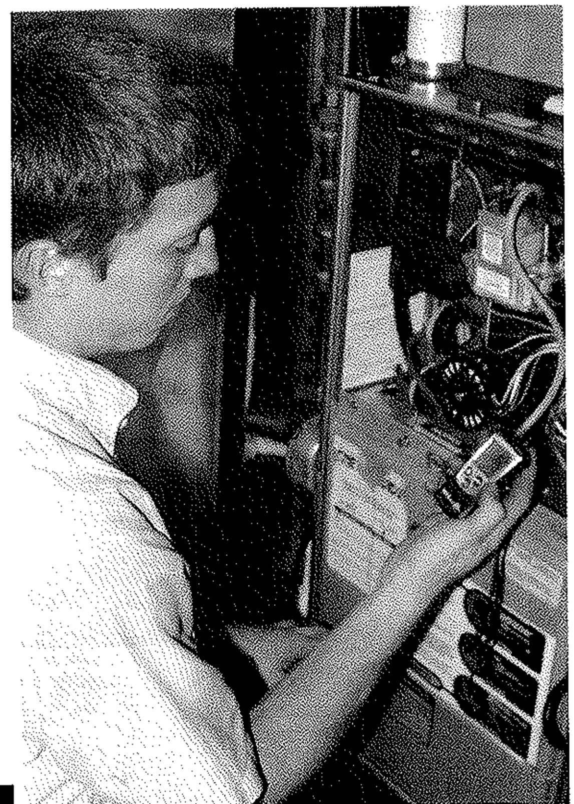
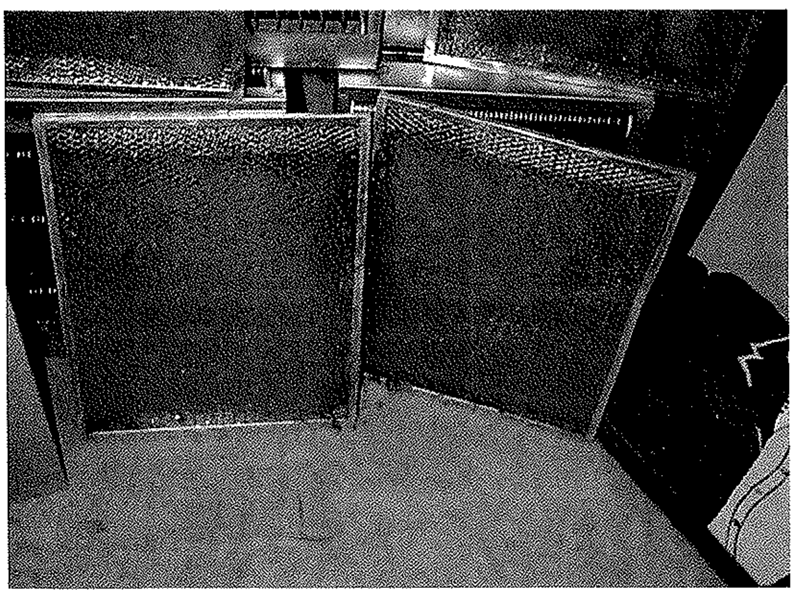
Adjustments

The second major reason why a system fails to perform properly is improper adjustment. As compared to a system which does not function at all because of a part failure, a system that is not in proper adjustment may cause the owner great dissatisfaction. The reason is that, in the former case, the owner is sure something is wrong so the service person is called and the condition is corrected. When a system is out of adjustment, however, the condition may develop so gradually that the owner may not be certain that something is wrong until after a period of considerable annoyance.

A system which is out of adjustment may result in an owner complaint because the:

- Heating capacity seems to be decreasing.
- Heating is uneven and drafty.
- Operating costs are rising.
- Noise level is rising.





Reduction in heating capacity is very often due to restricted air flow. The number one cause is dirty air filters. Every 5 percent reduction in airflow rate results in a capacity reduction of about one percent. Dirty fan blades can also reduce air delivery. Partially closed dampers and rugs, drapes or furniture placed so that air cannot move freely through a supply outlet or return grille will all affect heating performance.

Customer Complaints and Traditional Causes

"My furnace isn't giving me any heat"

Fuses could have blown. Gas line may be turned off. Fuel oil tank may be empty. Dirty filters. Blower or burner motor failed. Blower belt broken. Defective control. Low gas pressure. Pilot ignition system out. Inducer motor defective. Fuel oil burner nozzle stopped up. Fuel oil line frozen. Thermostat contacts not made or defective thermostat.

