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# Duct Systems

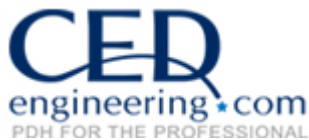
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Elie Tawil, P.E., LEED AP

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Continuing Education and Development, Inc.  
9 Greyridge Farm Court  
Stony Point, NY 10980

P: (877) 322-5800

F: (877) 322-4774

[info@cedengineering.com](mailto:info@cedengineering.com)

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# NONRESIDENT TRAINING COURSE

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# Utilitiesman (Advanced)

NAVEDTRA 14259

Although the words “he,” “him,” and “his” are used sparingly in this course to enhance communication, they are not intended to be gender driven or to affront or discriminate against anyone.

# DUCT SYSTEMS

As a Utilitiesman, you can expect to become involved in the installation of duct and/or ventilation systems designed to provide conditioned air or to remove less desirable air from a given space or facility. When sheet metal is to be fabricated into system components, the Steelworker provides the expertise. When duct board is used, fabrication and installation may be tasked to the Utilitiesman exclusively.

This chapter provides some key knowledge to aid you in the identification of types of duct systems and their installation, and factors you must be aware of in determining the sizes required to meet specified building requirements. Keep in mind that the term *air conditioned* refers to air that has been cooled, heated, dehumidified or humidified, or any combination of these.

## DUCT SYSTEMS

To deliver air to the conditioned space, you need air carriers. These carriers are called ducts. They are made of sheet metal or some structural material that does not bum (noncombustible).

Duct systems are also classified as high-pressure or high-velocity ductwork and low-pressure or low-velocity ductwork. The term *high-pressure* or *high-velocity* ductwork includes ductwork systems and plenums from the fan discharge to the final high-velocity mixing boxes, or other final pressure-reducing devices or any air supply system served by a fan operating with a static pressure range of 3 inches to 7 inches of water column (WC).

High-velocity or high-pressure systems with fan static pressures of 3 inches WC or greater are defined as high pressure. Usually the static pressure is limited to a maximum of 7 inches WC, and duct velocities are limited to 4,000 feet per minute (fpm). Systems requiring pressures more than 7 inches WC are normally unwarranted and could result in very high operating costs. Systems with velocities more than 4,000 fpm performs satisfactorily when all duct fittings are carefully designed and installed. However, velocity pressure losses are excessive and velocities more than 4,000 fpm are not recommended.

A high-velocity double-duct system begins with a high-pressure fan of class II or III design any conveys air through sound-treated high-velocity ductwork connected to sound and pressure-attenuating mixing units. Connections to the outlets of the reduction units are treated as low velocity.

Smaller sized ductwork, using higher velocities, permits conveyance of air to areas limited by construction and reduces floor-to-floor height. Round ductwork generally provides the greatest strength, tightness, and economy. However, oval and rectangular ducts can be used when large risers are involved.

A necessary component of the high-pressure system is the mixing box or unit. Its function is to blend air at two different temperatures for proper delivery to the rooms. This requires special pressure-reducing air valves at both hot and cold inlets, mixing baffles to prevent stratification of air, and sound attenuation treatment to absorb noise generated by the air valves.

Table 13-1.—Outlet Velocities for Optimum Performance of Fans

STATIC PRESSURE INCHES OF WATER	CENTRIFUGAL FANS OUTLET VELOCITY fpm	TUBEAXIAL AND VANEAXIAL FANS OUTLET VELOCITY AT WHEEL DIA. fpm
1/4	400- 100	950-1,500
1/2	550-1,450	1,350-1,900
3/4	700-1,750	1,650-2,350
1	800-2,000	1,900-2,700
1 1/2	1,000-2,500	2,350-3,300
2	1,150-2,800	2,700-3,800
2 1/2	1,250-3,200	3,000-4,300
3	1,400-3,500	3,300-4,700
4	1,600-4,050	
6	2,000-4,950	
8	2,300-5,700	
10	2,500-6,400	

The term *low-pressure* or *low-velocity* ductwork applies to systems with fan static pressures less than 3 inches WC. Generally, duct velocities are less than 2,000 feet per minute.

The choice between the use of low versus high-velocity systems requires architectural, mechanical, and structural considerations. Installation cost, temperature control, and operating cost should also be studied.

Low-velocity double duct systems are many years old. It was not until after World War II that their use became extensive. Space for the installation of the double ducts is a main consideration for this system and must be provided during initial planning. Difficulties in providing for this space in modern structures with low floor-to-floor heights and flush ceilings, together with the need for developing a compact distribution system for existing buildings, has brought about the development of high-velocity double duct systems. High velocity saves ceiling space and duct shaft

space, but requires greater attention in the selection of fans and equipment with regard to sound levels. Also, higher duct velocities require increased fan static pressures; therefore, increased operating costs. On the other hand, high-velocity systems are easy to balance and control and have much greater flexibility for partition changes and so forth.

Generally, high-velocity systems are applicable to large multistory buildings; primarily because the advantage of saving in duct shafts and floor-to-floor heights is more substantial. Small two- and three-story buildings are normally low velocity; however, both systems should be analyzed for each building. Table 13-1 shows outlet velocities for the range of optimum performance of typical ventilation fans.

