Comfort Cooling: Introduction

Lessons 1 to 7

Your Course Materials

You are about to join thousands of other active people in the heating and air-conditioning industry who have found HARDI's workbooks a convenient way to continue their job-related training and education. Your course materials have been specially prepared to make distance learning easy as well as convenient.

Your course materials include:

- A **text section**, which includes all of your learning information, drawings, tables, and charts. You will read assignments in the text section to expand your knowledge of the subject.
- **Self-check quizzes**, which are found in the text section at the end of each lesson. You should take these quizzes to monitor your progress toward learning the materials. An answer key provides all of the correct quiz answers, and can be found in the final appendix to the text section.
- **Online unit exams** are provided separately from the text section. Every HARDI workbook course has a specific number (2 to 4) of exams that will officially mark and track your learning progress. Unlike the self-check quizzes, the unit exams are intended to be an official record of your course completion.

Course Content

Learning Objectives

This course is designed to provide an overview of the principles, products and systems used in modern small system air conditioning for individuals having little or no prior knowledge about comfort cooling.

Specifically, upon successful completion of all assignments and tests in this course, the student should be able to:

1) Describe what is required to keep people comfortable.

2) List the building characteristics and weather conditions that affect building cooling loads.

3) Identify the components in ordinary unitary cooling systems and understand the function they perform.

4) List and understand the meaning of select technical terms encountered in the industry.

You will demonstrate accomplishing these objectives by successfully completing two written examinations during the training period.

Learning Tips

Many distance learning students might find these tips on how to study offered by Dr. Francis Robinson, The Ohio State University, worthy of consideration.

Dr. Robinson recommends the **SQ3R method.** The SQ3R method of reading assignments helps you to study more effectively. SQ3R is a formula that represents the words **Survey, Question, Read, Recite** and **Review.** This is how to use the formula.

1. **Survey** - Page through the lesson. Read the title, headings, sub-headings, the first paragraph or two, and the last paragraph. Study the illustrations, pictures, graphs, charts, and tables. Relate this information to what you already know.

Read notable notes found throughout the course. They are extended comments much as an instructor would offer when going over a lesson in class.

2. **Question** - Page through the lesson a second time. This time, ask questions about the material in the lesson. Turn the title, headings, and sub-heading into questions by adding who, how, what, where, when, and why. Form your own questions.

3. **Read** - Read the lesson and look for answers to your questions. Think along with the author; anticipate what the author is going to say. Use a dictionary to find the meaning of any words that you don't know.

4. **Recite** - Look away from the material and tell yourself what you have just read. Try to answer your questions from memory. Do this immediately after you finish each section of the lesson and immediately after you finish each lesson.

5. **Review** - Complete the self-check quizzes to see how much you remember. Use the answer key to see how well you did. Then, go back to the textbook to review the questions that you missed. The reference page where each answer can be found is also provided in the answer key.

If you follow the SQ3R formula method of reading and studying, you will be well-prepared to take each examination. Send only the examinations to the school for grading; do not send in the self-check quizzes.

Get Started Right Away.
Turn to Lesson 1.

Lesson 1 Overview

Where do you start a course like this? We decided to start with a discussion of how air conditioning has altered the way we live in North America. In doing so, we hope to stress the importance of air conditioning on modern life. We can live where we want, when we want, in comfort and health. So, this is an important industry that is doing an important service.

When you finish studying Lesson 1 and complete the self-check quiz following the lesson, you should be able to explain to others just how dramatically air conditioning has changed the way we live today.

Now read Lesson 1 which begins on the next page.

Lesson 1: Cool Times

People say — *"It's not the heat, it's the humidity."* What does that mean? When you finish this training course, you'll be able to judge the accuracy of that statement and explain its true meaning.

Air conditioning has literally revolutionized the way we live and where we live. Because air conditioning has evolved, the dramatic changes brought about have rarely been noticed by the general public.

One university economist said "air conditioning was the most profound technology advancement of the 20th century." What about the automobile, airplane, TV, or the computer? Before you agree or disagree with the professor, let's consider life without air conditioning.

Air conditioning has redrawn the map of commerce in North America by opening the hot, humid regions of the country to business development. Once air conditioning made living in the South and Southwest tolerable, individuals and business came in droves to populate the area. In the 1970s, the population in Florida grew by 44 percent and in Texas, by 27 percent. This was essentially repeated in the 1980s. Without air conditioning, Arizona would surely be sparsely populated today rather than a destination for retirement couples.

It has changed architecture, increased productivity, and created its own important industry where some 5 million central air-conditioning units are manufactured and installed each year.

Government and other private studies have proven that air-conditioning improves the efficiency of both office and factory workers and sharply reduces absenteeism.

Lighting and other electrical loads have increased to a point where cooling is often needed in a building's interior spaces even on cold winter days.

Air conditioning also makes year-round education possible.

It has even changed government. Before air conditioning, the U.S. Congress used to adjourn for the entire summer, as Washington DC was far too hot to deliberate and conduct the government's business.

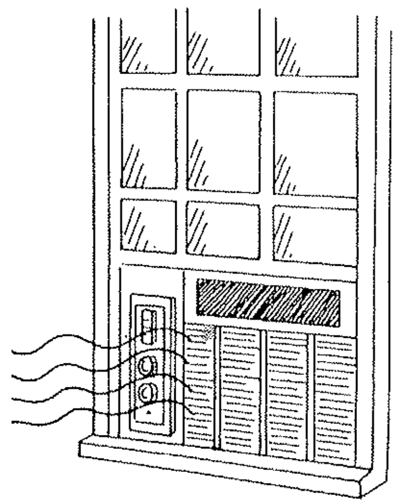
Other industries could not survive without air conditioning as well. Consider the computer chip industry and the pharmaceutical industry where clean, climate-controlled rooms are required. Refrigeration, while related, is another story entirely — food preservation, textile processing, printing plants, petrochemicals, etc.

An Evolving Technology

Modern mechanical air conditioning dates back to 1902, when Willis Carrier invented a mechanical system and installed it in a Brooklyn printing plant (Sackett-Wilheim) to reduce humidity that caused images to blur.

Dr. Carrier's called for his new system was an "Apparatus for Treating Air." It was an engineer named Stuart Cramer who was credited with first coining the term "air conditioning" back in 1906. He had designed a system for controlling humidity in textile mills.

The first exposure to an air conditioned building for the largest segment of the population was the motion picture theater. Grauman's Metropolitan Theater in Los Angeles became the first air conditioned theater in 1922. From then on, movie houses became the place to escape the summer heat if only for a few hours. "20 degrees cooler inside" was often featured on a banner hanging from a theater's marquee.



Window Airconditioner

Residential air conditioning was unusual before the 1960s. However, during the 60s, new installations grew at an exponential rate. Previously, people dealt with the heat by wearing light clothing or sleeping on the floor or outside their homes or apartments. Even meal preparation was altered in the summer.

Opened doors and windows, while screened, allowed insects, pollen, dirt and street noise to enter the home with associated discomfort. The wealthy spent their summers away from the city.

Most churches were not air conditioned, and people would be carried out during services because of the oppressive heat inside. Personal hygiene was challenged and clothing was often soiled by excessive perspiration. Almost everyone had a portable electric fan in an attempt to accomplish some type of relief from the heat.

Public and private vehicles were also without air conditioning, with patrons opening windows to catch the breeze — along with the debris carried about by the wind. Sooty faces were not uncommon among disembarking commuters.

Notable note: The first mass produced room air conditioner was marketed in 1929 by a household refrigerator manufacturer — Frigidaire.

Notable note: Cities are hotter than surrounding areas because of the "heat island effect." Glass windows and metal building materials reflect heat onto other buildings; streets and sidewalks absorb heat which then radiates heat into the air. Auto exhaust and other pollution trap heat. Lack of surface water in a city means more of the sun's energy raises air temperature rather than evaporates water. It is cooler in the country.

Today, people expect air conditioned buses and automobiles. And how many shoppers will visit non-air conditioned stores? Even the shopping malls themselves are enclosed and air conditioned so people can move from store to store in absolute comfort. And how about modern sports arenas — spectators even watch football and baseball in air conditioned comfort.

Personal Benefits of Air Conditioning

People spend 95% of their time in an indoor environment. Is it any wonder why maintaining a healthy environment is so important?

We are all well aware of the role that temperature extremes have in producing discomfort, illness and at times, even death. The very young and very old can succumb to excessive temperature and humidity. (Air conditioners have literally been rushed to areas of the country to help save lives during a heat wave.)

The health and well-being of individuals are definitely improved with summer cooling. For example, infants will not suffer as much from heat rash. They will also eat better and sleep better. Persons who suffer from hay fever and other allergies due to airborne pollen will experience significant relief (relief - not cure). Victims of asthma and heart trouble also find life much easier with comfort cooling.

Air conditioning in a building is important, not only for simple enjoyment, but for occupant harmony, work, and leisure activities. It is not an understatement to say our lifestyle has been permanently altered by air conditioning.

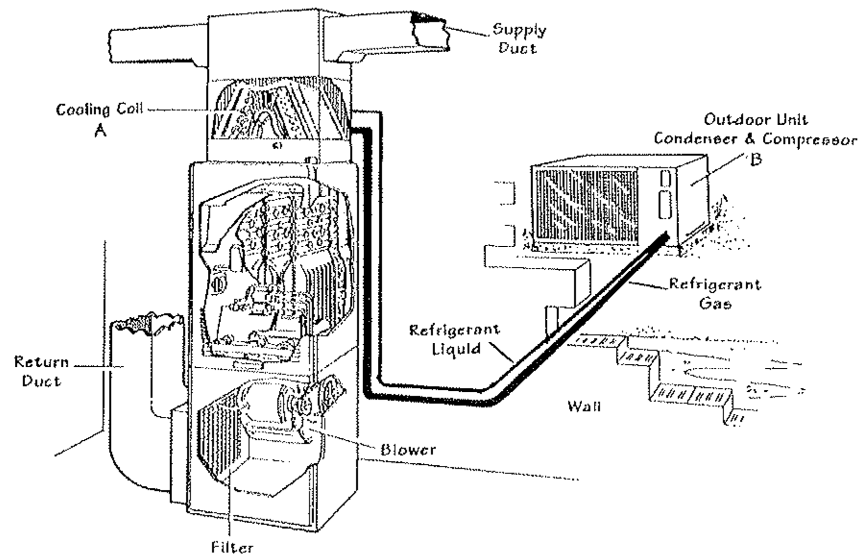
There are secondary benefits to air conditioning as well. Neighborhood noises are minimized because windows can be kept closed. Security is also increased because the building can be "buttoned up."

Is it possible that the economist might be right about air conditioning being the most profound advance of the 20th century?

The Anatomy of a Central System

Air conditioning systems are many and varied — as we'll learn as we progress through this course. For starters, let's take a quick look at one very common central residential system to launch our understanding of equipment and components as well as start to develop an understanding of the language of the industry.

What we have here is a central residential system featuring a *unitary split-system* air conditioning unit matched with a gas (burning) *furnace* and connecting metal *duct* system to channel conditioned air to all rooms. This is typical of what might be found in a Midwestern home with a basement.



A unitary split-system airconditioning unit mounted on a gas-fired furnace is a typical midwest installation.

The unitary split-system consists of two components, the cold "cooling" coil (A) placed above the furnace, and the outdoor condensing unit (B) which consists of the compressor or "pump" and a warm condenser coil. The two components are connected together by two copper pipes or lines that contain a special fluid called a refrigerant. One pipe carries *liquid* refrigerant to the cooling coil and the other carries *gaseous* refrigerant to the condenser. The compressor is the refrigerant mover — pumping refrigerant around and around between the two components.

The furnace is equipped with a fan called a *blower* that pushes air through the cooling coil to chill the air as it begins to move through the duct system — ultimately discharging into each room to cool the spaces and the occupants. Room air is at the same time drawn into the return air duct to be filtered, re-cooled and re-circulated through the house.

The compressor and the blower are powered by electric motors.

We will explore the split-system components in greater detail in later assignments, and cover other popular types of air conditioning units as well.

Self-Check, Lesson 1 Quiz

You should have read all the material in Lesson 1 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 Air conditioning has not revolutionized the way we live in North America.

2. T F Air conditioning opened up the humid regions of the United States to allow *year-round* living.

3. T F Air conditioning has not been proven to improve the efficiency of workers.

4. T F Cooling is often needed in a building on cold days because of heat produced by different electrical loads.

5. T F The computer chip industry is not dependent on air conditioning technology to provide clean room atmospheres.

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. Modern mechanical air conditioning dates back to 1902 when Willis Carrier invented a system to:

- ☐ A. air condition a movie theater in California.
- ☐ B. reduce humidity in a printing plant in Brooklyn.
- ☐ C. protect rare documents in Washington DC.
- ☐ D. cool an office building in New York.

7. People first experienced the effects of air conditioning in:

- ☐ A. supermarkets.
- ☐ B. department stores.
- ☐ C. motion picture theaters.
- ☐ D. public transportation.

8. The rapid growth of residential air conditioning began in the:

☐ A. 1950s.	☐ B. 1960s.
☐ C. 1970s.	☐ D. 1930s.

9. A unitary split-system mounted on a furnace consists of two components, the cold cooling coil inside and the:

- ☐ A. compressor outside.
- ☐ B. condensing unit outside.
- ☐ C. condenser outside.
- ☐ D. blower cabinet outside.

10. The components in a unitary split system are interconnected by two:

- ☐ A. copper pipes carrying refrigerant.
- ☐ B. steel pipe carrying refrigerant.
- ☐ C. plastic pipes carrying refrigerant.
- ☐ D. aluminum pipes carrying refrigerant.

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

Key Words

colds	cooling coil	relief	indoor	noise
music	humidity	sun	refrigerant	outdoor

11. People spend approximately 95 percent of their time in a/an ______________________ environment.

12. Very young and very old persons can succumb to the effects of excessive temperature and_______________________.

13. People with allergies can experience significant ________________ as a result of living in an air conditioned building.

14. A secondary benefit attributed to an air conditioned home is a reduction in neighborhood _________________ entering the home.

15. The fluid pumped by the compressor in an air conditioning unit is called a/an ______________________.

Lesson 2 Overview

It is not our intention in this lesson to teach engineering-level heat transfer. What we intend to do is explain in practical terms what energy is, how we measure energy in air conditioning and the three modes of transferring heat between two substances. Most important, you'll learn the difference between temperature and heat.

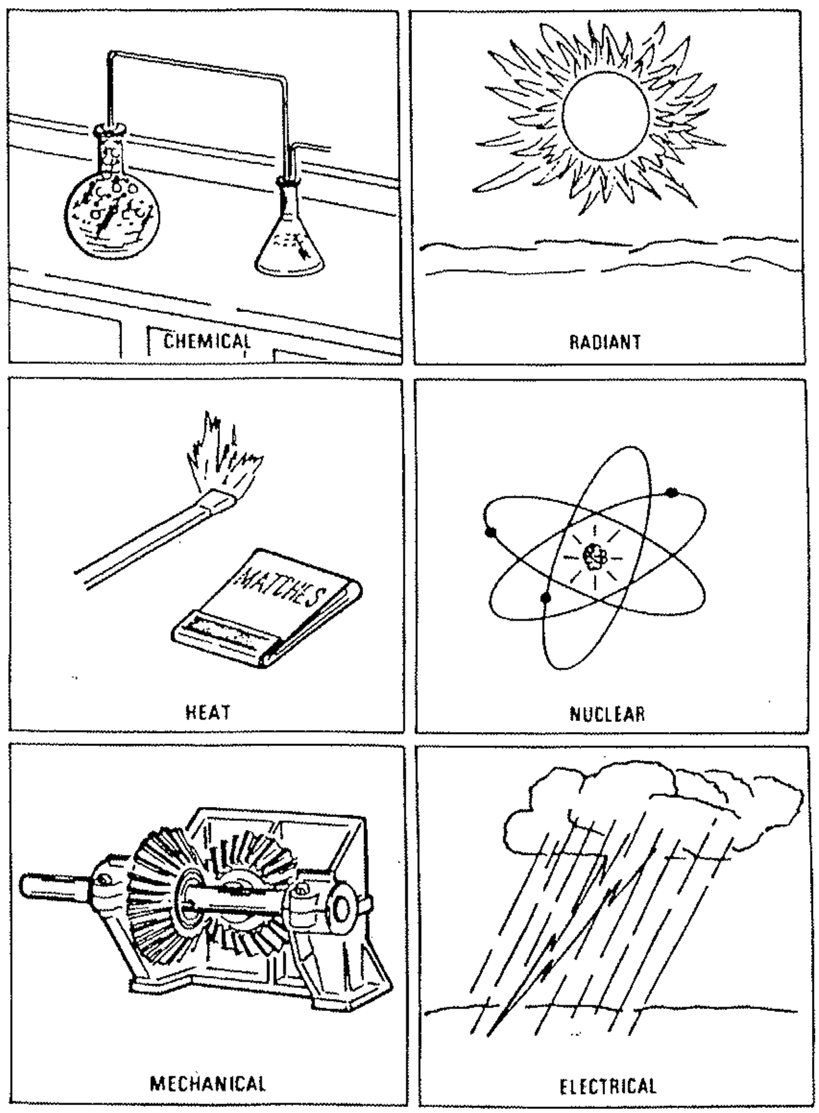
So, don't worry if your high school science is a bit rusty. You won't need it to get the benefit of this short lesson.

Now read Lesson 2 which begins on the next page.

Lesson 2: Back to High School Science

Before we talk about compressors, condensers, and the other elements making up air conditioning equipment, we need to review a few fundamentals about energy and the physics of solids, liquids, and gases — particularly *air.*

What exactly is energy? What is heat? Quite simply, **energy** is *the ability to do work* and **heat** is one *form* of energy. Other forms of energy include *electrical* energy, *chemical* energy, *solar* energy, *atomic* energy, and *mechanical* energy.



Heat is thought of as a "lower" form of energy since the other forms of energy can readily be converted to heat, but it is almost impossible to efficiently convert heat back into other "higher" energy forms directly. For example, when you strike a match, you convert the chemical energy in the match tip into heat along with some light. It is not possible to do the reverse — convert the heat back into the chemicals.

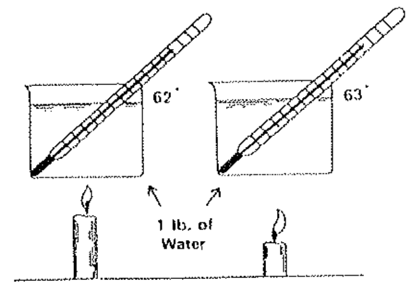
Today, scientists use molecular activity to explain heat. The greater the molecular activity in a substance, the greater the heat energy contained in the substance.

What we call the "temperature" of a substance is an indicator of heat *intensity* (but not heat quantity), and we usually measure temperature in degrees Fahrenheit (F) or in degrees Celsius (C). The higher the temperature, the greater the molecular activity. For the record, all molecular motion stops at *minus* 460 degrees Fahrenheit (-273 Celsius*).

* To convert Fahrenheit to Celsius use the formula C = (F-32) x .555
To convert Celsius to Fahrenheit use the formula F = (1.8 x C) + 32

Notable Note: The thermometer was devised in 1720 by a Hollander named Gabriel Fahrenheit.

At this temperature, the substance can be said to contain *no* heat energy. But a substance at any higher temperature contains some heat energy — even at 0° F. Temperature doesn't tell the whole story. Common sense tells us that 100 gallons of water at 100° F contains more heat than a thimble of water at the same temperature. So, heat *quantity* also depends on the amount (and type) of substance as well as its temperature.

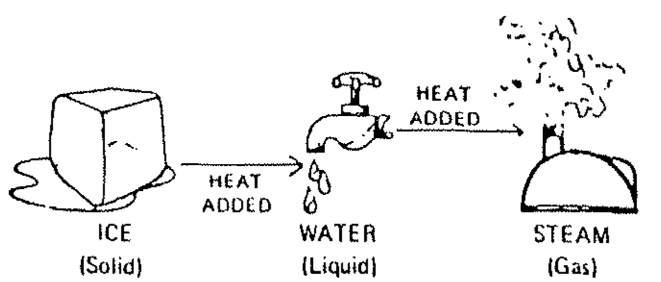


A Btu is the amount of heat required to raise 1 lb of water 1 degree. This is also an example of sensible heat.

To measure heat quantity, we have developed the Btu — British thermal unit. A Btu is simply the amount of heat required to increase the temperature of one pound of water one degree. If it were 2 pounds of water, it would take 2 Btus. If the substance wasn't water — air for example — it would take about 1/4 Btu to raise a pound of air 1°F.