"Not enough heat through the whole house"

Clogged filters. Inadequate sized unit. Insufficient input. Limit switch setting too low. Return air grilles obstructed. Air distribution system improperly sized. Wrong thermostat or thermostat settings. Thermostat affected by sun or heat from other sources. Improper setting of operational dip switches.

"It's drafty -- My feet are cold"

Improper distribution system design. Intermittent blower operation. Improper blower speed. Improper blower control setting. Furnace too large for house. Lack of insulation or excessive infiltration around windows and doors.

"The furnace is noisy" or "Fan is squeaking"

Blower noise because of bad bearings. Misalignment of blower pulley or motor pulley. Expansion and contraction of heat exchanger or ductwork. Solenoid valves. Improper adjustment of burner. Short supply or return ducts.

"Too much variation in temperature"

Too much thermostat differential. Improper heat anticipation in thermostat. Improper thermostat location. Incorrect blower speed setting and/or control setting. Unit too large.

"Furnace runs all the time"

Inquire if the house is at temperature of thermostat setting. Determine if the burner is on or just the blower running. Summer ventilation switch may be left on.

"Fuel bill too high"

Clogged or extremely dirty filters. Fuel prices increased since last year. Colder than usual winter temperatures. Poor burner installation or adjustments. System not balanced. Insufficient insulation or weather-stripping. Furnace is being over fired.

"Windows sweat"

Crawl space not covered with vapor barrier. Lack of storm windows or insulated glass. Unusual amount of canning or cooking. Improper venting of appliances such as furnace, clothes dryer or hot water tank. Too high of a humidistat setting. Humidifier installed without a humidistat control. Bathroom exhaust fans not working.

"Furniture drying out" or "Getting shocked from rugs"

No humidifier. Improper water supply to humidifier. Excessive infiltration.

"TV set is being bothered"

Blower not grounded. Electrical circuit not grounded. Humidifier motor not grounded.

"I See Soot"

Burner out of adjustment. Vent down drafting. Inadequate combustion air supply. Blower operating intermittently. Need longer blower cycles. System not balanced or improperly sized. Ducts need insulation. Register closed. Damper turned off.

"Blower runs all night"

Summer ventilation switch on. Fan control stuck. Outside temperature sufficiently low enough to keep blower running between cycles. Dirty filters.

"There's cold coming out of the registers"

Blower control set too low. Blower running too fast. Register or damper adjustments need to be made. Air feels too cool because of velocity.

"My floors are cold"

Air filtration through doors or windows. Lack of vapor barrier. Lack of insulation. Poor register selection or location. Undersized returns. No continuous air circulation. Open crawl space vents. Crawl space not insulated. Uninsulated slab. Garage doors open.

"My fuel oil furnace exploded"

Delayed ignition. Electrodes dirty and not properly set. Electrode porcelain cracked. Chimney plugged. Lack of combustion air.

"Furnace won't shut off; House is hot"

Thermostat stuck. Gas valve or relay stuck. Short in electrical wiring.

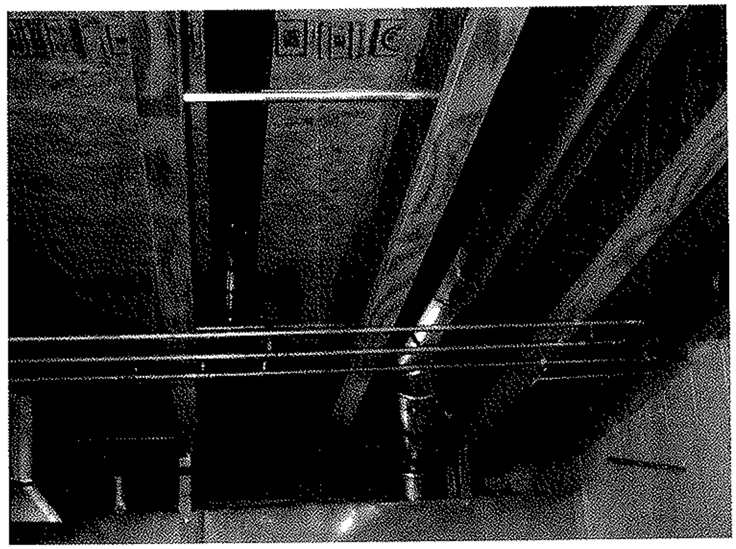
"Basement too hot"

Filters dirty. Leaks in duct system. Duct system uninsulated. Inadequate ventilation.

