Comfort Cooling: Introduction

Lessons 8 to 14

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.

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.

Lesson 8 Overview

We learned in Lesson 7 that buildings experience different rates of heat penetrations depending on the amount of insulation, glass type, and other characteristics. We also learned the importance of cooling load calculation.

Lesson 8 will discuss designing a method to calculate the cooling load. There are several accepted cooling load procedures that are used in industry, each with its own set of rules.

We will also cover some important factors to consider when calculating cooling load. Finally, we'll cover the best industry tools currently being used to calculate load.

Now read Lesson 8 which begins on the next page.

Lesson 8: What's a Cooling Load?

To accurately determine the size and layout of an air conditioning system, it is essential that a *load calculation* be made.

A cooling load is a mathematically determined Btu/hr *heat removal* requirement for a building under specified outdoor weather conditions and desired indoor temperature and humidity levels. The cooling load must be determined on a room-by-room basis in order to size and locate all the components that make up a central air conditioning system.

By computer or by hand, a load calculation is the vital first step in sizing.

Match Unit to Load

A cooling system of inadequate capacity will prove most disappointing to its purchasers. An oversized system — one with too much cooling capacity — not only will cost considerably more than necessary, but it will also give poor comfort performance.

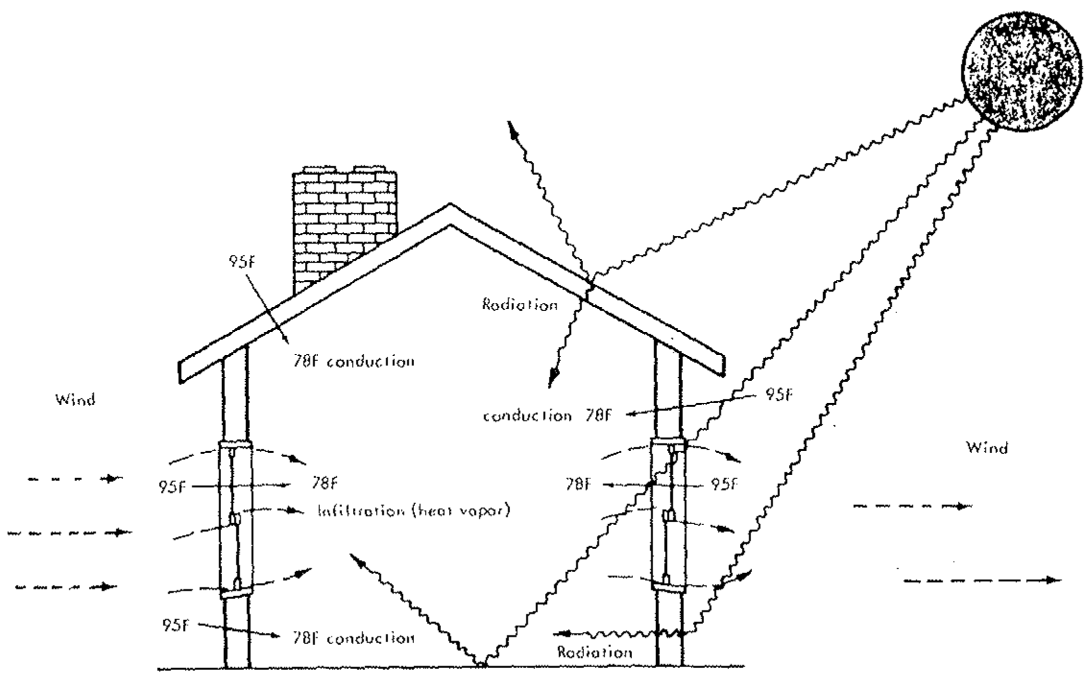
Ideally, an air conditioning system should run with some frequency. If the system has too much capacity, it will be off for long periods of time. During the time a unit is off, the humidity may increase in the conditioned space, thus defeating one of the chief benefits that air conditioning can provide — lower humidity.

The contractor trying to sell an oversized system will also find that his price probably will be considerably higher than that offered by the contractor who has accurately calculated the load and sized the system accordingly.

Simplified Methods

As we learned in the previous lesson on building thermal problems, many factors are involved in the heat gain of a building. As a result, the calculation of cooling load for summer air conditioning is somewhat more complicated than calculating heat loss. Simplified methods of making a cooling load calculation for residential and light commercial air conditioning have been developed. However, even simplified methods involve measurements and calculations — so much so, that software for computers has been written to speed the process and ease the drudgery.

Notable note: Heat gain is not exactly the same as a cooling load. The cooling load procedure involves a method of averaging the various heat gains occurring in the house at different times of the day to arrive at a maximum heat removal requirement on the cooling unit for the specified design conditions.



Three modes of heat penetration into a building are depicted above: conduction (solid arrows), infiltration (broken arrows), and radiation (wavy arrows). Conduction is the heat that flows through the materials surrounding the conditioned space because of the temperature difference between inside and outside. Infiltration is the direct entry of the warm outside air through cracks around windows, doors, etc. Radiation is the heat from direct sunlight on a surface.

As we already learned, house construction is important. A well-constructed and well-insulated house will have a smaller cooling load than a house of poor construction or one with little or no insulation.

Orientation of the house and its glass area are extremely important in air conditioning, but usually something the air conditioning designer can do little about. Radiation of the sun directly through large windows can add considerably to the cooling load and disrupt occupant comfort as we have learned.

Moisture Load

People and appliances in the house add to the cooling load. They are difficult to estimate and can disrupt comfort even in a residential environment.

The latent load is quite important in summer cooling. Moisture given off during cooking, by the occupants, and by outdoor air that infiltrates the house and are the chief sources of a residential latent load. For a typical residence, the latent load may range from 20 to 30% of the sensible load. If the sensible load was 20,000 Btu/hr, the latent load might range from 4,000 to 6,000 Btu/hr.

So, the cooling load is made up of the following —

- Direct solar (sensible) gain through windows
- Conduction (sensible) gain through roof, walls and windows
- Infiltration of warm, moist air to the inside (sensible & latent)
- Internal gains from people and appliances (sensible & latent)

Selecting Design Conditions

Every cooling load begins with a decision on indoor and outdoor design conditions to satisfy.

The indoor temperature used for estimating a residential cooling load is typically selected to be 75° F and 50% RH. As we learned in Lesson 4, the combination of temperature and humidity in which occupants feel comfortable can range from slightly above to slightly below these conditions.

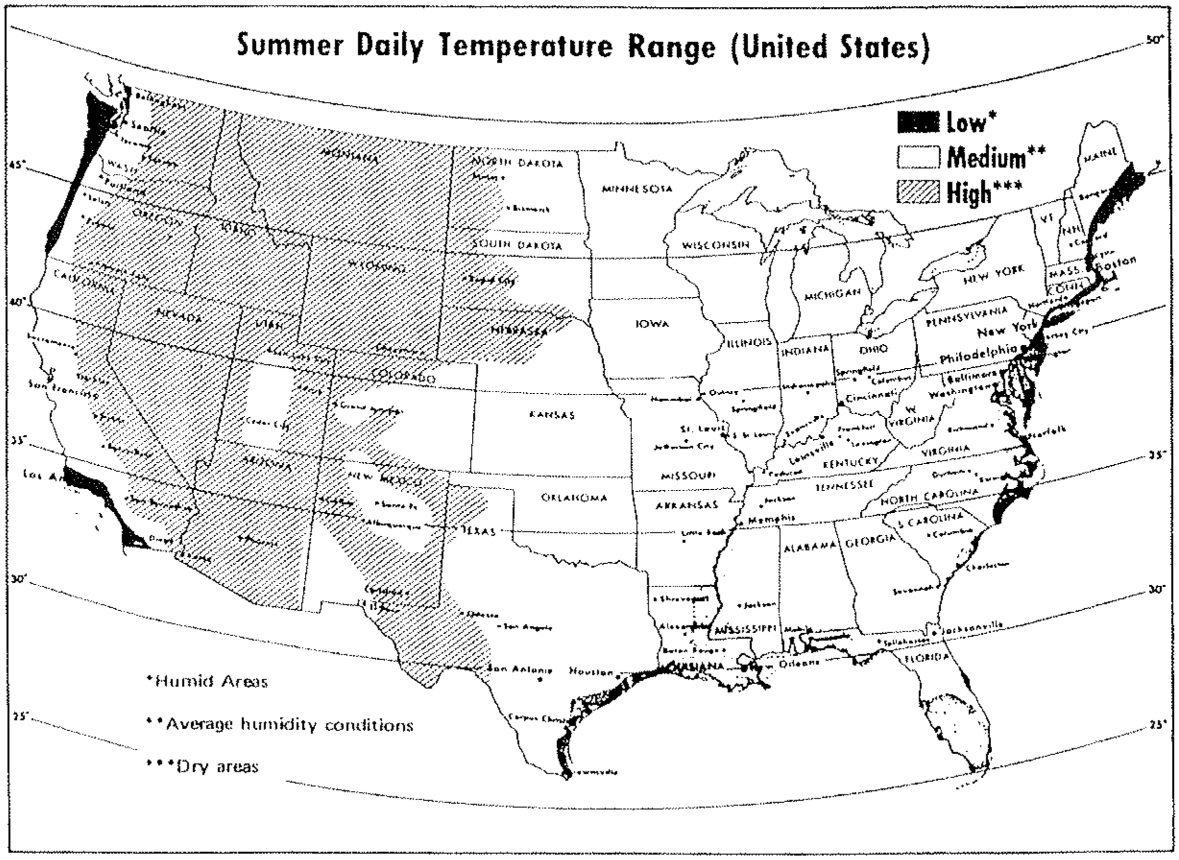
The outside design temperature is part of the other side of the sizing equation. Almost every cooling load procedure recommends some temperature *lower* than the maximum likely to be experienced each year — otherwise, a system would be oversized for most of the season. The most recent practice was to use a local outdoor temperature that occurs or is exceeded for only 2.5% of the hours in the summer season. Example: 95° F may be the preferred design temperature in a city where 95° F will likely occur or be exceeded for only 72 hours over an entire summer season.

Providers of cooling load manuals include a table of design temperatures for most cities in the United States and Canada — most often based on Weather Bureau records analyzed by ASHRAE. (Design temperatures based on 0.4, 1% and 2% of *annual* hours are now published.) If a design temperature for a particular city or town is not listed in the table, the designer may use a design temperature for the nearest town in the same latitude; taking into consideration possible variation due to local geographical peculiarities — near a lake, in a valley — and local operating experiences.

In addition to outdoor air temperature, the cooling load procedure must consider a reasonable outdoor design humidity to coincide with the design air temperature. The outdoor humidity is usually stipulated by a specified design *wet bulb* temperature. In most cases, the *mean* wet bulb temperature associated with the outdoor design temperature is chosen. For instance, for a 95° F design temperature, all the wet bulb temperatures that occur would be arrayed from high to low and the value in the *middle* would be the design wet bulb.

Another outdoor influence is the local *Outdoor Daily Temperature Range.* This is simply the difference between the maximum and minimum daily temperatures which occur in the summer cooling season. A daily swing of 20 degrees would mean for a high of 80°, we'd have a low of 60°, a high of 95° and a low of 75°, etc. A large daily temperature range reduces the daytime cooling load because the cool temperatures at night sub-cool the structure and reduce the heat build-up the next day. Some refer to this as the flywheel effect. Cooling load procedures account for this effect, as we'll see in a moment.

Notable Note: On a design day, actual room temperature may rise to 78° F in some procedures. This 3° swing permits more economically-sized installations without affecting occupant comfort.



Daily temperature range refers to the average swing between highs and lows during a summer. Less than 16° is considered low; 16° to 25° is medium, and over 25° is a high daily swing, e.g. cool desert nights with hot days in Arizona. Areas with cool nights obviously help reduce the cooling load.

Building "U-Factors"

To consider the heat transfer (gain) conducted through exterior walls, roof, doors, and windows, cooling load procedures usually specify a "U-factor" for each segment. The coefficient of heat transfer, called a "U" factor," is given in units of Btu per hour per sq ft of surface per degree temperature difference. Different types of construction have different U factors.

To arrive at the conduction through each building element (in Btus per hour), you must multiply the U-factor of the element (roof, door, etc.) by the measured area. Next, multiply that result by a design temperature difference between the inside and outside of the building.

Because of the effect of the hot sun on walls and roof, an *equivalent temperature difference* (ETD) is used. This combines the effect of sun and outdoor temperature on the conduction of heat through the building.

For example, the U-factor for an insulated frame wall might be 0.07 Btu/(hr sq ft °F). If the wall is 8 ft high and 25 ft long, its area would be (8 x 25) or 200 sq ft.

For an outside temperature of 95° and for a medium daily temperature range (16° to 25° swing), the equivalent temperature difference across the wall is 23.6° F. The heat gain through the wall is:

$$0.07 \times 200 \times 23.6 = 330.4 \text{ Btu/hr}$$

If the building was in a region that experienced a high daily temperature range (over 25° swing), the equivalent temperature difference would be reduced to just 18.6° and the estimated heat conduction through the wall reduced to:

$$0.07 \times 200 \times 18.6 = 260.4 \text{ Btu/hr}$$

Heat Transfer Multipliers

Most industry shortcut procedures pre-calculate U-factors and equivalent temperature differences and publish the results in easy to use tables of Heat Transfer Multipliers (HTM) for different outdoor design conditions and building construction.

Thus, only the area of the wall, floor, or roof need to be determined and multiplied by the proper HTM.

In our examples, the HTMs for the conditions stated would be 0.07 x 23.6 or 1.65 Btu/(hr sq ft) and 0.07 x 18.6 or 1.3 Btu/(hr sq ft) respectively.

Let's review what we know so far:

The heat gain by transmission through construction (other than glass) depends on a combination of the following:

1. Outside design temperature
2. Daily temperature range
3. The Heat Transfer Multiplier, which is in terms of Btu/hr per square foot
4. The wall and ceiling (maybe floor) area in each room

Heat Flow Through Glass

The heat gain from the intense rays of the summer sun shining through glass can be a major factor in determining the summer cooling load.

The combination of direct and diffuse solar and temperature difference (conduction) heat gain through glass is affected by type of glass such as:

- Single, double or triple glass
- Tinted (heat-absorbing) glass
- Reflective coated (low-E) glass

HEAT TRANSFER MULTIPLIERS (Cooling)							
Design Temperature	90	95		100		105	110
Daily Temperature Range	L or M	M	H	M	H	H	H
Walls and Partitions (Btuh per sq. ft.) Factors include heat gain for transmission and infiltration @ 7.5 mph							
No. 8 Wood Frame with Sheathing and Siding, Veneer or Other Exterior Finish							
(a) No insulation	6.5	8.0	7.0	10.0	8.5	10.0	12.0
(b) R=5.6 insulation (nominal 1½-in.)	3.0	4.0	3.5	5.0	4.5	5.5	6.5
(c) R-7.6 insulation (nominal 2-in.)	3.0	3.5	3.5	4.5	4.0	5.0	5.0
(d) R-11.1 insulation (nominal 3-in.)	2.5	3.0	3.0	4.0	3.5	4.0	5.0

Simplified methods for estimating a residential cooling load have been developed. Table above lists cooling heat Transfer Multipliers (HTM) for walls. The correct HTM is multiplied by the exterior wall area to estimate the sensible heat gain through the wall in Btu/hr for a specific outside temperature. Example: For a 95° F outdoor design temperature and a medium daily temperature range, a frame wall with R=11.1 insulation would have a HTM of 3.0 Btu/hr/sq ft. See circled values.

The direction windows face —

- North or in shade
- East or West
- South

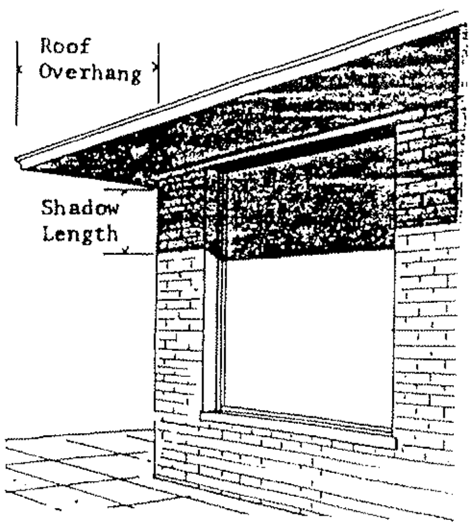
Shade offered by —

- Roof overhang (and latitude)
- Exterior awnings, solar screens
- Inside draperies, Venetian blinds, roller shades
- Mature shrubbery, or trees

And, of course, the temperature difference between indoors and outdoors. (Sometimes referred to as Delta T or ▲T.)

Location of Shade Line From Overhang

At 3:00 p.m. in mid-summer, the total heat gain through a single sheet of glass is about 93 Btu/(hr sq ft) - 55 Btu/(hr sq ft) is due to direct solar radiation, 26 Btu/(hr sq ft) is due to diffuse radiation and 12 Btu/(hr sq ft) due to the temperature difference across the glass. If the glass was entirely shaded from the outside, the 55 Btu/9(hr sq ft) of direct gain would not occur. There would be a 60% reduction in heat gain.



The length of shadow on a window cast by roof overhang depends on the hour of the day, time of year, and the orientation of the wall. For example, a 2 ft overhang would cast a shadow 3.2 ft long on a south facing window at 12:00 noon. By 3:00 p.m., the shadow would lengthen to 3.7 ft.

Since the length of shadows varies depending on time of day and time of year, simplified residential procedures pick a specific date (usually August 1) and average the shadow lengths over a 5-hour period.

Typically, the design manual will then offer simple *factors* for different window directions and latitudes that are multiplied by the length of overhang to find the average shadow length.

Are Floors Involved?

Heat gain from floors over a basement or *enclosed* crawl space or from a concrete slab on the ground is so small that it is most often simply disregarded. If the crawl space is open, the floor should be insulated and the heat gain calculated. This would also be true of a floor over a connected garage. Heat gains through basement floors and walls below grade are similarly not calculated. If the basement area is to be air conditioned, the heat gain through walls *above grade* should be calculated.

Air Leakage

Warm air will leak into a structure and cool air will leak out regardless of how tightly constructed the building appears to be. This air *infiltration* imposes a cooling load and must be included in the calculation procedure.

Infiltration imposes both sensible and latent (moisture) loads on cooling equipment. The hot air must be reduced in temperature and the high humidity must be removed by the equipment along with all the other building loads.

Tests in existing homes have led to the preparation of tables or formulas to estimate air leakage rates for different sizes of homes and for different levels of construction quality. Leakage is usually reported in air changes per hour (ACH). A listed rate of 1.0 ACH, for example, means the equivalent of the entire volume of air in the house is infiltrating every hour. Summer leakage rates can easily range from a low of 0.2 to a high of 1.0 air changes per hour.

Homes and light commercial buildings may also require positive ventilation over and above "natural" air leakage. This may be required by code or the desire of the designer and user. The impact of ventilation air on equipment can be minimized by using a Heat Recovery Ventilator. (See previous lesson.)

Occupancy Load

Heat given off by a person varies with type of activity, as we learned earlier. A person at rest gives off less heat than one who is performing heavy labor. For residential cooling calculations, however, about 300 Btus per hour per person is adopted as an average *sensible* heat gain. If six persons normally occupy the house, then 6 x 300 or 1,800 Btu/hr would be added for people. In some simplified procedures, the latent contribution might be averaged at 230 Btu/hr per person.

If the family does **considerable** entertaining, some additional allowance could be made for the occupancy load resulting from guests. This should not be overestimated, however. Doing so will result in over sizing the equipment.

The heat generated by kitchen and other appliances can be substantial. However, operation is usually of a short duration and appliances are seldom operated all at the same time. Exhaust fans adjacent to the appliances also help to quickly remove the sensible heat and any moisture from inside the building. For residential load calculations, a sensible appliance load of from 1,200 to 1,600 Btu/hr is assumed to account for the heat produced. In the case of light commercial applications, individual appliance loads based on ASHRAE averages may be included.

Taking Measurements

From the above brief discussion, it's obvious that careful measurements must be made of each room and notations made of wall construction, insulation, glass area, type of glass, shading, and orientation. When a new house is still in the planning stage, the measurements and information are obtained from house plans.

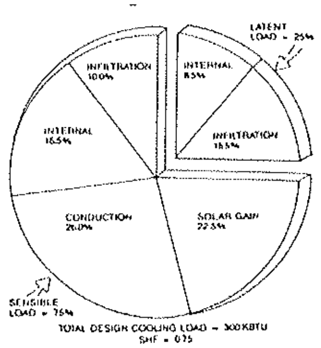
Estimating the cooling load on an existing home will involve actual measurements, unless blueprints are available. Even if the latter is the case, it would be safer to confirm these measurements and other details by inspecting the house itself. Your next lesson includes more information on making *"A Comfort Survey."*

Duct Gain

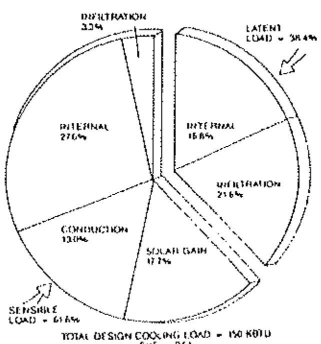
Whenever the air distribution system is routed outside the conditioned spaces, an attic or crawl space, even at times a basement, the rise in supply air temperature is a loss of energy and adds to the cooling load on the central equipment. Duct "gain" may add from 5% to 20% additional sensible load. If the ductwork is all contained within conditioned spaces, there is no added load on the equipment.

Total Sensible Load

A room cooling load typically consists of the sum of the wall, ceiling, glass exterior door, and sensible infiltration Btu/hr loads, plus a floor load if applicable. The total sensible cooling of the entire house is the sum of all the sensible loads of all the rooms in the building plus any duct and ventilation loads.



A. Conventional House



B. Improved Energy-Efficient House

Although sensible heat is the major part of the cooling load in a residence, the latent heat load must also be included to arrive at the total.

Latent Load

As previously noted, the latent load in a conventional residence ranges from 20% to 30% of the total sensible load. The advent of the energy-efficient house may alter this relationship as illustrated in the pie charts below. (Assumes a Florida location.)

In the conventional house (A), the latent load is 25% of the total (sensible & latent) load. This is equivalent to 33.3% of the sensible load. In the energy-efficient house the latent load is 38.4% of the total (sensible & latent) load. This translates into the latent load being 62.4% of the sensible load for the energy-efficient house.

Equipment selection is influenced by both the sensible and latent heat loads imposed by a structure. As a result, the term Sensible Heat Factor (SHF) is used to indicate the relationship of sensible and latent heat performance required by the equipment. The SHF is simply the ratio of the sensible load divided by the total load (sum of the sensible and latent loads). In house A, the SHF is 0.75 and in B, it is 0.61.

Equipment selected for each house should have comparable performance. That is, the sensible heat capacity relative to the total heat capacity of the equipment should have an SHF closely matching the house SHF. A different SHF can be engineered into the equipment by coil design and other operating characteristics. Thus, two pieces of equipment with the same total cooling capacity could have different sensible and latent removal performance.