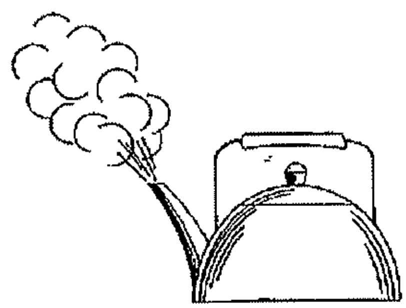
This is important to understand — heat only flows from a substance at a higher temperature to one at a lower temperature. In physical terms, heat cannot travel up hill. There must be a temperature difference between two substances to move heat energy — just like there must be a voltage difference to move electrical current in a circuit. No voltage difference, no current flow. No temperature difference, no heat flow.

If we keep adding heat to our pound of water, we, of course, see the water increase in temperature and ultimately boil and turn into steam. If we had started with ice, we would add heat, melt the ice, and then turn the water into steam. Adding heat can change the "state" of the substance from a solid (ice) to a liquid (water) and then to steam (a gas).



There is a very interesting phenomenon that occurs when ice melts and water turns to steam. During the conversion process, the temperature of the substance stays the same. Adding heat doesn't increase the temperature during a *phase* change. Adding heat before or after the transformation increases the temperature of the substance but not *during* the conversion. Heat added to a substance that changes phase and does not cause a temperature change is called **latent** (Latin for hidden) **heat**. Heat that *does* increase the temperature of a substance has a name too — sensible heat.

Latent heat can represent a great deal of heat too! It takes almost 1,000 Btus to convert a pound of water into steam at the "normal" boiling temperature of 212° F. It only takes about 140 Btus to heat the same amount of water from room temperature to 212° F.



Converting water to steam requires plenty of Btus.

Aluminum soda cans in contact with ice is an example of heat transfer by conduction. We'll be referring to sensible and latent heat again in later lessons.

We already mentioned that heat flows or transfers only from a higher temperature substance to one at a lower temperature, not the other way around. The mechanisms — how heat is transferred from one substance to another — is also of interest.

There are three modes or methods of heat transfer — conduction, radiation, and convection.

Conduction is the transfer of heat by actual contact between two substances at different temperatures. A good example of conduction is the ice chest. In this instance, warm beverage cans are cooled by actually being in contact with the cold ice. Another example would be a silver spoon placed in hot coffee. Very quickly, the handle becomes hot as the heat conducts rapidly along the length of the spoon.

Radiation is the transfer of heat from one surface to another that are **not** in contact with each other. Also, the air space between the surfaces is not a factor. One common example is radiation from the sun striking the roof surface of a home. The radiation is absorbed by the shingles and converted to heat, raising the roof surface temperature to perhaps 140° F, even though the air temperature around the roof may be only 80 degrees or less. Another example is standing in front of a roaring fireplace --- one can feel the heat directly from the hot surfaces.

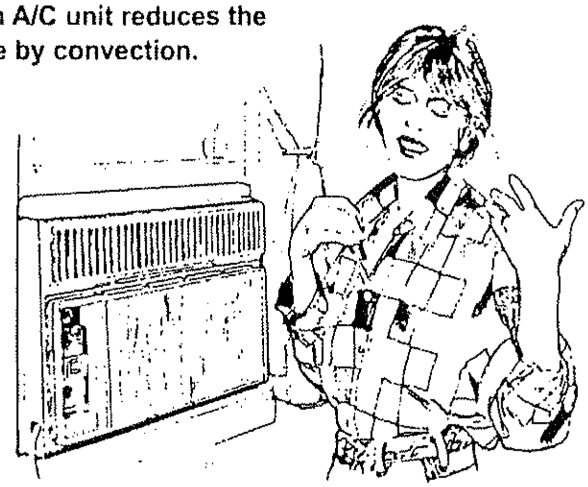
For radiation exchange to occur, the surfaces must "see" each other. Ducking into a shady spot to escape the hot sun on one's face is an example of blocking the exchange — the sun no longer "sees" your face. Thermal radiation is just one example of a whole family of electromagnetic waves emitted by surfaces. A microwave oven involves a form of radiation transfer generated electronically.

Radiation takes place between surfaces at any temperature, not just elevated temperatures.

We use the sun and fireplace as dramatic examples, but even walls and windows in an ordinary room undergo radiation heat exchange between other surfaces and with people, again, whenever there is a temperature difference.

Convection is the transfer of heat by the currents in a gas or liquid — air or water is of prime interest to us. Example: the cool air blowing from a window air conditioner reduces the air temperature in a room by convection heat transfer as room air circulates with the cool cooling unit air. Soup contained in a sauce pan on a burner is heated by convection. When you stir the soup, you increase convection currents and the soup heats up faster.

Cool air blowing from A/C unit reduces the room air temperature by convection.



Quite often, all three modes of heat transfer may be involved between two surfaces.

Self-Check, Lesson 2 Quiz

You should have read all the material in Lesson 2 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 greater the molecular activity in a substance, the greater the heat energy contained in the substance.

2. T F Temperature is an indication of heat intensity, not the quantity of heat.

3. T F All molecular motion stops at a temperature of plus 460° Fahrenheit.

4. T F A Btu is the amount of heat required to increase the temperature of air one degree Fahrenheit.

5. T F Heat can flow between two substances at the same temperature.

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. Using the formula F = (1.8 x C) + 32, convert 20° Celsius to Fahrenheit.

☐ A. 4.0° Fahrenheit.
☐ B. 53.6° Fahrenheit.
☐ C. 68.0° Fahrenheit.
☐ D. 93.6° Fahrenheit.

7. The quantity of heat in a substance is dependent on its temperature and:

☐ A. the amount of substance.
☐ B. the shape of the substance.
☐ C. the type of substance.
☐ D. the amount and type of substance.

8. Raising the temperature of 20 pounds of water one degree Fahrenheit would require:

☐ A. 5.0 Btus.
☐ B. 50 Btus.
☐ C. 2.0 Btus.
☐ D. 20 Btus.

9. Converting one pound of water into steam at normal room conditions would require almost:

☐ A. 10 Btus.
☐ B. 100 Btus.
☐ C. 1,000 Btus.
☐ D. 10,000 Btus.

10. Under normal conditions, two pounds of water would boil at a temperature of:

- ☐ A. 32° Fahrenheit.
- ☐ B. 64° Fahrenheit.
- ☐ C. 212° Fahrenheit.
- ☐ D. 424° Fahrenheit.

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

Key Words

dry	conduction	boiling	convection	decrease
sensible	radiation	circulation	evaporation	change

11. Latent heat changes the state of a substance during which time the temperature does not ______________________.

12. Heat that changes the temperature of a substance, but not its state is called ______________ heat.

13. Heat moving from one substance to another that are touching is termed heat transfer by ____________________.

14. Heat that travels to a substance through the air without affecting the temperature of the air is called __________________ heat transfer.

15. Movement in a gas or liquid that carry heat is referred to as _____________ heat transfer.

Check Your Answers!

Now compare your answers with those given in the answer key at the back of this book.

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

Lesson 3 Overview

We usually take air for granted —until it is in short supply or polluted. If we are going to treat air to make ourselves comfortable, then we should know a bit more about it.

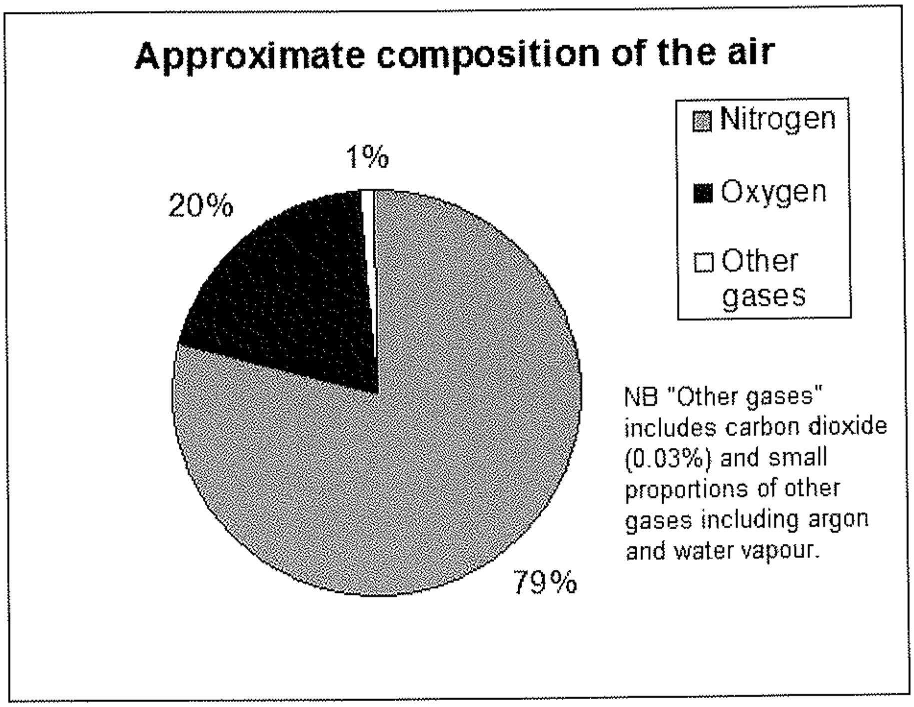
Lesson 3 continues our scientific investigation by examining the air we breathe and what it is — especially the water vapor in it that we call humidity. We'll also use basic arithmetic to delve deeper into basic air properties.

Now turn to Lesson 3 which begins on the next page.

Lesson 3: The Air We Breathe

That precious substance *air* is important to our life and to our comfort. Typically, we breathe in about 35 pounds of air per day to sustain life. The temperature of the air surrounding our bodies obviously influences our level of comfort.

What we call air is really a mixture of many gases — principally nitrogen, oxygen, argon, carbon dioxide, and *water vapor*. It also contains small traces of neon, krypton, xenon, helium, and hydrogen. Fortunately in air conditioning, we can neglect all of the rare gases and assume that the air to
be processed by air conditioning equipment consists solely of nitrogen, oxygen, and *water vapor.*



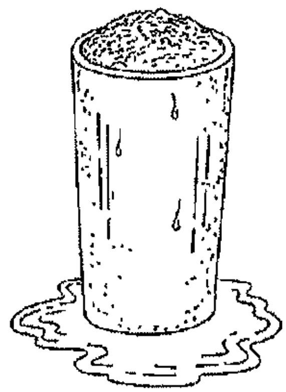
Conveniently, oxygen and nitrogen are always found in the same proportions — approximately 79% nitrogen and 21% oxygen by volume — so we consider these two ingredients a single gas and call it *dry* air. However, the possible proportions between dry air and water vapor vary enormously. What we call *humidity* is simply water vapor mixed in air.

For instance, the weight of water vapor may be as low as 0.000005 lb per pound of dry air during cold winter weather in Alaska. In the hot summer, it can exceed 0.02 lb per pound of dry air in many parts of North America.

As air temperature goes up, the air can "hold" more water vapor. In fact, *decreasing* the air temperature is one way we remove moisture from the air. The beads of water on the glass surface of a cool summer drink is an example of humid air contacting a cool surface causing water vapor in the air to *condense* on the glass.

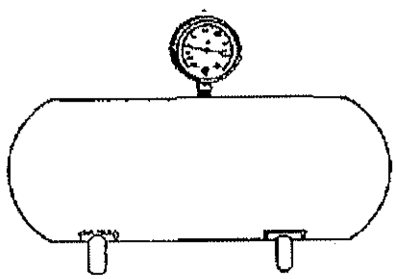
We might pause here and ask, "What's the difference between a *vapor* and a *gas?*"

In basic terms, vapors are substances in the gaseous state but are usually thought of as liquids at normal pressure and temperature — water is a good example. Gases are already in the gas phase at normal pressure and temperature — helium, for example, or air itself.



Water vapor in air condenses and appears on a cool surface.

Problem: How much air is there in a 5 cubic foot tank at a temperature of 150° F and a pressure of 100 psig?



Most of us, if we scratch our heads vigorously enough, will probably recall the terms *Boyle's Law* and *Charles' Law* from our high school science class. These laws govern the basic relationships of a gas. And while we are not going to use "higher mathematics" in this course, we should walk through a few simple examples. The weight, volume, temperature, or pressure of a gas can be calculated from the following expression:

$$PV = MRT$$

where P is the pressure exerted by the gas;
V is the volume of the gas;
M is the weight of the gas;
R is a constant (a number) depending on the type of gas;
and T is the temperature of the gas.

From this formula, we can find any one property of dry air if we know the other three. However, we must use scientific or *absolute* values of each property in the formula. Let's use a simple example.

Suppose we wish to find out how many pounds of dry air are in a five cubic foot tank. The thermometer in the tank reads 150° F and the pressure gauge on the tanks indicates 100 pounds per square inch. The local atmospheric pressure — the pressure exerted by the weight of the air column on the earth's surface — is 14.48 pounds per square inch — or 29.57 inches of mercury as reported on TV.

Here is how we proceed —

P in the formula must be the gauge pressure *plus* the atmospheric pressure and in units of pounds *per square foot.*

Hence, 100 +14.48 = 114.48 lb/sq. in. x 144 sq in/sq ft = 16,485 lb per sq/ft.

The temperature of 150° F must be changed to absolute temperature by adding 460° or 150 + 460 = 610° F absolute.

R for air is 53.35. Thus,

$$M = \frac{16{,}485 \times 5 \text{ (vol. of tank)}}{53.35 \times (460 + 150)}$$

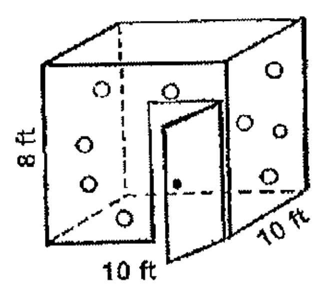
M = 2.53 lb of dry air in tank

The same formula would apply for water vapor, only R is now equal to 85.7. For instance, let's find the water vapor pressure for these conditions — 800 cubic feet of air in a 10 foot x 10 foot room with an 8 foot ceiling. Air/vapor temperature is 70° F and there is 0.5 pound of water vapor in the air.

$$P = \frac{0.5 \times 85.7 \times (460 + 70)}{144 \times 800}$$

= 0.197 or roughly 0.2 psia

(Note: again, 144 converts square inches to sq ft.)



If the barometric pressure in the room was 14.7 psi, this would indicate *total* pressure which is the sum of the dry air pressure and the water vapor pressure. This is *Dalton's Law of Partial Pressures* which simply states air and water vapor each occupy space as though the other is not there.

Thus the total pressure in this example is:
0.2 (vapor) + 14.5 (dry air) =14.7 psia (a is for absolute pressure)

Humidity

The water vapor in air is, as you probably already know, termed *humidity.*

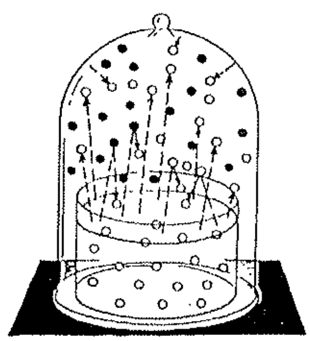
High humidity means, of course, a high amount of water vapor and a corresponding high vapor pressure. Low humidity means the air is "dry" with a low vapor pressure.

Notable Note: Evaporation versus Boiling

How can water in the form of "steam" be present in room air that's at 70° F? We all know that water boils at 212 °F. We also know that if we place an open pan of water in a 70 °F room, eventually the water disappears — it evaporates, it vaporizes. Boiling turns out to be a special case of rapid vaporization — so fast we can observe it. But vaporization is always taking place. Boiling occurs whenever the water vapor pressure just above the surface of the water equals or slightly exceeds the existing atmospheric pressure.

What affects the rate of vaporization? For one thing, the temperature of the water. Warmer water evaporates faster than cooler water. The surface area of the water exposed to the air also affects evaporation rate. Expose more water to the air and the evaporation rate goes up.

If we reduce the atmospheric pressure, evaporation increases. This, of course, is the principle behind the traditional pressure cooker only in reverse. By increasing the pressure inside the cooker, we increase the temperature that water begins rapid evaporation (boiling). This speeds up cooking time.



As might be expected, as more and more water evaporates into the air, we eventually arrive at a point when the air is saturated and in effect no more water evaporates.

If we place a large glass cover over the water pan, we would soon discover that the pressure inside the glass cover was higher than the atmospheric pressure outside. The difference is the pressure of the water vapor. In other words, the total pressure of the air/vapor mixture is equal to the sum of the air pressure and water vapor pressure.

Measuring Humidity

One method of measuring humidity is to use a sling psychrometer and a table.

A sling psychrometer consists of two accurate thermometers mounted side by side on a base that has a handle and pivot at one end. The bulb at the bottom of one thermometer is covered by a cloth "wick" coming from a small container filled with water. This thermometer is the wet bulb thermometer. The other is the dry bulb thermometer.

Holding the psychrometer by the handle, one whirls it in the air several times and then quickly notes the temperature readings on both the dry and wet bulb thermometers. It is usually necessary to repeat this several times until consistent (and therefore accurate) readings are obtained. Whirling the psychrometer causes water to evaporate from the wick of the wet bulb thermometer. Such evaporation cools the bulb of the thermometer. The amount of water vapor in the air controls the amount of evaporation. The more water vapor in the air, the less will be evaporated from the wick. Reducing the rate or amount of evaporation from the wick means there will be less difference in temperature readings between the dry bulb and the wet bulb thermometers, which indicates higher relative humidity.

For example, using the table on this page, if the readings obtained with the psychrometer are 75° F dry bulb (on the dry bulb thermometer) and 65° F wet bulb, the humidity is approximately 60%. What does this mean?

This means the *relative* humidity is 60%. We can define relative humidity as the amount of moisture actually in the air when compared to the maximum amount of moisture the air could hold at the same temperature (and barometric pressure). Thus, in our example, the air contains 60% of the water vapor it could hold. Air at 100% relative humidity is said to be saturated.

Dry Bulb Temperature º F	Relative Humidity – Percentage				
	40%	45%	50%	55%	60%
	Wet Bulb Temperature º F				
83	66	68	69	71	73
82	65	67	68	70	72
81	64	66	67	69	71
80	63	65	66	68	70
79	62	64	65	67	69
78	61	63	64	66	68
77	60	62	63	65	67
76	59	61	62	64	66
75	58	60	61	63	65

Note: For illustrative purposes, the relative humidity percentages in this table are approximate values.

In the next lesson, we'll talk more about humidity — and its effect on human comfort.

Self-Check, Lesson 3 Quiz

You should have read all the material in Lesson 3 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 air we breathe is really a mixture of many gases.

2. T F Oxygen is the largest gas found in air in percent by volume.

3. T F Water vapor is always found in the same proportion to oxygen and nitrogen in atmospheric air.

4. T F As the temperature of air decreases, its ability to hold water vapor increases.

5. T F Atmospheric pressure is the pressure exerted by the weight of water on the Earth's surface.

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. In the formula PV = MRT, P is pressure, V is volume and, M is weight. T is temperature of the gas and R is the:

☐ A. gas resistance. ☐ B. gas constant.
☐ C. gas density. ☐ D. gas purity.

7. Dalton's Law of Partial Pressures means that the pressure exerted by a mixture of gases is equal to:

☐ A. the difference in the pressure exerted by each gas.
☐ B. the pressure exerted by the predominant gas.
☐ C. the sum of the individual gas pressures.
☐ D. the average pressure of the individual gases.

8. One device to determine the relative humidity in the air is called the:

☐ A. sling humidity meter. ☐ B. sling hydrostat.
☐ C. sling hydrometer. ☐ D. sling psychrometer.

9. The wet bulb temperature is 65° F and the dry bulb temperature is 79° F. Using the Relative Humidity Percentage table, determine the % of relative humidity.

☐ 45%. ☐ 50%.
☐ 55%. ☐ 60%.

10. The pressure exerted by dry air is 14.3 psi and the vapor pressure is 0.15 psi; the total air/mixture pressure is:

☐ A. 14.3 psi. ☐ B. 14.15 psi
☐ C. 14.45 psi. ☐ D. 29.3 psi.

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

Key Words

gas	high	boils	condenses	low
saturated	vapor	superheated	proportion	combines

11. Oxygen and nitrogen are always found in the same _______________ in atmospheric air.

12. A substance in the gaseous state, but is liquid at normal pressure and temperature, is said to be in the _________________________ state.

13. Water vapor in air that __________________ on the surface of a cool glass appears as beads of water.

14. An air vapor mixture indicating 100% relative humidity is termed _________________air.

15. A large difference between wet bulb and dry bulb readings indicates ____________ relative humidity.

Check Your Answers!

Now compare your answers with those given in the answer key at the back of this book.

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

Lesson 4 Overview

People can exclaim "I'm comfortable" while lying in a hammock with a cool summer breeze blowing, or in the grandstand watching a horse race in autumn. But Lesson 4 is about what it takes to make people comfortable indoors.