"Cold basement"

Need to install a supply outlet and return air opening.

Poor Installation



Operating problems associated with poor installation most often involve the air distribution system. Fitting and duct connections are not fastened securely or made airtight. Ductwork is inadequately supported.

Construction debris is left inside the duct system or ducts are crushed or otherwise damaged at the job site.

The furnace vent system is also a trouble spot because of poor assembly and supports.

Trade workers often "hot wire" furnaces during construction to keep warm with possible damage to heat exchangers or the blower compartment is clogged with drywall dust and other foreign materials. (Please review the previous lesson on installation.)

Poor Design

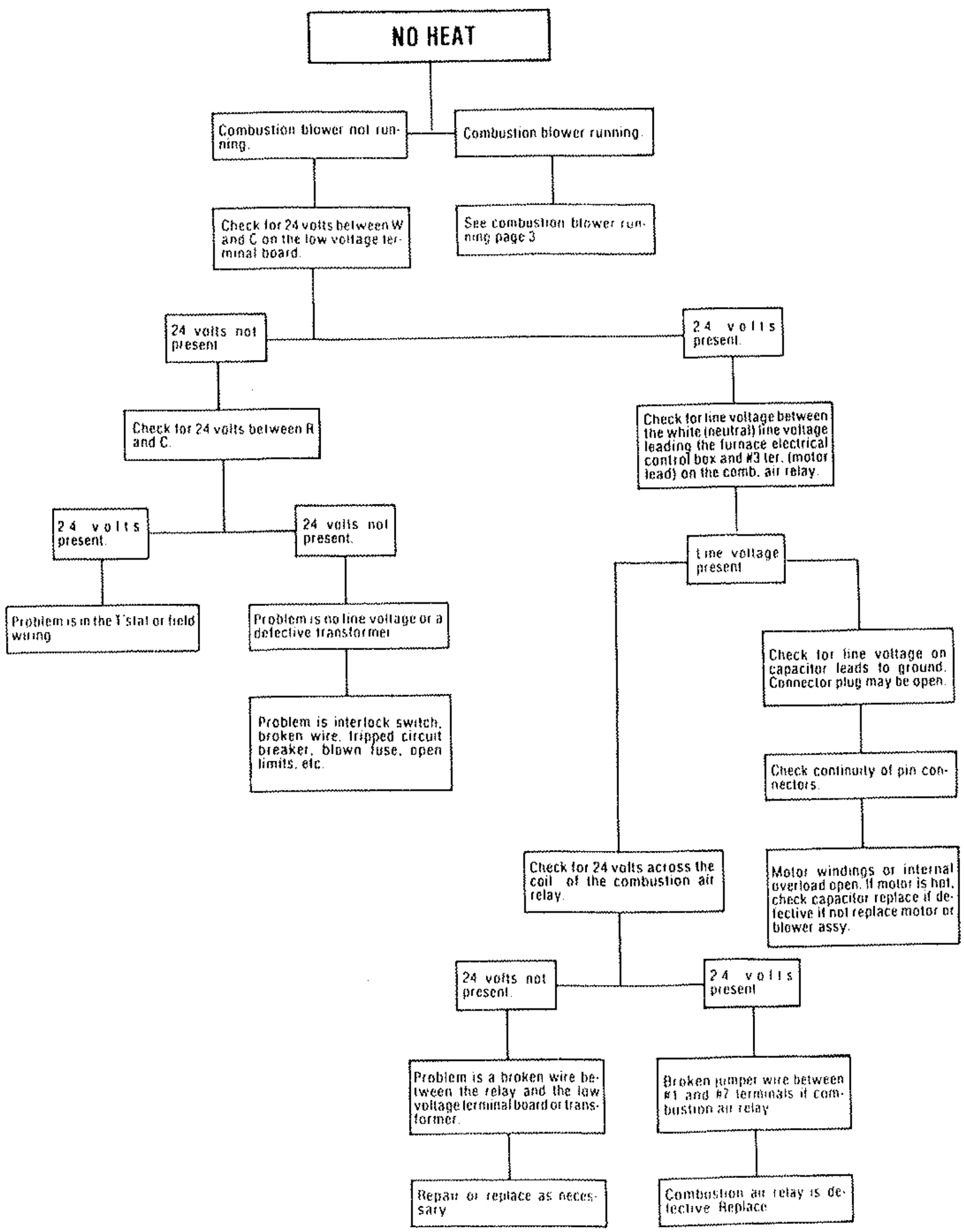
It almost goes without saying that if the system is flawed by poor design, customer complaints about performance could become a costly nightmare. Replacing an undersized furnace or adding new ductwork after the fact can eat up any profit on the job.