Ducts are made of many types of materials. Pressure in the ducts is small, so materials with a great deal of strength are not needed. Originally, hot air ducts were thin, tinned sheet steel. Later, galvanized sheet steel, aluminum sheet, and

**TABLE 13-2.—Materials for Ductwork**

Application	Material
Normal system handling dry air  1. Air conditioning 2. Ventilating	Galvanized steel  Fiberboard
Systems handling air at very high temperature  1. Kitchen exhaust	Black steel
System handling partially saturated air  1. Outside air intake ductwork 2. Exhaust ductwork near discharge outlet 3. Ductwork exposed to weather elements	Aluminum
Systems handling completely saturated air  1. Shower exhaust 2. Dishwasher exhaust 3. Ductwork exposed to salty atmosphere	Copper

finally, insulated ducts made from materials, such as asbestos and fiberboard, were developed. Passageways, formed by studs or joists, are sometimes used for return air when a fire hazard does not exist.

Ducts made of asbestos are no longer legal. If discovered, asbestos in any form must be removed and disposed of according to the laws and regulations discussed in chapter 16 of this manual.

The material used for the construction of ductwork depends on the application of the duct. Use table 13-2 as a guide in the selection of duct material. The thickness of the material depends primarily on the pressure developed within the duct, the length of the individual sections, and the cross-sectional area of the duct. The developed length of a section for a particular gauge can be increased by installing angle bracing around the duct. It is beyond the scope of this manual to include the

technical details necessary for the selection of proper metal thickness and section length for different pressures and for different cross-sectional areas of duct material. However when repairs are made, the same thickness of metal that was originally included in the system must be installed. Where the original ductwork was destroyed by pressure, repairs may include increasing metal thickness or adding of angle bracing.

Ducts are either round or rectangular in cross section. Although rectangular ducts usually have the advantage of saving room space and being easier to install in walls, round ducts provide less resistance to air flow and should be used whenever possible.

Additionally, round ducts require less material to construct; thus, by using round ducts, you can save both money and material during installation.

Initially, an air-handling duct is usually sized for round ducts. Then, if rectangular ducts are wanted or required, duct sizes can be selected to provide flow rates equivalent to those of the round ducts originally selected.

Table 13-3 is a ready reference to determine the size of a rectangular duct that equals the carrying capacity of a predetermined round duct. To use this chart, convert a rectangular duct with sides of 17 inches by 16 inches, respectively. First, come down the left-hand column until you reach 17 inches; then trace the line horizontally across the columns until you reach the column headed by 16 inches. At the center of these intersecting lines is 18.0 inches. This is the round duct size equivalent.

In the second example, following the same procedure, it is clearly shown that a 22-inch by 17-inch rectangular duct has a 21-inch round duct equivalent.

## **TYPES OF DUCT SYSTEMS**

In this section, the advantages and disadvantages of a double-duct system are discussed. Since there are many possibilities for an adequate duct system, one such system is modified to fit the needs of two different residential configurations.



**Table 13.3.—Duct Capacity Conversions**

The dimensions in this chart are in inches

Side Rectangular duct	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0
3.0	3.8	4.0	4.2	4.4	4.6	4.8	4.9	5.1	5.2	5.5	5.7	6.0	6.2	6.4	6.6	6.8	7.0
3.5	4.1	4.3	4.6	4.8	5.0	5.2	5.3	5.5	5.7	6.0	6.3	6.5	6.8	7.0	7.2	7.4	7.6
4.0	4.4	4.6	4.9	5.1	5.3	5.5	5.7	5.9	6.1	6.4	6.8	7.1	7.3	7.6	7.8	8.1	8.3
4.5	4.6	4.9	5.2	5.4	5.6	5.9	6.1	6.3	6.5	6.9	7.2	7.5	7.8	8.1	8.4	8.6	8.9
5.0	4.9	5.2	5.5	5.7	6.0	6.2	6.4	6.7	6.9	7.3	7.6	8.0	8.3	8.6	8.9	9.1	9.4
5.5	5.1	5.4	5.7	6.0	6.3	6.5	6.8	7.0	7.2	7.6	8.0	8.4	8.7	9.0	9.4	9.6	9.8