Lesson 4 is going to combine what we know about air and heat transfer and add new information about how the human body creates heat and needs to reject heat to stay at a nearly fixed internal body temperature. We will also establish the temperature and humidity indoors that is necessary to keep people comfortable under "normal" homelike activities.

Now read Lesson 4 which begins on the next page.

Lesson 4: What Makes People Comfortable?

In Lesson 2, we talked about sensible and latent heat and methods of heat transfer. In Lesson 3, we considered the makeup of air — most importantly that air almost always contains water in the form of a vapor. Now we are going to build on what we have learned to understand what makes people comfortable.

For purposes of our discussion, "comfort" might well be described as the absence of "discomfort." Ideally a person should be unaware of an air conditioning system — summer or winter. True, when a person comes into an air-conditioned space from a hot and stuffy out-of-doors, he or she will immediately notice that it is cooler, maybe even cold. However, after a person's body has made adjustments to these changed conditions, which is usually done in a matter of minutes, no one should be aware of the temperature, humidity or air movement, in the room.

Another factor that has become more important, especially in residential air conditioning, is noise.

The ideal system should be so quiet that a person is not aware that it is operating.

What are the conditions that interfere with *thermal* comfort? Several variables influence comfort or discomfort experienced by an individual — namely air temperature, humidity, and air motion. If we extend comfort to include a healthy environment, then air cleanliness or indoor air quality is critically important as well.

Human Metabolism

As anyone who has been sick and taken his own temperature knows, the human body maintains an internal temperature between 98.2° and 98.6° F. Heat is developed by the chemical processes involved in eating, drinking, and breathing. These chemical reactions, however, usually develop more heat than the body needs to sustain life and perform normal activities. Therefore, the excess heat must be rejected by the body.

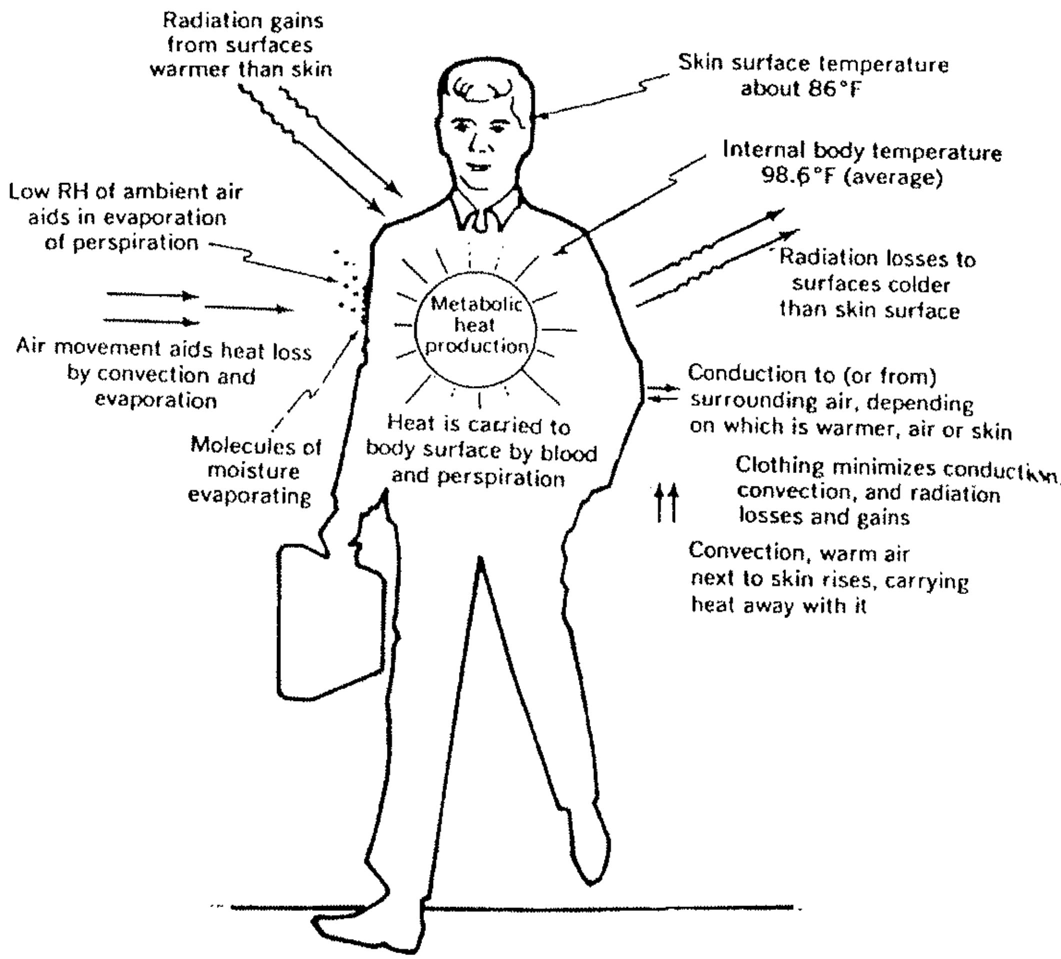
Skin surface temperature is typically around 86° F. If heat from the body is dissipated at too slow a rate, we feel uncomfortably warm. If the heat is given off too fast, we feel cold and shiver. Thus, the purpose of a cooling system (and a heating system for that matter) is to sustain an indoor environment so an individual loses heat at a *rate* that feels comfortable, that is, a person is unaware of losing body heat.

Scientists have actually measured the heat generated by people participating in various activities.

A person sleeping generates about 260 Btu/hr; when walking — about 800 Btu/ hr; and for heavy work such as swimming, a person could generate more than 2,000 Btu/hr. A person's size, weight, age, and gender all affect heat production as well.

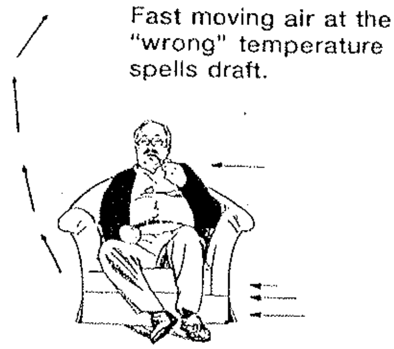
The heat energy which is generated internally must be dissipated — otherwise body temperature will rise and people will become ill. The body loses heat almost entirely by radiation, convection, and evaporation and, for all practical purposes, no conduction. (Feet on a hot or cold surface would contribute little to the overall heat gain or rejection process, but could affect the sensation of comfort.)

Loss or gain of heat due to radiation, you may recall, does not depend on the temperature of the air surrounding the body, but rather on the temperature of the surfaces the body "sees." The surface of the body will radiate (lose) heat to a colder surface, while a hotter surface will radiate (send) heat to the body. A common example is that of the body receiving heat from the surface of a sunny picture window in summer. A room with lots of glass poses a difficult challenge to maintain occupant comfort.



Air Motion

Air motion (convection) is one of the important ways a body loses heat, whenever the temperature of the air is below the skin surface temperature. Air motion not only carries away heat from the body, but it also has an extremely important influence on the rate of evaporation of perspiration from the body. This, in itself, is a most important factor in controlling the rate of heat loss from the body.



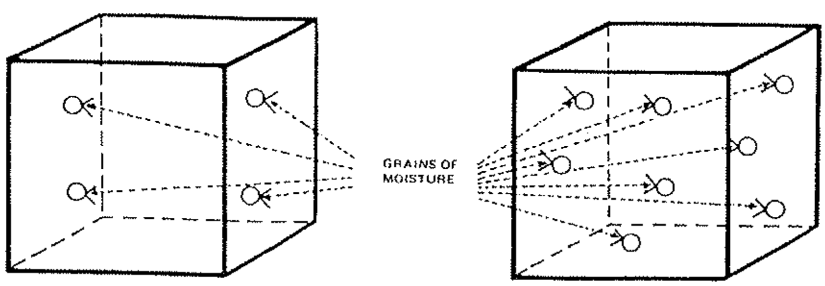
Excessive air motion, however, can cause uncomfortable "drafts" in an air-conditioned space. A draft is simply a combination of temperature and air motion that a person finds objectionable.

Laboratory studies have shown that air velocities in the range of 25 to 35 feet per minute at normal room temperatures are usually most satisfactory for the occupants of the space. If the velocity exceeds 50 feet per minute, the cooling effect is likely to be excessive for most people and they will complain of "drafts."

Humidity

The body loses heat by evaporation of perspiration from the skin. Evaporation of perspiration is a latent heat process and absorbs a great deal of heat, thereby cooling the body. The body is actually perspiring most of the time. Normally one is not aware this is taking place. When conditions of the air surrounding the body do not let perspiration evaporate as it is formed, visible droplets will appear on the skin.

1 Cubic Foot of Air at 70º F



Absolute Humidity = 4 Grains per Ft^3
Relative Humidity = 50%

Absolute Humidity = 8 Grains per Ft^3
Relative Humidity = 100%

The rate of evaporation is primarily due to the amount of water vapor in the air. As we learned in Lesson 3, we can report the level of moisture in the air in terms of *relative humidity,* in percent. Air with a low relative humidity (little water vapor) can absorb body moisture at a much faster rate than air with a high humidity. Thus, one might feel comfortable more in a hot, dry climate than in a humid climate where the local temperature is the same or even somewhat lower. Thus, the frequent summer complaint — "it's not the heat; it's the humidity" — has considerable scientific truth, but should be more correctly stated *it's not just the temperature;*

it's the humidity. One of the jobs of an air conditioning unit is to remove excessive moisture from the air.

Notable note: The ratio of how much moisture exists in the air compared to the maximum amount it could hold is really percent humidity. Relative humidity is actually the ratio of vapor pressure exerted by the water vapor actually in the air divided by the vapor pressure exerted when the air is fully saturated for the same temperature. However, there is little practical difference in the numbers. You may also encounter the term Absolute Humidity. This is the term used to describe how much water vapor is in the air in pounds or grains per cubic foot of air. It takes 7000 grains to equal one pound.

In the previous lesson, we offered this simple definition of relative humidity --- the percent of water vapor actually in the air compared with the maximum amount of water vapor the air could hold at the same temperature and barometric pressure. Thus, if the air holds half as much moisture as it possibly could, the relative humidity is 50%. If the air holds all the moisture it can, the relative humidity is 100%. Air movement also has an effect on the rate of evaporation. The greater the air movement, the greater the rate of evaporation of moisture from the skin. For example: the increased air movement produced by oscillating fans contributes to the comfort cooling effect by increasing the rate of evaporation.

Simultaneous Action

All three factors influencing body heat loss (radiation, convection, and evaporation), can, and usually do, occur at the same time. For example, a person can be sitting outdoors in the hot sun during the summer *gaining* considerable heat by radiation from the sun, while at the same time *giving off heat* to the surrounding air by convection and *losing* additional heat by evaporation of perspiration. If enough heat is given off by convection and evaporation, the person will feel comfortable even though the radiation from the sun is quite intense.

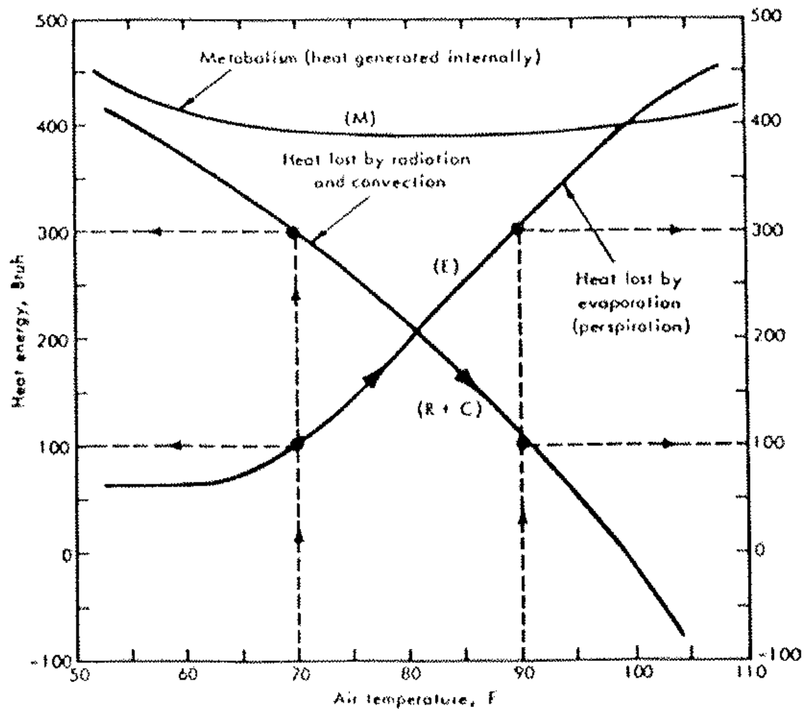
We can describe this with a simple formula: **M + E + R + C+/-S**

Where:
M = metabolic rate, Btu/hr
E = evaporative heat loss,
Btu/hr R = radiation heat loss,
Btu/hr C = convection heat loss,
Btu/hr S = heat storage (rise or fall in body temperature)

On the next page, we have created a picture (graph) of this relationship for a person sitting down in a normal environment. The scale along the bottom is air temperature — ranging from 50° at left to 110° at right. The vertical scale is heat energy — ranging from bottom to top from -100 to 500 Btu/hr. The curve marked E for evaporation heat loss moves up from left to right, while the curve marked R & C for combined radiation and convection heat loss moves down from left to right. The curve at the top marked M is the heat generated by the person sitting down (metabolism).

Let's first look at the situation when the air is at 70°. Move up from the bottom (dotted line) and you reach evaporative heat loss at 100 Btu/hr. Continue up and you reach radiation and convection loss at 300 Btu/hr. Total body loss equals 100 + 300 or 400 Btu/hr.

Notable note: In this example, the body loses 0.1 pound of moisture per hour at 70° but this increases to 0.3 pounds per hour at 90°.



How You Lose Heat

Now at an air temperature of 90°, the situation is reversed. Moving up at 90°,one reaches the radiation-convection curve at 100 Btu/hr and the evaporation loss at 300 Btu/hr. Thus, as the hotter air causes a reduction in radiation and convection heat loss, the body reacts by perspiring more and increasing heat loss by evaporation.

Body metabolism also increases with physical activity which in turn, increases heat loss by evaporation. When bowling, 70% of the total heat rejected by the body is by evaporation; 30% by radiation and convection even though the room air temperature may be in the 70s.

Comfort Range

What range of air temperatures and indoor humidity levels can people successfully tolerate and say they are comfortable? The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) has researched occupant comfort for many years and has established a range of temperatures and humidities that would provide acceptable comfort (by vote) of 80% of all the occupants.

For cooling, people cannot be comfortable in a high humidity environment, so conditioned spaces in a residential or commercial building should be kept at a humidity level not to exceed 60% RH. Air temperatures at this upper humidity could range from 72° to 77° F for occupant comfort. At a lower humidity, say 45% RH, temperatures could be a bit warmer, say, between

74° and 79° F. Most designers assume an indoor temperature of 75° F and 50% relative humidity to estimate the cooling load and size equipment, which we will talk about later.

Indoor Air Quality

In addition to the thermal conditions just reviewed, there are also health and other sensory factors to consider under the broader banner of occupant comfort. There is often a need to introduce "fresh" (outdoor) air for odor control and to assist in reducing any buildup of indoor pollutants that may irritate, or in some cases, be quite harmful to the occupants.

Traditionally, larger air-conditioning systems serving commercial or institutional establishments — stores, restaurants, office buildings, hotels, and other public buildings — are required by local code to blend a percentage of outdoor air with air recirculated through a building. Today, many communities make it mandatory for residential systems to provide a fixed amount of outdoor ventilation air as well.

In addition to providing outdoor air, it may be important to "treat" the air in a building using air cleaning devices to be discussed in a later chapter.

Today's occupants — at home or at work — are particularly health and fitness conscious and perhaps more aware of their indoor environment than previous generations. As noted in Lesson 1, air conditioning has become essential to living indoors in a modern society.

Notable note: Heating design conditions are slightly different — 70°F and 30% RH humidity indoors due to the fact that we dress differently in winter than summer and clothing is obviously a factor in heat rejection and overall comfort.

Self-Check, Lesson 4 Quiz

You should have read all the material in Lesson 3 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 Comfort is the absence of discomfort.
2. T F Noise is a part of a person's thermal comfort.
3. T F Air temperature, humidity, and air motion influence a person's thermal comfort.
4. T F The amount of heat generated by people working, swimming, or sitting at rest is a constant value of 260 Btu/hr.
5. T F Normal human deep body temperature ranges from 96.2° F to 93.6° F.

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. If waste heat from the human body is dissipated too slowly, a person will:

☐ A. feel cold and shiver.
☐ B. feel warm and perspire.
☐ C. feel comfortable.
☐ D. feel cold and then warm.

7. The actual role of a cooling system (or heating system) is to sustain an indoor environment that:

☐ A. adds heat to the occupants.
☐ B. removes heat from the occupants.
☐ C. keeps occupants from losing heat.
☐ D. allows occupants to lose heat at a proper rate.

8. Air motion over the skin not only helps to carry away sensible heat from the body; it:

☐ A. aids heat loss by evaporation.
☐ B. raises deep body temperature.
☐ C. increases heat gain at higher velocities.
☐ D. decreases blood supply to the skin.

9. The body loses heat predominately through three heat transfer processes, radiation plus:

☐ A. convection and conduction.
☐ B. convection and evaporation.
☐ C. convection and thermal.
☐ D. convection and metabolism.

10. The chemical process by which the human body converts food and drink into energy is called:

☐ A. calories.
☐ B. digestion.
☐ C. metabolism.
☐ D. fermentation.

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

Key Words

faster	draft	sensible	slower	50
75	latent	pollutants	breeze	wind

11. A combination of air motion and air temperature that a person finds objectionable is called a: ______________________.

12. Evaporation of perspiration on the surface of the skin is a/an __________ heat process.

13. Air with a low relative humidity can absorb body moisture at a much ____________ rate than air at high humidity.

14. The introduction of (fresh) outdoor air is necessary in some cases to reduce indoor that may irritate occupants.

15. For cooling, most designers assume an Indoor design air temperature of ____________ °F and an indoor relative humidity of ______________ %

Check Your Answers!

Now compare your answers with those given in the answer key at the back of this book.

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

Lesson 5 Preview

What makes the air coming out the air conditioning unit so cold? Once again, in practical rather than highly technical terms, we will learn how the various pieces of an air conditioning unit produce cold at one end and heat at the other. (Ever stand next to the back of a window air conditioner outside? Hot - isn't it?)

We will examine the cooling coil, compressor, metering device, and condenser coil up close. And, in a special notable note, we offer the simplest explanation of air conditioning that you'll likely encounter. To wrap it all up, we review the relationship between some refrigerants and the ozone layer.

Now read Lesson 5 which begins on the next page.

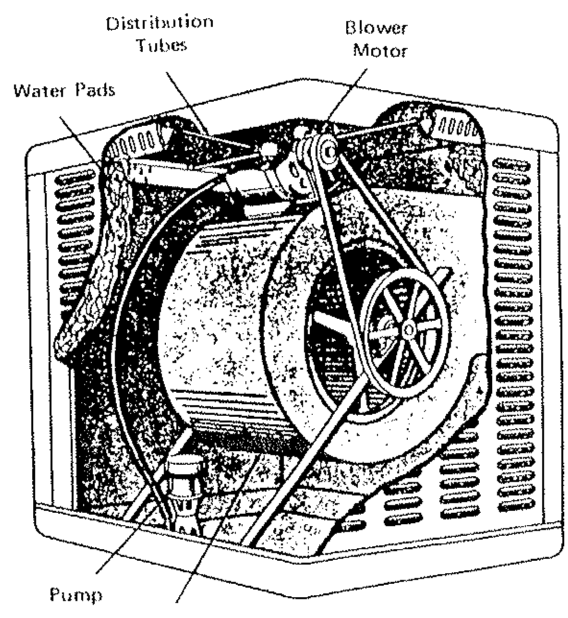
Lesson 5: How Cooling Units Cool

One of the earliest methods of providing comfort cooling was by means of an evaporative cooler. Use of evaporative coolers for comfort cooling was largely confined to areas having a hot/ dry climate, such as the Southwestern section of the United States. They have application in commercial installations even today where traditional air conditioning equipment may be too costly.

In its basic form, an evaporative cooler consists of a metal or plastic pad over which water is distributed by means of a small pump. A fan forces air through the wetted pad and then into the rooms to be cooled.

The air and water come in contact and the water evaporates by taking sensible heat from the air, thus cooling the air. In the process, the relative humidity of the air increases as the water evaporates (latent heat) and is carried along with the moving air. As an example of possible performance, if outdoor air at 100º F and a low 22% relative humidity entered the cooler, the air would leave the unit cooled to about 80º --- a drop of 20º --- but now with a 61% relative humidity.