So, ideally, design it right, install it right, and service problems will be few and far between.

On the previous few pages, we listed some common heating complaints expressed in the words most often used by the owner or occupants themselves. As might be anticipated, the vast majority of people have little knowledge of their heating system and how it works. The skilled service person must translate a lay person's explanation of the symptoms into possible technical causes.

Manufacturers provide troubleshooting information in many different formats --- as flow charts, tables, or even slide rules. These can be invaluable job aids even for the more experienced troubleshooter. Two examples are presented on the next pages to conclude this lesson.

SERVICE ANALYZER CHART



Spark To Pilot (Intermittent Ignition Devices (I. I. D.) Troubleshooting Chart		
Symptoms	**Possible Cause**	**Checks & Remedies**
No spark	Open in ignition cable. Ignitor improperly grounded. No voltage to ignition module. Ignitor improperly adjusted.	Check continuity of ignition cable if open -- replace. Check ground connections, insure good chassis ground. Verify 24 volts AC input to ignition module. Verify correct ignitor adjustment.
Spark, but no ignition	No gas to pilot assembly. Pilot orifice plugged. Gas supply tubing to pilot kinked. No voltage to gas control.	Verify supply pressure. Inspect orifice clean or replace if dirty. Inspection tubing to pilot assembly -- correct or replace. Verify voltage across terminals PV-MV/PV of module. If no voltage, replace module. If present replace gas control.
Spark continues after ignition	Ignition cable has no continuity. Poor flame impingement on sensor rod.	Check ignition cable for continuity. Check that flame covers both electrodes.
Main burner fails to light	No voltage to gas valve.	Verify voltage at terminals MV-MV/PV of module. If no voltage -- replace module. Check connections between module and gas valve, if OK replace gas valve.
Main burner shuts down	Unit improperly grounded.	Verify ignitor assembly is grounded properly.

Main burner fails to shut down at end of cycle	Defective thermostat. Defective ignition module.	Check thermostat. Remove MV lead from module -- if gas valve closes, replace module -- if not replace gas valve.

Self-Check, Lesson 15 Quiz

You should have read all the material in Lesson 15 before attempting this review. Answer all the questions to the best of your ability before looking up the answers provided in the Answer Key.

Please indicate whether the following statements are true or false by drawing a circle around T (to indicate TRUE) or F (to indicate FALSE).

True False

1. T F Good design, good installation, and good service are all necessary to assure customer satisfaction.

2. T F Periodic maintenance is viewed as the second phase of service work following installation and startup.

3. T F The first step in troubleshooting a service problem is to listen to the customer.

4. T F A good service operation can be important source of replacement and modernization work.

5. T F The customer can provide all of the information for solving a heating problem.

In the following multiple-choice questions, choose the phrase that <u>most</u> correctly completes the statement, and check the appropriate box for the corresponding letter in front of the phrase.

6. A broken belt, a worn out bearing and a shorted motor are examples of:

A. ☐ part failure.
B. ☐ improper adjustment.
C. ☐ poor installation.
D. ☐ poor design.

7. A gradual decrease in heating capacity is most often the result of:

A. ☐ an undersized furnace.
B. ☐ dirty filters restricting air flow.
C. ☐ a change in the Btu content of the fuel.
D. ☐ a large hole in the furnace heat exchanger.

8. A very common installation problem for poor performance in a new installation is:
A. ☐ rugs covering one or more registers.
B. ☐ gas pressure under furnace specifications.
C. ☐ debris left inside the duct system.
D. ☐ furnace fan running backwards.

9. An expensive cause for a performance complaint that can be and should be avoided is:

A. ☐ having to replace due to poor design.
B. ☐ having to re-balance the system.
C. ☐ having to return to clean up furnace area.
D. ☐ taking more time to instruct the customer.

10. Which of the following causes of window sweating is a construction not a heating system problem?

A. ☐ too high setting of humidistat.
B. ☐ condensation in furnace vent connector.
C. ☐ crawl space not covered with vapor barrier.
D. ☐ outside air intake clogged.

For the completion-type questions, fill in the blanks with the word (or words) that most accurately completes the thought.