Side Rectangular duct	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	22	24	26	28	30
6	6.6																			
7	7.1	7.7																		
8	7.5	8.2	8.8																	
9	8	8.6	9.3	9.9																
10	8.4	9.1	9.8	10.4	10.9															
11	8.8	9.5	10.2	10.8	11.4	12														
12	9.1	9.9	10.7	11.3	11.9	12.5	13.1													
13	9.5	10.3	11.1	11.8	12.4	13	13.6	14.2												
14	9.8	10.7	10.5	12.2	12.9	13.5	14.2	14.7	15.3											
15	10.1	11	11.8	12.6	13.3	14	14.6	15.3	15.8	16.4										
16	10.4	11.4	12.2	13	13.7	14.4	15.1	15.7	16.3	16.9	17.5									
17	10.7	11.7	12.5	13.4	14.1	14.9	15.5	16.1	16.8	17.4	18.0	18.6								
18	11	11.9	12.9	13.7	14.5	15.3	16	16.6	17.3	17.9	18.5	19.1	19.7							
19	11.2	12.2	13.2	14.1	14.9	15.6	16.4	17.1	17.8	18.4	19	19.6	20.2	20.8						
20	11.5	12.5	13.5	14.4	15.2	15.9	16.8	17.5	18.2	18.8	19.5	20.1	20.7	21.3	21.9					
22	12	13.1	14.1	15	15.9	16.7	17.6	18.3	19.1	19.7	20.4	21	21.7	22.3	22.9	24.1				
24	12.4	13.6	14.6	15.6	16.6	17.5	18.3	19.1	19.8	20.6	21.3	21.9	22.6	23.2	23.9	25.1	26.2			
26	12.8	14.1	15.2	16.2	17.2	18.1	19	19.8	20.6	21.4	22.1	22.8	23.5	24.1	24.8	26.1	27.2	28.4		
28	13.2	14.5	15.6	16.7	17.7	19	18.7	19.6	20.5	21.3	22.1	22.9	23.6	24.4	25	25.7	27.1	28.2	29.5	30.6
30	13.6	14.9	16.1	17.2	18.3	19.3	20.2	21.1	22	22.9	23.7	24.4	25.2	25.9	26.7	28	29.3	30.5	31.6	32.8
32	14	15.3	16.5	17.7	18.8	19.8	20.8	21.8	22.7	23.6	24.4	25.2	26	26.7	27.5	28.9	31	32.3	33.6	33.8
34	14.4	15.7	17	18.2	19.3	20.4	21.4	22.4	23.3	24.2	25.1	25.9	26.7	27.5	28.3	29.7	32.3	33.6	33.8	34.8
36	14.7	16.1	17.4	18.6	19.8	20.9	21.9	23	23.9	24.8	25.8	26.6	27.4	28.3	29	30.5	32	33	34.6	35.8

This chart depicts sizes of rectangular duct that are equal in carrying capacity to round ducts. To use this chart find the diameter of round duct in the chart. Then find one side of rectangular duct by reading up. Find the other side by reading left to the first row of numbers representing the other side of the rectangular duct.

A double duct system generally consists of a blowthrough fan unit discharging filtered air through stacked or adjacent heating and cooling coils into separate plenums and ductwork with thermostatically controlled mixing dampers at various room locations.

The inherent advantage of a double duct system is that individual room conditions can be maintained from a central system, within the limitations of supply air temperatures. This is done by the blending of hot and cool air through automatically controlled mixing devices. Another important credit is flexibility. In this regard, individually controlled rooms can be easily incorporated, at modest cost, after the building is completed.

In modern buildings of multiple exposures designed for variable functions and changing occupancy, individual room control is essential and a double duct system should be seriously considered.

Double duct systems for low pressure are usually tiered hot and cold ducts within the furred space. They are generally located above corridors. The manner of distributing proper temperature air to the room is through right angle, interlinked

mixing dampers operated by motors controlled through thermostats. In general, this type of system uses the same corridor plenum area around the ducts for conveyance of return or exhaust air. The residual volume of space left for this purpose is too often neglected. Inevitably, this results in insufficient relief for the rooms.

The main disadvantage of a double duct system is lack of stability of air quantities supplied to areas (rooms) because of varying duct static pressures.

All duct elbows, including supply, exhaust, and return, should be made with a center line radius of 1.5 times the duct width, parallel to the radius wherever possible. In no case should the center line radius be less than the width of the duct parallel to the radius. Where space does not permit the above radius, or where square elbows are indicated on plans, turning vanes of an approved type should be used.

Additionally, there are numerous adaptations and modifications of duct systems. Figure 13-1 shows a residential duct system with the furnace and central air unit located in the basement.