Obviously, if the outdoor humidity is quite high, comparatively little water will be evaporated and, consequently, little cooling effect will be achieved. Under the same circumstances, the relative humidity within the cooled space would also be too high to provide adequate residential comfort.



Evaporative Cooler

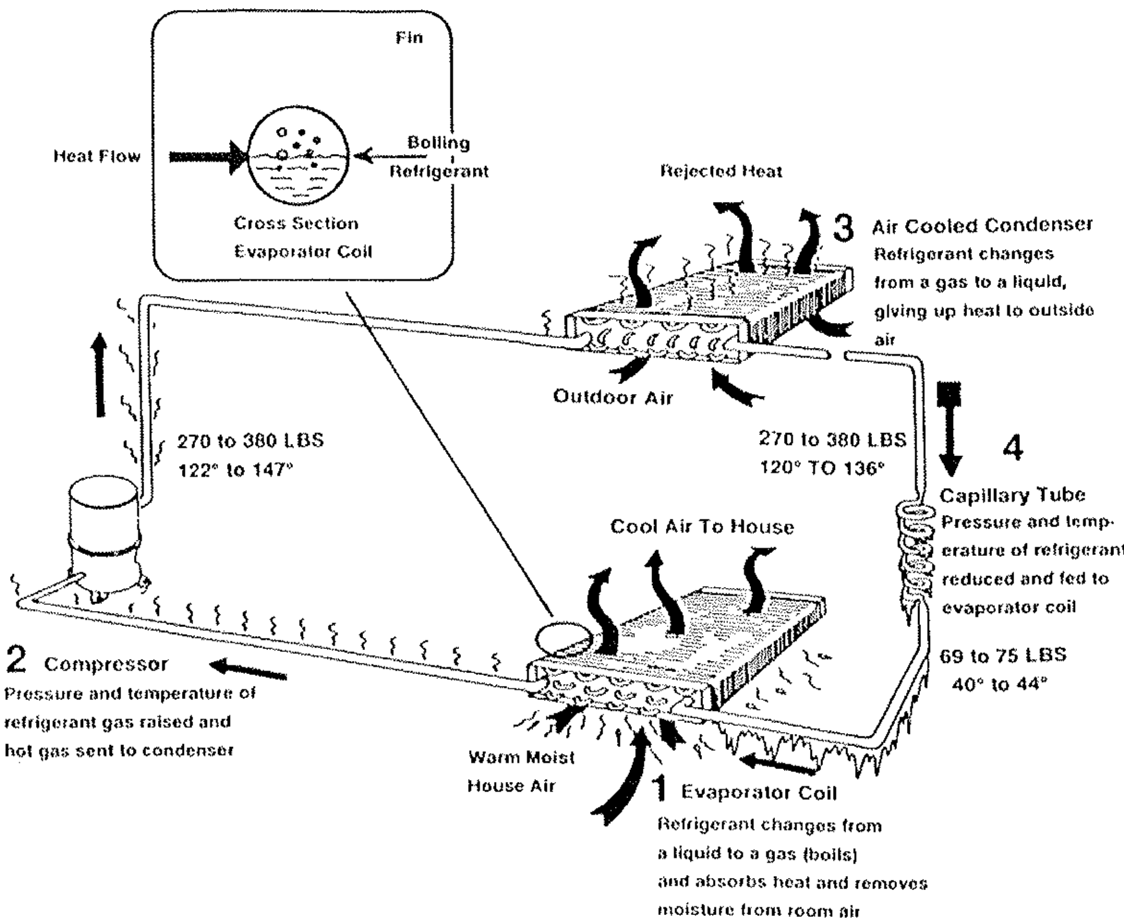
A properly designed evaporative cooler correctly installed under the right conditions can do a good job of sensible cooling. However, it does not “air-condition” because no latent heat is removed — in fact, moisture is added. Even so, this basic equipment can also provide economical relief cooling in coin-operated laundries, greenhouses, animal shelters ,and industrial spot cooling applications.

Notable note: An air washer is a form of evaporative cooler designed to clean the air by “washing” away airborne impurities. First patent dates back to 1897.

Mechanical Refrigeration

The most common method used to provide cooling for comfort conditioning is an electrically driven compression-type refrigeration system. There are four basic components in a mechanical refrigeration system (refer to figure below):

1. Evaporator Coil
2. Compressor
3. Condenser Coil
4. Metering device (Capillary tube shown)



Cooling by Mechanical Refrigeration

All of these components are connected by piping through which a special fluid called a refrigerant is circulated. The refrigerant changes from a liquid to a gas and back to a liquid again as it moves through the various components.

Let's start with the refrigerant. Refrigerant is a fluid that boils at a conveniently low temperature at a reasonable pressure. Water, you may recall, boils at 212° F at atmospheric pressure while one specific type of refrigerant boils at -41° F. That's too cold for comfort cooling, but if we keep the refrigerant under pressure, we raise the boiling temperature to any convenient temperature we want, say to +40° F.

Notable note: If we kept water under a vacuum, we would lower its boiling temperature and perhaps use it as a refrigerant as well

Considerable heat is required to make a liquid refrigerant boil and turn into a vapor. It is this absorption of heat from other substances in the process of boiling which results in cooling the substance.

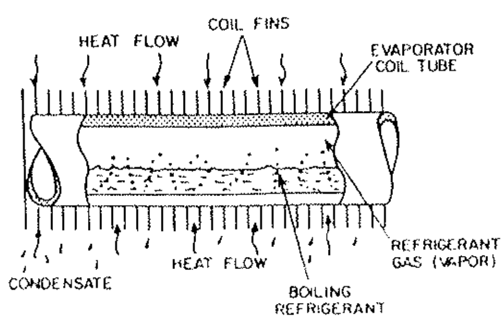
Where Cooling Takes Place

Cold liquid refrigerant is heated in the evaporator. In the process, the liquid refrigerant boils and becomes a gas. In air conditioning, the evaporating refrigerant is heated by the room air flowing through the evaporator. As the air gives up heat to the refrigerant, the air temperature decreases, perhaps from 75° to 55° F.

Notable note: The evaporator is often called the cooling coil in air conditioning applications.

An evaporator design commonly used in air conditioning consists of a coil of copper or aluminum tubes through which cold refrigerant flows and evaporates. Fixed on the outside of the tubes are closely spaced aluminum fins. The purpose of the fins is to increase the rate of heat transfer from the air to the refrigerant by increasing the area of the chilled surfaces in contact with the air.

Inside the evaporator



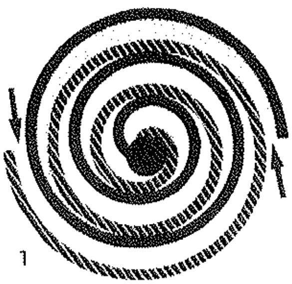
A drain pan is provided in the compartment that houses the finned evaporator coil. When air is cooled by passing through the evaporator coil, much of the water vapor in the air condenses into a liquid on the fins and tubes of the coil. Most of the liquid water formed on the fins and tubes of the evaporator drips down into the drain pan. It is usually disposed of through a condensate line leading to a floor drain or to the outdoors.

If refrigerant cost little or nothing, a refrigeration system could consist simply of a never-ending supply of refrigerant and an evaporator. The refrigerant gas would be allowed to escape to the atmosphere after it has performed its task of cooling the evaporator and the surrounding air or water. (See *Notable Note*). But refrigerant does cost money, and today it is actually illegal to vent refrigerant into the atmosphere. Therefore, a compressor and condenser are employed to recover the refrigerant gas as it comes out of the evaporator and to "recycle" it so that it can be used over and over again.

The Compressor

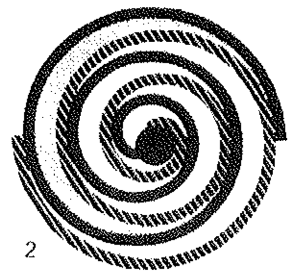
Two functions are performed by the compressor. First, it pulls the refrigerant gas out of the evaporator. Second, it compresses the gas to a higher pressure and, in the process, raises the temperature of the refrigerant gas. The refrigerant might enter the compressor at, say 61° F and at a gauge pressure of 75 psi. The compressor squeezes the vapor and increases its pressure to perhaps 295 psi with an accompanying increase in temperature to 195° F.

A traditional compressor consists of one or more cylinders containing pistons connected to a crankshaft rotated by an electric motor. There are also intake and exhaust valves at the top of the cylinder — in many respects not unlike an automobile engine. As the piston moves down, it pulls refrigerant gas in through the intake valve (suction valve). On the upstroke, the piston compresses the gas and discharges it through the exhaust (discharge) valve.



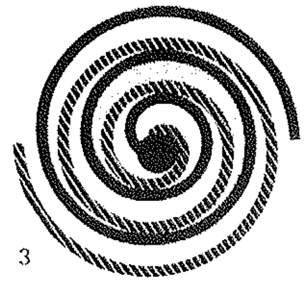
1

Compression in the scroll is created by the interaction of an orbiting spiral and a stationary spiral. Gas enters the outer openings as one of the spirals orbits.



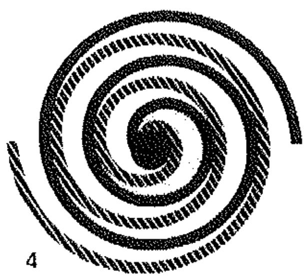
2

The open passages are sealed off as gas is drawn into the spiral.



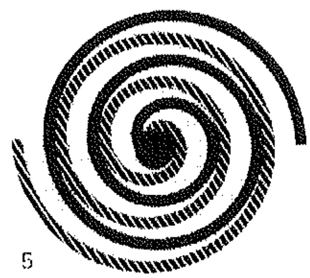
3

As the spiral continues to orbit, the gas is compressed into two increasingly smaller pockets.



4

By the time the gas arrives at the center port, discharge pressure has been reached.



5

Actually, during operation, all six gas passages are in various stages of compression at all times, resulting in nearly continuous suction and discharge.

How A Scroll Works

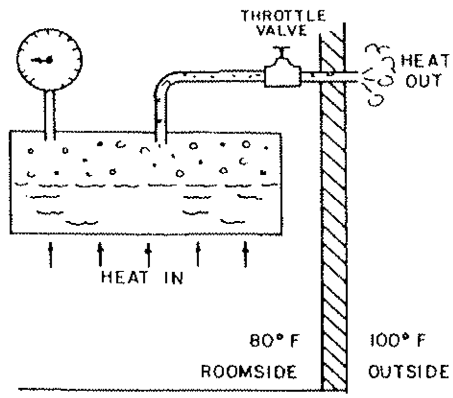
The scroll is a simple compression concept first patented in 1905. A scroll is an involute spiral which, when matched with a mating scroll form as shown above, generates a series of crescent-shaped gas pockets between the two members. During compression, one scroll remains stationary (fixed scroll) while the other form (orbiting scroll) is allowed to orbit (but not rotate) around the first form. As this motion occurs, the pockets between the two forms are slowly pushed to the center of the two scrolls while simultaneously being reduced in volume. When the pocket reaches the center of the scroll form, the gas, which is now at a high pressure, is discharged out of a port located at the center. During compression, several pockets are being compressed simultaneously, resulting in a very smooth process. Both the suction process (outer portion of the scroll members) and the discharge process (inner portion) are continuous.

There are other compressor designs in use. The "scroll" compressor in particular has gained in popularity. Two spiral shaped members — one fixed, the other movable — intermesh to form pockets. The movable scroll moves in an orbital path forcing entering gas to move from the outer pockets toward the center where the gas is reduced in volume and pressure increased.

If the motor that drives the compressor is entirely outside the compressor housing, it is called an *open* compressor. If the motor is sealed inside the compressor housing, it is called a *hermetic* or sealed unit.

Notable Note: A Really Simple Explanation of Air Conditioning.

Ever use a computer keyboard cleaner in a pressure spray can? After a few seconds, the can surface feels cold. The propellant inside has started vaporizing because the pressure drops when you press the trigger. Vaporization, as we know, absorbs heat.

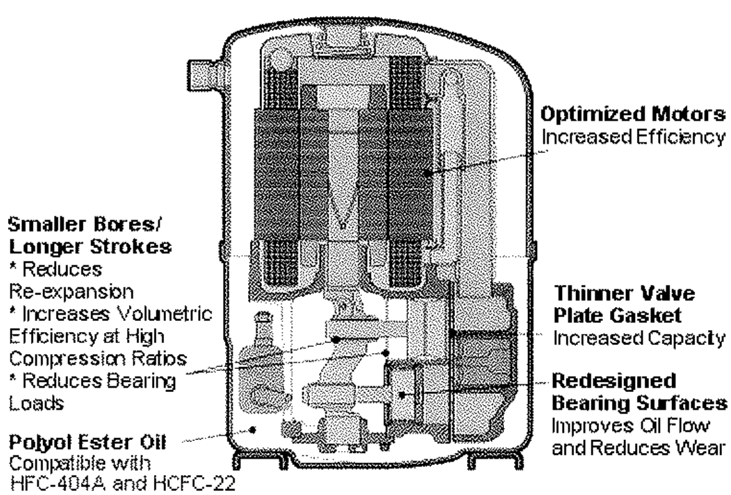


Suppose we have a large, closed drum half filled with liquid refrigerant and vapor under pressure and suspend it in a room with an air temperature of 80° F. Assume the refrigerant has a very low boiling temperature at atmospheric pressure, say -41.4° F (which HCFC-22 actually does).

Now let's open the drum and vent the refrigerant vapor out the top of the drum and out of the room. This will reduce the pressure inside and the refrigerant will start to vaporize (boil) since the refrigerant is above -41.4°. The drum will become cold as the refrigerant continues absorbing heat from the 80°air in contact with the drum. Eventually, the air temperature in the room will begin to decrease — given enough refrigerant in the drum. The heat taken from the room air is carried outside by the refrigerant vapor being vented.

If we added a second drum outside and captured the vapor rather than let it escape, we could refill the drum inside the room and continue the process.

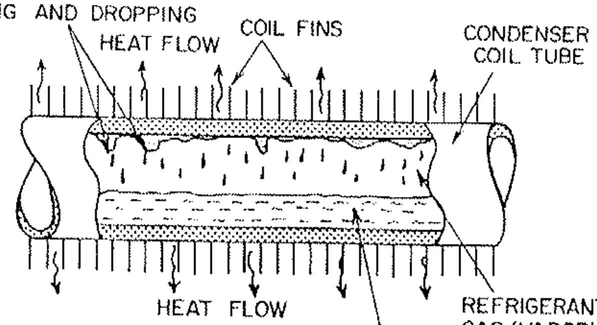
Most residential and small commercial air conditioners employ hermetic compressors. Hermetic systems have several advantages over open systems. The possibility of leaks is held to a minimum, and the motor windings are kept cool by being in contact with the cold refrigerant suction gas entering the compressor compartment. This improves motor performance.



Condenser

The hot, compressed refrigerant gas leaving the compressor moves into the condenser. Here, the hot refrigerant gas now gives up heat and condenses back into a liquid with little change in pressure. Outdoor air is usually used to "cool off" the hot refrigerant. If that is the case, it is called an air-cooled condenser.

Outdoor air, even at a temperature of 100° F, is much cooler than the refrigerant gas, which might be at 130° F inside the condenser. The air removes enough heat from the gas to make it condense back into a liquid state. Now the hot, liquid refrigerant can begin its trip back to the evaporator to start the cycle all over again.

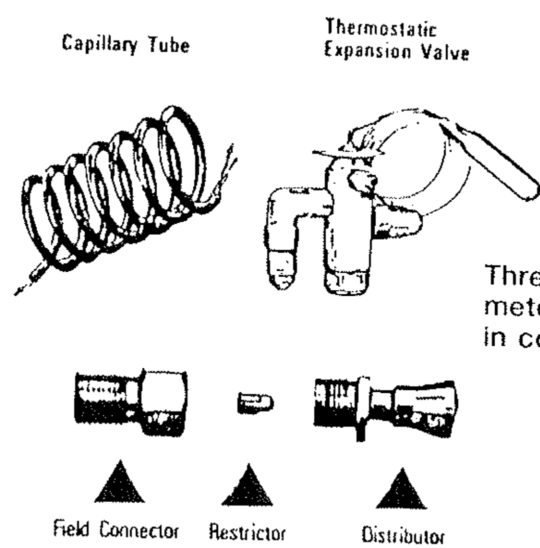


Inside the condenser

The All Important Restrictor

The high pressure liquid refrigerant is too hot to accomplish any cooling, so a vapor-compression type refrigeration cycle must have a device to impose a critical pressure drop and also regulate the flow of refrigerant into the evaporator.

When the hot, high pressure liquid passes through a small opening, there is a dramatic drop in pressure and some of the refrigerant flashes into a vapor. The vaporizing refrigerant picks up heat from the liquid refrigerant which in turn is cooled. Thus, on the leaving side of the restriction, we now have a low pressure, low temperature refrigerant liquid/vapor mixture.



Three types of metering devices in common use.

There are three common metering devices. A *capillary tube* is a length of tubing with a tiny internal diameter held to extremely close tolerances. It is used as a fixed restriction to separate the high and low pressure sides of the system, and meter the proper feed of liquid refrigerant. Since there are no moving parts, it is simple and trouble free if kept free of foreign material, and the refrigerant charge is critical in capillary tube systems.

In place of the capillary tube, there is also the restrictor or *orifice plate* device to regulate flow. Both the "capillary tube" and orifice plate are sized to match the size of the cooling unit. The "cap tube" is sized by the lengthening or shortening the section of tubing and for the orifice, the diameter of the inside diameter of the hole is increased or decreased.

The third metering device — the *thermostatic expansion valve* is not a fixed restrictor. It maintains high evaporator efficiency by varying refrigerant flow to the evaporator in proportion to changes in the Btu/hr load on the cooling coil — let's say as the room air increases and/or decreases in temperature and humidity.

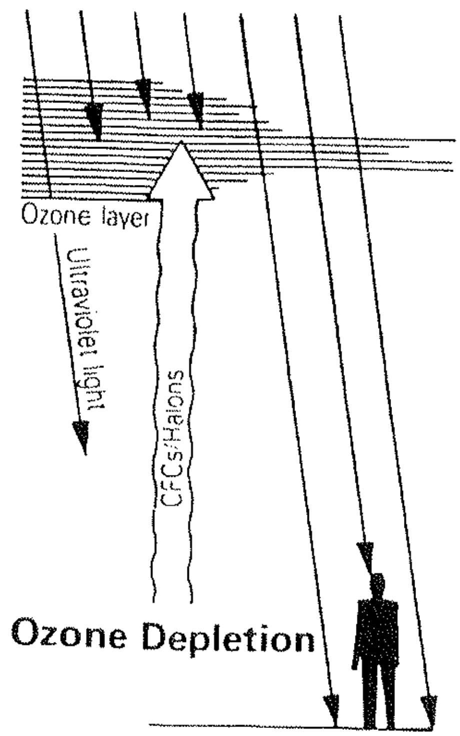
A thermal sensor bulb attached to the refrigerant suction line near the evaporator outlet detects changes in the refrigerant temperature. The sensor opens or closes the expansion valve slightly in an attempt to keep the refrigerant temperature nearly constant by increasing or decreasing the amount of refrigerant flowing.

Refrigerant and Ozone

We mentioned the importance of the refrigerant in the typical vapor-compression refrigeration cycle. There are over 80 recognized refrigerants. The most common ones used in residential and light commercial air conditioning have been from the halocarbon family of refrigerants. A chemical compound of carbon and one or more halogens — fluorine, chlorine, bromine, and iodine — are among the most active elements in chemistry.

A CFC refrigerant is one with chlorine, fluorine, and carbon as part of its structure. CFC means **C**hloro-**F**luoro-**C**arbon. A **H**ydro-**C**hloro-**F**luoro-**C**arbon is an HCFC refrigerant with a hydrogen atom in the chemical composition and less chlorine. And, a **H**ydro-**F**luoro-**C**arbon is a HFC refrigerant with *no* chlorine atom.