1	Name of Room		Long Residence				Entire House			
2	Running Feet of Exposed Wall						2 x (51 + 29) = 160			
3	Ceiling Height At Walls (Ft) and Gross Wall Area (SqFt)						8 & 3	160 x 8 = 1,280 & 160 x 3 = 480		
4	Room Dimensions (Feet) and Floor Plan Area (SqFT)						51 x 29	1,479		
5	Ceiling Slope (Degrees) and Gross Ceiling Area						0	1,479		
Type of Exposure			Const.. Number	Panel Faces	HTM		Area or Length	Btuh		
					Htg.	Clg.		Heating	S-Clg.	L-Clg.
6a	Windows and Glass Doors	a	Dine = 1E	N	42.0	14.0	20.0	840	280	
		b	Live = 1E	W	42.0	50.0	40.0	1,680	2,000	
		c	BR-1 = 1D	W	42.7	34.4	17.0	727	585	
		d	Upr Lvl S = 1D	S	42.7	16.8	30.0	1,282	504	
		e	Upr Lvl E = 1D	E	42.7	34.4	58.0	2,479	1,995	
		f	Base S HC = 1C	S	65.3	35.0	8.0	522	280	
		g	Base E HC = 1C	E	65.3	70.0	8.0	522	560	
		h	Base E H = 1C	E	65.3	0	4.0	261	0	
		i								
6b	Skylights	a								
		b								
		c								
7	Wood and Metal Doors	a	11N		26.25	9.1	17	446	155	
		b	11N		26.25	9.1	21	551	191	
		c								
8	Above Grade Walls and partitions	a	12B-0b-w		7.28	1.23	1,077	7,835	1,327	
		b	15A-5sloc (cool)			2.18	233		508	
		c	15A-5sloc (heat)		11.44		460	5,261		
		d	15A-5 = Average 15A-4 and 15A-6							
		e								
9	Below Grade Walls	a	15A-5sloc-5		6.00		800	4,800		
		b	Average 15A-5 and 15A-6							
		c								
10	Ceilings	a	16B-19ad		3.68	2.45	1,479	5,435	3,624	
		b								
11a	Passive Floors	a	21A-28		1.65	na	1,479	2,440	na	
		b								
11b	Radiant Floors	a								
		b								
12	Infiltration		Heat Loss		10,849 Btuh		WAR	10,849		
			Sensible Gain		883 Btuh		1.0		883	
			Latent Gain		1,286 Btuh					1,286
13	Internal	a	Occupants at 230 and 200 Btuh				# 4		920	800
		b	Scenario Number		1				2,400	
		c	Default Adjustments		None					
		d	Individual Appliances		None					
		e	Plants		None					
14	Subtotals		Sum lines 6 through 11a + line 12 + line 13					45,933	16,211	2,086
15	Duct Loads		ELF-Loss and ELF-Gain		na	0.049		na	797	
			Latent Gain							885
16	Ventilation Loads		Vent CFM		Exh					
17	Winter Humidification load				Gal / Day					
18	Piping Load									
19	Blower Heat								1,707	
20	Total Load		Sum lines 11b + line 14 through 19					45,933	18,714	2,972

Load calculation procedures require the organization of information – such as building areas and HTM's – on preprinted or computer spreadsheets. Computerized versions usually follow the same format. Worksheet above is from Manual J (8th edition) procedures published by ACCA.

Residential equipment should be sized to match or slightly exceed the sensible cooling load of the building. The sensible capacity of the equipment should not be more than 20 to 25% larger than the sensible load.

The unit's latent capacity will most often equal or exceed the latent load, but this should be checked. If the latent capacity is less, the next larger unit should be chosen.

Load calculation procedures require the organization of information — such as building areas and HTM's — on preprinted worksheets. Computerized versions usually follow the same format. The worksheet above is from Manual J procedures published by ACCA.

Review

This lesson is not intended to serve as a working guide for the calculation of a building cooling load. Our purpose has been to outline the problem and to describe in general how industry cooling load procedures address the problem.

In calculating the cooling load of a residence, several procedures can be followed which include all the necessary factors and form for a wide range of construction and weather conditions. Such procedures are detailed in Manual "J" published by the Air Conditioning Contractors of America (ACCA); Guide C-30 issued by the Hydronics Institute; and the Cooling and Heating Load Calculation manual published by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). Basic data regarding heat gain and heat loss can also be found in the ASHRAE Handbook of Fundamentals. Equipment manufacturers, too, offer simplified methods of estimating cooling loads.

Self-Check, Lesson 8 Quiz

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

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

True False

1. T F A cooling system should have a Btu/hr capacity that equals or slightly exceeds the estimated cooling load.

2. T F Oversized equipment does not affect comfort but may affect price.

3. T F The latent load for residential environment will range from 20% to 30% of the sensible cooling load.

4. T F The cooling load procedure is based on the hottest day likely to be experienced in the community in any given year.

5. T F Outdoor wet bulb temperature is not considered in residential cooling load procedures.

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

6. The "U-factor" for a building component is given in the following units:

☐ A. Btu per hour per square foot per degree temperature difference.
☐ B. Btu per hour per degree temperature difference.
☐ C. Btu per day per square foot per degree temperature difference.
☐ D. Btu per day per degree temperature difference.

7. A home with a 24,000 Btu/hr cooling load in an area with a high daily temperature range would have:

☐ A. a larger load built in a location with a low daily range.
☐ B. the same load built in an area with a low daily range.
☐ C. a smaller load built in an area with a low daily range.
☐ D. a smaller latent load built in a low daily range.

8. The Heat Transfer Multiplier (HTM) used in simplified procedures is a product of the:

☐ A. "R" value times the design temperature difference.
☐ B. "U" factor times the design temperature difference .
☐ C. "R" value times the equivalent temperature difference.
☐ D. "U" factor times the equivalent temperature difference.

9. Air leakage (infiltration) rate is defined in terms of air changes per:

☐ A. hour. ☐ B. cubic foot.
☐ C. square foot. ☐ D. conduction loads.

10. The cooling load for different types of glass combines

☐ A. internal loads. ☐ B. infiltration loads.
☐ C. moisture loads. ☐ D. conduction loads.

For the Questions 11-17, fill in the blanks with the word (or words) that most accurately completes the thought.

Key Words

load factor	glass	25	neglected	included
50	thermal	430	appliances	230
sensible	orientation	latent	300	heat factor

11. The length of shadow cast by a roof overhang depends on the hour of the day, time of year and ______________________ of the window.

12. The heat gain from floors over a basement, enclosed crawl space or concrete slab is ___________________________.

13. Air filtration imposes both a sensible and ________________ load.

14. The average load imposed by occupants is assumed to be _______________ Btu/hr sensible load and _______________ Btu/hr latent load.

15. A sensible load of from 1,200 to 1,600 Btu/hr is assumed for ________________ in an average home.

16. Equipment selection must be based on both the latent and sensible loads as defined by the sensible _____________ ___________ which is the ration of sensible load divided by the total load.

17. The sensible capacity of a cooling unit should not exceed the estimated sensible load by more than ___________ %.

18. Table 4 below lists HTMs for ceiling under a ventilated light colored roof. Find the correct HTM for the following conditions: Ceiling Insulation: R-19. Design indoor-outdoor temperature difference: 20º F. Daily Temperature Range: M (medium).

Table 4

No. 16 - Ceilings Under a Ventilated Attic Space Light Colored Roof	Summer Temperature Difference and Daily Temperature Range												
	10		15			20			25		30	35	U
	L	M	L	M	H	L	M	H	M	H	H	H	
	HTM (Btuh per sq. ft.)												
A. No Insulation	13.1	11.4	15.3	13.5	11.4	17.5	15.7	13.5	17.9	15.7	17.9	20.1	.437
B. R-7 Insulation	3.4	2.9	3.9	3.5	2.9	4.5	4.0	3.5	4.6	4.0	4.6	5.2	.112
C. R-11 Insulation	2.5	2.2	2.9	2.6	2.2	3.3	3.0	2.6	3.4	3.0	3.4	3.8	.083
D. R-19 Insulation	1.6	1.4	1.9	1.6	1.4	2.1	1.9	1.6	2.2	1.9	2.2	2.4	.053
E. R-22 Insulation	1.4	1.2	1.7	1.5	1.2	1.9	1.7	1.5	2.0	1.7	2.0	2.2	.048
F. R-26 Insulation	1.1	1.0	1.3	1.2	1.0	1.5	1.4	1.2	1.6	1.4	1.6	1.7	.038
G. R-30 Insulation	1.0	.9	1.2	1.0	.9	1.3	1.2	1.0	1.4	1.2	1.4	1.5	.033
H. R-38 Insulation	.8	.7	.9	.8	.7	1.0	.9	.8	1.1	.9	1.1	1.2	.026
I. R-44 Insulation	.7	.6	.8	.7	.6	.9	.8	7	.9	.8	.9	1.1	.023
J. R-57 Insulation	.5	.4	.6	.5	.4	.7	.6	.5	.7	.6	.7	.8	.017
K. Wood Decking, No Insulation	8.6	7.5	10.0	8.9	7.4	11.4	10.3	8.9	11.8	10.3	11.8	13.2	.287

HTM is _______________ Btu/hr per square foot of ceiling.

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.

...lved questions on this lesson?

Lesson 9 Overview

We know from the last lesson that to "do" a cooling load, you have to measure building components - walls, roof, windows, doors and floors.

In this lesson, we will offer some sketching tips when house floor plans aren't available. There are also examples of survey forms to guide the estimator in gathering all necessary information - which includes checking the electric service, adequate attic venting, existing duct and furnace equipment, plus locating drains for the condensate lines. The lesson also suggests talking to the owner about any unusual needs because of their lifestyle – smokers, entertain a lot, out of the ordinary cooking, allergies, etc.

There is also an overview of house styles and associated problems regarding installation of ducts and equipment. Lastly, there is a discussion of noise and how to minimize noise and neighbor complaints. It's a big lesson with lots of interesting suggestions.

Now read Lesson 9 which begins on the next page.

Lesson 9: Doing a Building Survey

Whether it's new construction or so-called add-on work, a *comfort survey* is required to determine "what's involved" in sizing and installing an air conditioning system in a specific building.
Most technical problems are solved in an orderly fashion and every solution starts with a thorough *understanding* of the problem. Therefore, a comfort survey is simply an orderly investigation of a new or existing building in order to determine all the pertinent *thermal* and *physical* peculiarities of the job.

Work With Plans or Sketches

In new or planned construction, the individual making the survey will probably be working from floor plans, schedules, and material specifications. In the case of existing construction, the survey will be based on an on-site inspection and sketch of the premises.

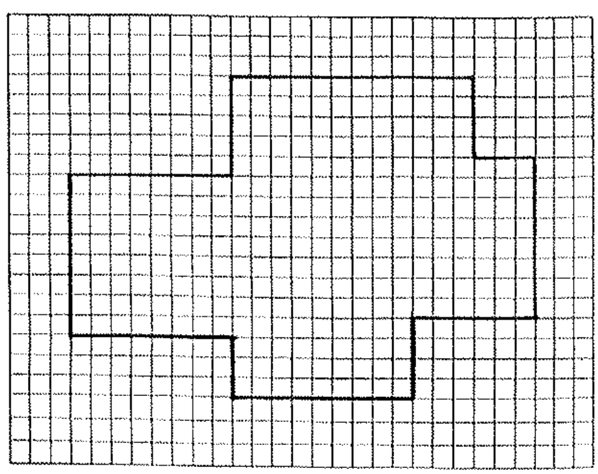
When working with floor plans supplied by the owner, architect or engineer, it is absolutely essential to make certain that the plans are up-to-date and include all revisions. Often, original plans have been revised several times. So, always check that you are working with the latest, most accurate plans.

Sketching Skills

In the case of an existing building, an on-site *sketch* is almost always necessary. Even if the owner can provide ancient floor plans, many times the building has been altered or rooms added by previous owners. So, again, don't accept floor plans for new or old structures on blind faith.

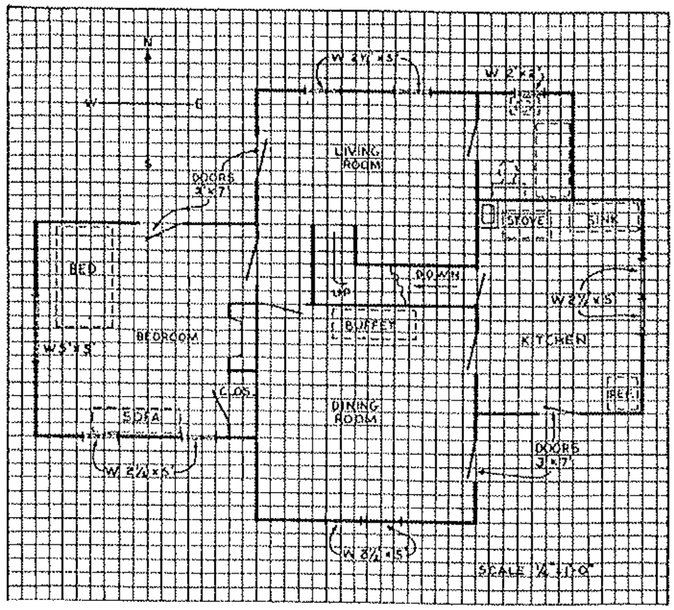
Quadrille rule pads make excellent sketch pads. The pads are lithographed in light blue ink that is generally non-reproducible on most copy machines. They are printed with 4 to 10 "squares" to the inch. Four and eight squares to the inch are the most convenient for sketching, since these dimensions readily translate into 1/4 inch equals 1 foot and 1/8 inch equals 1 foot "scales" respectively.

Quadrille rule pads (shown at right) with four squares to the inch make convenient worksheets for sketching to scale.



Armed with a tape measure, it's possible to measure the length of a wall in feet and sketch the exact dimension by merely counting squares and drawing the line accordingly. For example, a wall measured to be 13 ft, 6 inches long would be drawn 13½ squares long on the sketch pad.

Surveyor should start with the outline of the exterior of the building as above. Then, add interior partitions, windows and doors as shown at right.

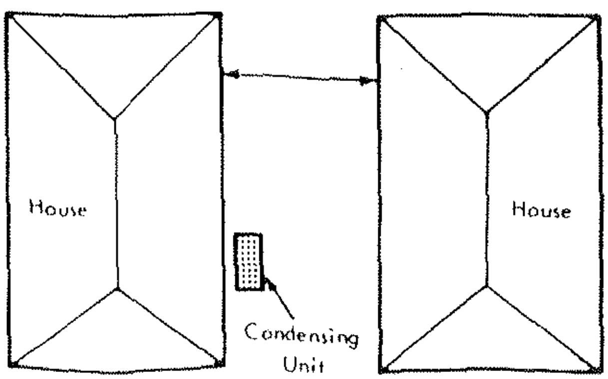


The best way to sketch an existing building is to start with the *exterior outline*. Once the exterior shape has been defined, interior partitions can be added with less chance of error.

In placing interior partitions, it's important to account for exterior wall thickness of at least 10 inches and interior partition thickness of 4 inches.

It's also useful to note spacing and direction of construction members, such as floor joists, roof trusses, etc. This will assist the designer later in routing ductwork and placing registers and grilles.

Because the condensing unit is typically placed outside, it is also important to indicate *property lines* and the proximity of adjacent buildings on any sketch. This information will be used to select and locate outdoor equipment to meet noise ordinances. We talk about this more a bit later in this lesson.



Note property lines and proximity of other buildings distance between buildings and location of condensing unit.

After verifying that all plans and sketches are accurate, the next step in a comfort survey is to identify and itemize all construction details that are needed to calculate the cooling load of the structure (this includes room, window and door sizes).

Rather than rely completely on memory, a number of survey checklists have been developed. Style and content of these survey forms vary with the user and his needs and the specific load calculation procedure he uses (there are variations in information required for specific calculation procedures). Example A is a *thermal* checklist.

In addition to thermal factors, there are, of course, physical factors that affect the selection and installation of an air conditioning system.

Again, much of the basic information required can be itemized in a simple checklist. Each individual should develop his own checklist to meet his specific needs. One example of this type of checklist is shown in Example B.

Finally, in the case of add-on work, information on an existing heating system must be compiled. This third "existing unit" checklist is shown in Example C.

What to Look For

In completing the various comfort survey checklists, it is often extremely difficult to determine some of the information required.

For example, wall insulation in an existing building. Unless the wall is actually opened for visual inspection or a special "heat flow meter" is used to measure the flow of heat through the wall, it will be necessary to take the word of the owner or rely on old material specifications as to the amount and type of insulation.

Edge insulation around the perimeter of slab construction is another example. As a general rule, if it is impossible to verify by inspection or with records, it is better to assume the worst condition for the sake of design.

Example A – Building Thermal Survey Form.

Design Conditions:

Dry Bulb	Summer	Winter
Indoor º F		
Outdoor º F		
Difference		

General Conditions:

a. Direction house faces: N NE E SE S SW W NW

b. House type: 1-story ☐ 2-story ☐ split level ☐

c. House age: new ☐ planned ☐ under construction ☐
existing ☐ approximate age ___________ years

Construction:

a. Walls: frame ☐ brick veneer ☐ masonry ☐
Insulation: none, 1", 2", 3½" ____________________
Interior partitions: single __________ double ________________
Color: dark ☐ light ☐

b. Ceiling heights: 1st floor ________ 2nd floor _______ 3rd floor _______
other _________ basement _______ crawl space _______

c. Roof: pitched ☐ flat ☐ vented ☐ yes ☐ no
Color: dark ☐ light ☐

d. Ceiling: attic above _______ under occupied floor
Insulation: thickness _________"
natural vent ☐ attic fan ☐

e. Floors: over basement ☐ over garage ☐ car-port ☐
over crawl space ☐ vented ☐ unvented ☐
moisture barrier to ground ☐ slab on grade ☐
insulation none, 1", 2", 3½" __________ edge insulation ☐

f. Windows: single pane ☐ double pane on storm ☐
double hang ☐ moveable ☐ fixed ☐
plain ☐ weatherized ☐ casement ☐
glass block ☐ certified ☐ non-certified ☐

Shading Type	Location				
	E	SE	S	SW	W
Roof overhang ft.					
Awnings					
Trees					
Garage, carport, porch					
Inside shades					
No shading					

Miscellaneous:

a. number of people _________
b. kitchen exhaust fan ☐
c. clothes dryer ☐ vented ☐ unvented ☐
d. special customer requirements:
frequent entertaining ☐
temperature ________ summer ___________ winter
relative humidity _________ summer __________ winter
e. fireplaces _______
f. special room treatment: workshop ☐ game room ☐ other ☐ _________
g. unusual lighting or appliance loads
h. skylights _________

Example B -- Building Physical Characteristics

Condensing method: air cooled ☐ water cooled ☐ cooling tower ☐ other ☐

Equipment unit location: basement ☐ utility ☐ attic ☐ outdoor ☐
other ____________ air cooled condenser _______________
cooling tower ____________ cooling tower pump __________

Note: Check to determine how and where equipment may be moved to final location -- door clearances, narrow halls, sharp turns, ceiling heights, stairs etc.

Clearance for equipment servicing ☐

Controls:

Heating only ☐ cooling only ☐ combination ☐ automatic changeover ☐ night set-back ☐
programmable ☐ color ☐ location ______________ set points ____________

Utilities:

a. Electricity: service capacity amps ________ volts _______ outside disconnect _________
Distance from entrance panel to desired location of outside condensing unit ___ feet
Distance from condensing unit to indoor unit _______ ft.
Distance from indoor unit to thermostat _________ ft.

b. Water source: city supply ☐ well ☐ water well GPM _____
maximum water temp. ________ available pressure ______ meter size _______
location ________ pipe size entry _______ from meter _________ Ph level ______

c. Water disposal: storm sewer ☐ sanitary sewer ☐ disposal well ☐ floor drain ☐
sump ☐ other _________

d. Condensate disposal: gravity ☐ condensate pump ☐ open floor drain ☐
trapped ☐ sump ☐ condensate material _________ size _______

e. Gas service: Type: natural ☐ propane ☐ heating value _______ Btu/cu. ft.
meter location _______________ LP tank location _____________ pipe size ________

f. Oil service: Type _________ heating value ________ Btu/gallon
tank location _____________ precautions __________________

g. Chimney: Masonry ☐ pre-fab ☐ size ____________ notes ______________
Liner ☐ size ____________

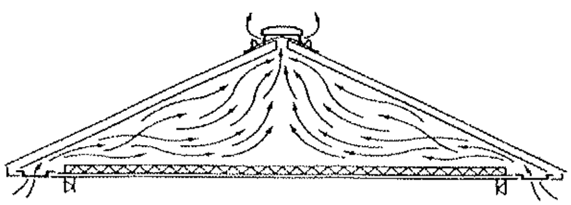
Be Sure of Adequate Vents

As explained in Lesson 7, adequate vent openings in attic spaces are essential to good cooling design. A comfort survey must include measurement of vent opening areas in both new and existing buildings.

Increasing venting effectiveness with improved natural venting systems or by the addition of forced attic ventilators can reduce ceiling heat gain. Hence, a comfort survey might also consider the problems and advantages of increasing natural ventilation or adding power ventilators.

Reducing ceiling heat gain by 20 to 30% is possible with improved venting, but obviously the reduction of ceiling heat gain by 20% does not mean an equal reduction in *total* load.

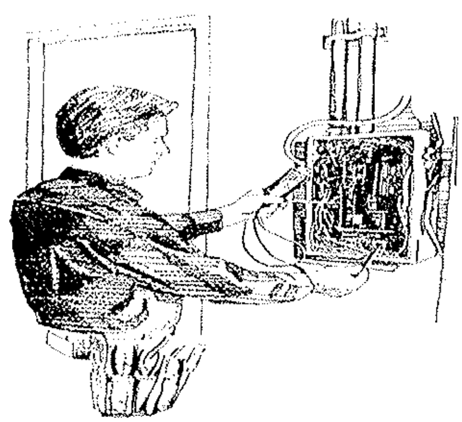
For example, if the roof represents 25% of the total load in a particular building, a 20% reduction in ceiling gain would mean just a 5% (.25 x .2) reduction in total cooling required.



Builders Must Provide Adequate Attic Vents

In the past, air conditioning personnel have not given adequate consideration to whether adequate venting of attic spaces was provided or not. Most people merely relied on the builder to do a good job. Today, the air conditioning technician cannot take anything for granted as far as the thermal fitness of the structure is concerned. He must do his own careful analysis and suggest useful changes to the builder or owner to achieve the most economical installation possible.

Electric Service



Besides surveying and listing all the factors affecting load calculations, attention must also focus on important "job" factors.

In both new and existing construction, one of the key job factors is adequate electric service. First, the voltage supplied must match equipment ratings. Next, the amperage rating of the service entrance must not be exceeded with the addition of the air conditioning unit.

A good rule of thumb for residential work is to assume 40 amps are required for general lighting and small appliances; and to that add the amperage draw of all major electrical appliances --- electric range, water heater, dryer, dishwasher, etc. --- and then add the amperage draw of the proposed air conditioning unit. If this total exceeds the raring of the service entrance, then, of course, the service entrance must be changed.

Example C – Existing System Survey Check Sheet

A. Heating system
1. Furnace type: Highboy ☐ Lowboy ☐ Counterflow ☐ Horizontal ☐
2. Supply system: Perimeter ☐ Overhead ☐ Inside wall ☐ Slab ☐
3. Return system: High inside wall ☐ Low inside wall ☐ Beneath windows ☐
Single return ☐ Multiple returns ☐
4. Duct type: Radial ☐ Loop ☐ Reducing plenum ☐ Extended plenum ☐

B. Furnace Blower
1. Direct drive ☐ # of speeds ☐ belt drive ☐ ECM ☐
2. Size of blower ☐ diameter in inches ______ width in inches ______
3. Blower pulley diameter in inches _________
4. Motor pulley diameter in inches _________ adjustable: ☐ yes ☐ no
5. Motor horsepower _______ RPM _________ Voltage, phase and cycles __________

C. Sizes
1. Size of plenum width _______ x depth _______ x height _______
2. Number of main ducts ☐ One: width _______ x depth _______ x height _______
☐ Two: width _______ x depth _______ x height _______
3. Number of branch ducts: ______________ size of each

4. Type of outlets	Quantity	Size
☐ baseboard	________	_______ x ________
☐ floor	________	_______ x ________
☐ wall	________	_______ x ________
☐ ceiling, round	________	_______ x ________
☐ ceiling, rectangular	________	_______ x ________
5. Type of inlets	________	_______ x ________
☐ floor	________	_______ x ________
☐ baseboard	________	_______ x ________
☐ wall	________	_______ x ________
☐ ceiling	________	_______ x ________
☐ baseboard out of wall	________	_______ x ________
☐ other	________	_______ x ________

6. Distance between outlet of furnace and first dust leaving plenum _______ inches
7. Distance from furnace to desired location of outdoor condensing unit ______ feet
8. If an upflow furnace located in closet, what is distance from top of furnace to top of closet door frame? __________
feet ________ inches

D. Miscellaneous
1. Is insulation present on or inside of ductwork? ☐ yes Nominal thickness ☐ no
2. Does insulation have vapor barrier on the outside? ☐ yes ☐ no
3. Are there balancing dampers in branch runs? ☐ yes ☐ no
4. Are drain provisions available near furnace? ☐ yes ☐ no
5. Will a condensate pump be needed to dispose of water from evaporator coil? ☐ yes ☐ no

Lastly, there must be "room" to make the electrical connection in the service entrance panel for the added air conditioning branch circuit.