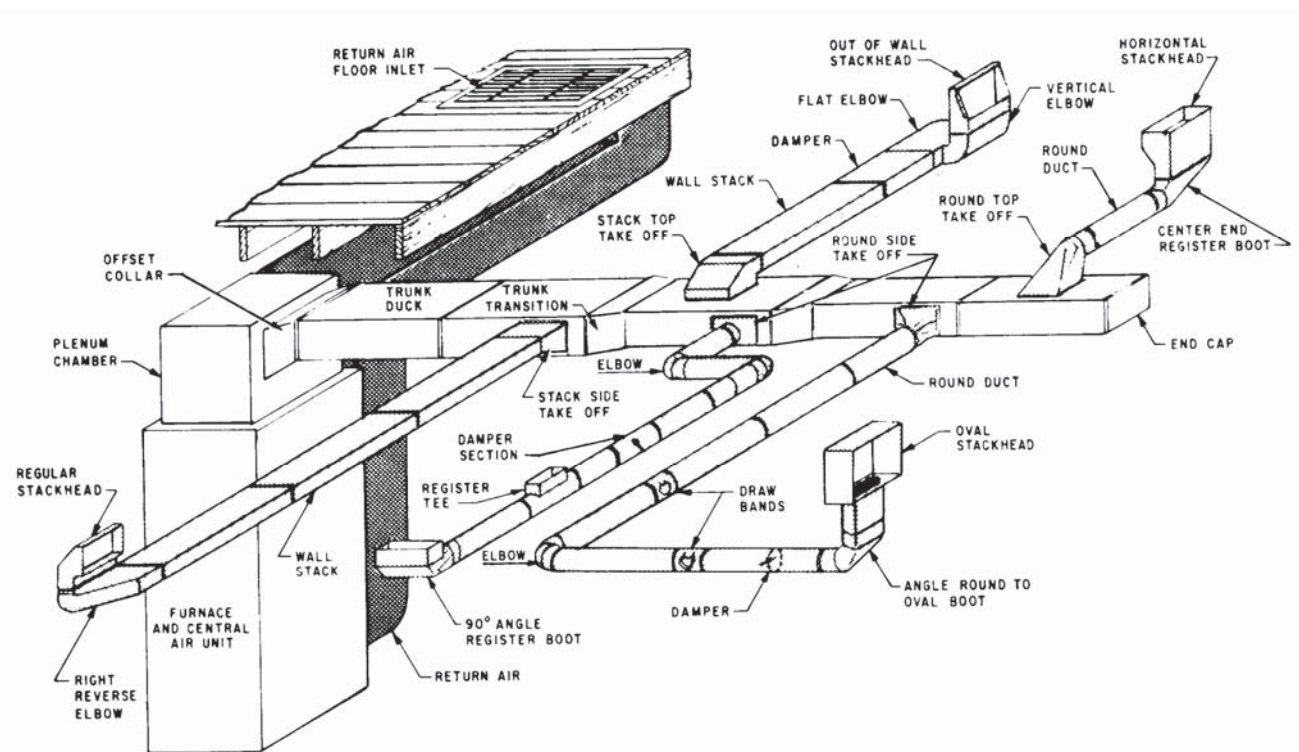


Figure 13-1.—Residential duct system.

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In figure 13-2, the same basic system is shown in a single-story house. The duct system is located in the overhead and the return air enters through the bottom of the central air-handling unit. When the duct system is located in a crawl space, basement, or attic, it should be insulated to maintain the existing temperature.

## DUCT CONSTRUCTION

In this section, basic sheet metal ducts, both round and rectangular, are discussed. Emphasis is placed on layout and pattern requirements. Then fiberboard duct construction and its use are discussed.

### Round Duct

Straight sections of round duct are usually formed from sheets rolled to a proper radius and assembled with a longitudinal grooved seam. Each end of a round section is swaged and assembled with the larger end of the adjoining section butting against the swage. Sections are held together by rivets, by sheet metal screws, or by solder. Where solder is not used, duct tape or liquid rubber (duct sealer) should be used as a covering at all joints. Rectangular ducts are generally constructed by bending corners and by grooving along the longitudinal seam.

The duct system should be constructed in a way that avoids abrupt changes in size,

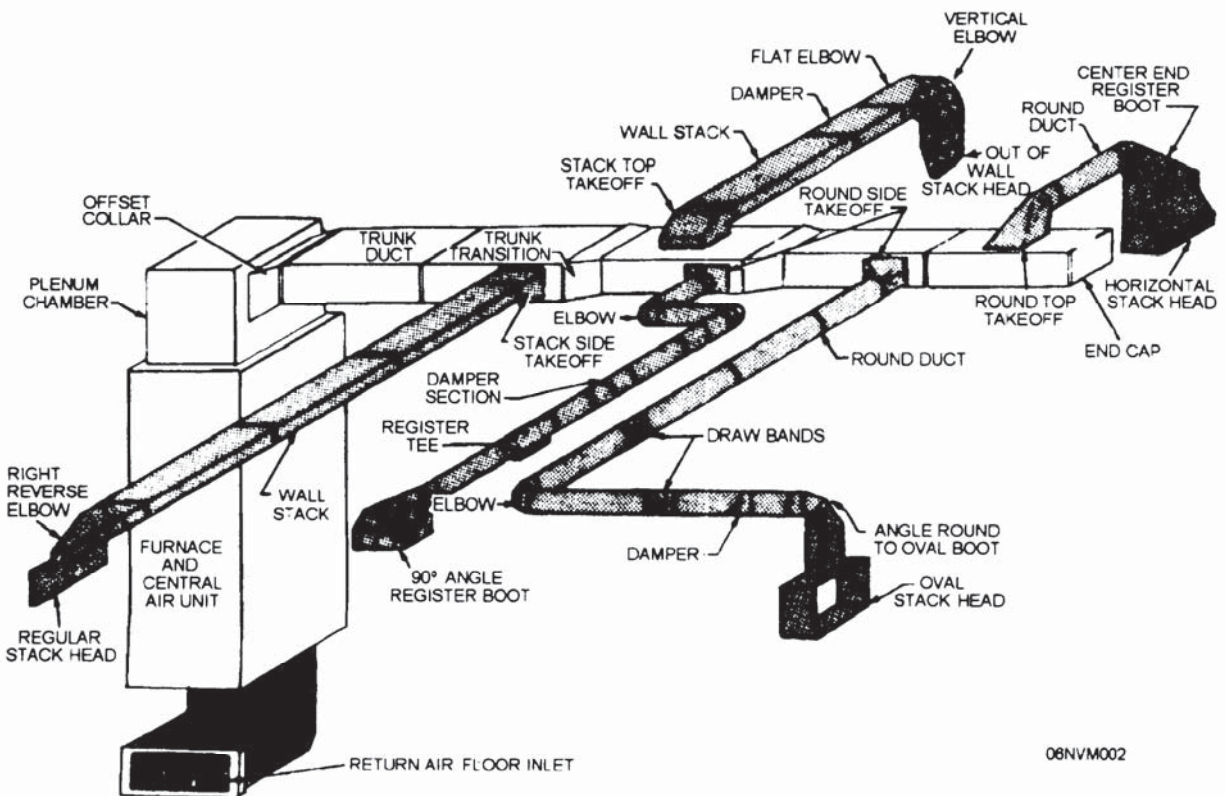


Figure 13-2.—Residential duct system.

direction, or other resistance conditions that can create unnecessary noise and reduce the air volume. The normal noise level of air flowing through a duct depends on the velocity of the air moving through the duct. This can be further reduced by lining or covering the duct with sound-absorbing material. The exterior of ducts that carry conditioned air can be covered with heat insulation materials to prevent heat transfer between ducts and the surrounding air. All materials used for duct lining and coverings must be noncombustible.