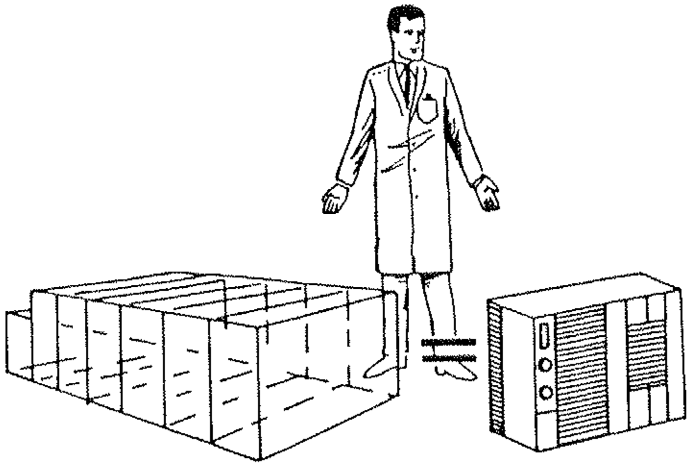
In 1990, the Clean Air Act made it a federal requirement to capture and recycle CFC and HCFC refrigerants. Why? The ozone layer is a protective shield around the earth that helps screen many harmful ultraviolet rays coming from the sun. The chlorine in these refrigerants, when allowed to escape into the atmosphere, is believed to ultimately react vigorously with ozone and reduce the size of the protective screen. CFC refrigerants are no longer manufactured and less harmful HCFC refrigerants are none-the-less being phased out and replaced with non-chlorine-based refrigerants. However, millions of air conditioners still rely on HCFC-22.



How Cooling Is Measured

Cooling capacity of equipment is measured in terms of the amount of sensible and latent heat extracted over a certain period of time. This could be described in terms of Btu per minute, per hour, or per 24 hours. The cooling capacity of an air conditioner, however, is usually reported in terms of a "per hour" basis, such as 24,000 Btu/hr.

The term "ton of cooling" is still widely used as a measure of cooling capacity. A ton of cooling is the number of Btu required to change a ton (2,000 pounds) of ice at 32° F to water at 32° F in a period of 24 hours. It turns out that 12,000 Btu/hr equals one ton of refrigeration effect.



2000 lb of ice melted in 24 hours = 12,000 Btu/hr or one ton of cooling

Actually, the term "ton" is largely used in a *nominal* sense. For example, an air conditioner of 22,000 Btu/hr capacity is still often described as being a "2-ton" unit when actually 2 tons would equal 24,000 Btu/hr. For this reason, the actual capacity in Btu/hr of an air conditioner is usually a much more precise figure than its rating in tons.

Notable note: The latent heat of ice is 144 Btu/lb; times 2,000 pounds divided by 24 hours equals 12,000 Btu/hr.

Self-Check, Lesson 5 Quiz

You should have read all the material in Lesson 5 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 Air moving through an evaporative cooler decreases in humidity and increases in air temperature.

2. T F Refrigerant in an evaporator boils and removes heat from air.

3. T F Fins on the outside of a cooling coil decrease heat transfer.

4. T F It is illegal to vent refrigerant into the atmosphere.

5. T F Refrigerant in a condenser cools, becomes liquid, and in the process rejects heat to outdoor 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. Moving through the compressor causes the refrigerant pressure:

☐ A. to increase and temperature to decrease.
☐ B. to decrease and temperature to increase.
☐ C. and temperature to decrease.
☐ D. and temperature to increase

7. The state of the refrigerant after leaving the condenser and entering the metering device is a:

☐ A. high pressure, high temperature liquid.
☐ B. low pressure, low temperature liquid.
☐ C. low pressure, high temperature liquid.
☐ D. high pressure, low temperature liquid.

8. CFC refrigerants are harmful to the ozone layer above the earth because of the:

- ☐ A. carbon in their chemical structure.
- ☐ B. chlorine in their chemical structure.
- ☐ C. bromine in their chemical structure.
- ☐ D. fluorine in their chemical structure.

9. Refrigerant R-22, widely used in residential equipment over the years, is a:

- ☐ A. CFC refrigerant.
- ☐ B. HFC refrigerant.
- ☐ C. HCFC refrigerant.
- ☐ D. PFC refrigerant.

10. Actual cooling capacity of air conditioning equipment is usually specified in terms of so many:

- ☐ A. tons.
- ☐ B. Btus per minute.
- ☐ C. Btus per hour.
- ☐ D. Btus per day.

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

Key Words

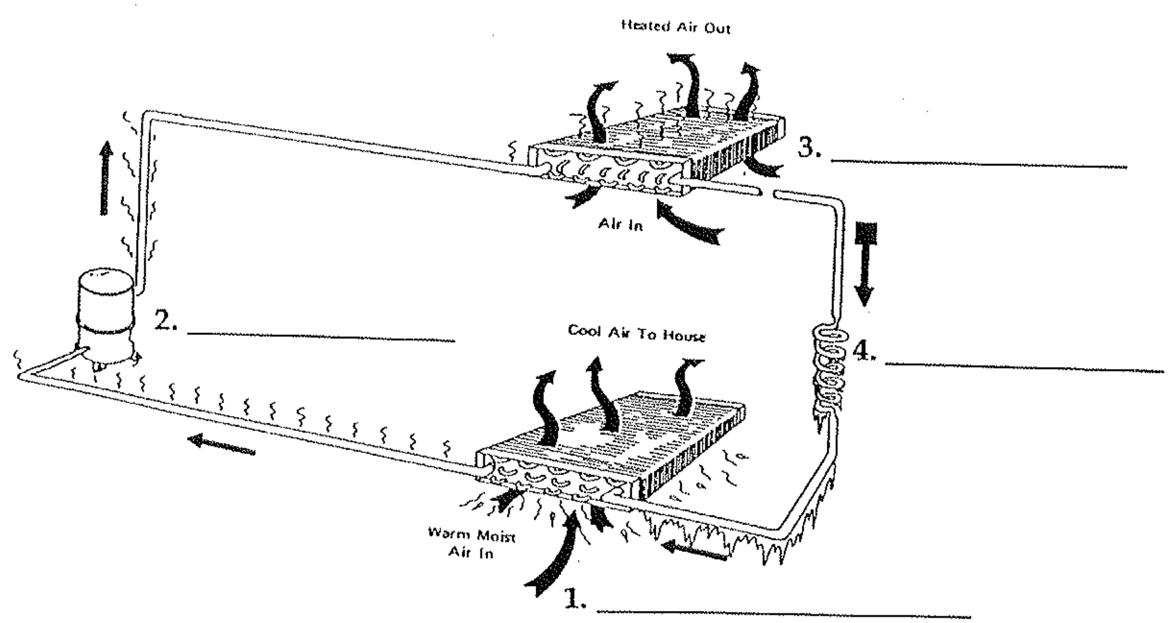
condenser	capillary tube	24,000	scroll	4,000
high	evaporator	draft	sensible	low
evaporator tube	metering device	compressor	coil	latent

11. A restrictor is one example of a/an ____________________ ______________ used in air conditioning refrigerant circuits.

12. Besides the reciprocating compressor, the _______________ compressor has been developed for air conditioning equipment.

13. A nominal two "ton" cooling unit has a Btu capacity of approximately __________ Btu/hr.

14. In the diagram on the following page, identify the system components by writing in the name in the spaces provided.



15. Briefly describe what is happening to the refrigerant as it moves through components 1, 2, 3 and 4 in the diagram from question 14.

1.

___

___

___

2.

___

___

___

3.

___

___

___

4.

___

___

___

Check Your Answers!

Now compare your answers with those given in the answer key at the back of this book.

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

Lesson 6 Overview

We now know that an air conditioning unit consists of a compressor, condenser, cooling coil, and metering device. Fortunately — or unfortunately — those basic parts can be configured in many ways to serve specific applications. This is not unlike an automobile engine, transmission, and wheels which can be configured into different forms of transportation --- from a luxury sedan to an off-road 4 x 4 to an SUV.

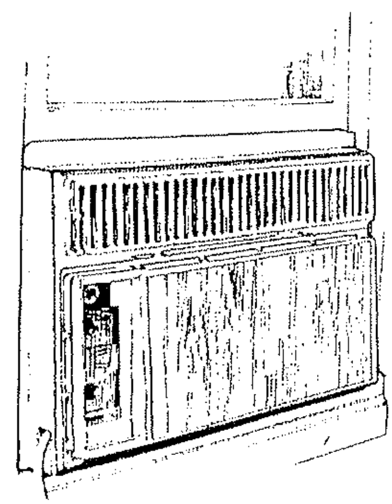
In this lesson, we'll review self-contained units, split-systems, rooftops, and mini-splits. We'll consider the energy ratings of equipment and conclude with an overview of filters used to protect equipment from dust and dirt and those air cleaning devices that do even better.

Now read Lesson 6 which begins on the next page.

Lesson 6: Many Models to Choose From

Air conditioning equipment can be designed and assembled into countless sizes, shapes, and capacities to meet almost limitless application possibilities. Hundred-story skyscrapers, auto assembly plants, a space shuttle assembly building, aircraft factories, and many more facilities require carefully — often uniquely — assembled air conditioning components to provide a proper thermal environment inside.

However, there are other building applications — small business offices, stores, supermarkets, garden apartments, schools, neighborhood shopping centers, light duty factories, restaurants, homes, condos, etc. — where "standardized" air conditioning units can provide quality cooling at a favorable price.

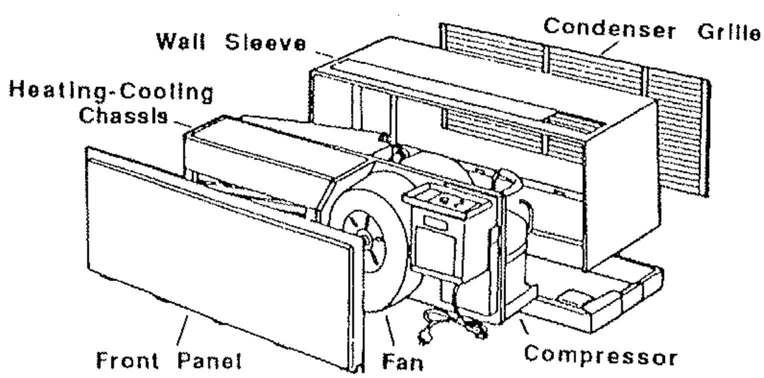


The term "Unitary" equipment has been applied to a family of complete cooling units that are produced in large quantities using automated production facilities. Through an effective manufacturer-distributor-dealer network, these economical, highly versatile cooling machines are available everywhere for installation.

Residential unitary equipment includes equipment with cooling capacities of 65,000 Btu/hr or less. Light commercial is equipment requiring three-phase electric service and in sizes up to 135,000 Btu/hr. Anything over 135,000 Btu/hr is considered commercial unitary equipment.

Self-contained Units

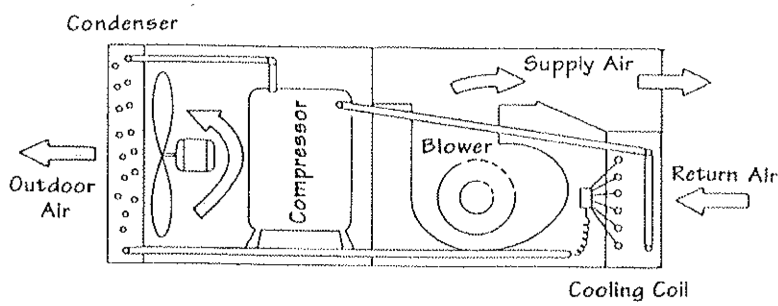
The most common example of a completely self-contained unit is a room air conditioner — although it is not really considered a unitary product. It is usually marketed through appliance dealers and home centers. These units are intended to install through a window, although some mount through a sleeve in a wall, often in small apartments.



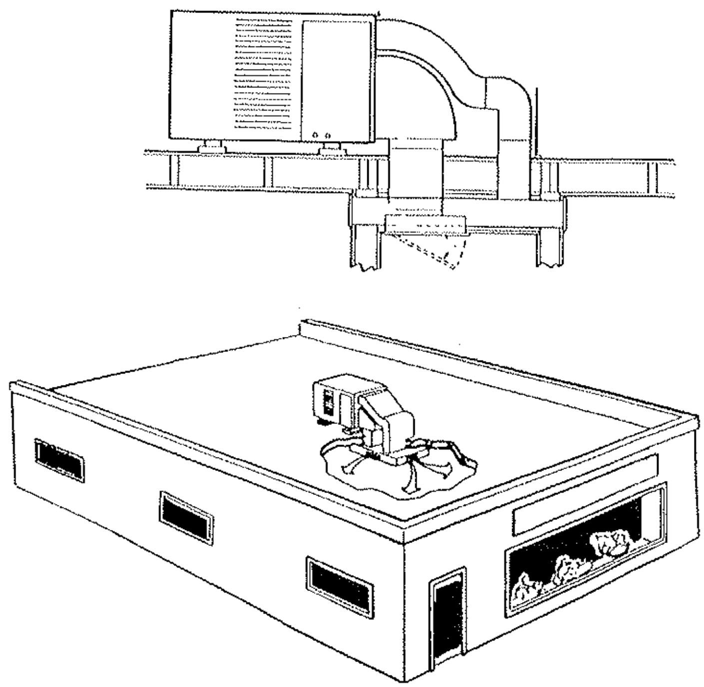
Packaged Terminal A/C Units

Combined in a single package are the motor-compressor, condenser, evaporator, controls, a blower for circulating room air through the evaporator, and a fan assembly for circulating outdoor air through the condenser. Ductwork is rarely connected to a window unit.

Through-the-wall units designed for commercial application such as air conditioning motel rooms are called Packaged Terminal Air Conditioners (PTAC's). Capacities range from 6,000 to 18,000 Btu/hr. This equipment is designed for more rugged duty and may feature a heating capability that uses central steam or hot water and, at times, even electric heaters.



Considerably larger single package unitary air conditioners are also manufactured. These, too, house all the major components in a single cabinet. However, they are usually connected to ductwork to distribute conditioned air to one or more spaces being cooled. Some designs are intended for rooftop installation (Some, too, can provide heating). Self-contained equipment arrives fully factory-charged with refrigerant.

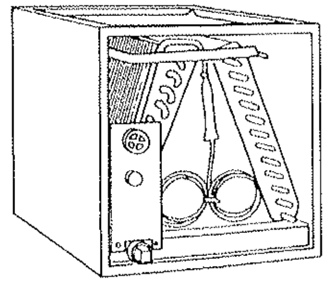


Large single package unitary equipment feature compressor/condenser/evaporator in one cabinet; often configured for rooftop installation.

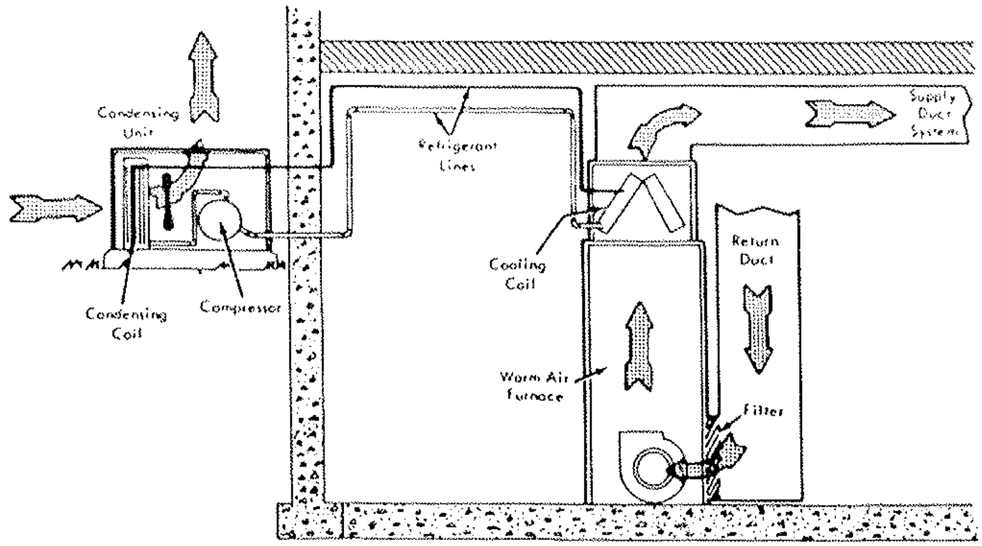
Split Systems

The split-system air conditioner is widely used for residential application. It consists of two packages: the evaporator section mounted indoors, and the compressor-condenser section, mounted outdoors.

It is necessary to connect the two sections with refrigerant lines and to run electric power supply and control circuits to both sections.

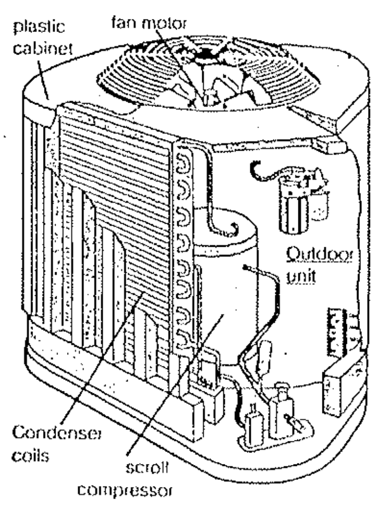


Split systems can be supplied with "precharged" refrigerant lines which makes installation easy. Both sections and the refrigerant lines are charged with the correct refrigerant at the factory. However, most split systems are installed using *line sets* that are filled with a holding charge of refrigerant or nitrogen. This requires the installing technician to check and adjust the refrigerant charge.



Split-system unitary air conditioning system installed in basement with a warm air furnace.

A common method to provide cooling in a residence having a forced warm air heating system is to install a cooling coil in the plenum of the furnace. The existing furnace blower is then used for both heating and cooling. The condensing section is installed outdoors.

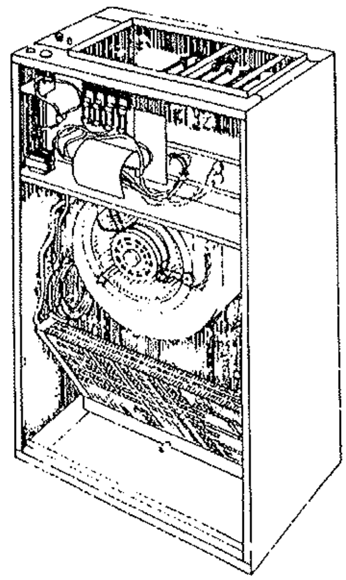


Very often, more air must be circulated for cooling than for heating. Therefore, it is important that duct sizes, blower motor speed, and register location be adequate for cooling when installing a first-time cooling unit in an older heating system. These same checks should be made even for replacement cooling in existing systems.

Manufacturers provide furnace models listed to "handle" specific sizes of cooling coils. Sometimes an oversized furnace may be necessary to accommodate a specific size of cooling unit. That is; the cooling load is unusually large, while heating load is small.

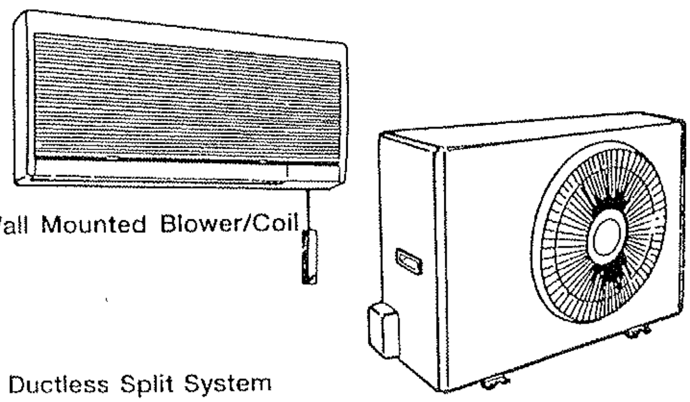
Typical condensing section featuring scroll compressor and wrap around condenser coil.

A split system can also be made up of an indoor cabinet complete with a blower, cooling coil, and filter. A separate duct system can be fitted to the indoor blower unit.



Indoor Cabinet with Coil, Blower and Optional Electric Heater

There are also ductless split-systems. As the name implies, no ductwork is involved. Rather, one or more wall-hung evaporators are served by a single condensing unit. Each evaporator has its own blower and thermostat control.

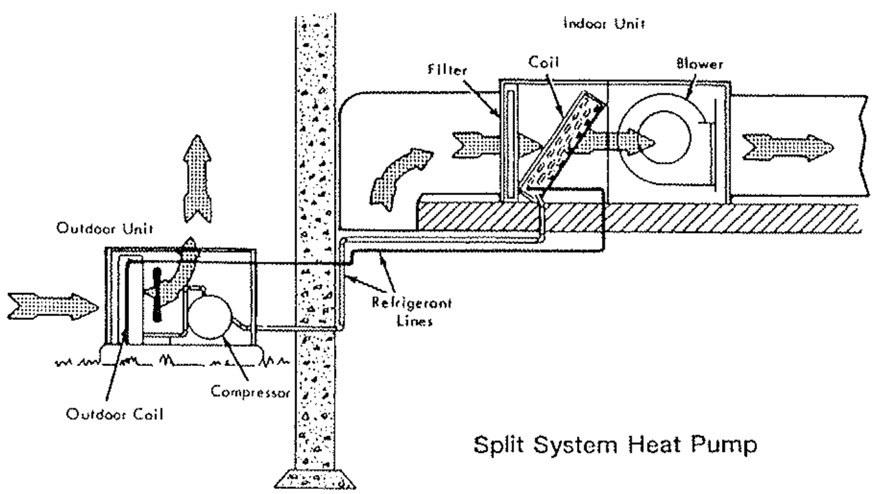


Ductless Split System

Heat Pumps

A heat pump makes use of the same basic operating principles as an air conditioner, but it is designed to supply cooling *and* heating.