Is Fan Adequate?

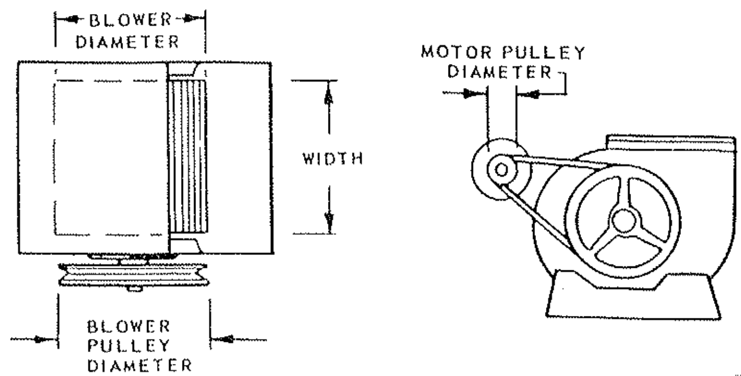
A second major item is the size of the existing blower in an add-on installation. Most survey forms include listing furnace blower details. Blower motor horsepower and rpm, blower type (direct or belt drive), and blower size (wheel diameter and width) are usually recorded.

Check Blower Specs

Blower details are important for the simple fact that cooling very often requires a larger blower and/or motor than heating. Why? Because adding a cooling coil to the system increases the resistance to air flow and air circulation for cooling is often higher than for heating. Thus, the blower must circulate more air against a higher system resistance --- all requiring increased rpm for an existing blower or a new, larger blower and motor.

While it is the function of a detailed engineering department analysis to determine adequate blower size for a specific job, Table 1 shows approximate performance characteristics for common blower sizes. This data suggests the following motor size rule of thumb for the purpose of a comfort survey:

24,000 Btu/hr.............1/4 hp
36,000 Btu/hr. .... 1/3 hp
48,000 Btu/hr. .... 1/2 hp
60,000 Btu/hr. .... 3/4 hp



The danger of overtaxing an existing blower and motor that are too small is great, since motor current draw increases from 3 to 5 times faster than the increase in blower speed. A 10% increase in blower speed causes a 33% increase in current draw. A 45% increase in speed would cause a staggering 205% increase in amperage draw by the motor. Thus, it is possible to quickly "burn-out" an overloaded motor.

Another important item to determine during a survey concerns provisions for draining condensate from the cooling coil. A survey should note the proximity of floor drain to the cooling unit. Will a condensate pump be an added requirement? And the local building code must be satisfied first! If the installation is in the attic, a special insulated condensate pan must be added beneath the cooling unit, or in some cases, a safety switch added to prevent condensate from overflowing and damaging the ceiling.

In analyzing an existing system, the dimensions of the available space in the furnace plenum must be noted in order to select a cooling coil that will fit. Even with new work, attention to the space allocated for the furnace and cooling coil must be accurately determined from floor plans. Many times, a good installation is merely a question of inches.

Table 1 – Blower Performance Characteristics			
Blower Size	**Volume CFM**	**Motor HP**	**Blower RPM**
9" diameter x 7" wide	800	¼	977
	1000	¼	1017
9" diameter x 9" wide	1000	⅓	970
	1200	⅓	995
	1400	½	1030
10" diameter x 8" wide	800	¼	837
	900	¼	840
	1000	⅓	845
	1200	⅓	855
	1400	½	872
	1600	½	892
10" diameter x 10" wide	1200	⅓	850
	1400	½	860
	1600	½	880
	1800	½	900
12" diameter x 9" wide	1200	⅓	695
	1400	⅓	669
	1600	½	705
	1800	½	715
	2000	½	728
	2200	¾	740
12" diameter x 12" wide	1800	⅓	688
	2000	½	695
	2200	½	705

In add-on work, it is also essential to single-line sketch the existing duct system and note register locations and sizes in each room. Later, this information can be used to determine if the number and sizes of duct runs is adequate for cooling. This is accomplished by comparing existing duct sizes with duct capacity tables from specific design manuals such as ACCA's Manual D. Most manufacturers of equipment provide simplified duct sizing tables as well.

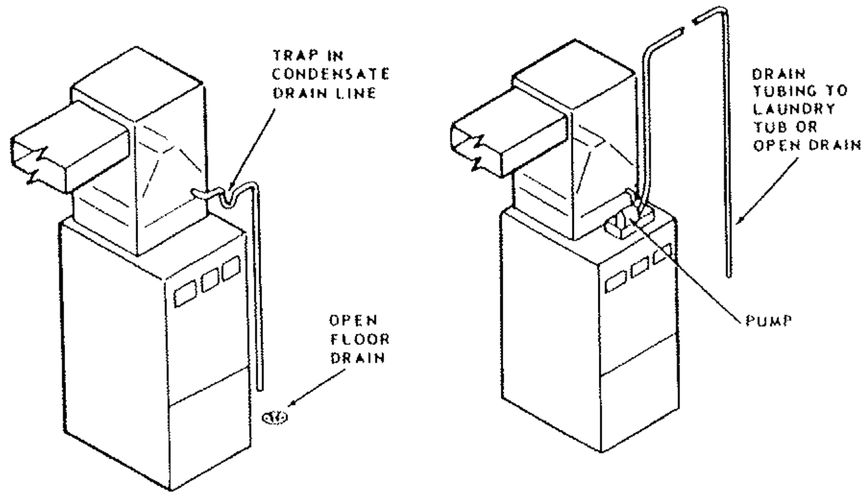
Watch For the Unexpected

A comfort survey can become a fairly routine task, but the experienced technician or salesperson is always looking for the unusual, not only in old buildings, but newly constructed ones as well.

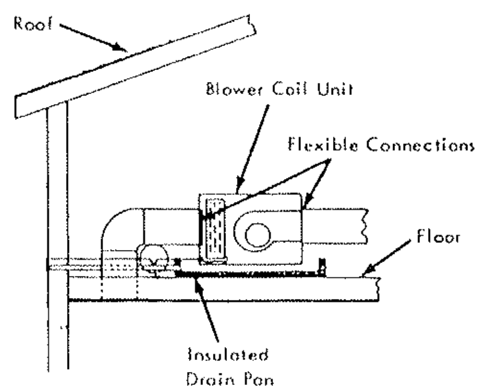
Look for unusual sources of heat gain: excessive air infiltration, rusted open fresh air intakes, or conversely, rusted closed kitchen exhaust fans, improperly installed insulation, poorly fitted windows and sliding glass doors, unusually high sources of moisture, etc.

Finally, equally important to the building survey is to discuss *occupant needs* with the owner or user of the proposed system. No two users are really alike. Living habits can affect system design almost as much as the structure itself.

As you learned in Lesson 8, occupancy load and other internal sources of heat gain can be significant. Internal moisture loads can be as much as 30% of the sensible heat gain in average buildings under average conditions.



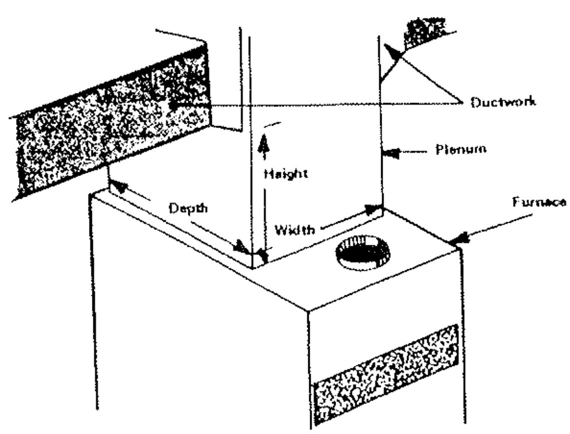
On the other hand, some families entertain a great deal in their home. Normal design procedures do not consider unusual "party" loads. Hobbies may affect design as well. Certain hobbies may generate excessive moisture or high internal heat could alter the system design.



Check Condensate Drain Requirements

The owner's plans may also include definite remodeling or expansion in the very near future.

The occupant's health may be a factor. Consider an individual with an allergy. He or she might require the addition of an electronic air cleaner, charcoal filter, UV light or the deletion of any sort of fresh air



Measure Space For Coil

intake in the duct system. Smokers might require more ventilation, certainly improved filtration.

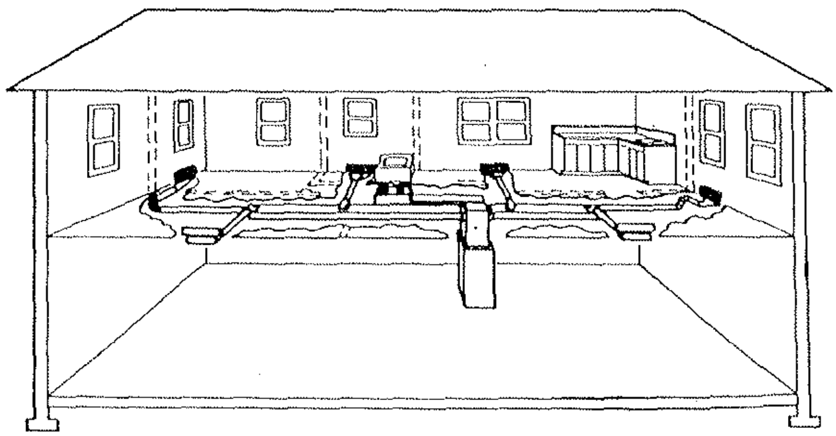
An individual who collects paintings or rare books might require a system designed for much closer humidity control than normally provided.

Elderly members of a family might require special controls to maintain slightly higher temperatures in certain rooms of the house.

From these few examples it must be apparent that the *personal interview* is an integral part of any comfort survey.

House Types

We will cover air distribution up close in our next lesson. Right now, let's review some of the general issues involved in making equipment and an air distribution system fit a building. We'll use several house types as examples.

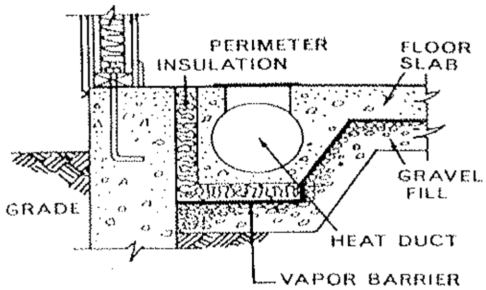


Equipment is readily fitted into homes with basements.

Three common types of houses encountered today are the one-story or *ranch type,* the *two-story,* and the *multi-level* house --- built over basements, crawl spaces, or on slabs.

The one-story house built over a basement is probably the easiest design. Equipment can be placed in the basement and cause little interference with respect to any ultimate use of the basement area. A minimum of labor will be required. Yet, a large rambling ranch house may present some design problems, even if it has a full basement, as duct runs from the central unit may become too long. One solution to this problem may be to install separate systems, each serving a portion of the house.

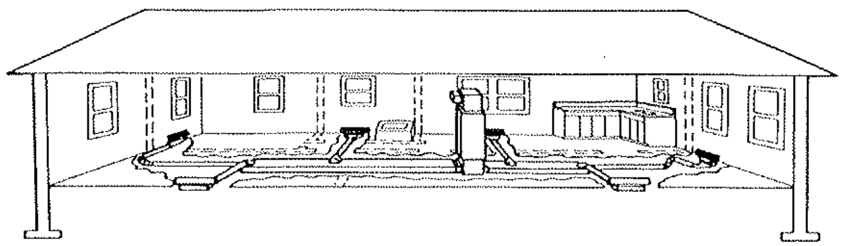
A ranch house built over a crawl space generally presents the same design problems as for the one-story house built over a basement. Equipment can be positioned in the crawl space or in a closet on the ground floor. However, there will be different procedures followed when installing a system for a house with a slab floor.



The ductwork must often be routed through the concrete floor. This is a difficult installation with careful preparation required before the concrete is poured. The builder and HVAC specialist must work together. Equipment would be installed in a utility room on the same level as the other room, as with a crawl-space house. In mild climates, the ductwork would be routed through the attic.

Multi-Story

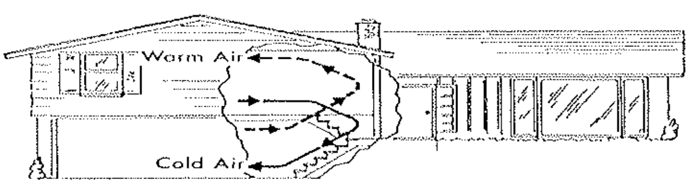
The two-story house presents some additional problems for proper design of a distribution system for air conditioning. First, there is the possible difficulty of locating convenient stud space to route and conceal ducts to the second floor.



Equipment goes in closet or attic when home has a crawl space.

Then, the fact that warm air tends to rise while cool air falls can complicate matters. This means that the second floor will more than likely tend to be warmer than the first floor. Therefore, the second floor may require more cool air than estimated by the load calculation.

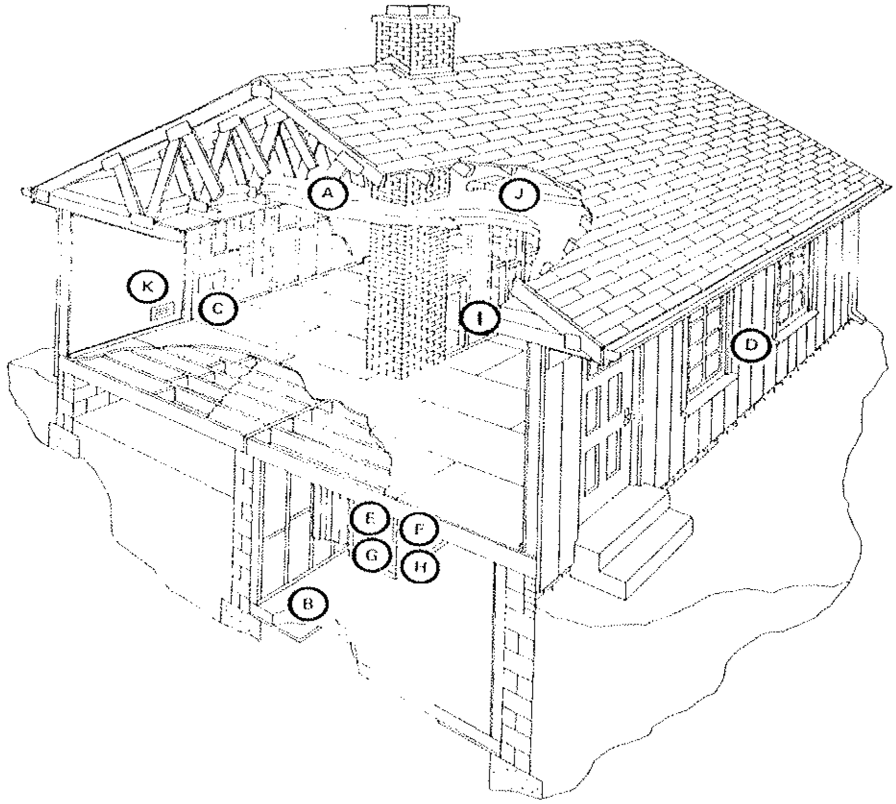
The problem may be less of an issue if the second floor contains only bedrooms which are occupied primarily at night. In some instances it is advisable to provide additional supply ducts to the second floor for use during the cooling season. Separate equipment, while expensive, or zone control can improve comfort in two-story houses.



Split level homes experience air exchange between levels.

The split-level house offers another challenge to the designer. Some of the problems are the same for both cooling and heating. For example, floors of rooms over the garage or porch should be heavily insulated to minimize heat gain in summer as well as heat loss in winter, because it must be assumed that these areas will usually be unconditioned.

Depending upon the design of the house and the use of the upper levels, it may be necessary to provide considerably more air for cooling the top level as in the case of a two-story house.



Notable Notes: A Basic Guide to Energy Savings

1. Effective insulation

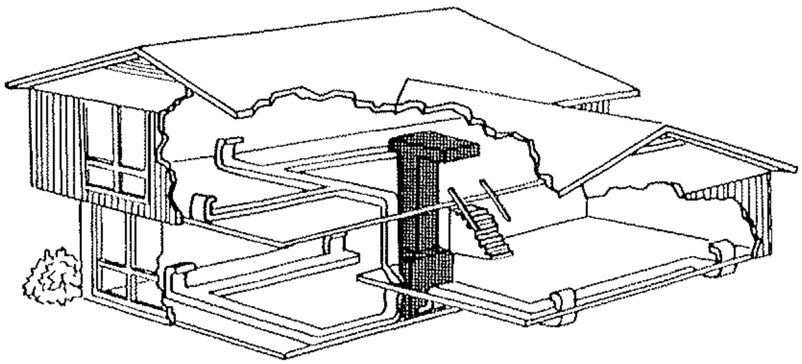
A. Insulation R-values meet standards for this climate to ensure minimum heat losses in the winter or heat gains in the summer.
B. Proper installation ensures insulation, fully protects walls, ceilings, and building perimeter.
C. Weather-stripping reduces air infiltration around doors, and windows.
D. Caulking and sealing reduces air leakage around doors, windows, and chimneys.

2. Efficient Heating and Cooling Equipment

E. Efficient air conditioning equipment uses less energy than standard equipment and saves on cooling bills.
F. An energy saving heat pump provides heating and cooling and can save 30 to 50% on electric heating costs.
G. Equipment performance, capacity, and energy efficiency are certified under a program provided by the Air Conditioning, Heating & Refrigeration Institute (AHRI).

3. Expert Heating and Cooling Installation

H. Equipment is properly sized to meet the needs of the house.
I. Air distribution system is sized for energy efficiency.
J. Air handling ducts are air-tight and insulated in non-conditioned areas.
K. Registers and grilles are located to give draft free insulation.

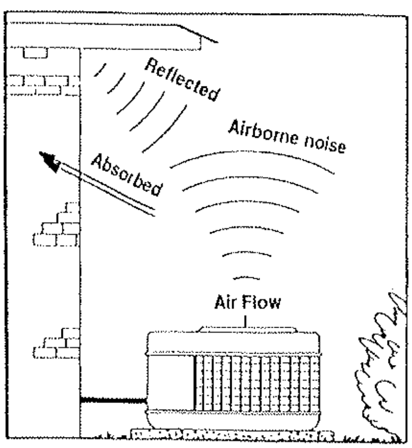


Routing ductwork through a multi-level house may be at times very difficult.

Zoning may be advisable for cooling (as well as heating) a split level house, or perhaps two separate systems will be a consideration. One of the two systems could be a conventional central air conditioning system while the second, a small, self-contained unit. The latter would be installed in the top level to augment the cool air delivered to that area from the central unit. If the house has an attached garage and the owner does not wish to cool this area, the walls between the garage and the house should also be thoroughly insulated.

Equipment Noise

Unlike most home equipment, central air conditioning units produce sounds that are detected *outdoors*-especially by neighbors without air conditioning. The Air-Conditioning, Heating & Refrigeration Institute (AHRI) has developed a simplified equipment rating standard in decibels (dB) and also an application standard. They are respectively AHRI Standard 270 for rating and AHRI Standard 275 for application.



Rating of manufacturers' equipment is published by AHRI and participants in the program list their standard ratings in their catalogs as well.

Airborne sound emitting from an outdoor air conditioning condensing unit can be reflected and absorbed by the adjacent building surfaces.

The dB rating does not reflect acceptable or unacceptable design criteria directly. While a piece of equipment can be labeled with a single rating number, sound or noise is very definitely a consequence of environment. An automobile engine sounds louder inside a garage than out because inside, the sound is bounced back and forth off the garage walls-thereby amplifying sounds. So too a condensing unit with a sound rating of say 62 dB would sound louder installed in a narrow areaway between two buildings than say behind one building with open areas on all sides. However, using the data in AHRI Standard 275 it is an easy task to account for the effects of site conditions.

Sounds are produced by vibrations. Vibrations can be airborne or travel through solids and liquids --- hence sounds can too. An auto mechanic places his ear near a wrench pressed against an engine to pinpoint a noise. Swimmers beneath the surface can hear the sound of two objects struck together under water. These are examples of sounds moving through a solid, the wrench, and a liquid, the water.

Generally though, it is airborne sound --- sound transmitted through the atmosphere --- that is of particular concern in the case of outdoor air conditioning equipment. Sounds that travel from the equipment to adjacent neighbors, not by direct connections, but by air waves. Vibrating mechanical equipment actually causes very small pressure changes in air; eventually, the air transmits the vibrations to the human ear.

Location is Important

Obviously, if the air conditioning unit was not located in front of a neighbor's window or facing his patio, the sound level there would be reduced. Advance planning is necessary if the air conditioning unit is to be placed where it will create the least amount of sound for neighbors or on the user's own patio.

The first step in planning is to find the best location for the unit. Properly screened with shrubbery or decorative fencing that doesn't block the air flow, an air-conditioner can be hidden from view even when placed in front of a home. Many air conditioning units are designed with clean, functional lines and come in colors that blend with the walls of the home. They can become almost invisible from the curb if fencing or shrubbery blends in with the rest of the landscaping in front of the home.

Little can be done to lower the sound level of the equipment after it is installed. What little can be done is usually costly and less effective than if sound control had been considered before installation.

Experience Helps

Conducting an effective comfort survey comes with experience. In the beginning, the air conditioning technician or salesperson must be prepared to go back to the job site, make extra phone calls, etc. because this or that fact was not ascertained. But thoroughness should be the ultimate goal. For, with a thorough and complete survey comes a savings in time and effort, both of which lead to a more profitable installation and a very satisfied customer.

Self-Check, Lesson 9 Quiz

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

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

True False

1. T F A comfort survey is an investigation to gather thermal and physical information on a building to be air conditioned.

2. T F Most building plans and sketches are drawn to a 1/4 or 1/8 inch equals 1 foot scale.

3. T F Data on existing ductwork is essential to achieve a successful add-on installation.

4. T F The existence of adequate attic ventilation openings must be verified to assure minimum ceiling heat gain.

5. T F An existing furnace blower may not be adequate because adding a cooling coil increases resistance to air flow.

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. Speeding up a blower by 10% will result in a ______ increase in motor current draw.

☐ A. 3%. ☐ B. 33%.
☐ C. 10%. ☐ D. 20%.

7. Condensate drains may cause problems and must be installed according to:

☐ A. manufacturer's instructions. ☐ B. homeowners' preference.
☐ C. local building code. ☐ D. contractors experience.

8. A critically important aspect to any comfort survey is to:

☐ A. discuss occupant special needs.
☐ B. find out how long owners lived in house.
☐ C. determine how much customers can afford to pay.
☐ D. determine how long occupants plan to stay.

9. A slab floor house with a perimeter system poses special HVAC problems because:

☐ A. the slab takes a long time to cure.
☐ B. ducts are difficult to install in a slab.
☐ C. the slab is hard to cool .
☐ D. there is no room for the air handler.

10. An often overlooked problem in a comfort survey is:

☐ A. the time necessary to deliver the equipment.
☐ B. the labor costs to install the system.
☐ C. adequate room for the outdoor unit.
☐ D. the potential for noise by the outdoor unit.

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

Key Words

zone control	air	property	included	open window
harder	easier	water	Standard 275	electric
walls	Noise Criteria 40			

11. Multi-level and two-story homes may be good candidates for ________ ____________.

12. Noise rating of outdoor condensing units is covered by ______________ published by the Air Conditioning, Heating & Refrigeration Institute.

13. Sound transmitted through ____________ is the greatest concern when locating outdoor condensing units.

14. The distance between a condensing unit and a ______________ line may be specified by local code.

15. Single story homes are __________ to cool than two-story homes.

16. Checking for adequate __________ service is a key priority when conducting an existing house survey.

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 10 Overview

All the fancy equipment in the world cannot overcome a poor air distribution system. In fact, it is the air distribution system that makes central air conditioning different— it is not just a plug-in appliance. Air distribution must be "engineered" or customized for the house.