Ducts should be constructed for easy maintenance. They should have access plates or doors included to facilitate cleaning and inspection. It is important that the correct size duct (as specified on the prints or drawings) be used for the construction of the duct system. The amount of air to be carried depends on the size of the duct. This determines the pressure loss in the system—the larger the quantity of air moving through a duct of a given cross-sectional area, the greater the friction loss. Similarly, with a given quantity of air to be delivered, the friction loss increases in inverse proportion to the sizes of ducts provided to carry the air. Therefore, the power required at the fan for delivering a given quantity of air increases rapidly as the duct size is decreased. It is important to bear these facts in mind when it is necessary to replace or to change sections of ducts. The same size new duct should be used unless proper design provisions are made for a change in size.

### **Rectangular Duct**

Straight sections of rectangular duct are normally formed by personnel in the Steelworker rating. This is normally accomplished on bending-brake type of equipment. Then the rectangular ductwork is joined together as mentioned earlier.

Straight sections of ducts can usually be laid out without a pattern. However, elbows, transitions, jump fittings, and so forth, require a pattern. While Steelworkers perform the task, you, as a planner, need to be aware of the time required to draw and fabricate the required patterns. Also bear in mind that if this is a one-time job, you can make the pattern of paper or cardboard. When there

are large numbers of the same size and dimension fittings to be constructed, you should make the pattern of sheet metal.

### **Fiber Glass Duct**

A fiber glass duct is constructed of molded glass fibers covered with a thin film coating. This coating is usually of aluminum, but vinyl or other plastic coatings are sometimes used. Since they are made of glass fibers, the ducts are inherently insulated. Also, they are primarily used where insulation is a factor. Fiber glass meets military specifications for a flame spread rating of less than 25 and a smoke development rating of less than 50 for insulating material. The thickness of fiber glass ducts allowed for use in Navy installations must range between 3/4 inch to 2 inches, depending upon the size of the duct.

The nature of a fiber glass duct requires that it be supported with 1-inch by 1/16-inch galvanized steel strap hangers shaped to fit the duct. For round ducts, these supports must be on not less than 6-foot centers. Rectangular and square ducts up to 24-inch spans may be supported on 8-foot centers. Ducts larger than 24 inches require support on 4-foot centers.

The applicability of fiber glass ducts on heating systems is sometimes limited by the adhesive used on the protective outer covering to cause it to adhere to the fiber glass material. Unless aluminum surface duct is used, the specification of the duct should be checked carefully to ensure that it does not fail when heated over 250°F.

Fiber glass ducts can be molded into a variety of shapes for special uses. Round ducts and reducers are available from manufacturers' stock. For most purposes, however, the duct is supplied flat in the form of a board, with V-grooves cut into the inner surface to allow folding to make a rectangular section. The ends of the boards are molded so that when the rectangular duct is formed, two sections of the same size fit together in a shiplap joint to ensure a tight joint in positive alignment. It is important to exercise care in selecting a board of adequate size to complete the desired duct before beginning cutting and

grooving operation. In all cases, the inside diameter of the duct is the determining factor for board size. To determine board size see table 13-4.

To form a rectangular duct, the flat duct board is measured accurately and grooves are cut at the proper locations. The board is then folded into a rectangular shape. When the board is cut, an overlapping tab is left and this is then pulled tight and stapled. Tape is applied and the joint is heat sealed. Joints between sections are made by pulling the shiplap end sections together.

The joint is then completed by stapling, taping, and heat sealing the junction as shown in figure 13-3.

Sheet metal ducts expand as they become hot and contract as they become cold. The degree to which expansion and contraction becomes an installation factor depends upon the temperature of the air surrounding the ducts and the temperature of the air moving through the ducts. Fabric joints are often used to absorb this duct movement. Additionally, fan noise and furnace or air-conditioner noise tends to travel along the