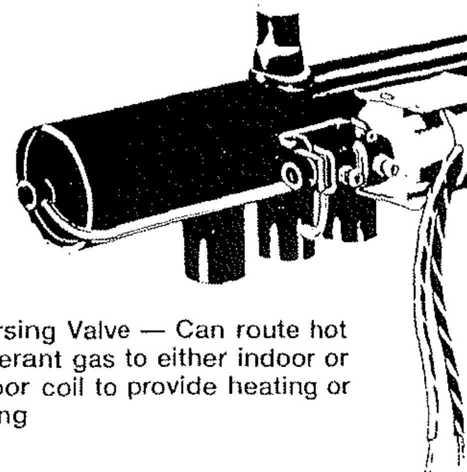
The function of any refrigeration circuit, as previously explained, is to transfer or move heat. A conventional air conditioner transfers the heat of indoor air to the outdoor air. A heat pump reverses this process — it brings heat extracted from the outdoor air inside to warm room air.



Split System Heat Pump

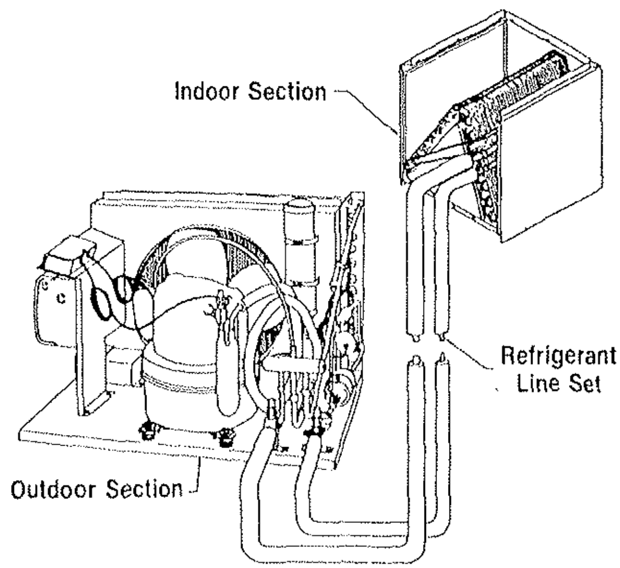
The most common way of switching the heat transfer process from cooling to heating is to change the flow of refrigerant with respect to the evaporator and condenser coils. When heating, rerouted refrigerant flow makes the indoor coil become the hot condenser and the outdoor condenser becomes the evaporator or heat absorber.

The change from cooling to heating and vice versa is accomplished by an automatic "reversing" valve which directs the flow of refrigerant leaving the compressor between the two coils. Because the function of each coil changes between heating and cooling, it is customary to refer to the coils as the indoor coil (or section) and outdoor coil (or section) rather than simply an evaporator or condenser.



Reversing Valve — Can route hot refrigerant gas to either indoor or outdoor coil to provide heating or cooling

As with air conditioning units, heat pumps are available in single package and split-system configurations. Split system heat pumps feature an outdoor section containing the compressor, and an indoor blower/coil section often including optional electric heaters. However, split system heat pumps can also be teamed with conventional furnaces using just an indoor coil above the furnace.



Split System Heat Pump Designed to Install with Furnace

Rating of Unitary Air Conditioners

As mentioned previously, the cooling capacity of air conditioning units is rated roughly in tons and specifically in Btu/hr. Capacity ratings of most unitary air conditioners are now certified under programs sponsored and administered by Air-conditioning, Heating & Refrigeration Institute (formerly ARI). This means that manufacturers who participate have their published cooling capacities verified by a third party. Updated directories of Certified Unitary Equipment can be downloaded at www.AHRInet.org.

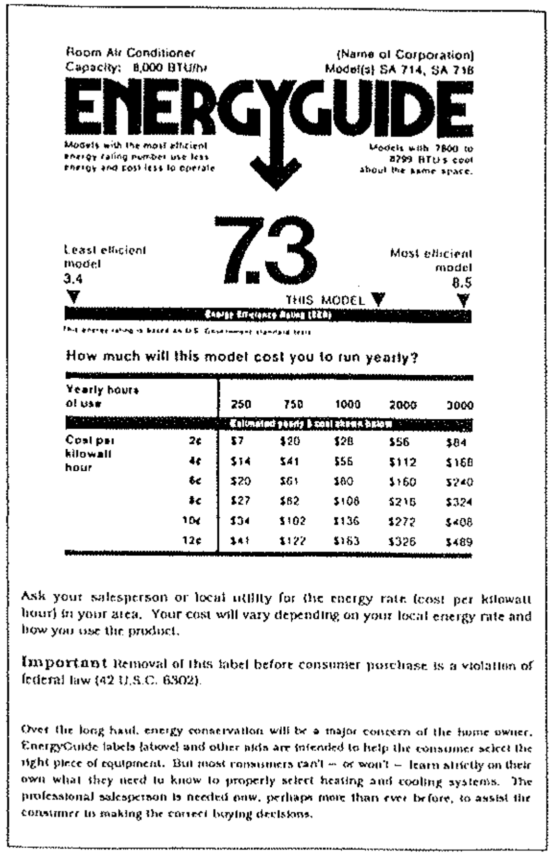
The listed and advertised capacity of an air conditioner is determined at standard rating conditions of the certification test. The actual installed cooling capacity of an air conditioner will vary somewhat with changes in the dry bulb and wet bulb temperature of both the indoor air being cooled and the outdoor air circulating through the condenser.

In 1975, the air conditioning industry introduced the Energy Efficiency Ratio (EER) to assist consumers in selecting the most energy efficient equipment. An EER is defined as the standard cooling capacity in Btu/hr divided by the watts input to power the equipment. A unit with a standard rating of 23,000 Btu/hr requiring 3,000 watts of electricity would have an EER of 7.7. The higher the EER, the greater the efficiency of the unit at standard rating conditions.

In 1979, the U.S. Department of Energy established new testing procedures designed to provide consumers with *seasonal* or *annual* efficiencies so that a dollar and cents operating cost comparison could be made when selecting equipment.

The Seasonal Energy Efficiency Ratio (SEER) is defined as the total cooling provided by a unit during a normal usage period divided by the watt-hours input required over the same period. Again, the greater the SEER number, the greater the seasonal operating efficiency. For heat pumps, the Heating Seasonal Performance Factor (HSPF) is used. It is defined as the total heating output of a unit during normal usage divided by the total electric power input for the same period.

Yellow Consumer EnergyGuide Label


Room Air Conditioner
Capacity: 8,000 BTU/hr

(Name of Corporation)
Model(s) SA 714, SA 718

ENERGYGUIDE

Models with the most efficient energy rating number use less energy and cost less to operate

Models with 7800 to 8799 BTU's cool about the same space.

Least efficient model 3.4

7.3

THIS MODEL

Most efficient model 8.5

How much will this model cost you to run yearly?

Yearly hours of use		250	750	1000	2000	3000
Cost per kilowatt hour	2¢	$7	$20	$28	$56	$84
	4¢	$14	$41	$56	$112	$168
	6¢	$20	$61	$80	$160	$240
	8¢	$27	$82	$108	$216	$324
	10¢	$34	$102	$136	$272	$408
	12¢	$41	$122	$163	$326	$489

Ask your salesperson or local utility for the energy rate (cost per kilowatt hour) in your area. Your cost will vary depending on your local energy rate and how you use the product.

Important Removal of this label before consumer purchase is a violation of federal law (42 U.S.C. 6302).

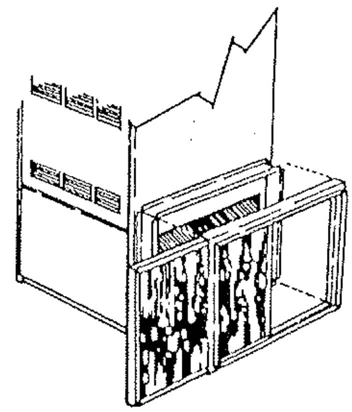
Over the long haul, energy conservation will be a major concern of the home owner. EnergyGuide labels (above) and other aids are intended to help the consumer select the right piece of equipment. But most consumers can't – or won't – learn strictly on their own what they need to know to properly select heating and cooling systems. The professional salesperson is needed now, perhaps more than ever before, to assist the consumer in making the correct buying decisions.

Finally, the Annual Performance Factor (APF) for a heat pump is defined as the total heating and cooling provided in one year divided by the electric power used in that same year.

Allied with the testing program is an "Energy-Guide" label that is affixed to some types of equipment. The Energy Guide provides consumers with operating cost information so that the consumer can make a rational selection among the various products.

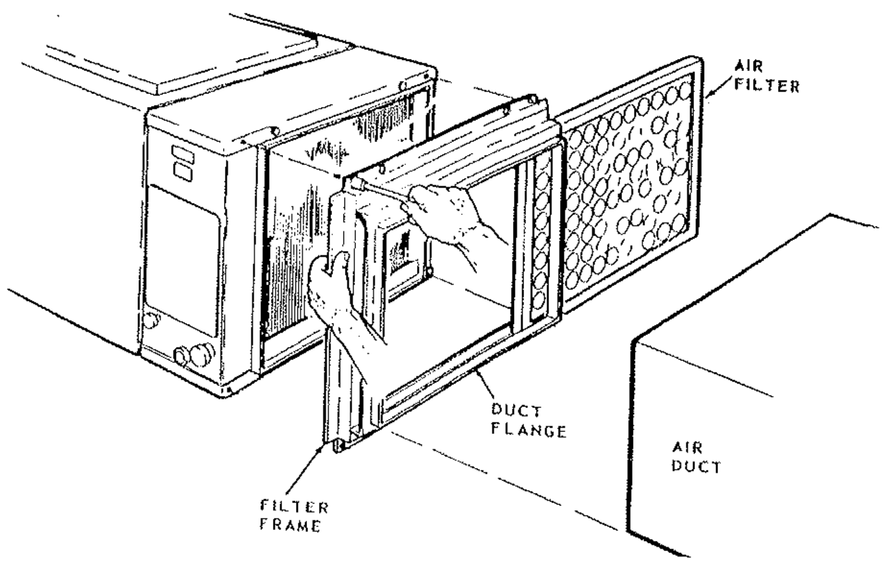
As a result of product improvements, equipment listed in the AHRI directories has shown a striking improvement in efficiency over the past few years. In 1981, only 23 percent of the central units listed had SEER ratings of 8.5 or higher. By 1985 that figure had already increased to 66 percent. Presently, no equipment with an SEER less than 13 can even be manufactured.

Filter Equipment



An air filter is an essential part of all air conditioning equipment. In many cases, the removable filter is an integral part of the equipment cabinet. In other cases, the filter may be inserted in the return duct system. In an earlier time, the important purpose of the filter was to protect the blower and cooling coil from dirt accumulation and reduced performance.

As Indoor Air Quality (IAQ) has become an important factor in overall comfort and health, more attention is being paid to higher quality filtration.

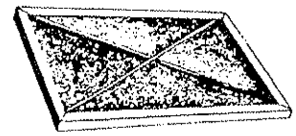


The wet surfaces of the cooling coil are very effective filters in trapping summertime airborne particles such as pollen to which many people suffer allergies. To do a more effective job of cleaning the air, and still continue to protect equipment, manufacturers can provide various filtering materials and entire filtering units which can capture small particles that are often most trouble- some to the human condition.

Notable Note: Small particles are more difficult to capture and often can reach deep inside the lungs. Large particles do not stay suspended in the air very long and settle out on room surfaces.

First of all, there are *disposable type* and *permanent type* panel filters. Some disposable filters are made of glass fibers with a cardboard frame and are usually about one inch thick — although some may be thicker. These filters should be replaced several times during the heating or cooling season for optimal results. A permanent filter is made of foam, metal mesh, or plastic and may be washed clean and reused. Typically, panel filters provide minimal effectiveness against small particles.

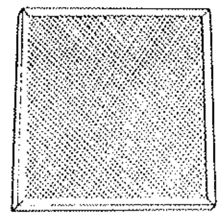
A denser material is used in the dry type extended surface filter. This can be a simple upgrade for the one-inch panel filter or be made several inches wide and compete in performance with high efficiency electronic air cleaners or EACs.



Foam Filter

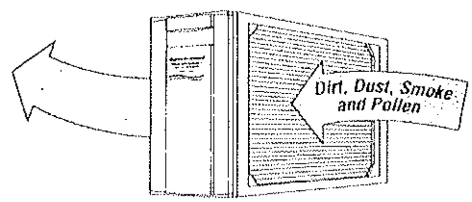
The EAC and high efficiency extended surface filter are capable of removing up to 95% of airborne dirt and irritants, odors, and tobacco smoke, and up to 99% of the airborne pollen present in the home.

The technical operation of the EAC is quite simple and the device uses very little energy. Basically, the electronic cleaner puts an electrical charge on the dust particles that enter the front of the unit. These particles are then attracted to alternately charged plates called cells.



Metal Mesh Filter

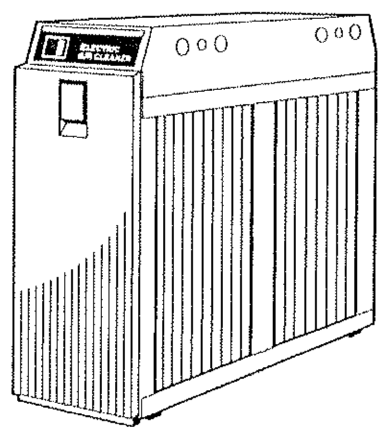
The electronic air cleaner may have a control which monitors the unit's performance. The control automatically indicates when the filter is dirty and is in need of cleaning. Residential size cells can be washed in a household dishwasher.



Extended Surface Pleated Filter

Filter performance is reported in terms of the *weight* of dust removed in percent and called *arrestance*. This is useful in evaluating large particle performance. A *dust spot* efficiency is an indication of small particle cleaning. A filter might have an arrestance of 60% but a dust spot efficiency of only 15%. Obviously, the higher the dust spot efficiency, the cleaner the air that passes through the filter equipment.

Odors which are in the gaseous state cannot be effectively filtered with either EACs or extended surface filters. Charcoal filters have been used successfully to remove selective gaseous contaminants — especially cooking odors.



Electronic Air Cleaner - EAC

Self-Check, Lesson 6 Quiz

You should have read all the material in Lesson 6 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 Unitary refers to equipment components that are assembled in the field one at a time.

2. T F A window air conditioner is an example of a split-system.

3. T F PTACs are typically connected to ductwork for air distribution throughout the spaces served by the equipment.

4. T F A furnace blower cannot be used to circulate cool air because of the low supply air temperature involved in air conditioning.

5. T F Equipment cooling capacity can be certified under a program sponsored by ASHRAE.

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

6. In the outdoor section of a split system air conditioning unit, you will normally find:

☐ A. only the compressor.
☐ B. only the condenser.
☐ C. the compressor and condenser.
☐ D. the compressor, condenser and air handler.

7. Self-contained (single package) unitary equipment comes from the factory with:

☐ A. line sets with a holding charge.
☐ B. pre-charged line sets.
☐ C. fully charged components and tubing.
☐ D. partially charged components and tubing.

8. Equipment that can provide both heating and cooling by reversing the refrigerant flow is called a:

- ☐ A. sump pump.
- ☐ B. heat pump.
- ☐ C. dual pump.
- ☐ D. reverse pump.

9. The cooling provided by a unit over a normal usage period divided by the Watt-hours input is the units:

- ☐ A. EER.
- ☐ B. SEER.
- ☐ C. APF.
- ☐ D. HSPF.

10. The intent of the one-inch disposable or "throw-away" filter is to:

- ☐ A. filter out small particles that enters the lungs.
- ☐ B. trap large particles that cause dust on furniture.
- ☐ C. clean the air of odors.
- ☐ D. protect equipment from dirt accumulation.

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

Key Words

condenser	spot staining	efficiency	PTAC split	carbon
arrestance	evaporator	electrical	charcoal	dust spot
ductless split	high	compressor	magnetic	resistance

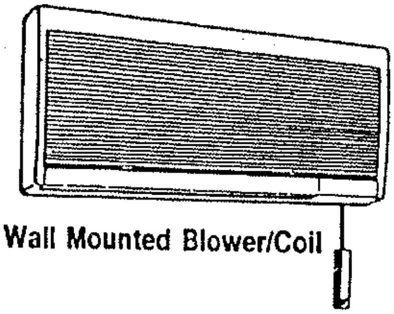
11. Filter performance that measures the weight of dust removed from the air is called filter ____________________.

12. An indication of a filter's small particle performance is termed a filter's ____________ ____________ efficiency.

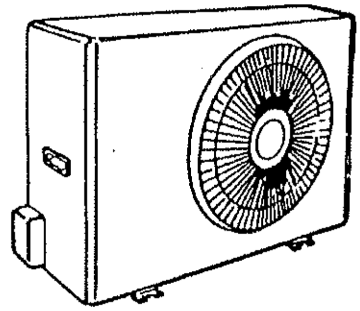
13. Selective odors can be removed by means of ________________ filters.

14. An electronic air cleaner imposes an ________________ charge on dust particles as a means to effectively collect small particles.

15. The cooling equipment shown below is an example of ____________ ____________ system.



Wall Mounted Blower/Coil



Outdoor Condensing Unit

Check Your Answers!

Now compare your answers with those given in the answer key at the back of this book.

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

Do you have any unresolved questions on this lesson?

Lesson 7 Overview

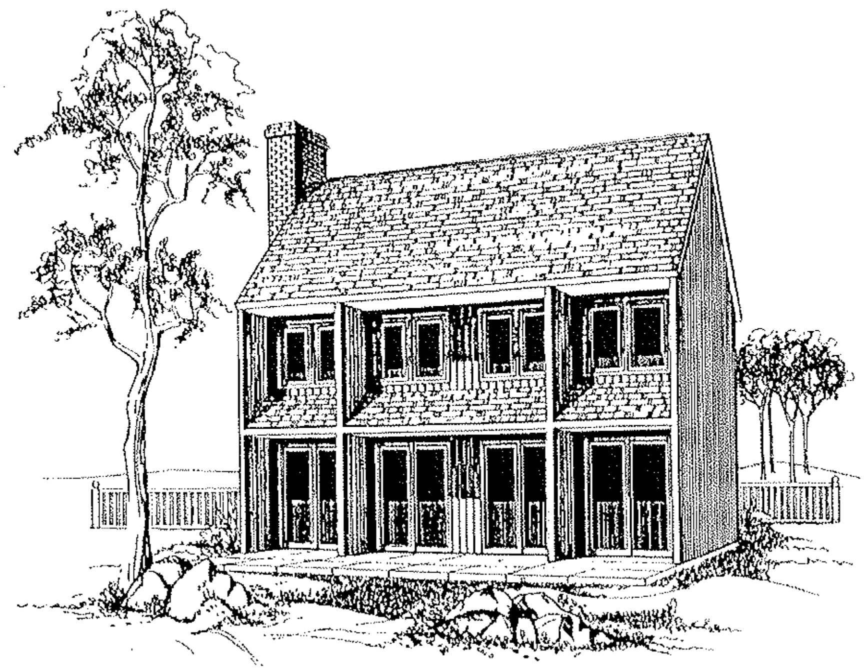
We know from everyday experience that the sun can bleach paint and warp building materials in short order. Those same rays cause great quantities of heat to penetrate a building. We must, of course, get rid of this heat if we are going to keep people cool.

Lesson 7 points out some important building characteristics that are essential to practical cooling.

In addition, Lesson 7 talks about the importance of insulation: good glass - properly located - use of shading and landscaping and, very important, proper roof ventilation to keep heat and humidity out. We'll also discover some unintended side effects of exhaust fans and heat recovery ventilators.

Now read Lesson 7 which begins on the next page.

Lesson 7: A Building's Thermal Problems



One example of how the designer can ease the burden on cooling equipment. South glass in this architect's rendering is protected from the rays of the sun using a large roof overhang and extended walls.

A building loses heat in winter and gains heat in summer. Who hasn't opened the door of a closed-up summer home in August and felt the blast of heat when entering inside?