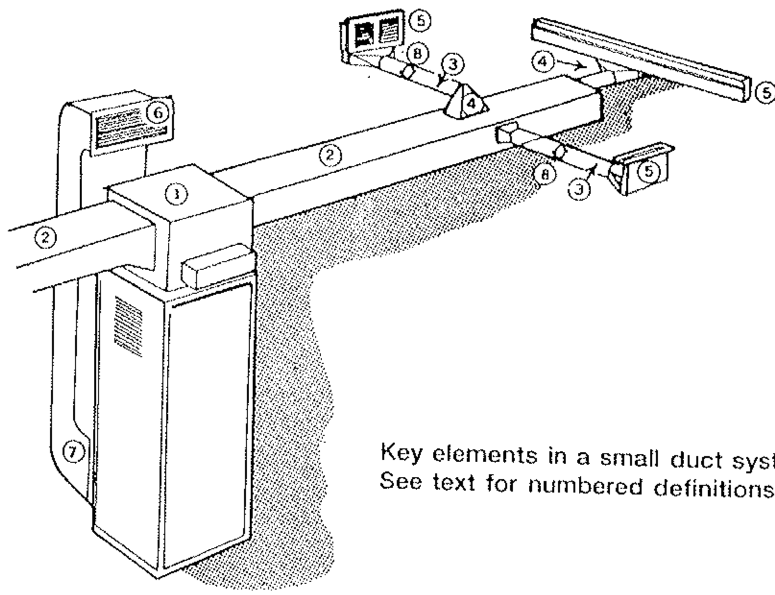
In Lesson 10, you will learn:

- the names of the various parts of a duct system
- the meaning of the term "resistance to air flow"
- approaches to sizing ducts to provide the correct air flow to each room
- the need for insulation to save energy and avoid condensation
- the basic types of duct systems
- the need for fine-tuning the system by balancing and adjusting the air flow through the system

As with cooling load procedures, there are a number of industry-supported duct design procedures in use. This lesson gives you the necessary background information before undertaking the study of specific procedures.

Now read Lesson 10 which begins on the next page.

Lesson 10: Moving Air for Comfort



Key elements in a small duct system. See text for numbered definitions.

Equipment cools and dehumidifies the air. Filters clean the air. For whole house comfort, the conditioned air must be distributed throughout the building in the correct amounts without drafts or noise.

The design and installation of the air distribution system is every bit as important as the selection and installation of the correct equipment. As we learned in Lesson 9, finding room and ways to route ductwork is also a real challenge.

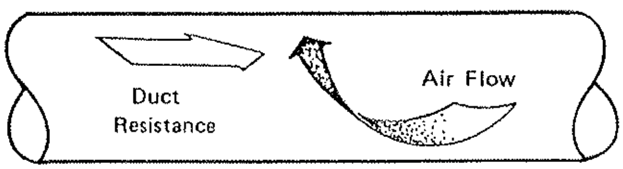
Your Basic Duct System

The major parts of a duct system consist of:

1. **Supply plenum** - the central collecting chamber for the conditioned air leaving the air conditioning unit.
2. **Trunk duct** - distributes the large volume of air from the supply plenum to other parts of the building.
3. **Branch ducts** - tap into the trunk ducts to bring air to individual rooms.
4. **Fittings** - such as elbows, boots, take-offs, angles, etc. are required to route the ductwork through and around joists and studs.
5. **Supply outlets** - on the end of the branch duct project the conditioned air into each room to mix with room air.
6. **Return air intakes** - grilles which permit air from the conditioned space to enter the return side of the system leading back to the air conditioning unit.
7. **Return duct** - collects air from the return grilles to carry back to the air conditioning unit.
8. **Volume dampers** - required for each supply outlet (in the branch duct, riser, or outlet itself) to regulate the amount of air flowing so that the system can be properly balanced.

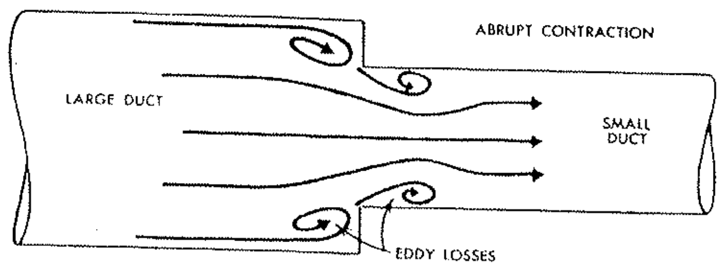
Friction and Air Flow

Air or water flowing through a piping system requires energy to overcome an opposing resistance to flow called friction. The purpose of the equipment blower is to provide energy in the form of pressure to overcome the resistance to flow imposed by the duct system.

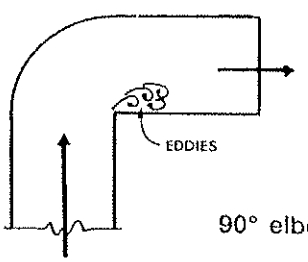


Straight ducts (at left) resist airflow because of wall friction. Any change in duct geometry (below), imposes resistance primarily because of turbulence – swirling pockets of air – as the air stream is disrupted to turn or change shape. As a result, fittings just inches long can cause the same resistance as 5, 10, 20, or more feet of straight duct resistance. The exact amount depends on fitting streamlining.

Even a length of duct perfectly straight and apparently smooth, offers resistance to air flow created by the *friction* between the inside surface of the duct and the air.



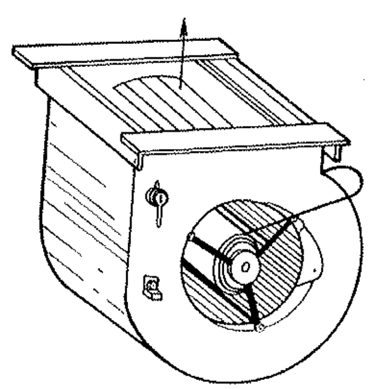
There is also *turbulence* as an energy waster. Turns and changes in duct geometry cause some air to begin swirling into tiny whirlpools that consume energy which is reflected by a loss of pressure. Quite often, the fittings in a duct system cause more resistance than the straight ducts themselves.



90° elbow

For example, one elbow just inches long may cause the same resistance (pressure loss) as a duct 10 feet long because of turbulence as the air is forced to turn.

The blower overcomes the duct resistance. Air on the inlet side is a low pressure and air on the outlet side is a higher pressure. Pressure always goes from a high to a lower pressure.



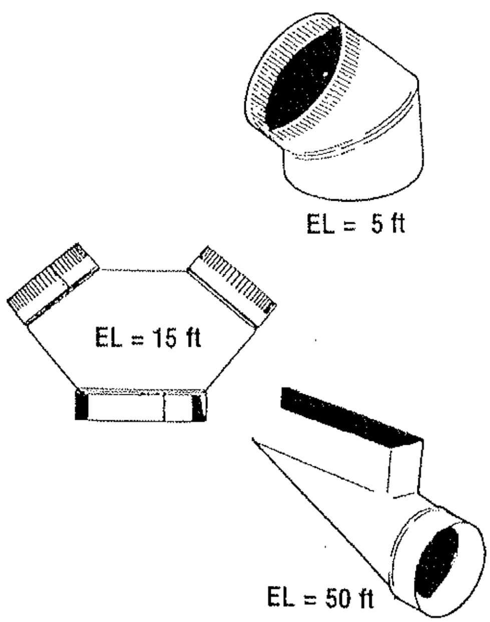
A square or hard turn elbow may impose twice as much turbulence as a gradual turn. So there are good and not so good fittings as well.

The frictional resistance of straight ducts and fitting resistance can both be measured and reported as a pressure loss in inches of water column (IWC).

Notable note: Your car's tire pressure is about 30 psig (pounds per square inch). The equivalent in inches of water column would be about 831 IWC (27.68 x 30). Peak pressure in a residential duct system is often 0.5 IWC – very low pressure. In the metric system pressure is measured in Pascal's. Duct pressure would be about 125 Pa or 0.125 kPa.

As an example: If we want to push 15 pounds of air per minute through a six inch round duct 50 feet long, the duct would impose a 0.15 IWC resistance. A fan pushing air at the entrance would have to overcome this resistance. If the fan could not produce 0.15 IWC pressure at the required air flow rate, then the amount of air moving through the duct would be reduced.

We could change to a larger 8-inch round duct. The fan now would only have to produce a pressure of 0.04 IWC to move the 15 pounds of air. Thus, for a given quantity of air, a larger duct imposes less resistance (pressure loss) than a smaller duct of the same length. Matching the fan and ductwork is the key to successfully moving air.



For design convenience, fitting losses for small systems are most often listed in terms of equivalent length of straight duct rather than IWC pressure loss. A 45° elbow might impose the same resistance as 5 ft of straight duct of the same size --- hence the fitting's equivalent length (EL) is 5 ft.

At left are a few examples of fittings and their approximate equivalent length.

It is essential that the duct system be laid out using a minimum number of fittings and using fittings with low loss (low EL) characteristics. If the system is poorly designed using high loss fittings and undersized, the correct amount of air will not be delivered by the blower.

Within limits, a blower may be speeded up to overcome higher resistance. However, doing so requires more power with a consequent increase in operating costs and higher noise level. Increasing blower speed often requires a larger motor, as was mentioned in the previous lesson on making a comfort survey.

Sizing Ducts

In addition to using a minimum number of good fittings, the duct system must also be sized --- made big enough --- to provide the proper amount of conditioned air to each space.

Small duct systems are sized based on the following:

1. The amount of air to be delivered to each space (from the cooling load).
2. The fan pressure available to "move" the air.
3. The effective length of the duct runs (fitting EL lengths plus actual duct length).

Notable Note: A comprehensive duct design procedure is the subject of a separate course called Residential Duct design and is based on ACCA Manual D.

By tradition, air flow is given in terms of CFM — cubic feet of air per minute, not pounds per minute. Fan pressure, as we know, is given in terms of inches of water column (IWC). Knowing these values and duct equivalent length, it is possible to correctly size the branch and trunk sections of a duct system. Simplified tables, as illustrated on bottom of page 110, are used to ease the designer's work.

Simplified Sizing Guide

C.F.M.	Heating BTU	Cooling BTU	Round Pipe	Square Pipe	Floor Diffuser*	Sidewall Diffuser°	Baseboard Diffuser*	Return Grille*
32	2,400	970	4					
60	4,400	1,820	5			10x6	24"	
100	7,400	3,030	6	3½ x10	2½ x10		48"	10x6
120	8,900	3,640		3½ x12	2½ x12	12x6		12x6
145	10,700	4,390	7	3½ x14	4x14	14x6		14x6
180	13,300	5,450		8x6				
210	15,600	6,360	8					
270	20,000	8,200		8x8				24x6
290	21,500	8,800	9					
300	22,200	9,100						30x6
370	27,400	11,200		8x10				
390	28,900	11,800	10					
460	34,000	13,900		8x12				
500	37,000	15,200	11					
560	41,500	17,000		8x14				
620	45,900	18,800	12					
660	48,900	20,000		8x16				
770	57,000	23,300	13					
800	59,300	24,200		8x18				
900	66,700	27,300		8x20				
930	68,900	28,200	14					
1000	74,100	30,300		8x22				
1100	81,500	33,300		8x24				
1140	84,400	34,500	15					
1200	88,900	36,400		8x26				
1300	96,300	39,400	16	8x28				
1400	103,700	42,400		8x30				
1500	111,100	45,500	17	10x24				
1700	125,900	51,500		10x26				
1800	133,300	54,500	18					

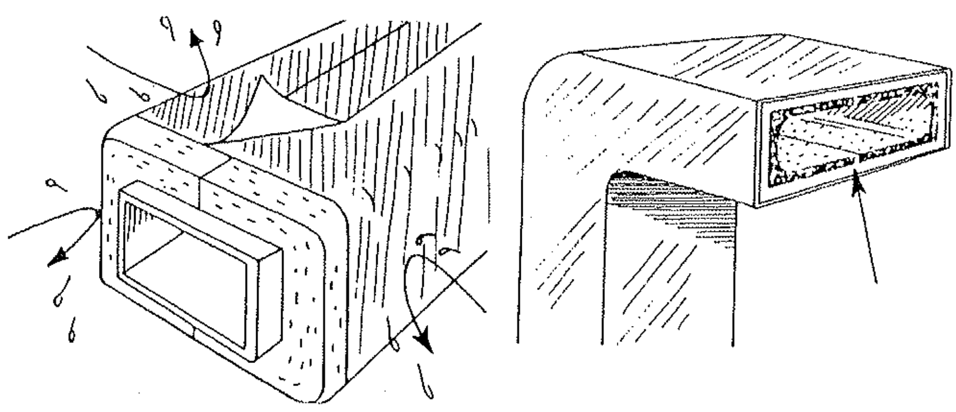
Based on 0.1 IWC supply and 0.1 IWC return and average number of fittings. For one or two long branch lines suggest one size larger pipe.

However, it is absolutely essential that the user of simplified sizing procedures be aware of the assumptions and limitations of the sizing charts.

Insulating Ductwork

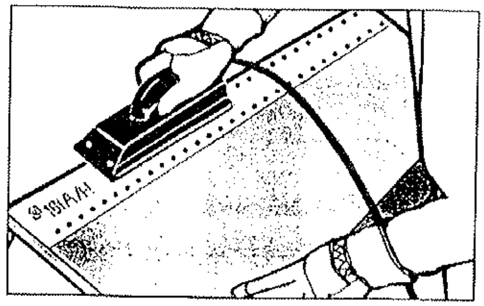
Ductwork is usually fabricated from galvanized steel but may also be both rigid and flexible fibrous glass materials.

Air flowing through ducts from a central cooling unit to the spaces to be conditioned will absorb heat because the air in the duct is around 60º F and the air surrounding the ductwork may be at 75°, 85°, or even 130° F in an attic. If the ducts pass through spaces that are air conditioned, such heat absorption is useful in keeping the spaces cool. If a space is not air conditioned, however, the heat absorbed reduces the cooling capacity of the air by raising its temperature before it reaches its destination.



Exterior duct insulation with vapor retarder (barrier) is required by code. Duct liner (right arrow) can be used to satisfy insulation levels in some applications. A combination of both is also used.

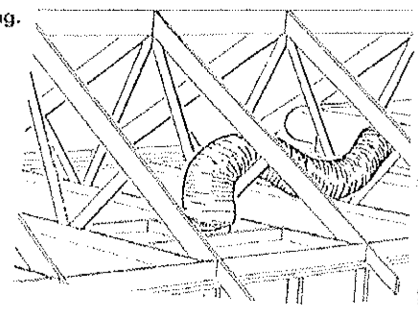
Fiberglass ductwork requires heat activated tape closure on longitudinal seams or a mastic and glass fabric tape application.

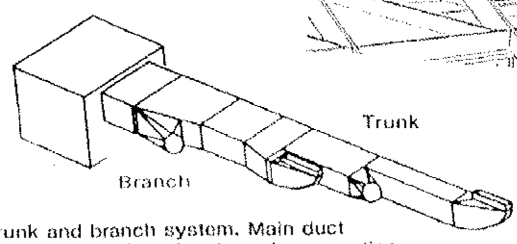


Galvanized ductwork that passes through attics, crawl spaces, or other non-air conditioned spaces must be covered with insulation. Local codes may require it. A vapor retarder outer surface should be part of the insulation to prevent moisture from penetrating the insulation and condensing on the cold duct. Wet insulation sharply reduces the effectiveness of the insulation, which, of course, adds to the cooling load. Wet surfaces can also become a potential breeding ground for contaminants.

Some contractors prefer to install the insulation on the inside of the ductwork as they fabricate it in the shop. One advantage of this arrangement is the duct liner reduces noise transmission through the ducts.

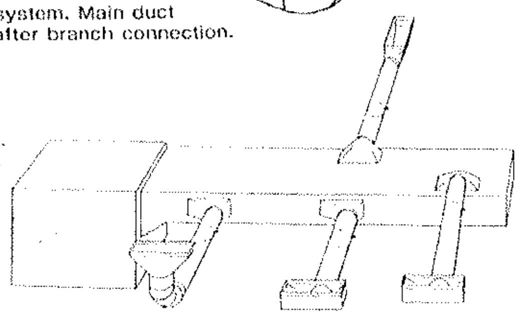
Flexible duct eases duct routing.

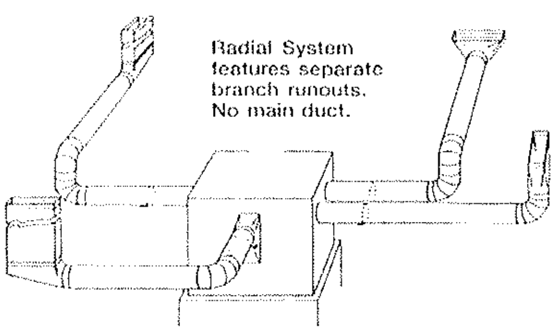




Trunk and branch system. Main duct decreases in size after branch connection.

Extended Plenum. Main duct stays a constant size.





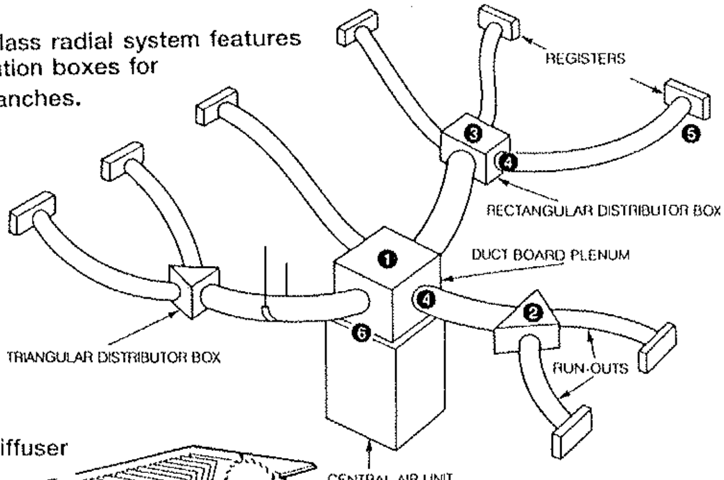
Radial System features separate branch runouts. No main duct.

The use of one inch (R- 4.3) or 1-1/2 inch (R 6.5) fibrous glass materials for ductwork includes a vapor proof jacket of vinyl or reinforced aluminum covering and eliminates the need for a separate insulation wrapper in many instances.

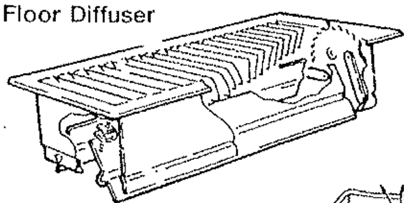
Flexible duct has become popular for both supply and return duct systems, especially those installed in attic spaces. Flexible duct permits long, smooth, gradual bends, and an installer can route the duct system around tight and difficult obstructions with great ease. Branch run-outs can also be quickly fitted between trunk and supply outlet. Both insulated and non-insulated flex duct is manufactured.

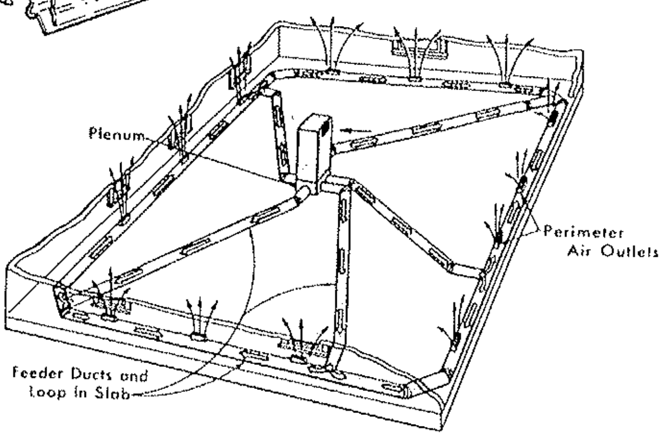
Thorough duct sealing for both metal and non-metal residential ductwork is being mandated by quality designers and by energy conscious code authorities trying to meet both local and national installation codes.

Fiber glass radial system features distribution boxes for sub-branches.



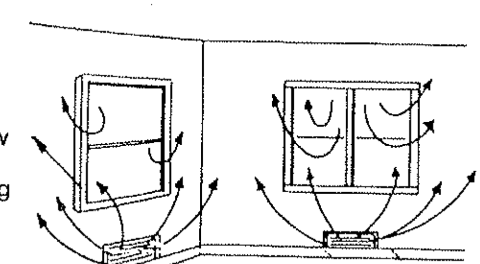
Floor Diffuser

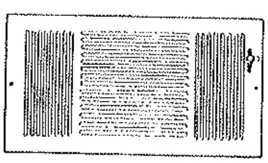




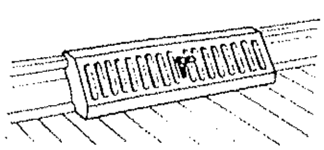
Loop system for slab construction in cold climates.

Ideal for heating, low wall locations can provide good cooling if sized right.





Low Wall Diffuser



Baseboard Diffuser

System Types

We can classify air distribution systems in a couple of ways --- first, based on the geometry of the ductwork---as trunk and branch, radial, and perimeter loop.

The *trunk and branch* system features a large main duct carrying air to usually round branch duct that serve individual supply outlets. The trunk or main duct is decreased in size as conditioned air is delivered to branches along its length. One version of the trunk and branch is called an extended plenum system where the trunk is kept a constant size for its entire length. A radial system features individual branch runs from the plenum attached to the cooling unit. This has also been called a spider system. A variant uses a fiberglass distribution box to make sub-branches off the initial run-out.

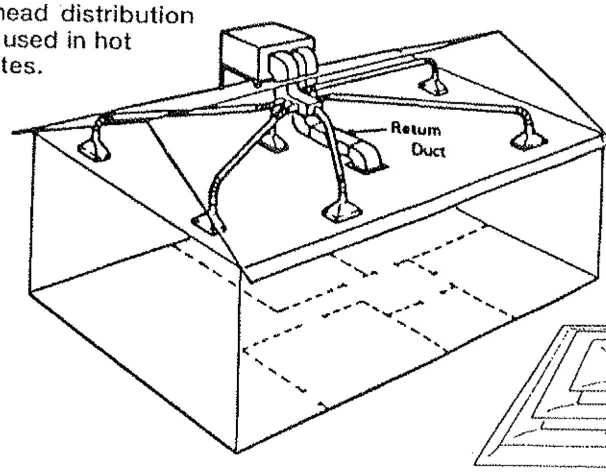
The perimeter loop system has a characteristic supply loop which runs along the outside walls of a room or entire building. The loop is fed conditioned air at various points in the loop. This geometry was devised primarily to complement slab-on grade house construction for heating in cold climates.

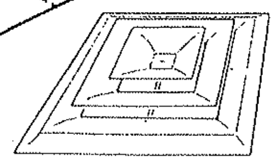
Classified by Outlet Location

Secondly, we can classify our air distribution arrangements based on supply *outlet location*:

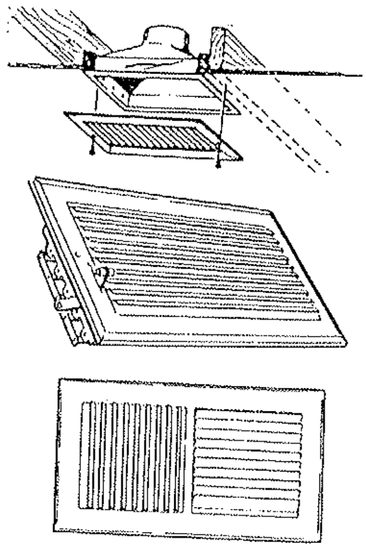
- along outside wall --- (a perimeter system)
- in ceiling
- on inside wall (low or high)

Overhead distribution often used in hot climates.

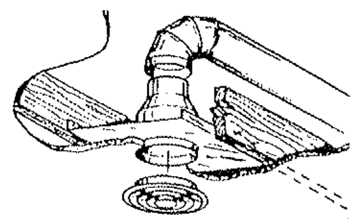




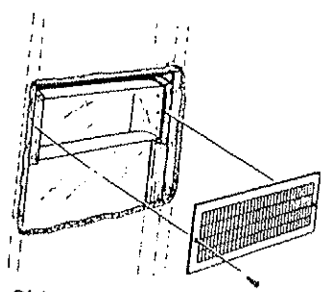
Square Ceiling Diffuser



Rectangular Ceiling Diffusers



Round Ceiling Diffuser



High Sidewall Diffuser

Perimeter supply outlets right in the floor or low in the outside walls give superior results for winter heating in cold climates, and generally can give good results for cooling.