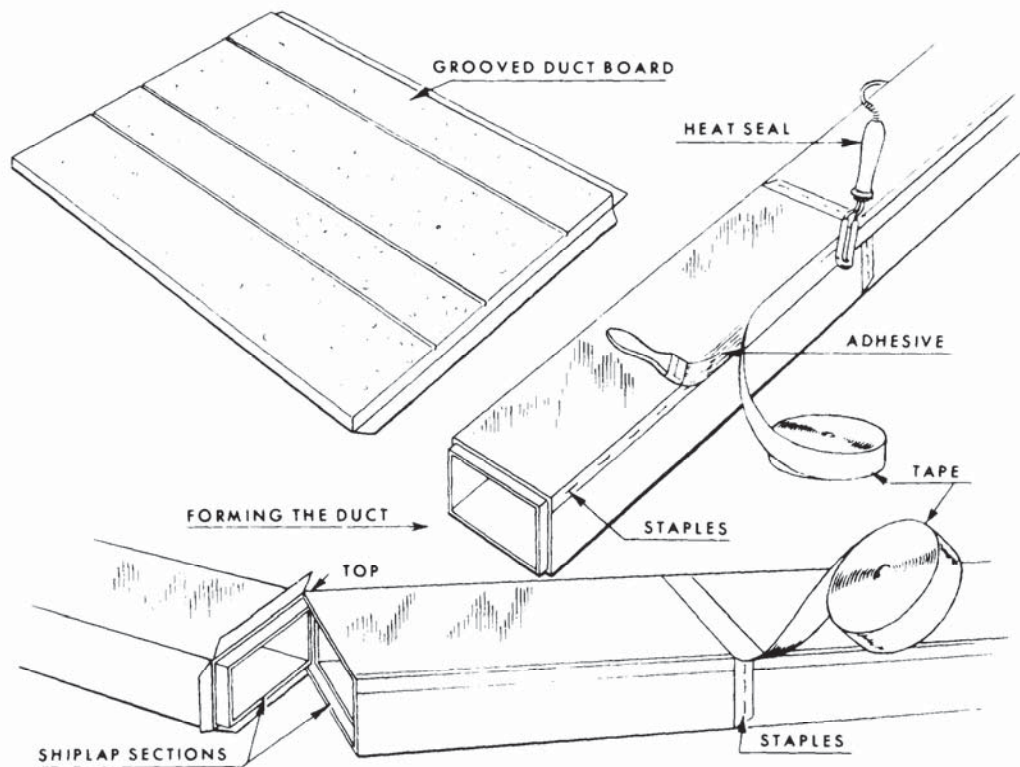
Table 13-4.—Duct Board Length Selection Chart

	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
6	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76
7	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78
8	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80
9	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82
10	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84
11	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86
12	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88
13	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90
14	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92
15	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94
16	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96
17	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98
18	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100
19	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102
20	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104
21	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106
22	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108
23	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
24	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112
25	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114
26	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116
27	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118
28	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120
29	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120	
30	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120		
31	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120			
32	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120				
33	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120					
34	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120						
35	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120							
36	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120								
37	94	96	98	100	102	104	106	108	110	112	114	116	118	120									
38	96	98	100	102	104	106	108	110	112	114	116	118	120										
39	98	100	102	104	106	108	110	112	114	116	118	120											
40	100	102	104	106	108	110	112	114	116	118	120												
41	102	104	106	108	110	112	114	116	118	120													
42	104	106	108	110	112	114	116	118	120														
43	106	108	110	112	114	116	118	120															
44	108	110	112	114	116	118	120																
45	110	112	114	116	118	120																	
46	112	114	116	118	120																		
47	114	116	118	120																			
48	116	118	120																				
49	118	120																					
50	120																						

\*For 1½-inch board—ADD 4 INCHES to these dimensions.

\*For 2-inch board—ADD 8 INCHES to these dimensions.





**Figure 13-3.—Forming rectangular fiber glass ducts from duct board.**

metal ducts. Therefore, fabric joints (usually constructed of heavy canvas) are used to join the branch ducts to the plenum.

### **SIZING DUCT SYSTEMS**

There are numerous factors to be considered when sizing duct systems. These factors cause you to make modifications and adjustments throughout the planning and installation process to develop an efficient working system. First, you must calculate the air volume required for heating and for cooling the required space. This will assist you in determining the necessary duct size, fan size, fan speed, and so forth, that is needed to circulate the conditioned air. While determining the heating and the cooling factors, you should think in terms of air circulation throughout the building and in each individual room or space. Remember, air movement is determined by the type of return airflow that you use.

Four other important duct system components are diffusers, grilles, registers, and dampers. Each of these components has a direct correlation

between functional design, amount of air accommodated, and the air movement pattern.

The elbows within the duct system are a major source of airflow restriction. Whenever possible, you can gain efficiency by installing long sweeping elbows. Short 90-degree elbows should be used sparingly on long duct runs. However, they can be used very effectively with a minimum of air turbulence and airflow restriction when installed just before diffusers, grilles, and registers.

Your final duct calculations involve taking unit pressure drops and total pressure drops throughout the system. Some of the major contributing factors to these pressure drops are as follows:

- Length of duct
- Duct material and interior finish
- Changes in duct size
- Number of elbows

Normally, you will be installing a duct system according to preestablished blueprints and drawings. Occasionally you may need to refer to other sources and review trade association standards. The ASHRAE Handbook of Fundamentals has three chapters dedicated to methods and procedures for selecting proper duct sizes. You should become familiar with the contents of these three chapters; particularly, if you are involved in the design phase of an air-conditioning system.

### BALANCING DUCT SYSTEMS

A duct system is always installed to fulfill specific requirement features related in some way to the health and welfare of human beings. Equally important is the fact that a properly balanced operating system results in lower operating costs and significant utilities conservation. Consequently, it is important that these systems, regardless of the function, operate properly. When a duct system is initially installed, the required pressures and performance data are available from the construction drawings and the manufacturer's instructions. After installation, pressures and performance requirements should be measured to ensure proper airflow at different locations. Once the proper airflows are established, little change should take place within the system. Maintenance personnel must ensure that the system is operating correctly by conducting certain periodic tests. Tests are used for the initial and subsequent setting of grilles, diffusers, dampers, and registers to obtain the necessary airflow required by specifications, codes, regulations, or trade association standards.