Key Words

blockage poor adjustments job aids overheated part failure
instructions down drafting switch ground clogged filters

11. The easiest malfunction to uncover is probably ____________________________.

12. Troubleshooting information in tables, slide rules and flow charts are commonly referred to as __________________.

13. A common complaint of "fuel bills too high" is usually caused by ___________________.

14. Furnace cycling that interferes with TV reception is probably a result of a poor electrical ______________.

15. A "I see soot around the furnace" complaint is often the result of ______________ in the vent system.

Check Your Answers!

Self-Check Lesson 7	*Reference Page*
1. True	2
2. False	9
3. False	9
4. True	8
5. False	10
6. A	11
7. C	10
8. D	12
9. B	8
10. C	9
11. spreading	7
12. grille	6
13. extended plenum	4
14. radial	6
15. distribution	6

Self-Check Lesson 8	*Reference Page*
1. False	2
2. False-	3
3. True	3
4. True	4
5. False	6
6. A	5
7. B	5
8. C	5
9. C	6
10. D	8
11. humidistat	9
12. decrease	3-4
13. condensation	7
14. gallons/day	8
15. defrost	10

Self-Check Lesson 9	***Reference Page***
1. False	2
2. False	8
3. True	2
4. False	3
5. True	8
6. B	4
7. D	3
8. B	3 & 6
9. A	2
10. D	8
11. adsorption	5-6
12. dust spot	6
13. washing	4
14. pressure	8
15. frames	8

Self-Check Lesson 10	***Reference Page***
1. True	2
2. True	2
3. False	3
4. False	11
5. True	4
6. D	3
7. C	4
8. A	5
9. C	6
10. A	8
11. parallel	10
12. series	10
13. compound	10
14. safety	9
15. ladder	12

Self-Check Lesson 11	***Reference Page***
1. False	2
2. True	2
3. True	2
4. True	2
5. True	4
6. A	4
7. A	4
8. B	7
9. C	7
10. B	2
11. registration	3
12. 90B	4
13. hazard	5
14. resistance	5
15. building	6

Self-Check Lesson 12	***Reference Page***
1. False	3
2. True	3
3. False	4
4. False	4
5. True	5
6. C	7
7. A	8
8. D	9
9. C	12-13
10. D	13 & 15
11. approved	6
12. servicing	6
13. combustion	8
14. air tight	9
15. temporary	11

Self-Check Lesson 13	***Reference Page***
1. True	3
2. True	2
3. False	5
4. False	5
5. False	5
6. B	5
7. D	6
8. A	7
9. C	8
10. A	8
11. 100 cubic feet	9
12. therm	9
13. 2,500	8
14. 3,414	8
15. butane/propane	4

Self-Check Lesson 14	***Reference Page***
1. False	2
2. True	2
3. False	2
4. True	3
5. False	3
6. C	4
7. B	4-5
8. C	5
9. B	5
10. B	8
11. balance	3
12. 6.5/10	2
13. fin-tube	7
14. panel	8
15. 80-125	7

Self-Check Lesson 15	***Reference Page***
1. True	2
2. True	2
3. True	3
4. True	2
5. False	7
6. A	3
7. B	4
8. C	7
9. A	7
10. C	5
11. part failure	3
12. job aids	7
13. clogged filters	5
14. ground	6
15. down drafting	6

Appendix B: Glossary

A Selected List of Terms

ABSORPTION SYSTEM: A refrigerating system in which the refrigerant gas from the evaporator is chemically absorbed in another liquid, which is pumped to a higher pressure and released in a generator upon the application of heat.

ACOUSTICAL: Pertaining to sound.

ACOUSTICAL DUCT LINING: Duct with a lining designed to control or absorb sound and prevent transmission of sound from one room to another.

AIR CLEANER: A device designed for the purpose of removing airborne impurities such as dust, gas vapor, fumes, and smoke. Air cleaners include air washers, air filters, electrostatic precipitators, and charcoal filters.

AMPERE: The strength of an electrical current. The current produced by an electromotive force of one volt acting through a resistance of one ohm.

BLOW (THROW): The distance an air stream travels from the face of a supply oudet to a point from the face at which air motion is reduced to a velocity of 50 feet per minute.

BTU, BRITISH THERMAL UNIT: The quantity of heat required to raise the temperature of 1 lb. of water 1°F.

CHARGE: Amount of refrigerant in a system; or to put refrigerant into a system.