If a system of ductwork is being designed only, or primarily, for cooling, as it may be in the south and southwestern parts of the country, a perimeter type layout is seldom used. However, most authorities still agree that a year-round system in cold regions of the country should be a perimeter configuration --- even in well-insulated structures.

All three duct configurations --- trunk and branch, radial, and perimeter loop --- can be used to provide perimeter outlet locations.

When heating is of secondary importance, overhead distribution is most often used to position supply outlets in ceilings or high on inside walls. Ceiling outlets may be centered in the room or positioned in the ceiling along the outside walls of the room.

Supply Outlets

The number and size of supply outlets needed for a cooling system are dictated by the room by room cooling load.

With *underfloor* duct routing, the choice in supply outlets is usually between baseboard, floor diffusers, and perhaps low sidewall or floor registers.

Perimeter outlets can provide excellent cooling performance, provided a few precautions are taken. One involves assuring adequate throw to project cool supply air high up into the room. This can be achieved by following the manufacturer's register sizing instructions.

Another precaution is to provide at least one diffuser in each principal room with a "clear field" along a wall --- no short drapes or window ledges to deflect the cool air supply jet.

A third involves using a suitable number of outlets in each room. Two or three small outlets are generally preferred over one or two large ones. A common rule of thumb for residential work is that a single outlet should never supply more than 4,000 Btu/hr cooling.

For duct systems routed *overhead*, ceiling diffusers are available in round, square, and rectangular shapes. They are most frequently used in areas of the country where winters are mild, but summers are long and hot. In areas where below-freezing temperatures often occur and where warm floors are highly desirable, use of ceiling diffusers usually is not recommended for heating.

Cost, of course, is always a consideration, and forces compromises when duct routing becomes difficult and expensive.

Return Intakes

Return air grilles may be located in the floor, baseboard, high in the sidewall, or in the ceiling. Much is said about the effect that the placement of returns can have on the temperature uniformity in a room. In fact, the return has very little effect --- certainly far less than is generally believed. And a poor supply system can never be remedied by altering the return arrangement. Most often, returns are inadvertently *undersized.*

The main concern with return grilles is to size them big enough to:

- handle the returning air volume
- avoid whistling noise because of high air velocity
- avoid placing returns where people sit and cause a draft

A residential return should probably handle no more than 2 to 3 CFM per sq inch of actual see-through opening (called free area).

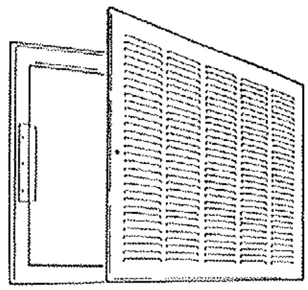
As far as placement is concerned, consider these guidelines:

- low for heating only
- high for cooling only
- for a year-round system: place them high if a perimeter system is used; place them low if a

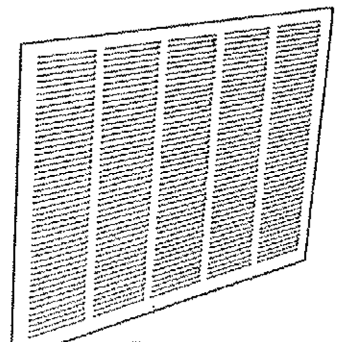
high supply system is installed

In any event, if you make certain the supply system is right for the job, the problem of where to put the returns becomes academic.

The function of a return air grille is simply to provide a cover over the return duct opening. The type of grille cannot significantly influence the approach of the moving air stream entering the grille.

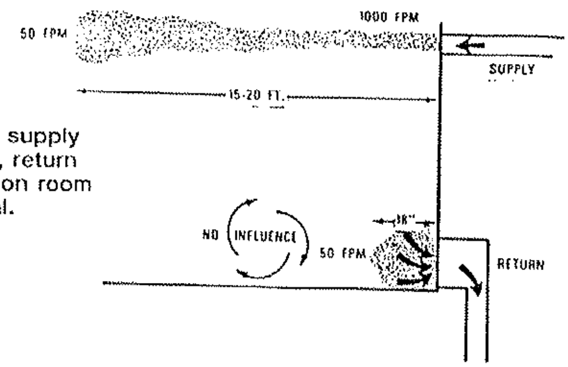


Return Filter-Grille



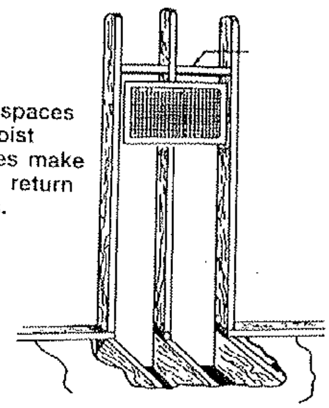
Basic Return Grille

In small installations, a single "central" return air intake can be made satisfactory if interior room doors are undercut to allow air to flow from each room and reach the return grille. In larger systems serving extended ranch-type or two-story and tri-level houses, multiple return air intakes are usually required.



Compared to supply register (top), return intake effect on room air is minimal.

Studies have shown that stud and joist spaces are extremely difficult to make air tight. Still, many code authorities continue to allow the use of joist spaces and stud spaces to be used as connecting return air paths.



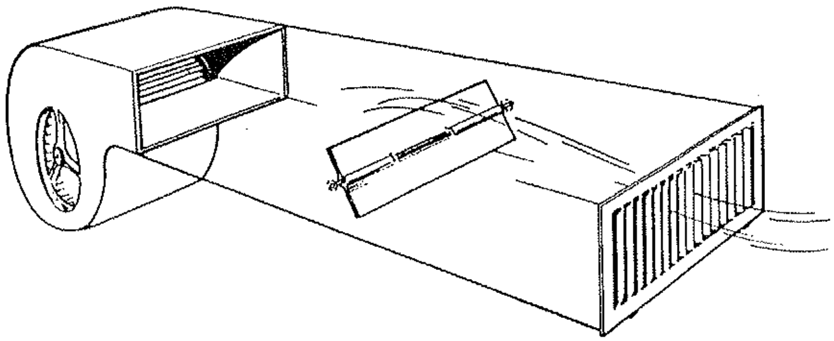
Stud spaces and joist spaces make leaky return ducts.

However, energy conscious installers are relying on a fabricated return duct system assembled with the same care as the supply side of the system.

Balancing the System

Even the most carefully designed and expertly installed air distribution system will probably have to be "balanced" so that each room will be maintained at the temperature desired by the occupants.

Balancing is accomplished by adjusting up or down the amount of air delivered to each supply outlet. This is done by changing the setting of the volume dampers located in a branch duct or at times in the supply outlet itself. A change in blower speed may also be required to assure that the correct total CFM of air is circulating through the equipment.



Volume dampers should be installed in duct systems to allow for convenient balancing and rebalancing the system for seasonal changes.

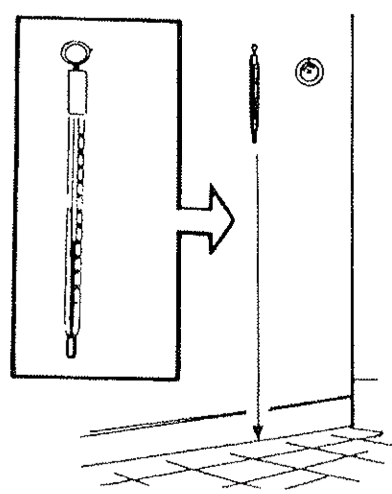
All duct systems must be balanced for best performance.

A year-round system properly balanced for heating may not be correctly balanced for cooling, and vice-versa. A room with a northern exposure, for example, may require more air for adequate heating than is needed for cooling during the summer. Thus, the person who installs a year-round air conditioning system should plan to balance the system once for cooling and once for heating if best results are to be obtained. Seasonal damper positions should be noted for the owner.

Techniques

The two most commonly used methods of balancing an air conditioning system are the thermometer method and the air velocity method.

In the thermometer method, the technician places one thermometer in each room and one at each thermostat location. The thermometers are at the same height from the floor as the thermostat that controls the equipment, and they are located in each room so they are not influenced by heat sources such as lamps, direct sunlight, or a sun-warmed wall. All the volume dampers and registers are wide open at the start of the balancing.



Volume dampers in ducts supplying rooms which have the lowest temperature readings are closed slightly to reduce the amount of air supplied to those rooms. This not only cuts the amount of air delivered to these rooms, but also increases slightly the air delivered to other rooms.

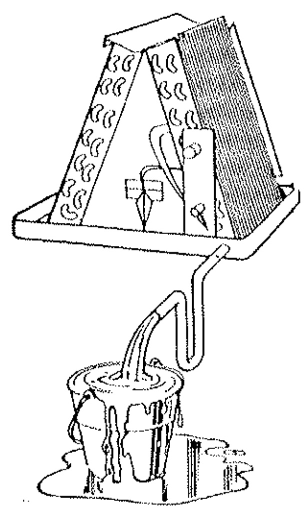
Another way to balance the air distribution system is to measure the actual air volume delivered by each supply outlet.

The technician uses an *air meter* and takes several readings of the air velocity at each outlet. Using this measured velocity and the effective area of the register, supplied by the manufacturer, the technician can determine the CFM entering the room. The measured CFM is then compared to the design CFM noted originally for each register when the system was designed.

Although the air velocity method of balancing can be used in residential work, it is employed chiefly in the large commercial systems.

The total amount of air flowing through the cooling unit can also be adjusted to slightly increase or decrease the split between sensible and latent capacity of the unit. Decreasing the CFM through the unit tends to increase latent capacity at the expense of sensible capacity. Conversely, increasing the CFM increases sensible capacity and decreases latent capacity.

As a rule of thumb, in areas where outdoor humidity is high, common practice might be to circulate about 300 to 320 CFM per 12,000 Btu/hr total cooling capacity; while in dry areas, circulating about 400 to 420 CFM per 12,000 Btu/hr might be preferred. This, of course, affects the Sensible Heat Factor (SHF) of the equipment as previously described in Lesson 8. Exact manufacturer minimum and maximum CFM requirements must be followed to stay within rated cooling performance.



Self-Check, Lesson 10 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	All duct systems impose a resistance to air flow that must be overcome by the blower.
2. T	F	Because of turbulence, fittings can cause more resistance in a system than straight length of duct.
3. T	F	Blower performance is listed in terms of so many pounds of air circulated per minute.
4. T	F	Ducts that leak air may disturb the pressure balance within the building.
5. T	F	Small duct systems are sized based on the floor area of each room served.

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

6. The pressure loss of fittings used in small duct systems is reported in terms of:

☐ A. inches of water column. ☐ B. feet of water column.
☐ C. equivalent number of elbows. ☐ D. equivalent lengths of straight pipe.

7. Small duct systems are normally fabricated using:

☐ A. black or ductile pipe.
☐ B. galvanized steel or fibrous glass.
☐ C. plastic or stainless steel.
☐ D. aluminum or copper.

8. To be effective against condensation as well as heat transfer, exterior duct insulation must be:

- ☐ A. wrapped with a vapor retarder.
- ☐ B. sealed with water resistance pressure tape.
- ☐ C. two or more inches thick.
- ☐ D. heat sealed with a hot iron

9. The number and size of supply outlets is determined primarily by the:

- ☐ A. floor area of the room.
- ☐ B. number of exposures of the room.
- ☐ C. cooling load of the room.
- ☐ D. orientation of windows in the room.

10. In a cooling only application, the preferred located for a return air is placed:

- ☐ A. low on an inside wall.
- ☐ B. high on an inside wall.
- ☐ C. under a window.
- ☐ D. outside the room in a hallway.

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

Key Words

zone control	increase	4,000	balancing	ceiling
dampers	baseboard	extended plenum		40,000
decrease	trunk & branch	tuning		

11. Adjusting the airflow supplied to each room after installation is called ________ the system.

12. The amount of air supplied to each conditioned space can be regulated by adjusting ______________ in the duct system.

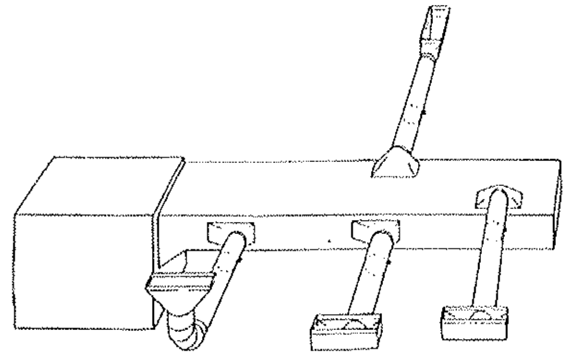
13. Decreasing the air flow (CFM) through the cooling unit tends to _____________ the latent cooling capacity.

14. A rule of thumb for residential applications is that a single supply outlet should never supply more than _________ Btu/hr of cooling capacity.

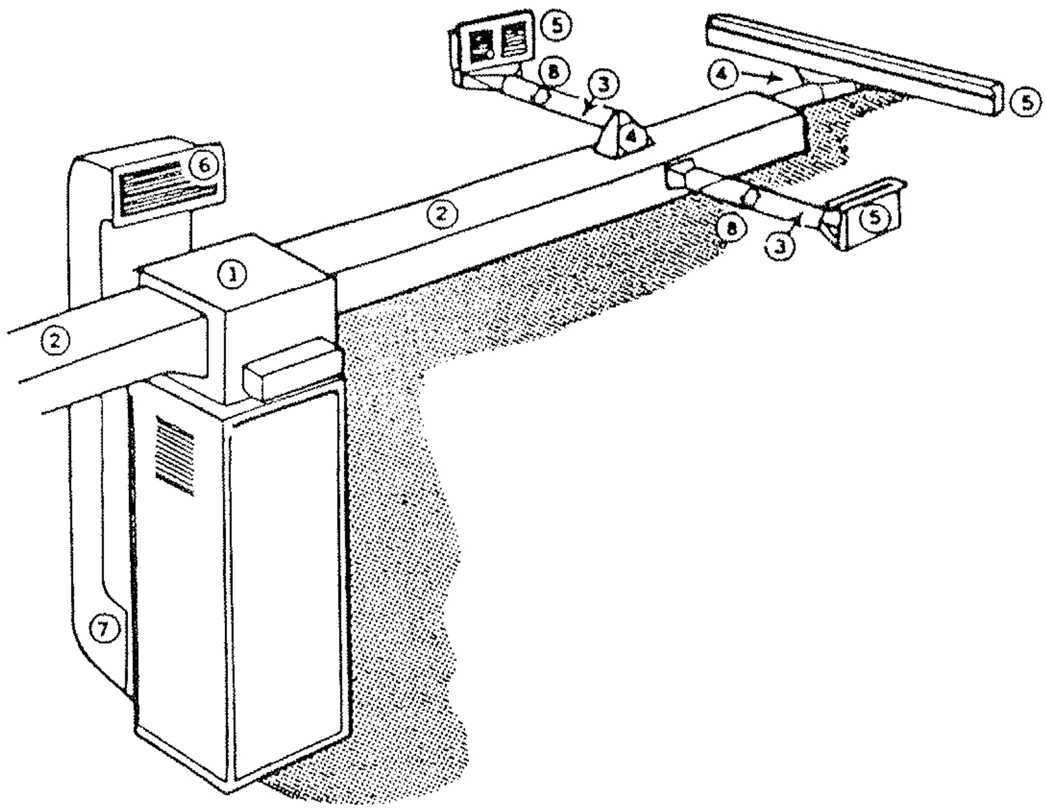
15. In areas of the country where winters are mild but summers are hot, ___________ diffusers are generally installed.

16. Identify the type of duct system illustrated here.

Answer ___________________________



17. Identify the parts of a typical duct system according to the numbers on the illustration below.



1. ______________________ 2. ______________________ 3. ______________________

4. ______________________ 5. ______________________ 6. ______________________

7. ______________________ 8. ______________________ 9. ______________________

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 11 Overview

Up to this point, our focus has been on the most popular type of air conditioning system - DX coil, electric-powered equipment with air-cooled condensing and duct distribution of air.

In this lesson, we will study some of the other types of systems - chilled water, water-cooled condensers, absorption cooling, ground water systems, engine driven and the on-going search to use solar to power air conditioning. We'll also talk about a couple of refinements to standard systems like desuperheater water heaters, economizers, and heat pipes.

Now read Lesson 11 which begins on the next page.

Lesson 11: Other System Choices

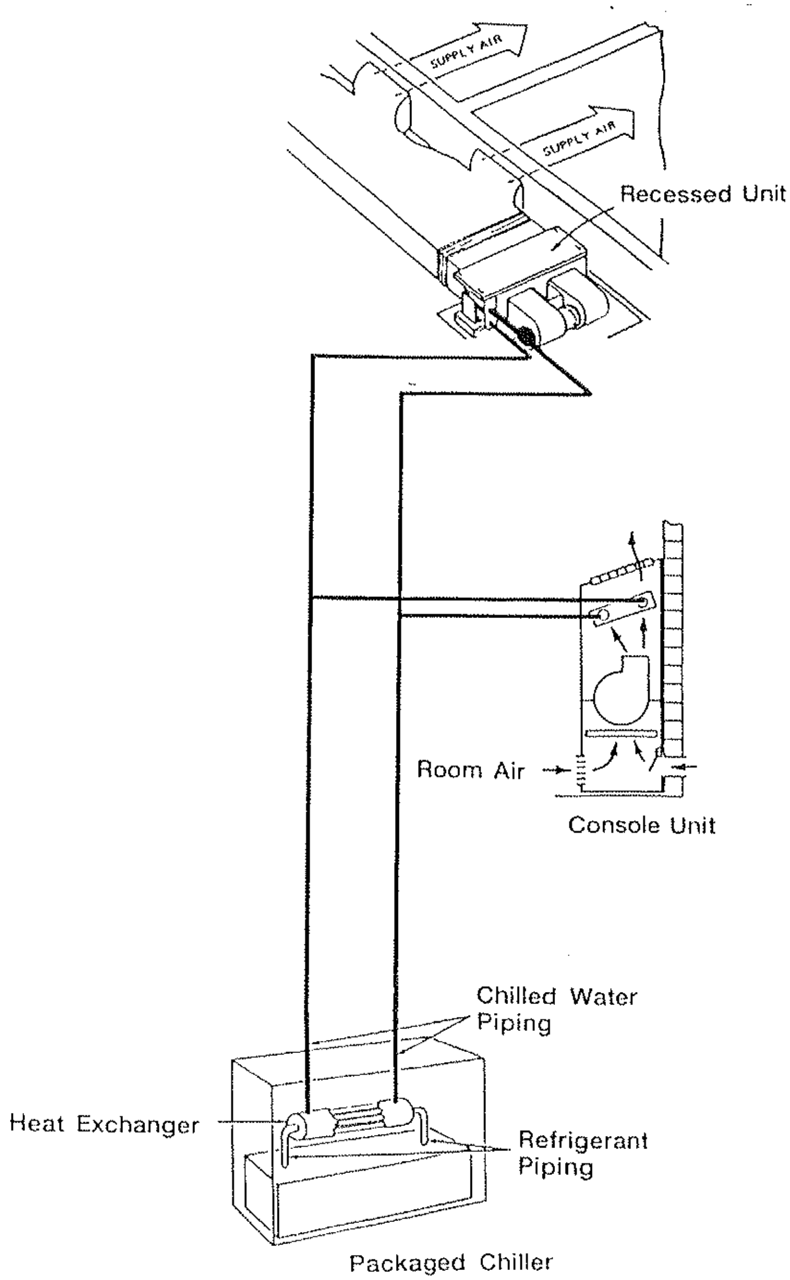
Up to this point, we have focused on ducted central air-cooled unitary equipment. There are, of course, other types of equipment and systems used to condition buildings. Here are a few.

Using Chilled Water

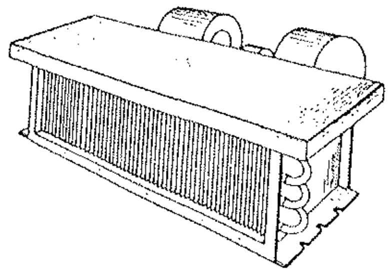
Chilled water systems can be used to air condition buildings. Apartments and hotels are often likely applications. Large custom homes may also be candidates.

Packaged water chillers are available over a considerable range of sizes and types. In sizes less than 25 tons, reciprocating compressors are used almost exclusively. For larger capacities, chillers may employ screw and centrifugal compressors as well as reciprocating compressors.

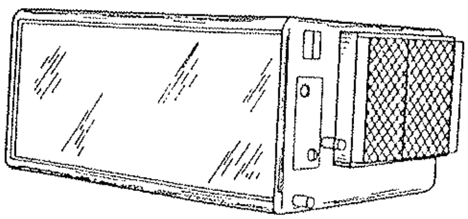
They are called "packaged" chillers because the refrigerating equipment needed to chill the water is combined into one assembly. The chilled water is circulated by means of one or more pumps to vertical or horizontal fan-coil units.



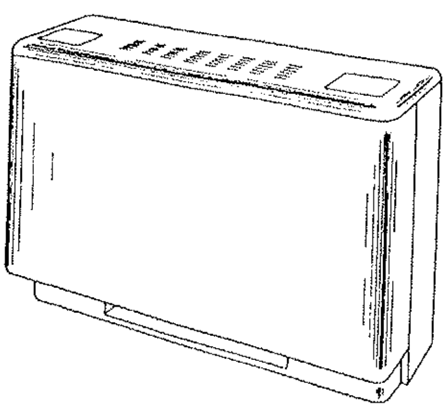
Chilled water system (above) is another approach to comfort cooling. Pump (not shown) circulates chilled water to remote fan-coil units.



Horizontal "recessed" unit



Horizontal cabinet model



Console unit

At left: Three types of fan coil sections.

Each terminal unit is equipped with its own blower and filtering system to circulate room air over the cold pipes and the cooled air back into the room. The same piping system could also be used to circulate hot water for heating.

The advantage of chilled water is the ability to conveniently route small pipes through building construction, provide local temperature control and have the efficiency associated with a single central cooling unit.

Console fan-coil units used in chilled water systems are typically located beneath windows so that they will be effective during winter heating when hot water is circulated.

Horizontal recessed models are often placed in furred-down ceilings.

Vertical air handling units are installed in small closets looking a lot like a heat pump air handler.

Absorption Cooling

Like a conventional vapor-compression system, an absorption refrigeration system depends on the evaporation of a liquid refrigerant to accomplish cooling.

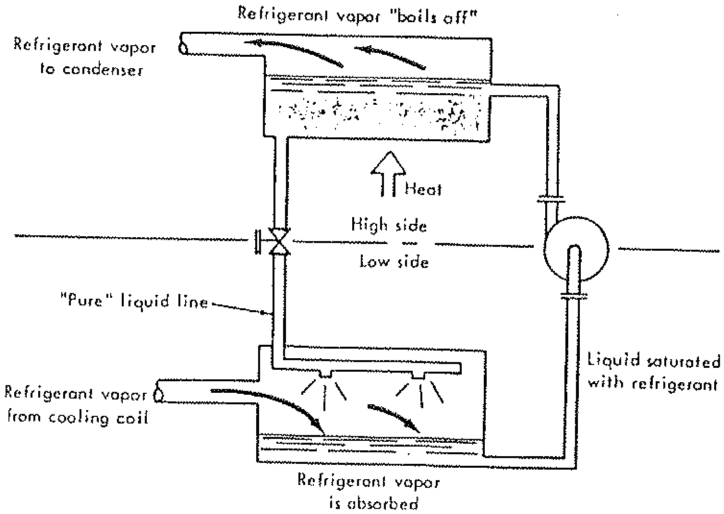
The essential difference between the "mechanical" and "chemical" system lies in the manner in which the evaporated refrigerant is recovered and condensed so that it can be used over and over again. An *absorber-generator* replaces the mechanical compressor.

The absorber can be equated to the intake of the compressor; the generator, to the discharge side. A schematic is shown here.

Refrigerant vapor from the evaporator enters the absorber where the vapor is *dissolved* by a liquid. The refrigerant/liquid solution is then "pumped" to the generator which is at the higher pressure of the condenser. Now the liquid is *heated* in the generator by a gas flame which drives the refrigerant vapor out of solution and the gas enters the condenser to complete the cooling cycle. The liquid, now free of the refrigerant, is returned to the absorber to repeat the process.