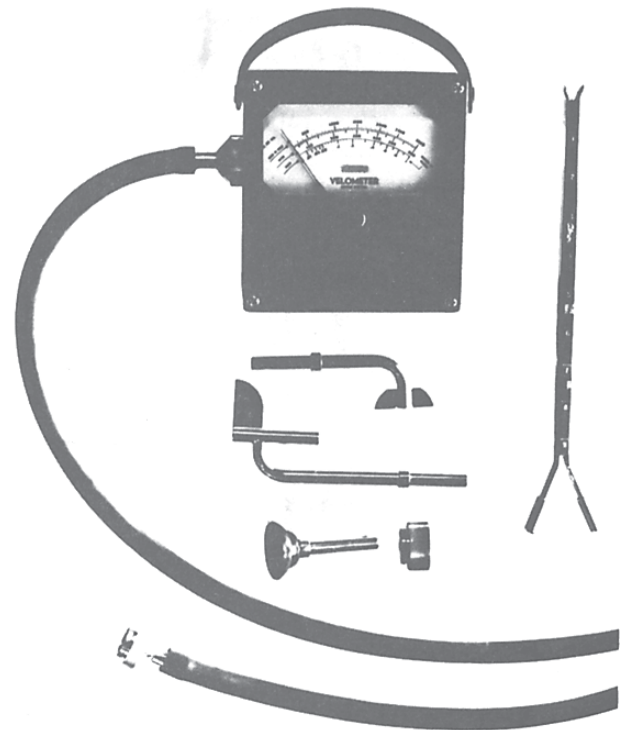
It is important to understand the pressure in a duct carrying a moving stream of air. Certain changes in an existing duct system are often necessary and you should be able to accomplish these changes. In addition, malfunctioning duct systems require immediate attention, and an understanding of the basic elements of the system is required before troubleshooting and corrective action can be undertaken. Furthermore, before a duct system can be properly balanced, certain essential knowledge of airflow is required.

Static pressure is a measure of the outward push of air on the walls of a duct. When air is not moving within a duct because a damper at the outlet is closed, the static pressure can be measured by means of a pressure gauge installed in the wall of the duct. If the damper in the duct is then opened and the air is flowing, static pressure continues to be present. It will be reduced when the damper is

opened, but the static pressure can still be read on the gauge.

When air is flowing in a duct, there is another pressure—in addition to the static pressure—that can be measured. This is the pressure exerted by the moving airstream. This pressure acts in a plane perpendicular to the direction of airflow. To illustrate, imagine a horizontal duct without any air flowing in it. When a thin, flat piece of metal is suspended with a movable hinge from the top of the duct, it will hang straight down when air is not moving. When air flows, the hinged piece of metal swings upward toward the top of the duct. The velocity pressure is the force that causes the deflection of the hinged vane (obviously, the greater the air velocity, the greater the pressure acting on the hinged vane and the greater its deflection from the perpendicular).

The velocity pressure cannot be measured as easily as the static pressure. When a hollow tube is inserted in the moving airstream, and a gauge is connected to the end of the tube, the gauge registers a certain pressure. This pressure is larger than the static pressure because the gauge indicates the sum of the static and the velocity pressure. This sum is known as the total pressure. Since



87.177

Figure 13-4.—Velometer set.





87.257

Figure 13-5.—Pitot probe.

total and static pressure can be easily measured, the velocity pressure can be found by subtracting static from total pressure. In most problems concerning duct systems, air pressure is expressed in terms of inches of water (1 pound per square inch = 27.74 inches of water.)

At the time of initial installation of a duct system, the design data should be recorded. After initial start-up, the system should be balanced so that each air outlet is adjusted to the design rate of flow. During the initial balancing procedure, the actual design rate of flow is sometimes not achieved, but the flow is within the range of acceptable standards. When such conditions exist, they should be noted on the design data sheet where they may be considered by maintenance personnel during repairs or the rebalancing of the system. After the system is balanced and proper operation is assured, static pressure measurements are taken throughout the system. Also, the total pressure difference across the fan (the difference between the suction total pressure and the discharge total pressure) is noted. Although these initial measurements can be used for checking the design of the system, their main function is to serve as reference data for future tests. If the system fails to function properly at any time, another set of measurements should be taken and compared to the original set.

## AIR BALANCING INSTRUMENTS

Numerous instruments designed for air balancing requirements are available from different manufacturers. Those that are most commonly used are discussed in this section.

### Velometer

This instrument is particularly adaptable to maintenance work because of its portability, wide scale range, and instantaneous reading features. Its accuracy is suitable for most air velocity and static pressure readings. Since velometers are made by several manufacturers, the instruction sheets for any instrument should be thoroughly understood before attempting to use it. A

functional velometer set consists of the basic meter with hoses and accessories as shown in figure 13-4.

**MEASURING DEVICES.**— There are four measuring devices used with the basic meter for determining air velocities and pressures. They are the pitot probe, low flow probe, diffuser probe, and static pressure probe.