Sun & Temperature Combine

Heat penetrates inside a building by conduction through the structure since there is often a temperature difference between outdoor air and the air inside and, as we know, heat flows from a higher temperature to a lower temperature.
But a powerful multiplier is the sun. Radiant heat from the sun is what really heats up the walls and makes a roof so hot to the touch. This solar heat increases the effective temperature difference across the wall or roof which substantially increases heat gain. The sun beating on a wall may make a 20 degree outside air to indoor air temperature difference equivalent to a 25 or 30 degree temperature difference, with a resulting increase in heat flow into the house.

Other Heat Drivers

Infiltration of hot outdoor air through the cracks around windows and doors also contributes significantly to the heat gain, causing both a rise in temperature and indoor humidity.

In summer, the moisture content of outdoor air is usually higher than indoors --- certainly higher than desired inside. Infiltration of this moisture laden air raises the relative humidity of indoor air.

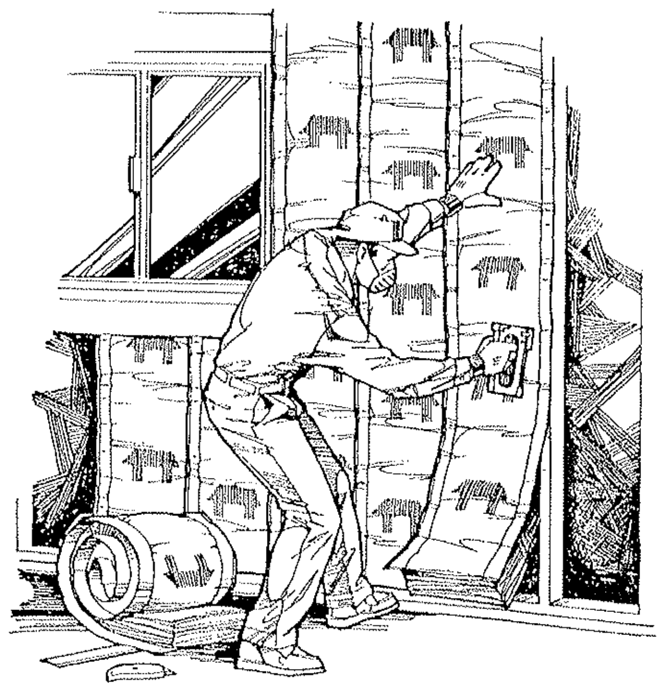
Indoor humidity is also elevated by cooking, washing, bathing, and by the occupants themselves. You may recall, if the relative humidity of indoor air exceeds 60%, the occupants begin to feel uncomfortable.

The sensible heat produced by electric lights and motors, by cooking, by heating of water, etc., increases the heat gain in summer. People in the conditioned space also generate sensible heat as we already learned.

Considering the number and variety of drivers that contribute to building heat gain, just the physical *size* of the structure is not an accurate indication of the total heat gain occurring.

Insulation

Certain materials retard the flow of heat better than others. We call the good heat retarders insulation. Insufficient insulation in a building can require a larger and more expensive air conditioning unit than would otherwise be needed. Operating costs are also affected by the level of insulation installed.



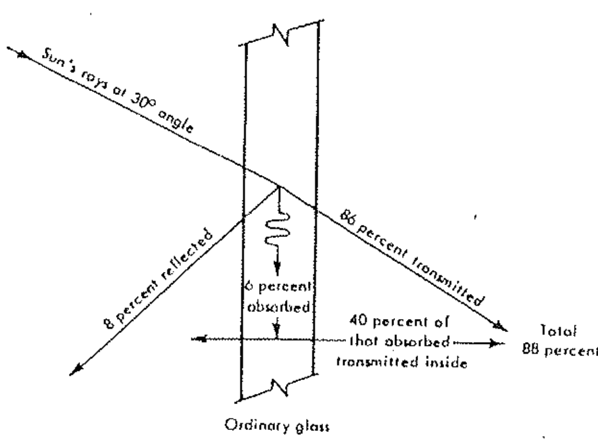
In the past, the recommended level of thermal insulation (blankets, batts and loose fill) was stated in terms of "so many" inches (thick) in walls, ceiling, and floor. Today, insulation manufacturers refer to recommended "R" numbers. The R value reflects the resistance to the flow of heat offered by the insulation. The higher the number, the greater the resistance or insulating quality. R-19 is better than R-11, for instance.

Specifying inches has been abandoned because of the variety of insulation materials available today and the fact that materials vary in heat conductivity per inch thickness. Thus, 3 inches of one type may not provide the same insulating effect as 3 inches of another.

Reflective Insulation

One or more sheets of reflective foil each separated from touching one another by an air space can also act as a barrier to heat flow. The reflective foil reduces heat transferred by radiation. Reflective foil is often used in conjunction with batt type insulation in attic spaces. Insufficient insulation or complete lack of insulation in the walls, ceilings, and sometimes the floor of a building will not only affect the cost of air conditioning equipment and operating expense, but also affect occupant comfort. Insulated walls and ceilings will have "cooler" inside surfaces, causing less heat to be radiated between the occupants and these surfaces.

Materials in wall construction and the amount and type of insulation can have a dramatic impact on the heat conducted through the building component. Consider, for example, typical frame construction which consists of siding material over sheathing attached to 2 by 4-inch wood or steel studs. The interior side of the wall may be plaster or some form of paneling, but most likely drywall. These materials and the air space between the inner and outer walls (without reflective foil) offer minimal resistance to the flow of heat. If all the stud space is filled with insulation, however, the heat transmission through the wall may be as little as *one-third* as much as when no insulation is used.

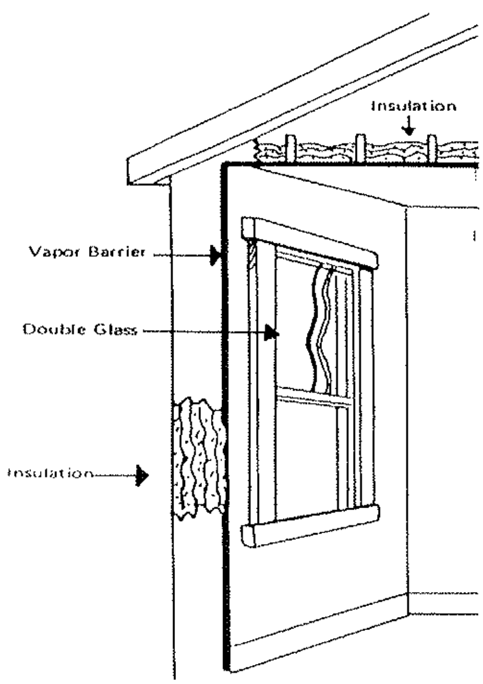


ORDINARY GLASS transmits about 88 percent of the solar heat directed at its surface. Eight percent is reflected and 6 percent is absorbed. Values change with sun angle and thickness of glass

This does not necessarily mean that use of insulation will reduce the size of equipment needed by one-third. However, the added insulation will definitely improve the efficient operation of the cooling system and help reduce their cost of operation.

Insulation installed in *interior* walls, while not affecting or reducing heat gain, may help reduce sound transmission. To insulate a house for thermal protection, read *Notable Note on next page.*

Dealing With Solar Heat

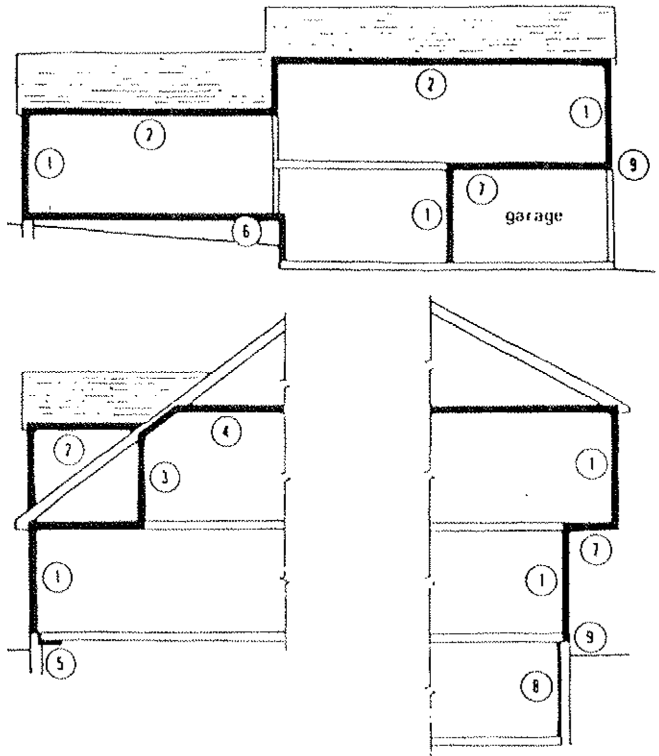


Good Construction Cuts Cost

A roof that is light colored will considerably reduce the amount of heat gain by direct sunlight. White or light-colored roofing materials *reflect* much of the heat from the sun. Dark roofs — like a blacktop driveway — *absorb* much of the sun's heat and transmit it into the attic, which ultimately enters the rooms below. A really major source of heat gain is direct solar radiation through *windows.* The design trend over the years towards more extensive glass areas in homes and small commercial buildings poses a great challenge for the air conditioning specialist.

Under some conditions, single pane glass transmits up to 88% of the direct solar radiation that strikes its surface. Once inside, the solar radiation warms all the surfaces and eventually room air. Consider your automobile parked in the sun!

Notable Note: Where to insulate a home for thermal protection.



1. **Exterior walls**. Sections sometimes overlooked are the wall between the living space and an unheated garage or storage room, dormer walls, and the portion of wall above the ceiling of an adjacent section of a split-level home. Pack insulation in narrow spaces between jambs and framing.

2. **Ceilings** with cold spaces above and dormer ceilings. An attic access panel can be insulated by stapling a piece of mineral wool blanket to its top.

3. **Knee walls** when attic space is finished as living quarters.

4. **Between collar beams**, leaving open space above for ventilation.

5. Around the **perimeter** of a slab on grade.

6. **Floors** above vented crawl spaces. When a crawl space is used as a plenum, insulation is applied to crawl space walls instead of the floor above.

7. **Floors** over an unheated or open space such as over a garage or a porch. The cantilevered portion of a floor.

8. **Basement walls** when below-grade space is finished for living purposes. Mineral fiber sill

sealer between sill and foundation provides an effective wind infiltration barrier.

9. In back of **band or header joists.**

General Guidelines

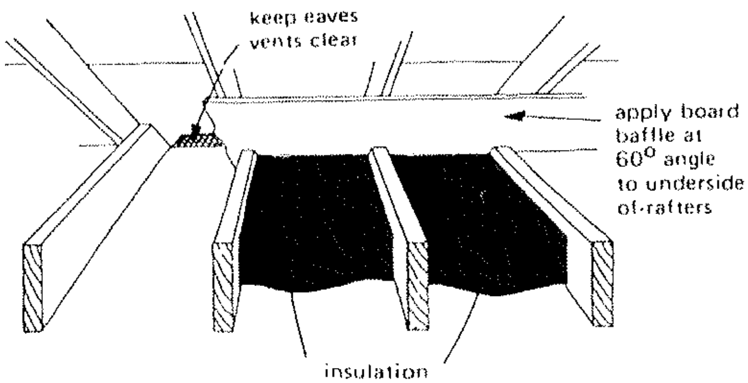
1. Install insulation so the vapor barrier side faces the interior of the home — that is, the area heated in winter.

2. Insulate all large and small spaces of the building section.

3. Place insulation on the cold side (in winter) of pipes and ducts.

4. Staple flanges snugly against the sides of framing members.

5. Repair major rips or tears in the vapor barrier by stapling vapor barrier material over the tear or by taping the torn barrier back into place.



Ceiling Insulation Guidelines

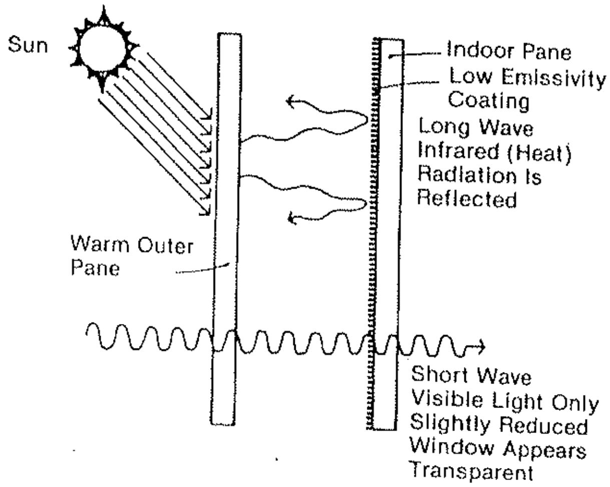
Blowing wool should be installed by an experienced contractor so that proper density, coverage, and thickness will be provided and all hollow spaces will be filled. Pouring wool may be applied in unfinished attic areas by emptying the bags evenly between ceiling joists, paying particular attention to the manufacturer's recommendations as to proper thickness and coverage per bag. The wool may be leveled with a wood slat or garden rake. Be sure that eaves ventilation openings are not blocked. A method of protecting these openings is shown in figure above.
Small openings, such as those around a chimney, should be hand-packed with mineral wool. Cavities, drops, or scuttles should be covered with insulation or the sides and bottom areas should be insulated.

Be sure that recessed lighting fixtures and exhaust fan motors protruding into the ceiling are not covered with insulation.

In floored attics, floor boards may be removed as required for access to the space to be insulated.

Check for obstructions such as bridging and conduit between openings.

So far as *direct solar radiation* is concerned, using double glazing (storm windows, or normal double pane windows) is of comparatively little benefit. Normal insulated glass (a double sheet of regular glass separated by a 1/4 inch air space in a common frame) cuts transmitted direct solar radiation only a little — from 88% down to perhaps 70%.



But if one of the sheets of the double glass is special heat absorbing glass (usually the outer sheet), then the direct solar radiation transmitted can be reduced to perhaps 64% or so. And special low emissivity coated (low-E) glass on the inner sheet can be effective in turning back almost half the direct solar radiation — only about 55% getting through.

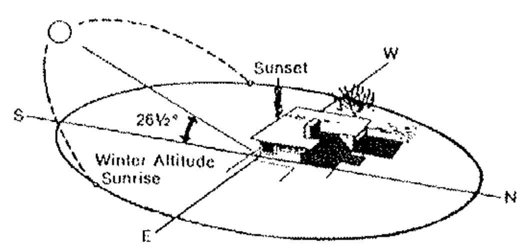
Low E glass is illustrated to the left. The inner pane is coated with a special material that effectively blocks long wave infrared heat radiation will have little effect on short wave visible light. Heat absorbing and reflective glass are also effective, but reduce light transmission to a greater extent than low E glass.

Remember now, we are talking only about direct and unshaded rays from the sun. Double glazing of any type reduces *conduction* heat gain with equal effectiveness as conduction heat loss. So, it still benefits the homeowner to keep his storm windows in place during the cooling season.

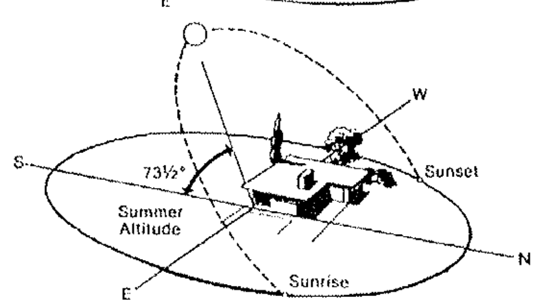
Start With *Good* Design

Direct radiation from the sun through windows should be minimized as much as possible for best results in summer air-conditioning. In designing a new home, this can be accomplished in several ways.

First, consider how the house is "oriented," on the property. Can the building be turned so any large glass areas face in a northerly direction to avoid the sun's rays? If, not, perhaps the floor plan can be rearranged. The builder should be aware of the importance of orientation on cooling and occupant comfort.



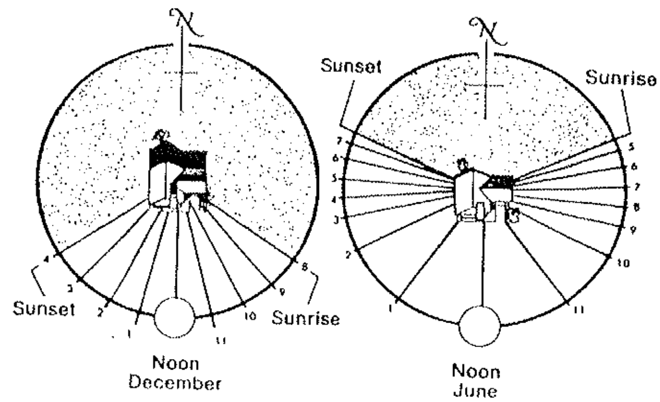
Large glass areas facing *east* permit lots of strong summer morning sun to enter the house until perhaps 11:00 a.m. Even worse: A hot sun entering large *west* facing windows



starting around 2:00 p.m. would no doubt be greatest at the same time as the peak daytime temperature and rising internal loads. West rooms may become warm several hours after sunset.

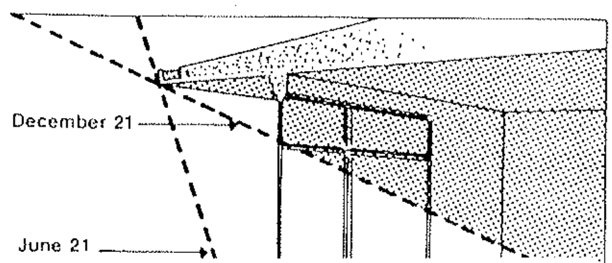
The sun's position in the sky (at right) affects the amount of heat absorbed on building surfaces. Winter sun is actually closer and hotter, but lower in the sky than the summer sun. Diagram shows the noontime altitude angle for 40º North latitude. Columbus, Ohio is 40º North.

The diagram to the right makes a comparison between the sun's hourly position in December and in June. Note that with the sun higher in the sky in summer, there are more daylight hours. From the observer's perspective, the sun rises in the northeast in June rather than the southeast as in December. Graph is representative of standard time, not daylight saving time.



South glass, too, is exposed to direct solar radiation from late morning to early afternoon — but can be easily shaded by adequate roof overhang. East and west glass cannot be effectively blocked by roof overhang because of the low sun angle in the morning and evening.

Because the sun is lower in the sky in winter, a roof overhang does not completely block the rays of the sun from entering through south glass (December 21 illustrated). However, in summer the sun is higher and blocked at noon on June 21.



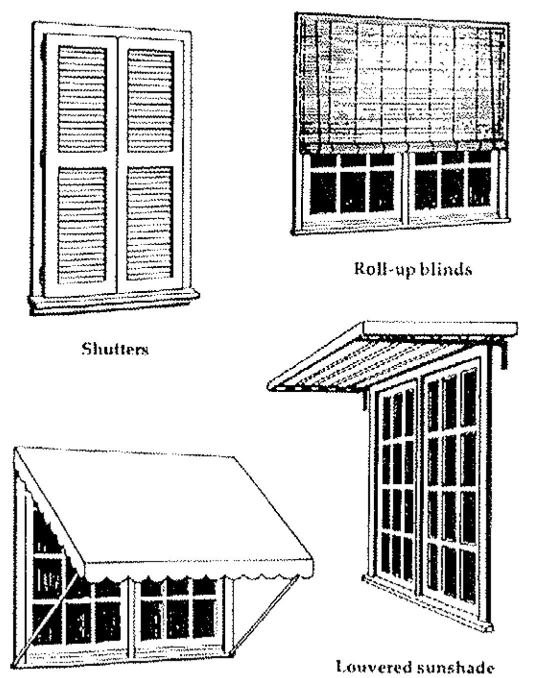
So the general rule is put the largest glass areas facing north (or south protected by overhang), to use minimal glass areas facing east and west whenever possible.

Sha

Use of Shading

In existing homes, with or without the benefit of good orientation and protective roof overhang, the effects of direct solar transmission through glass can be reduced by use of *exterior* awnings or solar screens, *inside* draperies, Venetian blinds, or roller shades.

It is obvious that inside shades, draperies, and



Shutters

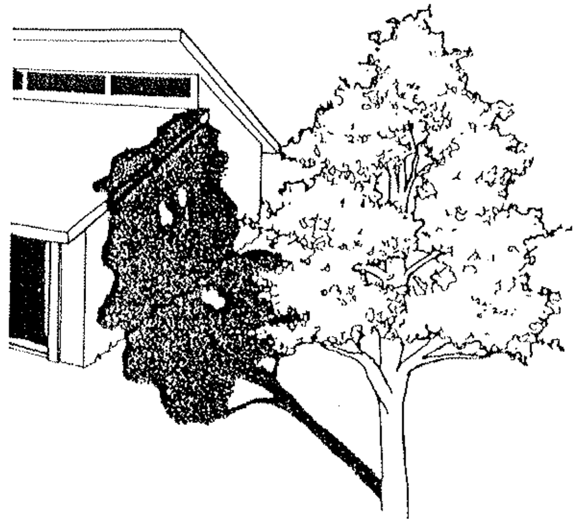
Roll-up blinds

Louvered sunshade

Awning

blinds are not as effective as outside devices in reducing direct solar gain, because some of the heat from the sun will have already penetrated the glass to the conditioned space before encountering the shading device.
These same add-on solutions can, of course, be added to even new, well-oriented homes.