Notable note: Steam is often a source of heat energy in large absorption systems. Sometimes waste

heat from industrial processes can be used to provide cooling.



Absorption systems can be designed to cool air directly or to chill water that cools air by means of fan-coil units as just described.

Built-up System

Built-up systems are generally used for large commercial and industrial applications of air conditioning. The same basic components are used but are individually selected by a mechanical engineer. The various components are installed and connected in the field instead of in the factory.

What's An Air Handler?

The general term "air handler" is used to describe a range of products that can differ markedly from each other. Under this broad banner, one can generally list the following sub groups:

1. Central Station Air Handlers - factory assembled versions of traditionally built-up systems for large and medium-sized buildings.

2. Chilled Water/Hot Water Fan-Coil Packages - containing filter, blower and hot and/or chilled water coils. Ductwork can be and is often used.

3. DX Blower-Coil Package - containing filter, blower and direct expansion coil. Ductwork can be and is regularly used. (Required when no furnace available to mount coil and supply fan.)

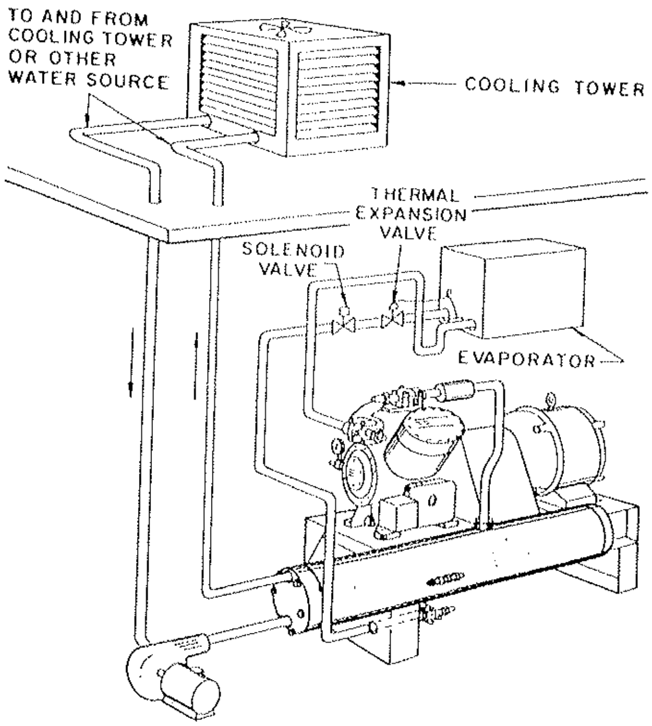
Water-Cooled Condensers

Condensers that use water rather than air offer a number of advantages for certain type installations. The condensers are more compact and the compressor can operate at a lower discharge pressure -- easing the load on the compressor and motor.

On the other hand, maintenance is higher because of water-side fouling, which reduces heat transfer. Fouling, in turn, is caused by sediment, biological growth, and corrosive products. Cleaning by brush and chemical means is required. Water itself may be quite costly to purchase simply to pass through the condenser.

Cooling Tower

Today, water is so expensive and scarce that most cities have laws governing its use in water-cooled condensers. A cooling tower is almost always required, as it *recycles* the water used in a water-cooled condenser. So, rather than running the water through the condenser and discharging it into a sewer, it is used over and over again with only small amounts added for losses.

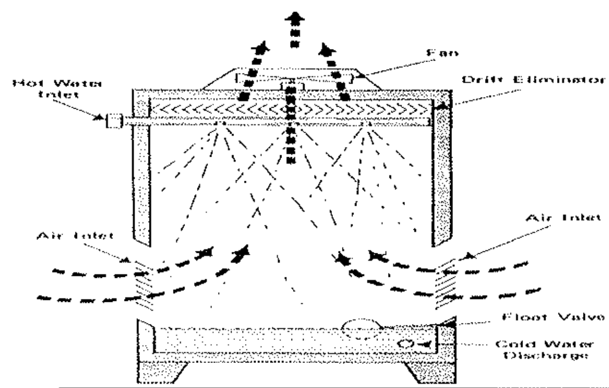


Condenser is cooled by water rather than air. Cooling tower on roof "cools" warmed water for reuse.

The temperature of the cooling water leaving a condenser is increased perhaps by 15° or more. The temperature of this water can be reduced by means of the cooling tower and then recirculated through the condenser to pick up more heat.

A cooling tower can be constructed of metal, wood, or plastic. It is located outdoors. In a *direct* tower, warm cooling water leaving the condenser is pumped into the cooling tower through spray nozzles. Pans force outdoor air through the water sprays. As the air moves through the tower, some of the cooling water *evaporates,* thereby reducing the temperature of remaining water. The cooled water collects at the bottom of the tower and is pumped back to the condenser to once again pick up heat.

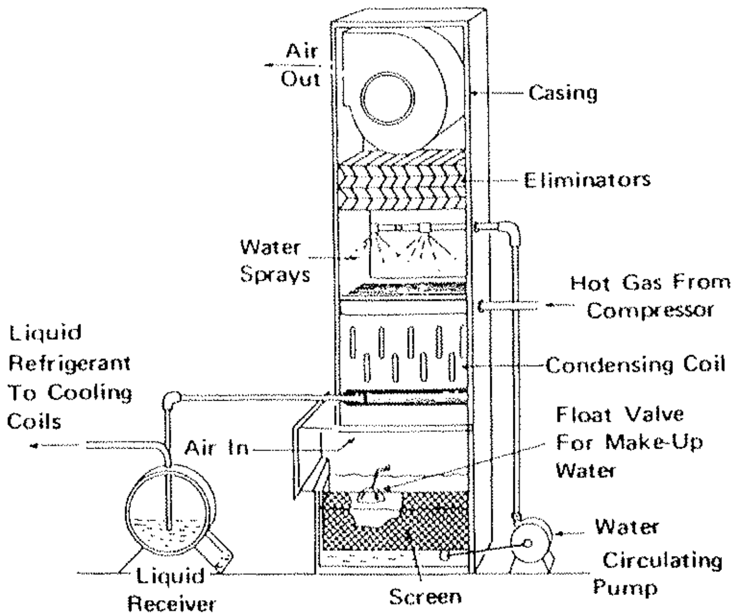
Some towers do not use fans and rely on *natural draft* to move outdoor air through the water spray. Some towers also are *indirect* designs and the condenser water is circulated through tubes rather than sprayed.



Direct type cooling tower cools condenser cooling water by partial evaporation through water-air contact.

Evaporative Condensers

A combination condenser/cooling tower is called an evaporative condenser. The hot gas from the compressor flows through tubing inside the evaporative condenser. Water from spray nozzles flow *down* over the tubing. At the same time, air is forced *up* over refrigerant tubing. Some of the water evaporates, cooling and condensing the refrigerant vapor flowing inside the tubes.

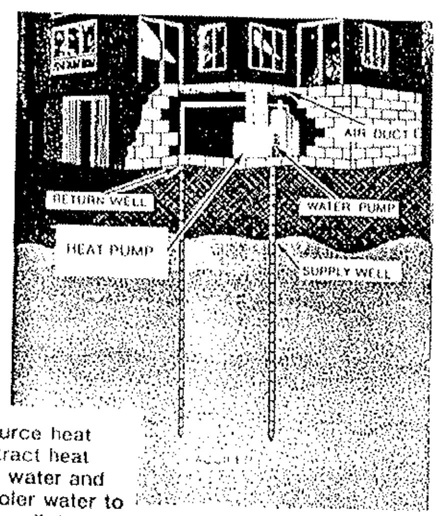


Shown at left: Evaporative condenser uses air and water to condense refrigerant vapor.

An evaporative condenser requires less water and water chemical treatment than a cooling tower with a separate condenser, and operates at lower condensing temperatures than air-cooled condensers.

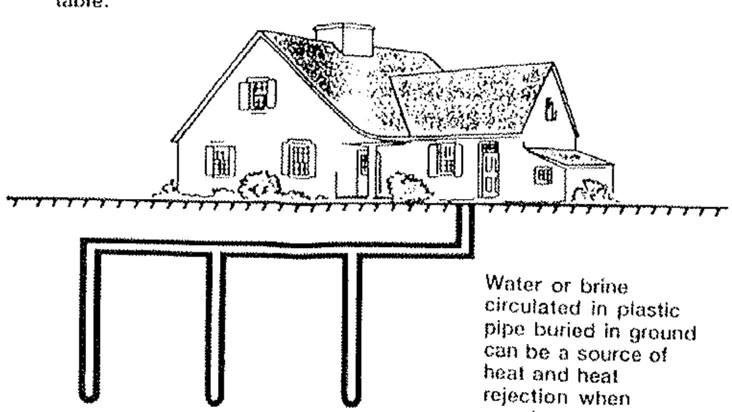
Well Water Systems

A few areas are blessed with a plentiful supply of well water that is sufficiently cold and otherwise satisfactory to use for air conditioning. Such well water can be piped to fan-coil or air-handling units and then returned to the ground through a "dry well" arrangement. The "dry well" is normally required by local building codes. Where well water systems are used extensively, draining the water into the sewer, rather than returning it to the ground, could significantly lower the local water table.



Water source heat pump extract heat from well water and return cooler water to a second well to avoid lowering water table.

By adding a water-source heat pump to a two-well system, both economical heating and cooling can be provided. When direct use of the cool well water can no longer handle the load, the heat pump provides mechanical cooling. In winter, the well water is a source of low temperature heat for the heat pump which then operates in the heating mode. Some savings in operating cost have been demonstrated using the well concept.



Water or brine circulated in plastic pipe buried in ground can be a source of heat and heat rejection when coupled to a water source heat pump.

Using the Ground

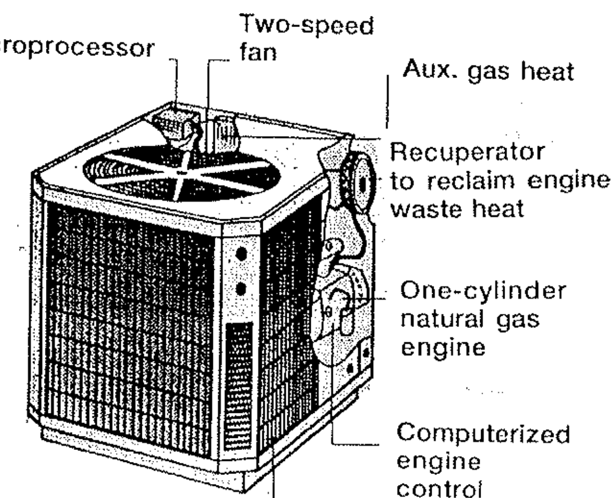
Heat pumps connected to a closed loop of plastic piping buried in the ground have a broader application than direct well water systems. Such systems are referred to as *geothermal* heat pumps or ground loop systems.

The soil several feet below the surface remains at a relatively uniform temperature year-round. Thus, water or brine circulated through the earth coil can provide a source of heat energy in winter and absorb heat from the condenser during cooling when connected to a heat pump.

Buried loops can be installed horizontally or vertically. Loops can also be placed at the bottom of a man-made water pond or lake.

Engine Driven Cooling

Another method of providing air conditioning is to use a natural gas internal combustion engine to drive a refrigerant compressor. The balance of the cooling circuit is essentially the same as would be employed with an electrically-driven compressor.

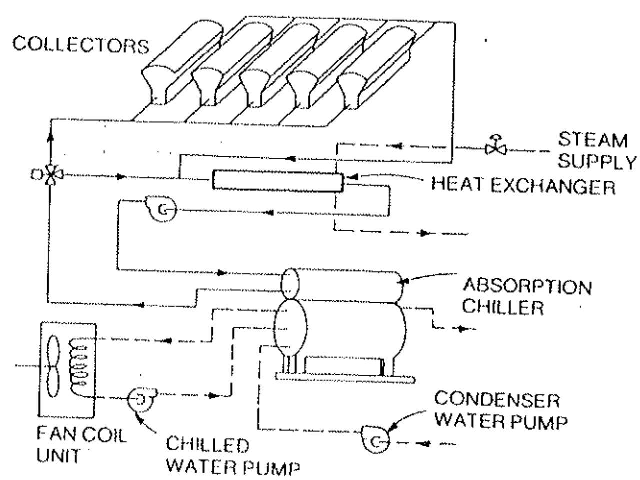


Natural gas engine driven heating-cooling unit for residential applications.

Various types of large gas-engine air conditioning systems have been employed successfully for many years in commercial applications. Their use in residential air conditioning has expanded with a current design built around a microprocessor-controlled, one-cylinder natural gas engine.

Solar Cooling

It is also possible to use solar heat to produce cooling. One tested technique is to use solar-heated water to power an absorption air conditioning unit. Water between 190° and 210° F is required. Auxiliary steam is available to boost the water temperature on overcast days.



Experimental solar powered absorption cooling system once considered for small commercial applications.

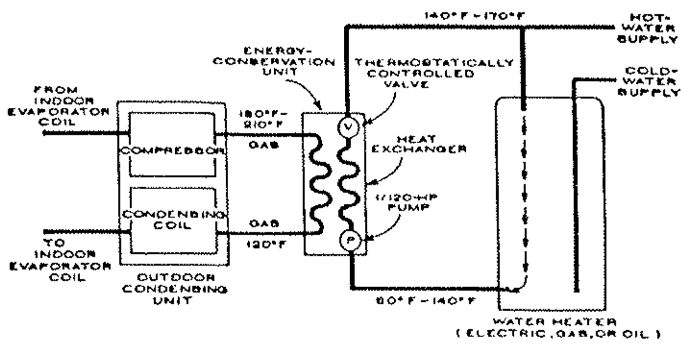
Another, more exotic system is to use refrigerant gas as substitute "steam" to drive a turbine driven compressor. The refrigerant is vaporized by heat from the solar collector, expanded through the turbine;

condensed, and recycled. The compressor, in turn, is connected to a conventional cooling or heat pump circuit.

With perhaps the exception of solar-heated domestic water heaters, the future for solar energy appears to be in producing electricity through photo-voltaic cells rather than elaborate "mechanical" arrangements to use the sun as a low temperature source of heat energy.

Energy Saving Components

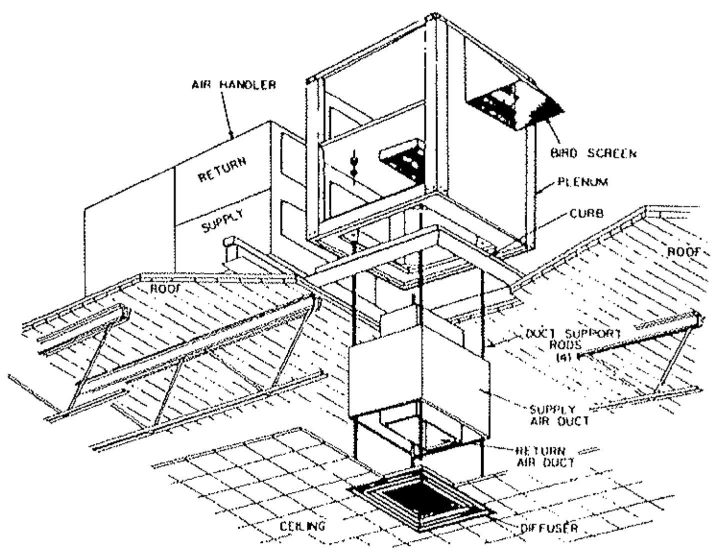
There are a number of accessory components that have demonstrated energy conserving capabilities in many installations.



Schematic of a Desuperheater Water Heater

For example, a number of leading manufacturers now offer "desuperheater/water heaters" to add to an air conditioning unit. ARI Standard 470 provides testing and rating procedures for these devices.

A desuperheater/water heater takes some of the heat normally rejected (and wasted) by an air conditioning condensing unit and uses it to heat domestic water.



Economizer plenum added to a rooftop airconditioning unit to provide "free" cooling.

Here's how it works: A refrigerant-to-water heat exchanger is placed ahead of the condenser. As the hot refrigerant gas leaves the compressor, it first passes through the heat exchanger and gives up some heat to the cold water circulating from the bottom of the domestic water heater. The somewhat cooler refrigerant gas then continues on to the condenser to reject its remaining heat and becomes liquid refrigerant again. Meanwhile, the heated water is returned to the top of the water heater.

It appears that a typical unit can provide about 10 gallons of hot water per hour per ton of cooling capacity. In addition to saving on the cost of heating water, a second benefit is a slight reduction in the cost of operating the air conditioning unit as well.

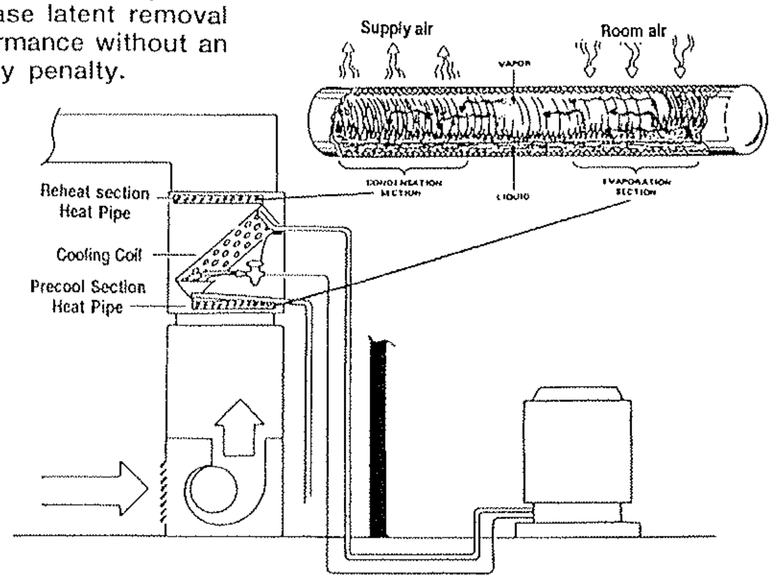
Another accessory that can help conserve energy is the addition of an economizer unit. This introduces cool outside air for comfort conditioning when both outdoor temperature and humidity conditions are low enough to be an effective source of cooling.

Once popular just for relatively large commercial systems, economizers are now available and used for smaller size installations.

The Heat Pipe

A mini-refrigeration circuit can be recreated in a copper tube. One end acts as the evaporator, the other the condenser. A vacuum is pulled on the pipe and a common refrigerant is charged into the tube. The refrigerant can be boiled on one end, flow to the other end and condense, and be carried back to the opposite end (either by gravity or a wicking material) to be boiled again. In the process, lots of heat is transferred from one end of the pipe to the other.

Heat pipe added to a residential cooling coil can increase latent removal performance without an energy penalty.



Called a heat pipe, several rows of heat pipes can be used to form an air to air heat (recovery) exchanger.

One use in small system air conditioning is to increase the latent removal performance of cooling units without the energy cost associated with reheat systems. One end of the heat pipe becomes a pre-cooling section in front of the cooling coil, and the other end becomes a reheat section for supply air leaving the coil.

Hot humid air might enter the cooling unit at 79°, pass through the heat pipe, and be reduced in temperature to 69°. Next, the now cooler but still humid air passes through the cooling coil to be dehumidified.

The air leaves the cooling coil at about 49°, passes through the reheat section of the heat pipe and is warmed to 59° as it enters the air distribution system. Reheating is, of course, used to avoid circulating excessively cold supply air.

Self-Check, Lesson 11 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 Apartments and hotels are suitable prospects for air conditioning using chilled water systems.

2. T F Chilled water systems do not allow for local temperature control.

3. T F In absorption cooling, heat is used to dissolve refrigerant vapor into a liquid solution.

4. T F Compressors coupled to water cooled condensers operate at higher discharge pressures compared to air cooled condensers.

5. T F A dry well is part of a well water cooling system to avoid lowering the local water table.

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

6. A vertical air handler used in chilled water systems is a good candidate to be installed:

☐ A. in a small closet. ☐ B. beneath a window in a room.
☐ C. in a furred-down ceiling. ☐ D. in a crawl space.

7. Water cooled condenser maintenance cost can be high because of the cost of water and:

☐ A. equipment first cost. ☐ B. cleaning cost to reduce fouling.
☐ C. pump power cost. ☐ D. installation cost.

8. A cooling tower is included in an air conditioning system to conserve on:

☐ A. refrigerant in the condenser. ☐ B. cooling water for condenser.
☐ C. electrical energy consumption. ☐ D. the size of equipment required.

9. Equipment that *combines* the *condenser and* cooling tower into *one unit* is called:

☐ A. an air/water condenser.
☐ B. an indirect cooling tower.
☐ C. a dry cooling tower.
☐ D. an evaporative condenser.

10. A cooling tower that does not rely on fans to move *outdoor air* through the water spray is called:

☐ A. a forced draft cooling tower.
☐ B. an indirect cooling tower.
☐ C. a natural draft cooling tower.
☐ D. a direct cooling tower.

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

Key Words

zone control	geometric	desuperheater	heat pipe	electricity
economizer	efficient	baseboard	manually	geothermal
microprocessor	heat pump			

11. One modern engine driven cooling unit is based on a/an ____________ ______________ controlled one-cylinder natural gas engine.

12. A/an ________________________ water heater can provide about 10 gallons of "free" hot water from heat rejected by a condensing unit.

13. A/an _____________________ unit uses outside air to provide a building with "free" cooling under the right temperature and humidity conditions.

14. A/an _________________ can be added to a cooling coil to increase latent heat removed by the equipment.

15. The best application of solar energy for cooling appears to be in the direct conversion of _____________________ to power equipment.

16. Extracting heat from the earth through a series of buried coils is termed a/an ____________ heat pump system.

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 12 Overview

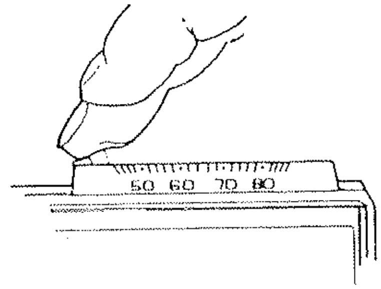
As you will quickly learn in Lesson 12, control arrangements are endless. Each manufacturer devises its own control strategy, and while many control "parts" are the same on small systems, they may be configured differently.

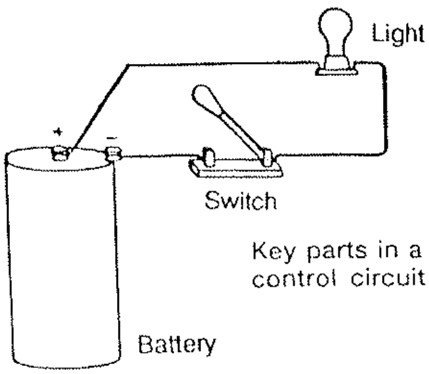
In this lesson, we will simply introduce the key parts of a control circuit; examine operating controls and safety devices, consider solid state devices, and examine how control "diagrams" might be presented for clarity, including terminal alpha designation by function.

Now read Lesson 12 which begins on the next page.

Lesson 12: Keeping It All Under Control

It all starts with the thermostat. A central air conditioning system is "controlled" -- that is, turned on and off by a device that detects a change in room air *temperature*. When the air temperature goes up, the thermostat switches the air conditioning unit on. When the temperature goes down, the thermostat switches the equipment off. The difference in temperature *on* and temperature *off* is called the *operating differential* of the thermostat.





Key parts in a control circuit

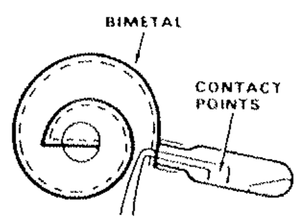
Automatic controls in air conditioning are simply interconnected switches that either turn on and off (or restrict) -- the flow of electricity, gas, refrigerant, water, etc. Changes to temperature, pressure, electric current, or some other measurable quantity may be used to trigger the switch which opens a valve, closes a damper, or activates a relay.

A basic control circuit contains a *power source, a switch* and *a load* connected by wires. An *automatic* control circuit would feature a switch that responds "automatically" to a measurable change. In the case of a light switch, we might detect motion or the onset of darkness to regulate building lighting.

In our review, let's first look at operating controls, then associated safety devices.