COMFORT AIRCONDITIONING: The process of treating air so as to control simultaneously its temperature, humidity, cleanliness, and distribution to meet the comfort requirements of die occupants of the conditioned space.

COMPRESSOR: That part of a mechanical refrigeration system that receives the refrigerant vapor at low pressure and compresses it into a smaller volume but at higher pressure.

CONDENSATION: The process of changing a gas into a liquid by removal of heat, as when water vapor is condensed into water on a cold surface.

CONDENSER: That part of a mechanical refrigeration system that receives the refrigerant vapor at high pressure and temperature and condenses it into liquid refrigerant at high pressure and temperature.

CONDUCTION: The transfer of heat from a warmer body to a cooler substance by direct contact.

CONVECTION: The transfer of heat by the circulation of a liquid or gas. such as water or air.

DEGREE DAY: A unit used to estimate fuel consumption and to specify the heating load in winter, based on temperature difference and time. There are as many degree days for any one day as there are degrees F. difference in temperature between the average [1] temperature for the day and 65
°F.

DEHUMIDIFY: To reduce or remove moisture from the air.

DEW POINT: The temperature at which the air can hold no additional water vapor and begins to form visible liquid droplets on cool surfaces.

DOUBLE GLAZING: Glazing consisting of two thickness of glass with an air space between them.

EVAPORATION: Change of state from a liquid to a gas. At 70° about 1,054 Btus are required to evaporate one pound of water.

GAS, NON-CONDENSABLE: Gas in a refrigerating system, such as air which does not condense at the temperature and partial pressure at which it exists in the condenser, and therefore imposes a higher head pressure on the system.

HEAD PRESSURE: Operating pressure measured in the discharge line at a compressor outlet.

HEAT, LATENT: A term used to express the energy involved in a change of state such as from a liquid to a gas.

HEAT, SENSIBLE: A term used in heating and cooling to indicate any portion of heat which changes the temperature of the substance involved without changing its physical state.

HEAT, SPECIFIC: The ratio of the quantity of heat required to raise (or lower) the temperature of one pound of a substance one degree F. to the amount required to raise the temperature of one pound of water one degree (Btu/lb°F).

HERMETIC UNIT: A compressor which has its motor sealed inside of the compressor housing and cooled by refrigerant vapor.

HIGH SIDE: Parts of a refrigerating system maintained at the pressure of the condenser.

HUMIDIFY: To add moisture to the air.

HUMIDISTAT: A control device activated by a change in humidity used for automatic control of relative humidity.
HUMIDITY, ABSOLUTE: The quantity of water actually in the air. Given as the weight of water vapor per unit volume (pounds or grains) of moisture per cubic foot of dry air.

HUMIDITY, RELATIVE: The ratio of the quantity of water vapor actually in the air to the water vapor the air could possibly hold at the same temperature and barometric pressure.

INFILTRATION: Air flowing into a house through cracks, loose construction, or other openings.

LOW SIDE: Parts of a refrigerating system at the evaporator pressure.

OHM: The unit of resistance. The resistance of a conductor in which one volt produces a current of one ampere.

PLENUM: A supply air compartment maintained under pressure and connected to one or more distributing ducts.

RADIATION: Transmission of energy by means of electromagnetic waves. Heat so transmitted increases temperature of objects it strikes in its path without increasing temperature of air through which it passes.

REFRIGERANT: A coolant that produces a useful refrigerating effect by its absorption of heat while expanding or vaporizing at practical pressures.

SHORT CYCLES: Refers to short and more frequent periods of on/off time when a system is delivering conditioned air.

TEMPERATURE, DEW POINT: The temperature at which the condensation of water vapor in the air begins.

TEMPERATURE, DRY BULB: The temperature indicated by an ordinary thermometer.

TEMPERATURE, WET BULB: The temperature read on a wet bulb psychrometer constructed and used according to specifications.

THERMOSTAT: An instrument which responds to changes in temperature to control (turn off/off) components in a cooling or heating system.

TON, OF REFRIGERATION: Quantity of heat required to melt one ton, 2,000 pounds, of ice in twentyfour hours. This is equivalent to 12,000 Btu's per hour.

VALVE, EXPANSION: A device which regulates the flow of refrigerant from the liquid line into the evaporator. It also separates high side from low side of a system.

VELOCITY: In heating and cooling, velocity usually refers to the rate of flow of the air in the ducts or rate of flow of the air through the registers and grilles. It is almost always expressed in feet per minute.

VOLT: The unit of electromotive force, or potential difference, equal to that force or difference