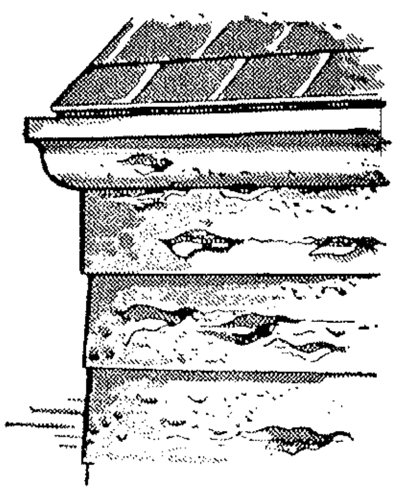
Landscaping Helps



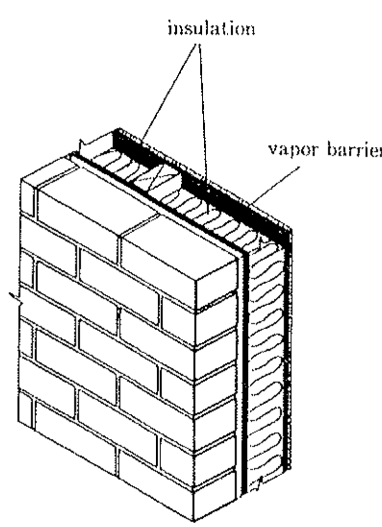
Optimum building orientation is not always possible, even with new construction. Designers may then call upon the landscape expert to plan shade trees and shrubbery to block direct solar radiation from falling on east and west portions of the building.

Fencing, too, can be helpful in blocking the sun when it is low in the sky. Dense trees and fencing also make good windbreaks.

Moisture in Construction



Recall that it takes about 1,000 Btu to boil a pound of water and conversely, it would take about 1,000 Btu to condense a pound of steam into water. Thus, excess moisture is an energy issue as well as a physical problem. At this point, let's consider the physical effect of excessive moisture. Many homes have moisture problems in both winter and summer. In winter, hidden moisture condensation damages building materials, such as peeling and blistering exterior paint. Damp materials can become an ideal breeding ground for harmful bacteria, fungi, and spores (mold on basement walls, for example) .Use of vapor retarders to keep moisture contained plus adequate ventilation to let the building "breathe" are both critically important to keep a house structurally sound and a healthy environment for the occupants.

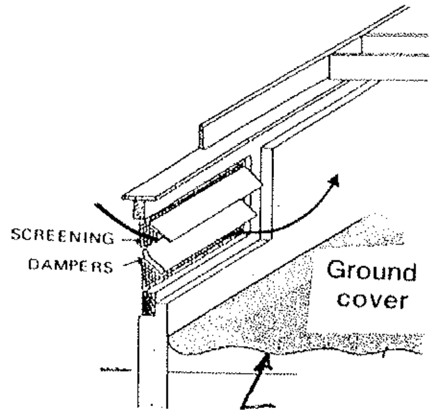


Insulation installed in the walls and other building components should be fitted with a vapor retarder (also called vapor barrier) facing toward the inside. This is a material that substantially reduces the amount of water vapor than can pass through the material and condense inside walls and attics.

The effectiveness of materials to resist moisture penetration is given in *perms,* which is the amount of moisture in grains per hour that can penetrate through the material. Ordinary homes and buildings use vapor retarding materials having a perm of 1.0 or less.

Ventilated Crawl Space

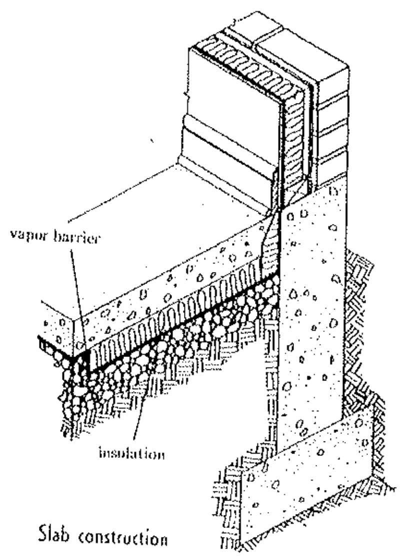
A crawl space must be properly insulated and have a good groundcover membrane over the earth floor to restrict evaporation of moisture traveling upward from lower layers of soil. In summer, it may be necessary to ventilate the crawl space even with the ground cover. Thus, any ductwork and pipes in the crawl space must be insulated to prevent heat gain and possible condensation of moisture on the ducts.



Slab floors must be well insulated at the edges and water-proofed below to avoid moisture problems.

Notable Note: As much as 18 gallons of moisture per day have been measured in a crawl space under a small home without ground cover

An unoccupied basement is seldom cooled directly. Ductwork running through a basement should be insulated for summer cooling. Air in the average basement tends to be humid. Basement moisture could condense on uninsulated ducts and cause water damage. Again, the insulation must be fitted with a vapor retarder on the outside surface.



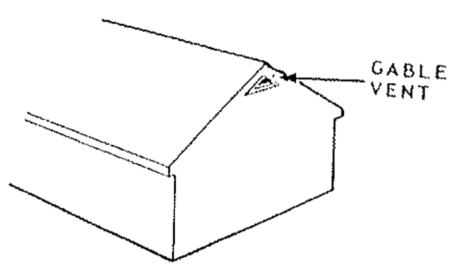
Slab construction

Attic Ventilation

Circulation of ventilation air through spaces *above* ceiling insulation in an attic or roof/ceiling combination is useful in lowering air temperatures in these spaces and thereby reducing ceiling heat gain. In winter, ventilation serves to reduce the danger of condensation by purging moisture that migrates through the ceiling from spaces below.

As we'll learn in Lesson 8, all cooling load calculation guides are based on the assumption that correct ventilation openings are provided by the builder. If minimum openings are not provided, heat gain rates through ceilings will be higher than estimated, with resulting poor cooling operation.

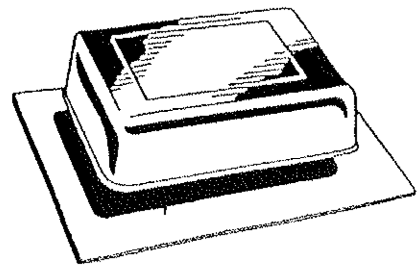
Consider this example: A gable roof with gable vents only and *without* a vapor retarder in the ceiling should have 1/2 sq ft of vent opening per 150 sq ft of ceiling on *each* end of the structure. A 1,000 sq ft ceiling would need 3.34 sq ft of vent opening on each end. If a vapor retarder is placed in the ceiling, the openings can be reduced to less than 1 sq ft on each end of the

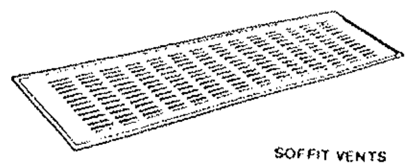


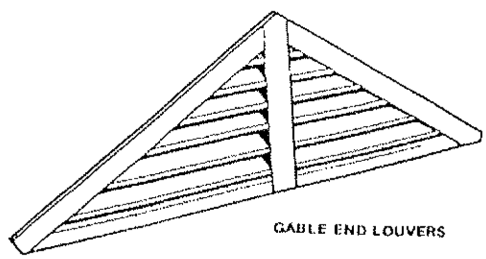
structure.

There are a variety of roof vent products used by builders, such as the roof vent, soffit vent, and the gable end louver just mentioned.

Occupant Ventilation





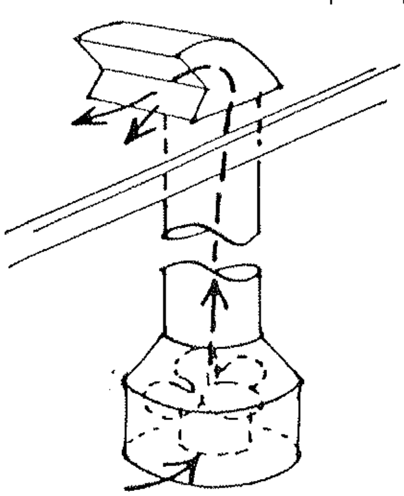


Forced ventilation has traditionally been required in commercial applications by code. In ordinary homes, there has been enough "natural" infiltration around windows and doors to provide sufficient ventilation for the occupants.

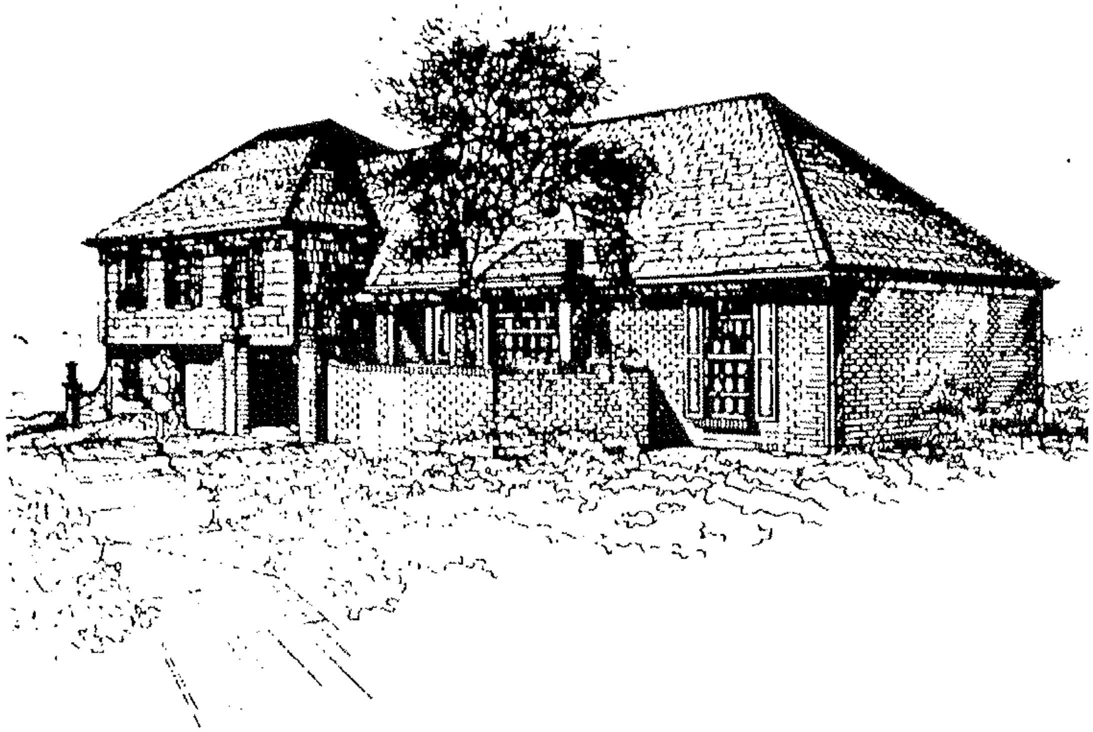
Exhaust fans to remove smoke, odors, and moisture resulting from cooking or bathing, can be most helpful and are usually required by code. But, it was rarely necessary to provide a ducted source of outside air to replace this exhausted air during the cooling season. In fact, if there was a ventilation system for winter use, it would be closed during cooling, as a general rule.

The modern well-insulated home often presents quite a different problem. There may be inadequate "natural" air leakage to purge odors and provide *makeup air* for the air discharged by exhaust fans. Local codes may require some level of forced ventilation for single-family homes and apartments.

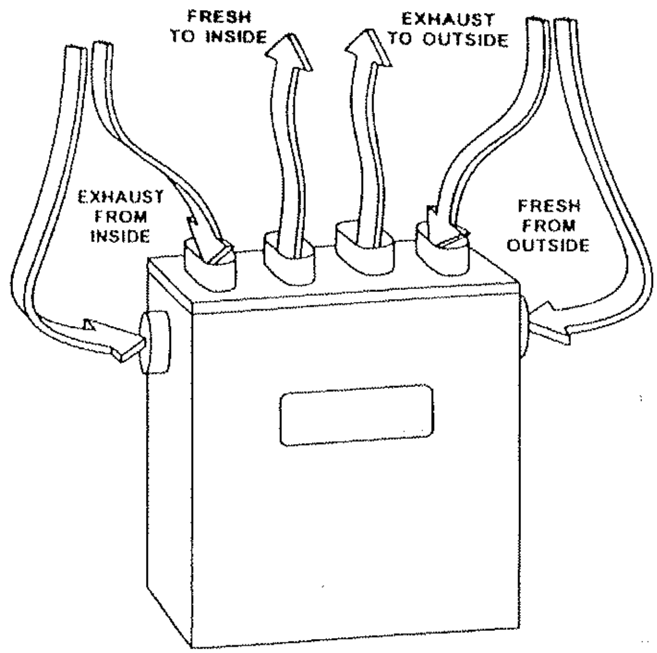
As a result, some designers specify air-to-air heat recovery ventilators (HRVs). HRVs feature sensible and perhaps latent heat transfer between incoming warm outside air and room air being exhausted. This provides positive ventilation with a minimum impact on the building load and energy consumption. The HRV can reduce the temperature of the incoming summer air and certain models can also reduce the moisture in the incoming air.



The air discharged by exhaust fans (at left) is usually replenished by natural air infiltration.



Tight homes require Heat Recovery Ventilators (shown at right) to bring in make-up air and save energy at the same time.



If a house has a fireplace, it should have a tightly fitting manual damper. This is important in heating and cooling, as an open flue can upset the normal air circulation of the house and be a source of heat gain in summer and loss in winter. Glass fireplace doors are equally effective.

Constructing a home or building to successfully withstand the rigors of weather, and people living inside is no easy task. In this lesson, we have merely touched the surface. New studies on the thermal and moisture problems and solutions are reported constantly. Keep informed.

Notable Note: HRV performance can be certified through a program offered by the Home Ventilating Institute division of the Air Movement and Control Association.

Self-Check, Lesson 7 Quiz

You should have read all the material in Lesson 7 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 sun is an important contributor to heat penetration through a building's roof, exterior wall, and glass.

2. T F Infiltration is the forced introduction of outside air into a house or other building.

3. T F Humid outdoor air leaking into a house lowers the humidity level indoors caused by cooking and bathing.

4. T F The physical size of a house is a good indicator of the actual heat gain likely to occur on a hot day.

5. T F Building insulation requirements are specified in inches.

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. Single pane glass can conduct up to:

☐ A. 0.0% of <u>direct</u> solar radiation. ☐ B. 0.8% of <u>direct</u> solar radiation.
☐ C. 8.8% of <u>direct</u> solar radiation. ☐ D. 88% of <u>direct</u> solar radiation.

7. Double pane glass substantially reduces direct solar heat gain if one sheet is:

☐ A. high E coated glass. ☐ B. low E coated glass.
☐ C. high white coated glass. ☐ D. low white coated glass.

8. In the northern hemisphere, the least desirable location for glass windows or sliding glass doors is:

☐ A. facing north. ☐ B. facing south.
☐ C. facing East. ☐ D. facing west.

9. In addition to installing a vapor retarder (barrier), damage caused by excessive moisture can be reduced by:

- ☐ A. adding insulation.
- ☐ B. installing metal stops in walls.
- ☐ C. providing adequate ventilation openings.
- ☐ D. sealing windows and doors.

10. To operate properly, the air discharged by kitchen and bath exhaust fans must be replenished with:

- ☐ A. outside air.
- ☐ B. indoor air.
- ☐ C. basement air.
- ☐ D. air from the cooling unit.

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

Key Words

Inside	spot staining	codes	heat recovery	tree
soffit	ground cover	landscape	dampered vents	dust spot
outside	heat exchanger	pump	register	
	inspectors			

11. One device to transfer heat between exhaust air and incoming outdoor air is called a/an ______ _______________ ventilator.

12. Outside ventilation may be required by local building _________.

13. Roof, gable and ____________________ vents are openings to provide attic ventilation to reduce heat gain and avoid moisture condensation.

14. A crawl space must always be provided with a good _______________ ______________ to reduce moisture migration into the floor and house.

15. Shading devices placed on the _______________ of windows provide the best protection against solar heat gain.

Check Your Answers!

Now compare your answers with those given in the answer key at the back of this book.

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

YOU ARE NOW READY TO TAKE YOUR ONLINE UNIT EXAMINATION, EXAM #1.

GOOD LUCK!

Appendix A: Safety Tips on Handling Refrigerants

The handling and storage of fluorinated refrigerants is considered dangerous enough so that the U. S. Department of Transportation (DOT) prescribes how much refrigerant can be loaded into containers and also specifies working and test pressures for these containers. Also, the Clean Air Act forbids venting of any refrigerants into the atmosphere.

Here are some safety tips:

1. Wear safety goggles and gloves for personal protection whenever handling refrigerant cylinders, transferring or charging refrigerants.

2. Don't tamper with fusible plugs, relief valves or discs in cylinders. They are designed to release excessive internal pressure.

3. Never apply a direct flame to a refrigerant cylinder. This can cause chemical decomposition of the refrigerant, weaken cylinders and raise internal pressure beyond safe limits.

4. Never warm a cylinder above 125º F even using "accepted" and well controlled heaters, blankets, etc.

5. Always "crack" a service valve open gradually to assure positive control of gas flow.

6. Don't interchange refrigerants. Cylinders are color coded; White is R-12, Green is R-22, Red top or band is R-500, Orchid is R-502, and R-410A is Rose.

7. Liquid refrigerant can cause "frost bites." Wash hands immediately upon contact. If eyes are contaminated, wash with mineral oil if possible (except for ammonia gas); then use a boric acid solution. (Note Safety Tip # 1 rule -- above.)

8. Refrigerant vapors are dense (heavy). They can collect in low spots and could cause asphyxiation (lack of oxygen) in sufficient quantities and in poorly ventilated space. Avoid inhalation of concentrated vapors.

9. Refrigerant vapors exposed to air, open flame or hot surfaces and water may decompose into more toxic products.

10. Before loosening any valves, bolts, screws, etc. holding parts in place, see that pressure or vacuum differences are relieved.

11. Properly dispose of throw away refrigerant cans and cylinders. Do not use them for any purposes. Do not use old refillable cylinders if date stamp on shoulder is more than five years old.

12. Go easy on muscle power and don't do anything in a hurry.

Appendix B: Answer Key to Self-Check Quizzes

The answer to each quiz question is grouped by lesson number. The student is encouraged to refer back for those questions missed and reread the material.

Self-Check Lesson 1

1. False
2. True
3. False
4. True
5. False
6. B
7. C
8. B
9. B
10. A
11. indoor
12. humidity
13. relief
14. noise
15. refrigerant

Self-Check Lesson 2

1. True
2. True
3. False
4. False
5. False
6. C
7. D
8. D
9. C
10. C
11. change
12. sensible
13. conduction
14. radiation
15. convection

Self-Check Lesson 3

1. True
2. False
3. False
4. False
5. False
6. B
7. C
8. D
9. B
10. C
11. proportion
12. vapor
13. condenses
14. saturated
15. low

Self-Check Lesson 4

1. True
2. False
3. True
4. False
5. False
6. B
7. D
8. A
9. B
10. C
11. draft
12. latent
13. faster
14. pollutants
15. 75°/50%

Self-Check Lesson 5

1. False
2. True
3. False
4. True
5. True
6. D
7. A
8. B
9. C
10. C
11. metering device
12. scroll
13. 24,000
14. 1. evaporator 2. Compressor 3. condenser 4. capillary tube
15. 1. refrigerant boils 2. refrigerant vapor & temperature raised 3. refrigerant vapor turns to liquid 4. pressure & temperature of liquid decreases

Self-Check Lesson 6

1. False
2. False
3. False
4. False
5. False
6. C
7. C
8. B
9. B
10. D
11. arrestance
12. dust spot
13. charcoal
14. electrical
15. ductless split

Self-Check Lesson 7

1. True
2. False
3. False
4. False
5. False
6. D
7. B
8. D
9. C
10. A
11. heat recovery
12. codes
13. soffit
14. ground cover
15. outside

Appendix C: Glossary

As you progress through this introductory course on cooling, you may find this list of definitions useful.

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 outlet 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 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 Btu's 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 twenty-four 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 which will cause a current of one ampere to flow through a resistance of one ohm.