Operating Controls

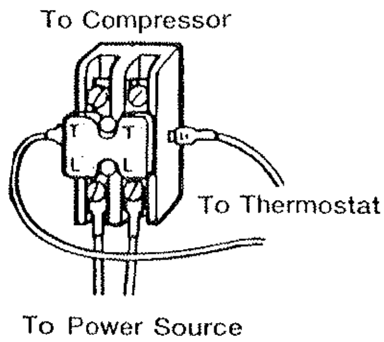
A room thermostat contains a sensor that reacts to changes in room air temperature. The sensor may be a bimetal element that changes shape with changes in air temperature, or an electronic element that changes electrical *characteristics* with changes in air temperature. The sensor opens or closes an electrical switch -- just as you would manually open or close a wall switch to turn a light on or off.
In this case, however, we are switching the compressor on and off in the air conditioning unit.



Thermostat switch

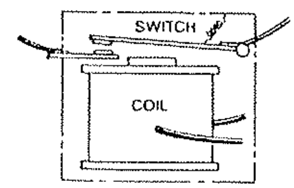
Starting and stopping the compressor obviously regulates the cooling output of the equipment.

Notable note: Single phase hermetic compressors also require electrical capacitors to assist in getting the motor turning. This could be a permanent split capacitor or separate start and run capacitors, depending on the type and size of motor used.



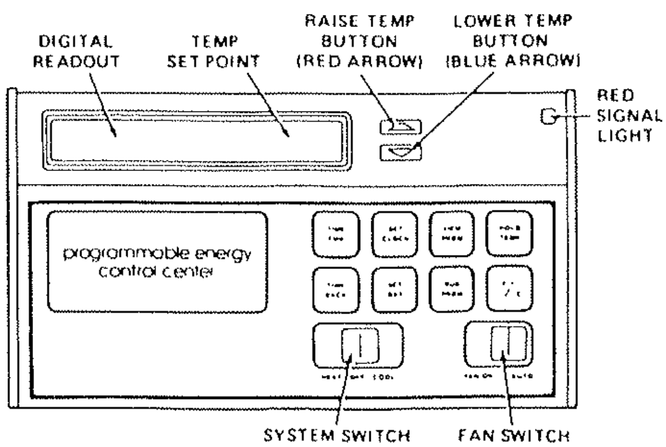
To start and stop the compressor, the thermostat switch controls the flow of *low voltage* electricity to another switch called a *contactor.* The contactor consists of a *magnetic coil* that is energized by the thermostat and pulls electrical contacts together to complete a *higher* voltage electrical circuit to the compressor's motor. Most often, we have 24 volt thermostats turning on and off 240 volt power to the compressor motor.

The condenser fan motor in the case of air-cooled equipment would also be started and stopped along with the compressor.



Besides starting and stopping the compressor and condenser fan, it may also be necessary to start and stop the circulating air supply. This means turning the power on and off to the blower motor. The thermostat does this through another switch called a fan *relay.* Essentially, a relay is merely a light duty contactor. It cannot carry the same level of electrical current as a contactor.

Most thermostats provide an option to cycle the blower motor with the compressor or leave the blower running. In this case, we use a *manual* switch that the occupant can turn to operate the blower continuously (on) or cycle on/off (auto) with the compressor.



Besides these basic operating switches, we have safety devices to protect equipment and occupants which are *independent* of the room thermostat demands.

Notable note: In a water-cooled system, the condenser cooling water pump would be started and stopped in addition to any cooling tower fans as the compressor was cycled on and off.

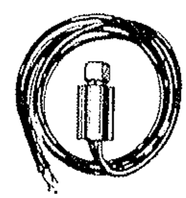
Compressor Motor Safety

The motor driving the hermetic compressor of an air conditioner is protected by an *internal overload* device that breaks the electrical circuit to the motor if the motor *windings* get hot. This condition can occur if the motor becomes stalled or "locked," or if voltage supply to the motor drops too low.

This protection is intended to prevent *burning out* the motor windings, even as a room thermostat might be trying to turn the compressor on. If, for some reason, the protection is not built right into the motor windings, the same protection can be added external to the hermetic unit.

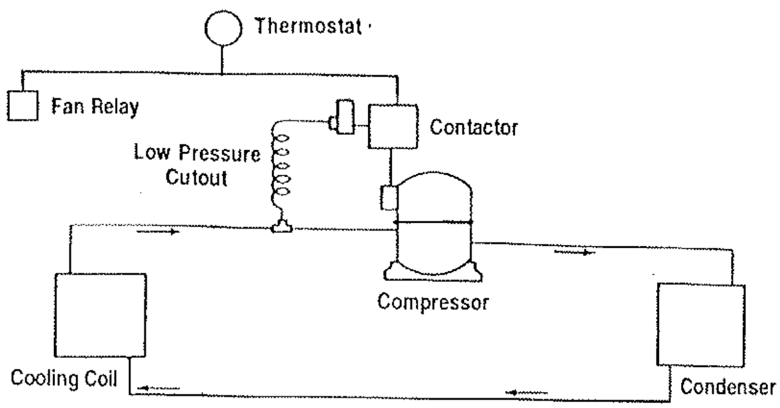
Pressure Safety

Safety switches sensitive to refrigerant *pressure* are employed on refrigeration systems, including air conditioners, to shut down the equipment when unusual pressures are detected, prompted by the loss of refrigerant charge, the condenser coil becoming dirty, or the condenser fan failing.



One type of pressure cutout

A high-pressure *cut-out* switch turns off the compressor motor when the pressure on the discharge side of the compressor (and condenser) exceeds a pre-set point.



Low pressure cut-out switches shut off the system when the pressure on the suction side (evaporator and suction line) drops below a certain pressure point. Low pressure cut-outs are always used with water chillers to prevent freezing the water and consequent damage to the chiller.

A pictorial representation of the operating and safety controls in a small air conditioning unit. Can you find the pressure safety device just discussed?

The pressure switch or remote tubing is physically brazed or mechanically connected to the refrigerant piping and electric wires from the switches are connected in the control wiring to interrupt the power source and stop the compressor.

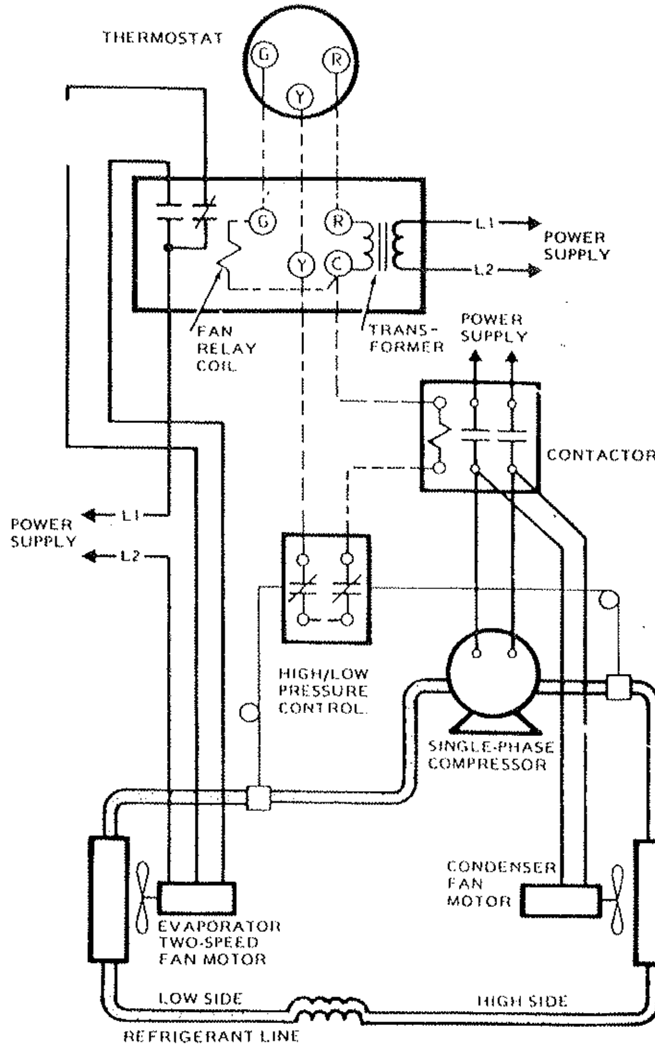
Not all residential air conditioning units include high or low pressure cut-out switches. The compressor motor overload is used as the first line of defense against unusual pressures in the refrigerant circuit.

Control Arrangement

Let's examine how these basic devices would be arranged in a typical air cooled air conditioning unit.

This first figure shows in abbreviated or block fashion, the basic items needed in a small air conditioning control system. Illustrated are the thermostat, fan relay, contactor, and for our purposes, a low pressure cut-out.

The next diagram illustrates the wiring requirements for our basic control system. Note that a new component has been added -- a transformer.



A *transformer* converts high voltage, say 120 volts, to low voltage electricity to power the room thermostat.

While it is possible to make and use a thermostat that operates on regular line voltage, such devices are generally less sensitive because they must be constructed of heavier materials to carry the higher voltage and current.

Thus, most ordinary thermostats require 24 volt electricity and a transformer is required in most control circuits.

Note: In this case, the high-low pressure safety devices are arranged to interrupt the low voltage circuit to the contactor. If either safety switch is open, no low voltage power will be supplied to the contactor coil even if the thermostat switch is closed and calling for cooling.

Changing from heating to cooling and vice versa, can be accomplished manually or automatically. Manually shifting a lever at the thermostat can change the system from the heating unit to the cooling unit. Also, depending on control sophistication, it may change the speed of the blower and change seasonal damper settings.

Notable note: switches in a wiring diagram are illustrated like this when they are normally closed and like this when they are normally open. Normally means in the non-powered or de-energized condition.

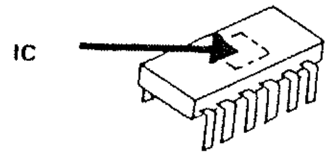
Some installations feature automatic changeover thermostats so that the system can either heat or cool, depending on the indoor temperature. The occupant of the house does not have to manually change any switches for this to happen. Such a control arrangement is particularly convenient during spring and fall days when heating may be needed during the morning or evening and cooling may be necessary during mid-day and afternoon.

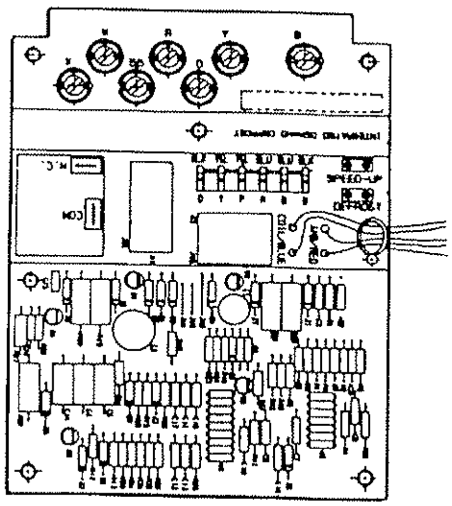
The industry has introduced a large number of solid state components to replace certain electromechanical controls. These devices can do many of the same functions as older controls, but solid state devices can also accomplish control functions that were previously impractical. For example, consider the programmable thermostat.

In addition to automatic changeover, the electronic thermostat allows the user to "program" desired indoor conditions for a week, including different arrangements for weekends.

Four separate time-of-day temperature settings are possible. This could result in considerable energy savings, with no loss of comfort during occupied times for working families and small businesses.

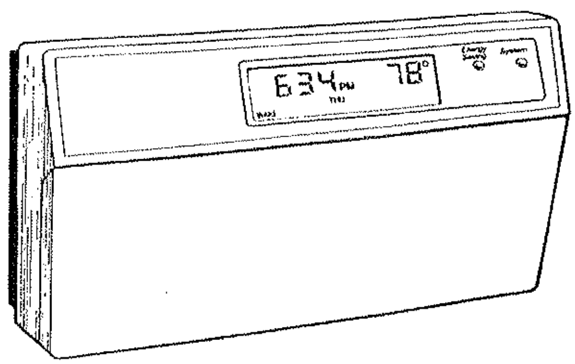
The term "solid state" is in comparison to the glass encased vacuum tubes used in early radios and TV sets. *Semiconductor* is perhaps the more appropriate electrical classification -- components based on materials that are neither good conductors of electricity nor good insulators. These devices can control electric current without any moving parts; they are small in size and light in weight. The transistor made from silicon is a typical solid state device.





Central Circuit Board

When thousands of transistors and other semi-conductors are simultaneously formed on a small 1/4 inch square "chip" of material, the result is an integrated circuit (IC). A microprocessor is a special IC that can process information — a kind of circuit boss — given instructions to do specific tasks.

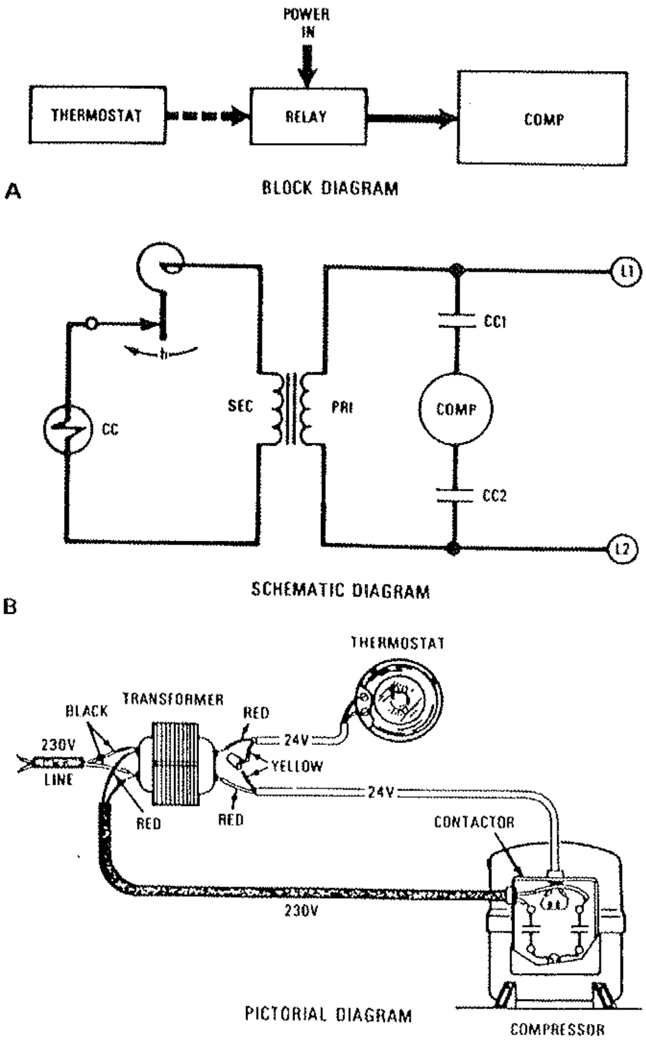


An electronic thermostat can provide more precise room temperature control than most previous electro-mechanical thermostats. In addition, the solid state thermostat can offer programmable features that save energy.

Manufacturers have gathered many of these solid state devices and ICs and provided a central control board for equipment.

Control Circuit Graphics

Control circuits may be illustrated using several methods — a block diagram, a schematic diagram, or a connection diagram.



The block diagram (A) is purposely simple, showing essential concepts and sequences only. Block diagrams are often used as an introductory step to explaining complex control systems where the technician might immediately become bogged down with a myriad of details before understanding basic organizational concepts and priorities.
The schematic diagram (B) shows every wiring detail and component using a code — a kind of circuit shorthand. It may also be referred to as an elementary or ladder diagram. This type of diagram is usually affixed to the equipment and also published in installation instructions.

Reading and understanding control wiring diagrams requires a great deal of training and on-the-job experience. First of all, the code – the graphic symbols used by the manufacturer – must be learned.

The Air Conditioning, Heating & Refrigeration Institute's Standard 130 lists preferred symbols to represent the functions of commonly used electrical parts and controls. This is a voluntary standard -- thus not all manufacturers prepared diagrams may conform exactly.

The connection diagram (pictorial diagram) often used along with the ladder diagram, attempts to show the control circuit as it really is and may be used in training materials as well as printed instruction manuals. It is also called the physical or pictorial diagram by some.

There is also notation by the manufacturer to *field* and *factory* wiring on most wiring diagrams. As the names imply, field wiring and connections must be made on-site by the installer. Factory wiring is completed by the manufacturer and comes with the equipment.

The industry has generally agreed on terminal designation based on a *color code* for small system wiring. Most widespread: **W** terminals (and white wire) involve a heating function. **Y** (yellow wire) involves a cooling function. **G** (green wire) relates to the fan function. **R** (red wire) means power from the transformer. **RH** and **RC** relate transformer power for heating and cooling circuits respectively.

Example: thermostat demand for cooling would mean a connection through terminal **R** to terminal **Y** to switch on the compressor, and from **R** to **G** to turn on blower fan.

An older notation based on *function* may still occasionally be encountered on old installations — **F** for fan, **C** for cooling, **H** for heating, etc. Even a combination terminal identification may be uncovered from time to time — **C/Y** for cooling, for example.

Other common notations include L for incoming line or the power source side and the T for the terminal or switched side to connect the load. These notations would be found on diagrams and terminals posts on devices such as a contactor.

Configurations Endless

Almost any control strategy is possible. Manufacturers of controls can furnish multi-purpose devices that can be configured in any number of ways to achieve a designer's and user's objectives.

Zone control is perhaps a readily recognized example of added sophistication. In this case, two or more thermostats control dampers in the duct system, as well as starting and stopping the compressor in response to air temperature swings in different areas of a house -- on the second floor, lower level, bedrooms, or east and west wings of a large house.

A humidistat could also be used to have cooling equipment respond to humidity levels as well as temperature levels in the home.

What we covered here are just the very basics. More focused study of controls is encouraged.

Self-Check, Lesson 12 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	Central air conditioning systems are turned on and off by a wall-mounted thermostat sensing room surface temperature.
2. T	F	To regulate cooling output, the thermostat starts and stops the flow of refrigerant by closing the expansion valve.
3. T	F	Power is supplied to a compressor motor through a contactor that switches high voltage electricity on or off.
4. T	F	An electric relay is a heavy duty contactor that can carry heavier electrical loads.
5. T	F	Safety devices function independently of thermostat demand.

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

6. The safety device directly involved with protecting compressor motor windings from overheating is the:

☐ A. room thermostat.
☐ B. contactor coil.
☐ C. internal thermostat.
☐ D. low pressure switch.

7. Most thermostats used to control central residential equipment operate on:

☐ A. 18 volts.
☐ B. 24 volts.
☐ C. 36 volts.
☐ D. 48 volts.

8. Transistors and other semi-conductors etched on a small quarter-inch "chip" form what is called:

☐ A. an integrated circuit.
☐ B. a central control panel.
☐ C. a programmable thermostat.
☐ D. a solid state transformer.

9. The type of wiring diagram most often affixed to the access panel of a cooling unit is a:

☐ A. block diagram.
☐ B. schematic or elementary diagram.
☐ C. pictorial diagram.
☐ D. connection diagram.

10. A common upgrade to a single control system today is:

☐ A. an outdoor reset control.
☐ B. a high pressure cut-out control.
☐ C. a zone control arrangement.
☐ D. two speed fan control.

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

Key Words

save energy	batteries	fan	factory
heating	cooling	bimetal	microprocessor
switch	field	manually	save time

11. The basic control circuit contains a power source, ________________________ and a load connected by wires.

12. A thermostat may use a sensor composed of a/an _________________ or electronic element.

13. Programmable thermostats can be set for a day or longer to _________ ________________.

14. Connections done at the time of installation is termed _______________________ wiring.

15. The wiring color code used: today would mean that a Y terminal or yellow wires involve a______________________ function.

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 13 Overview

No matter your present job or interest in the A/C industry, a basic understanding of the service procedures is very helpful. It is every bit as important as how equipment works and all the other things you have studied so far.

In Lesson 13, we start out by stating how important it is to tell people how to use the A/C system. Then we talk about three types of service - start-up, periodic maintenance, and troubleshooting. The last is what most of us think of when we say service - fixing something that's broken. We cover service troubleshooting methodology as well as what owner/users can do on their own. Lastly, we return to the ban on CFC venting.

Now read Lesson 13 which begins on the next page.

Lesson 13: User Friendly

Today, when we hear the expression "User Friendly", many of us think first about software that makes using a computer easy. But the phrase really applies to almost any technical product — for example, the controls on your car's dash are said to be user-friendly. So too, with the operation and maintenance of air conditioning systems. You must help make comfort cooling user-friendly to the person who knows little or nothing about air conditioning.

When someone sells, installs, or repairs a central air conditioning system, he or she should take the time to familiarize the user with details on the operating characteristics of the equipment. The following are a few suggestions on what to tell and do for the owner/user.

Provide Start-up and Check-out

After the system has been installed, a qualified person who is familiar with the operation of the system should place the equipment under all modes of operation to insure that it is functioning correctly. The owner should be shown the location of the disconnect switch and the thermostat, be instructed in how to start, operate and stop the units, and adjust room air temperature settings. The manufacturer's installation and operating instructions should then be delivered to the owner and reviewed with them.

Explain How to Get Best Performance

The owner should be told that, unlike a heating system, excess capacity is not usually provided in residential and small commercial cooling systems, in order to keep equipment size — and initial cost — at a minimum.

Accurate sizing also insures more frequent operation and cycle rates to help maintain better humidity control at partial load conditions. Consequently, with little or no reserve capacity, owner operating habits can influence the cooling system performance considerably.

Starting and stopping times are critical. Walls, roofs, and furnishings store heat from early morning solar heat gains and release this heat at a later hour — possibly when outdoor temperatures are the highest. This storage effect, coupled with the close sizing of a system's cooling capacity to the calculated cooling load, dictates that the air conditioner must be in operation *prior* to the time of the peak load in order to keep pace.

Most experts recommend 24-hour operation because that's what the estimated load is based on; nonetheless, many owners prefer to shut off the equipment in late evening hours to avail themselves of any cool night air. Under these conditions, however, the cooling equipment must be started very *early* the next day, even before outdoor temperatures become uncomfortable, in anticipation of the peak heat gain to occur in the later hours of the day.

Some general operating recommendations to offer are:

- keep all doors and windows closed
- keep curtains, drapes or awnings drawn on sunlit windows
- keep storm windows up, since they can reduce conduction heat gain if left in place (may

reduce infiltration as well)

Set thermostat to desired room temperature and do not make frequent changes to it. Start unit early in the day (if not on 24-hour operation); otherwise, do not expect immediate comfort conditions. Some compressor units have need for electric power for a crankcase heater even during off periods, so use an on-off switch for desired operation rather than a main power disconnect switch.

Types of Service

Complaints are valuable to every air conditioning industry employee, whether or not you are directly involved with customer service.

There are three kinds of services performed on a cooling system. *First* is the installation start-up, during which the system becomes operational and is tuned for optimum efficiency (see Lesson 10).

The *second* phase of servicing involves *periodic maintenance* of the system throughout the lifetime of equipment.

And, *third,* troubleshooting or emergency service.

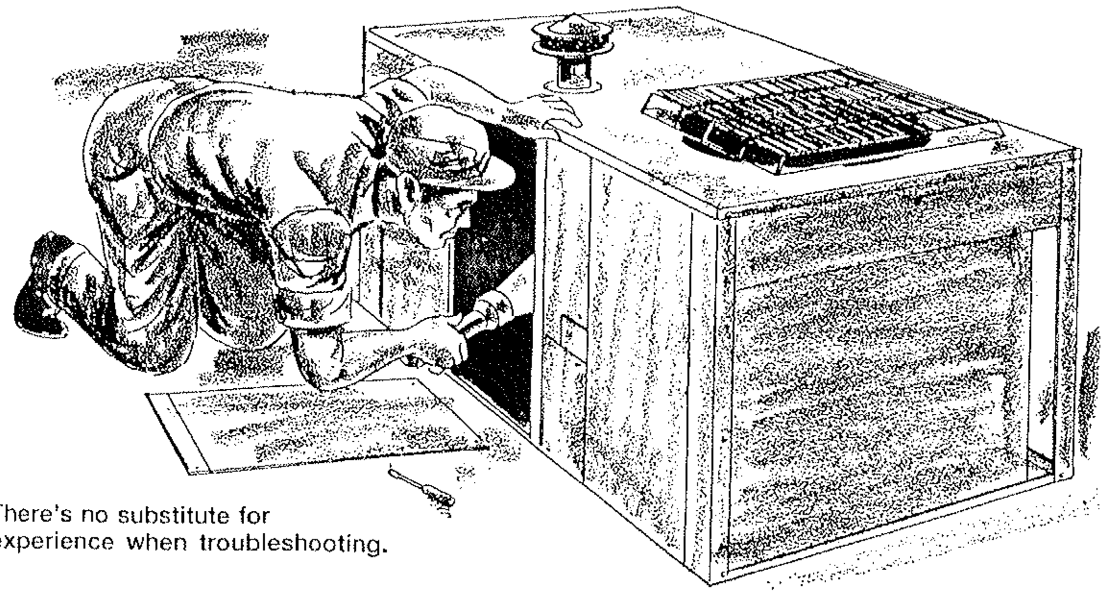
All servicing must be done *safely.* When working around cooling systems, care must be taken to guard against burns and electrical shock.

Preventative Maintenance

The quality of service can make the difference between success and failure in the air conditioning business. The customer expects not only a good installation, but also prompt and efficient service in the event of trouble. Many successful contractors sell their customer on the practical aspects of preventative maintenance. This means an annual inspection of the cooling equipment, made during the spring to insure that the system is in good working order at the start of the cooling season. This will reduce the probability of an emergency service call in the middle of the summer.

Troubleshooting

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



There's no substitute for experience when troubleshooting.

Unless an individual is an extremely experienced service person, the basic approach to troubleshooting has simply got to be by means of a *process of elimination*. Four basic steps are recommended:

1. The complaint is noted.
2. The symptoms are determined.
3. The cause for each symptom is checked.
4. The trouble is remedied.

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

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

- part failure,
- improper adjustment
- poor installation
- poor design

Part Failure

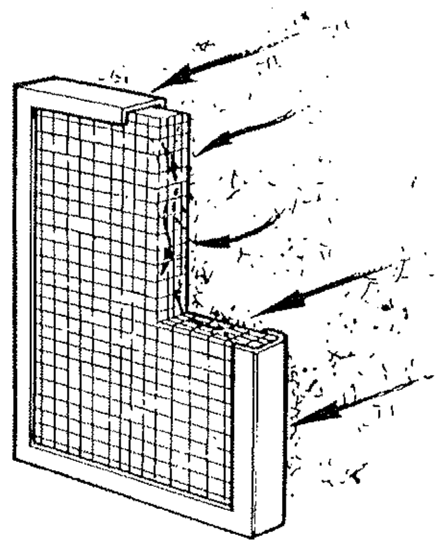
A part failure is, perhaps, the easiest malfunction to correct since, once detected, a simple replacement puts the system back into satisfactory operation. Many part failures are quite obvious; for example, a broken belt, a worn-out bearing, or an open circuit breaker. Some, however, require considerable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

Parts fail for several reasons, all of which can be summarized as follows:

1. defective in manufacture
2. subjected to conditions beyond their rated capacity
3. not properly maintained
4. worn out from usage

Adjustments

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



Dirty filters are a common cause of reduce performance.

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

1. cooling capacity seems to be decreasing
2. cooling is uneven and drafty
3. operating cost is rising
4. noise level is rising

Dirt is the enemy of any type of equipment. Cooling capacity can be significantly reduced due to dirt accumulation on the air filter. Every 5 percent reduction in air flow rate results in a capacity reduction of about 4 percent. Dirt which is allowed to accumulate on the blades of the fan, dampers which restrict air flow unnecessarily, and rugs or furniture placed so that air cannot move freely through a supply outlet or return grille will all have the same effect upon capacity as the dirty filter.

The Notable Note starting on this page lists some common cooling complaints expressed in the terms most often used by the owner or occupants themselves and possible sources of the problem.

As might be anticipated, the vast majority of owner/occupants have little knowledge of their cooling system and how it works. The skilled service person must translate the non-technical person's vague explanation of the problem into more concrete terms by asking the right questions — what exactly do you mean not cool enough, the system is noisy, etc. Can you show me?

Our list of service complaints includes the seven most likely to be encountered by the technician.

Specific makes and models of air conditioners can vary widely with respect to such details as controls, motor protection, motor starting, etc. Therefore, the manufacturer's suggestions on service for specific models should be followed closely.

Notable Note: "Cooling Complaints & Possible Causes"

1. NOT COOLING!

A. Compressor Will Not Operate.

1. Thermostat setting too high.
2. Thermostat defective.
3. Fuse blown.
4. Loss of refrigerant charge.
5. Defective pressure switch.
6. Head pressure too high.
7. Compressor is stuck.
8. Power failure.
9. Low voltage.
10. Defective starter or capacitor.
11. Faulty wiring.

B. Blower Will Not Operate.

1. Drive belt broken.
2. Motor defective.
3. Faulty wiring.
4. Defective relay.

2. NOT COOL ENOUGH!

1. Thermostat setting too high.
2. Blower belt slipping.
3. Blower running backwards.
4. Blower motor cycling on overload.
5. Air filters dirty or plugged.
6. Compressor short-cycles.
7. Cooling coil plugged with frost.
8. House opened during cool evening hours. (Humid outside air increases latent load.)
9. Owner won't operate system long enough.
10. System short of capacity due to:
    a. Low refrigerant charge.
    b. Overcharge of refrigerant.
    c. Air or non-condensable gases in system.
    d. Dirty condenser.
    e. Belts slipping on condenser fan.

f. Compressor valves leaking.
g. Condenser air short-circuiting.
h. Expansion valve or strainer plugged.

3. TOO COLD!

1. Thermostat setting too low.
2. Defective thermostat.
3. Blower speed too low.
4. Oversized air conditioner.

4. SOME ROOMS WARMER THAN OTHERS!

1. Distribution system improperly balanced.
2. Volume dampers not at correct setting.
3. Extra supply duct for cooling not open.
4. Some windows open.
5. Inadequate branch duct.
6. Incorrect air distribution within room.
7. Occupancy of room greater than originally planned.

5. HUMIDITY IS TOO HIGH!

1. Latent load factor was ignored in sizing system.
2. Blower speed too high.
3. No moisture barrier in crawl space.
4. Appliances such as clothes dryers not properly vented.
5. Excessive capacity of system causes frequent cycling.
6. More than normal amount of bathing, washing clothes, etc.
7. No exhaust fan in kitchen to remove moisture resulting from cooking.
8. Family does more entertaining than had been allowed for.
9. Some windows open.

6. SYSTEM IS NOISY!

1. Faulty bearing on blower.
2. Blower pulleys not aligned.
3. Short duct runs.
4. Compressor is noisy due to:
   a. Worn or scored bearings.
   b. Defective expansion valve.
   c. Overcharge of refrigerant.
   d. Overcharge of oil.
   e. Air or non-condensables in system.
   f. Shipping or hold-down bolts not removed or loosened.
   g. Broken compressor valves.
   h. No oil.

7. ELECTRIC BILL IS TOO HIGH!

1. Air conditioning unit is too large.
2. Insufficient insulation in house.
3. Thermostat setting too low.
4. Some windows open.
5. Owner improperly informed about operating costs.

It is critically important to determine what caused a fuse to blow, for example, or the refrigerant to leak, and make repairs accordingly to prevent the issue from happening again. This advice would apply to almost any complaint. If such repairs are not made, the trouble may not only become chronic but more serious as well.

This is particularly true of a refrigerant leak. The leak that lets refrigerant escape from the system may also allow moisture to enter.

Moisture in a refrigeration circuit can make the system inoperative. Moisture is believed to be one of the chief causes contributing to the burn-out of motors in compressors.

For a variety of reasons, the insulation on the winding of a hermetic compressor motor will sometimes fail, thus permitting a short circuit. This will create a sudden and great increase in heat, thereby burning off much of the remaining motor insulation.

A motor burn-out not only makes the compressor inoperative, it may also contaminate the rest of the system with acids or sludge. Therefore, a system must be thoroughly cleaned if a burn-out has occurred. If the system is not cleaned, the replacement motor-compressor unit generally will quickly burn out also.

What Owners Can Do

Owner should be instructed that outdoor equipment can be covered in the winter, and painted surfaces can be waxed for protection in a manner similar to an automobile's exterior finish. Coils can be washed with a garden hose by directing a fine water stream from the inside to the outside of the unit, but care must be taken to avoid bending the fins on the condenser coil and electric power must be OFF during cleaning. Also, point out that no shrubs or plants should be placed near the intake or discharge ends of the unit.

Filters should be inspected every 30 days and, where the owner is expected to maintain the filters, he should also receive instructions on their inspection and changing. Sizes and ordering instructions should also be given. For lubrication, point out manufacturer recommendations in the manuals provided by each company and left in the owner's hands. Be sure to explain equipment and labor guarantees.

As with all automatic and mechanical devices, central air conditioning requires periodic servicing by competent personnel. Service contracts should be offered to the owner. Regular maintenance inspections will prolong equipment life and reduce the frequency of emergency service calls — all of which result in lower owning and operating costs.

Unnecessary Calls

Whether or not a service contract is written, or if the equipment is under warranty, the owner should obtain the dealer's name and service department telephone number. A copy should also be permanently placed on the unit.

To avoid unnecessary calls and extensive interruptions in cooling operation, it is often convenient to provide a check list in case of a cooling failure. Things to do before calling the service person might include: check for blown fuses or open circuit breakers, dirty filters, broken fan belt; check reset button, open dampers; check to see if the thermostat is set too high, etc. Both the owner and the contractor benefit from such a simple checkout routine.

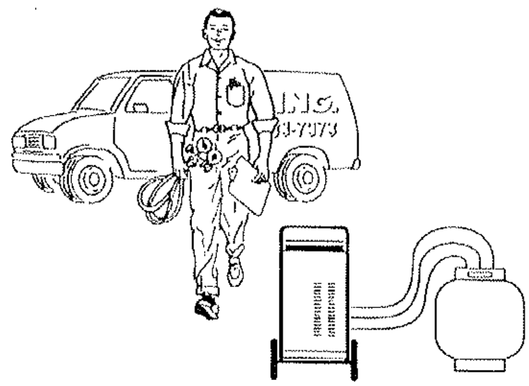
CFC/HCFC/HFC Venting

HCFC-22 is a very safe and stable refrigerant for use in buildings. However, it is suspected of being a factor in the depletion of the stratospheric ozone layer that protects the earth from harmful radiation. That is why newer refrigerants are being used such as R-410A and R-407C to name a few. Even with these new refrigerants, it is still illegal to vent any refrigerant to the atmosphere.

As a result, under the Clean Air Act, it is unlawful to deliberately vent any refrigerant into the atmosphere when servicing air conditioners and heat pumps.

The Environmental Protection Agency (EPA) is responsible for administering the requirement under the Clean Air Act.

The law requires the use of approved refrigerant recovery/recycling equipment while doing repairs. These machines must be tested and certified by an EPA-approved testing organization. No one may open the refrigerant side of a heat pump or air conditioner unless he or she is an EPA certified technician. Only certified technicians can purchase refrigerant as well.



The consumer will probably have little or no knowledge about the law and how these requirements affect the cost to repair equipment. This subject should be carefully explained to the customer.

Most people don't understand the significance of the ban against venting refrigerant, consequently they may be surprised at the cost of a repair. Explain the law first.

Self-Check, Lesson 13 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 installer should review the operating instructions of the cooling system with the occupants.

2. T F Owner operating habits have little effect on cooling performance and comfort achieved.

3. T F 24-hour operation is not recommended for residential cooling installations because it is expensive.

4. T F Cooling units with crankcase heaters need electric power at all times.

5. T F Storm windows kept in place offer no advantage during the cooling season.

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

6. The need for an emergency service call can be reduced through:

☐ A. preventative maintenance. ☐ B. start-up fine tuning.
☐ C. good operating instructions. ☐ D. set it/forget it thermostat setting.

7. The easiest malfunction to uncover and correct is:

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

8. A common cause for an occupant complaining about inadequate cooling is:

☐ A. the thermostat is set too high. ☐ B. a window is left open.
☐ C. a dirty filter. ☐ D. the unit was not started early.

9. The underlying cause for compressor motor burn-out is:

- ☐ A. high refrigerant pressure.
- ☐ B. low refrigerant pressure.
- ☐ C. dirty contactor.
- ☐ D. moisture in the system.

10. The no venting of refrigerant law under the U.S. Clean Air Act is administered by the:

- ☐ A. U.S. Department of Energy.
- ☐ B. U.S. Consumer Products Safety Commission.
- ☐ C. U.S. Environmental Protection Agency.
- ☐ D. U.S. Department of Justice.

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

Key Words

home owners	approved	fan	heating	tools
factory	adjustment	certified	installers helper	experience
servicing	manually			

11. No one can open and service the refrigerant circuit unless the person is an EPA ________________ technician.

12. Service technicians must use ________________ recovery/recycling machines certified through an EPA recognized testing organization.

13. Changing filters and keeping equipment clean of debris are maintenance items that ____________ ____________ can be trained to do.

14. There is no substitute for ________________ when troubleshooting an equipment problem.

15. Improper system __________________ is difficult to uncover with a visual inspection.

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 14 Overview

Lesson 14 will help you get along with customers and co-workers when faced with a disagreement.

We'll study how to handle a problem by taking any complaint seriously, no matter how trivial it may first appear. Then, we'll spend time uncovering the cause of the problem and how it can be "fixed" to the other person's satisfaction. Lastly, we'll attempt to explore how to say "no" gracefully.

Now read Lesson 14 which begins on the next page.

Lesson 14: People Friendly

In addition to repairing equipment and being a teacher to make the system user friendly, industry personnel must be people friendly too, and very often repair the broken *relationship* between the customer and the company. While it's not our intention to make a human relations expert out of you, here are a few thoughts on handling customer complaints.

Customers have a right to expect you to *listen* to their complaints. They usually believe their problem is unique and they desire satisfaction — from you! Everyone can expect to run into complaints — it's a guaranteed fact of servicing. It's how you handle the problem that can convert a complaint into an asset.

Complaints can take any of a number of forms — "Your company doesn't keep its promises." "Your service is terrible." "The #%^$#& %* thing doesn't work right ..." and many more.

Depending on a person's ability to handle complaints, they can be shattering, frustrating, costly experiences — or positively priceless opportunities to sew up a customer's allegiance and business.

Handling the Problem

People who have learned to turn complaints to their advantage say it can usually be done in one or all of four areas. These are:

- your Attitude and Approach
- your Capacity for "Discovering the villain"
- your Ability to Find Solutions
- your Knack for Cashing in on Complaints

Take Complaint Seriously

Attitude and Approach: The real "people person" sees a complaint for what it really is --- a chance to be of service to a customer when that service is most wanted. A golden opportunity to prove to a customer that his problem is your problem.

You can't expect a customer to believe you care unless you show him that you do. This means, first of all, *"taking the complaint seriously."*

Whether your customer thinks you're giving him the evil eye or grumbles about defective merchandise is immaterial. The point is, as far as he or she is concerned, there is a legitimate beef. Minimize the seriousness of his problem *in any way* and you immediately compound his grievance because you are, in effect, challenging his judgment.

Display Genuine Concern

Besides, a person with a gripe is in no mood to be reasonable. Not at first, anyway. Above all, he craves an audience, someone to whom he can pour out his tale of woe. Therefore, the smart employee gets to his customer at once.

Once there, listen. Look interested. Display concern. Get all the facts. Don't speak until you're certain that he has nothing more to say. A talked-out customer is the easiest to deal with.

Then summarize, in your own words, his net valid complaint. This serves two purposes. First, it disarms the complainer by showing him how closely you have followed what he's been saying. Second, it helps you keep his points straight in your own mind. Next to letting off steam, what the disgruntled customer wants most is satisfaction.

If his complaint is justified, be quick to admit it — but be sure to explain why things went wrong and why a recurrence is all but impossible. Otherwise, your assurance that "it won't happen again" may sound like a hollow promise.

One training director has found the phrase, "Now that we know..." followed by a specific remedy for the complaint, a most valuable good-will winner. In her own words: "A customer who raises cain frequently feels a little sheepish after laying into you. "Now that we know"... helps him save face. It's a way of thanking him for pointing out an error or shortcoming. At the same time, it's a promise that any future complaints will receive the same prompt attention. For a short phrase, it does a whale of a job.

Cement Relationship

Summing up, one wholesaler advises: "Welcome complaints as voluntary tip-offs to what you can do to cement relations with your customers. It's the person with the *silently nursed dissatisfaction* who should worry you, for you'll *never* know how you can be of maximum service to him. The most skillful doctor in the world can't treat a patient who refuses to say where it hurts."

Discovering the Villain

The biggest mistake an employee can make in handling a complaint is to pin the blame on someone in the front office. Avoid that approach like the plague. *Passing the buck* can only arouse suspicion, as if you were saying, "It's not my fault, but I'll help you anyway." Rather than dig up excuses, ask your customer, "What happened?" That way, you boil the whole issue down to what went wrong rather than who is to blame.

Ally yourself with him in a search for the common enemy — the cause of his complaint. When you find it, get rid of it. Sometimes the grievance is based on error. When that's the case, a calm review of the circumstances may divulge the reason for the complaint.

When facing a complaint, consider these possibilities, as they could save a lot of sound and fury:

Improper use of product* or *service — Even the simplest gadget in the world that is used incorrectly won't operate effectively or measure up to the claims of the manufacturer. How often has a heating and air conditioning customer complained about the equipment failing to provide the temperatures promised, yet the trouble has been found to be dirty air filters that have not been changed?

Here is an opportunity to change a complaint into a sale — the sale of an annual maintenance contract. Be sure to check on your customer's handling of your product or service. Often the basis for the complaint could be simple misuse.

Improper diagnosis — Sometimes a customer gets worked up over frequent safety trip-outs. When the serviceperson arrives, she can find no malfunction to cause the safety trip-out, until finally a temporary low voltage condition is found. Always check for an outside factor over which you have no control. It may well be the cause of the complaint. Find it if you can— and make a friend.

Misunderstanding — Many complaints are based on lack of information. The customer whose free service period has lapsed or who misreads your company's guarantee bases her complaint on a different frame of reference from you. Such "emotional static" can lead to a verbal free-for-all. A few well-placed questions and some patient answers can clear the air.

But suppose the customer's complaint is justified? What then? Then it will be up to you to find solutions that are mutually acceptable to the customer and your *company.*

The main reason for investigating a complaint is to undo some kind of damage — to profits, products, or peace of mind. However, this is easier said than done.

The first step in finding a mutually acceptable solution is for you to familiarize yourself with your company's facilities and adjustment policies. Precisely what guarantees does it offer? Who is responsible for installation, maintenance, and billing? How soon can parts be replaced? And how far does his authority go to make adjustments?

The answers to such questions will automatically set limits to the kind of redress that can be offered a customer. But the result will be proposals that can be lived up to.

When it is known what *can* be done for a dissatisfied customer, tell him — precisely, correctly, and honestly. If an immediate answer cannot be given, tell him it will be taken up with your superior, and that he will have the answer within a few days. Whenever possible, give him just a little *more* than he expects or demands by way of allowance or replacement.

The second step toward finding mutually acceptable solutions is to ask the customer, after telling him what will be done to rectify the error, *"Is that acceptable to you?"* Encourage his comments on the justice of the solution, for such encouragement pays a double dividend. It indicates confidence in the fairness of the proposal, and it proves that the company's only interest is his total satisfaction. If you, your company or merchandise are at fault, settle the complaint on the spot. People are *generally* reasonable. What they want — and have a right to expect — is fair play. Erase the cause of a complaint and in nine cases out of ten, you will hear no more about it.

When You Must Say "No"

Not every complaint can always be adjusted to the customer's complete satisfaction. When he wants more than you can give him, try this four-step approach:

- *Carefully explain why you cannot do what he asks.*
- *If possible, draw a parallel with his or her own line of business.*
- *Be firm, but always pleasant.*
- *Stress the benefits of your products and services.*

All meaningful or legitimate complaints should be reported back to your superiors and kept on file. The frequency of a specific complaint might suggest a weakness in a product or installation. Feedback in the form of a complaint can therefore lead to improved equipment, training or company procedures.

Finally, many times complaints or problems arise because the customer has not been properly educated as to the operation and care of the system or unit. Never place the blame on the customer for the improper care or operation of equipment. It is the company's *responsibility* to provide good instructions. The Consumer Products Safety Commission has stated *"They (manufacturers, wholesalers and dealers) must be in a position to advise the buyer competently on how to use and how to maintain and repair the product (sold)"*

Be certain equipment is properly labeled and that complete instructions are provided the customer.

Self-Check, Lesson 14 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 Any customer has the right to expect you to listen to his complaint.

2. T F Promises not kept by the company is a frequent complaint by customers.

3. T F A complaint is not the time to undertake an opportunity to improve customer allegiance and get more business.

4. T F You can ease the conflict by putting the blame on some other department in the company.

5. T F Far too many complaints are based on a lack of proper information by the customer.

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

6. The vital first step in preparing to handle complaints is to:

☐ A. offer customers a free gift.
☐ B. tell them this happens often and is no big deal.
☐ C. tell them it's a manufacturing problem.
☐ D. know your company's adjustment policies.

7. You can improve the environment surrounding a complaint at the very outset by:

☐ A. taking the complaint seriously.
☐ B. offering to repair everything.
☐ C. explaining complaints are not part of your job.
☐ D. delaying any action until customer calms down.

8. One of the most successful ways to disarm an irate customer is to:

- ☐ A. interrupt his/her explanation.
- ☐ B. summarize the issue at the end.
- ☐ C. keep nodding your head yes.
- ☐ D. let him know at the outset company policies.

9. If a customer's complaint turns out to be justified:

- ☐ A. try to get the customer to compromise.
- ☐ B. tell him/her the equipment was a poor choice.
- ☐ C. explain "Now that we know, here's what we'll do."
- ☐ D. call the supervisor for help.

10. To really repair the relationship with the unhappy customer:

- ☐ A. give him a little more than he expects.
- ☐ B. delay any decision as long as possible.
- ☐ C. be overly friendly.
- ☐ D. send them to someone else to retell the entire complaint.

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

Key Words

home owners	approved	skeptical	picture
silently	explain	feedback	comparison
experience	reasonable	customer	certified

11. The Consumer Product Safety Commission places responsibility on the seller to ________________ how the use and care for products sold.

12. Complaints when tracked can be a source of important _______________ on faulty equipment or installation procedures.

13. Most people are __________________ and have a right to expect reasonable accommodations and no stonewalling to avoid added expense.

14. It is the customer with a/an ____________ nursed complaint that can be more harmful to a company's reputation.

15. When you must say no, draw a/an _________________ with the complainers own line of work.

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 #2.

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.

Self-Check Lesson 8

1. True
2. False
3. True
4. False
5. False
6. A
7. A
8. D
9. A
10. D
11. orientation
12. neglected
13. latent
14. 300 sensible heat/230 latent
15. appliances
16. Heat Factor
17. 25%
18. 1.9

Self-Check Lesson 9

1. True
2. True
3. True
4. True
5. True
6. B
7. C
8. A
9. B
10. D
11. zone control
12. Standard 275
13. air
14. property
15. easier
16. electric

Self-Check Lesson 10

1. True
2. True
3. False
4. True
5. False
6. D
7. B
8. A
9. C
10. B
11. balancing
12. dampers
13. increase
14. 4,000
15. ceiling
16. extended plenum
17. 1. Supply plenum 2. Supply trunk 3. Branch ducts 4. Fittings 5. Supply outlets 6. Return air intakes 7. Return duct 8. Volume dampers

Self-Check Lesson 11

1. True
2. False
3. False
4. False
5. True
6. A
7. B
8. B
9. D
10. C
11. microprocessor
12. desuperheater
13. economizer
14. heat pipe
15. electricity
16. geothermal

Self-Check Lesson 12

1. False
2. False
3. True
4. False
5. True
6. C
7. B
8. A
9. B
10. C
11. switch
12. bimetal
13. save energy
14. field
15. cooling

Self-Check Lesson 13

1. True
2. False
3. False
4. True
5. False
6. A
7. D
8. C
9. D
10. C
11. certified
12. approved
13. home owners
14. experience
15. adjustment

Self-Check Lesson 14

1. True
2. True
3. False
4. False
5. True
6. D
7. A
8. B
9. C
10. A
11. explain
12. feedback
13. reasonable
14. silently
15. comparison

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.