The pitot probe (fig. 13-5) is a stainless steel measuring probe with a standard length of 12 inches and a diameter of 1/2 inch. It is suitable for measuring velocities at supply openings and at return openings. Its primary purpose is to measure velocities within ducts. It is not recommended for velocity ranges below 300 fpm.

The low flow probe (fig. 13-6) is used for measuring velocities in open spaces. It connects directly to the meter and permits measurement of air by placing the instrument directly in the air currents. It is useful for measuring drafts in rooms and air velocities at ventilation hoods and spray



87.258

Figure 13-6.—Low flow probe.

booths. Only velocity ranges from 0 to 300 fpm are applicable to this device.

The diffuser probe (fig. 13-7) is used for measuring air output at duct supply diffusers. It can also be used with some meters on return air diffusers. The meter reading and the K factor established by the diffuser manufacturer can be used to determine air volume outputs.

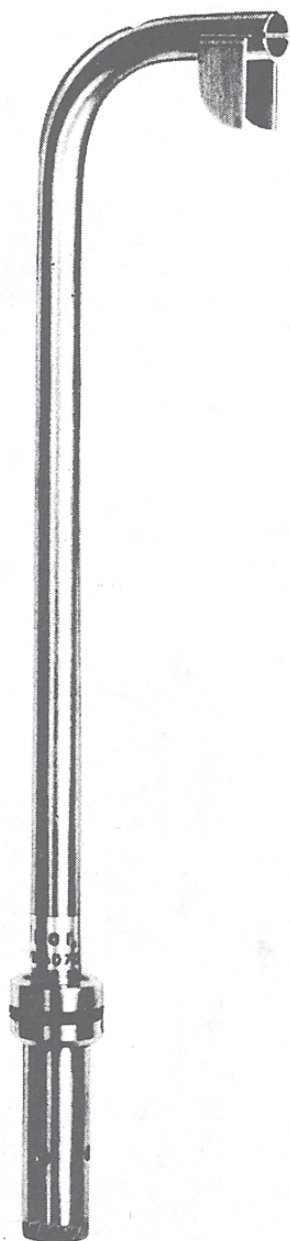


Figure 13-7.—Diffuser probe. 87.259

The static pressure probe (fig. 13-8) is used for measuring drops across blowers or fans in duct systems. The probe is carefully placed over an opening in the wall of a duct so as to form a positive seal. The hole should not be less than one-quarter inch in diameter.

RANGE SELECTORS.— These are devices (fig. 13-9) that permit a rapid change of measuring ranges without the need for shifting to separate jets for each range. They are provided with connections that accept the various probes. These probes can also be connected to the meter. With the exception of the low flow probe, measurements may require a range selector.

#### Manometer

A manometer is an instrument that indicates air pressure by employing the principle of

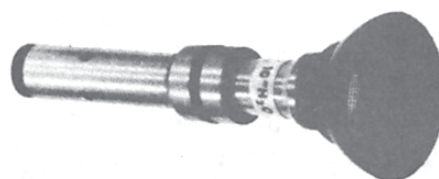


Figure 13-8.—Static pressure probe. 87.260



Figure 13-9.—Range selector. 87.261

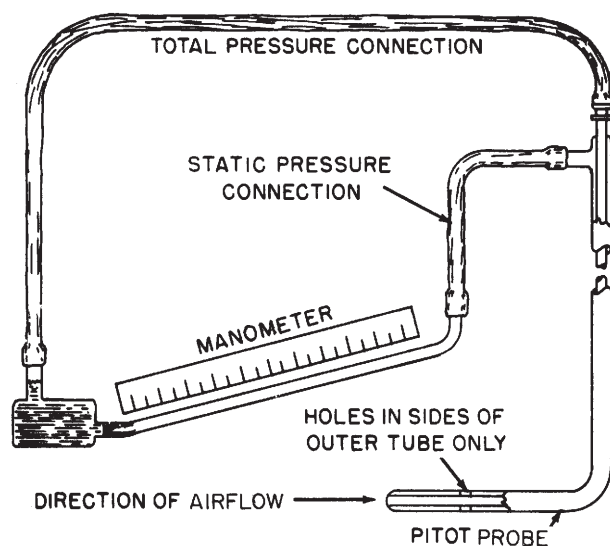
balancing a column of liquid of known weight against air pressure. The units of measure used are pounds per square inch, inches of mercury using mercury as the fluid, and inches of water using water as the fluid.

The simplest form of manometer is the basic U-tube type. Several variations of the basic type are presently used in air movement applications, for example, the inclined type (draft gauge) and the combination inclined and vertical type. An inclined manometer with a pitot probe is shown in figure 13-10. Many commercially installed central duct systems have permanently mounted manometers connected to duct interiors with static pressure tips.

### Rotating Vane Anemometer

The rotating vane anemometer (fig. 13-11) consists of a propeller or revolving vane connected through a gear train to a set of recording dials that indicate the number of linear feet of air passing in a measured length of time. It requires correction factors and frequent calibrations, and it is not as accurate as the velometer.

The primary application for a rotating vane anemometer is the measurement of grille velocities on heating, cooling, and ventilating installations; however, it may not be suitable for exhaust measurements or for measurements on very small grilles.



87.179

Figure 13-10.—Inclined manometer with pitot probe.

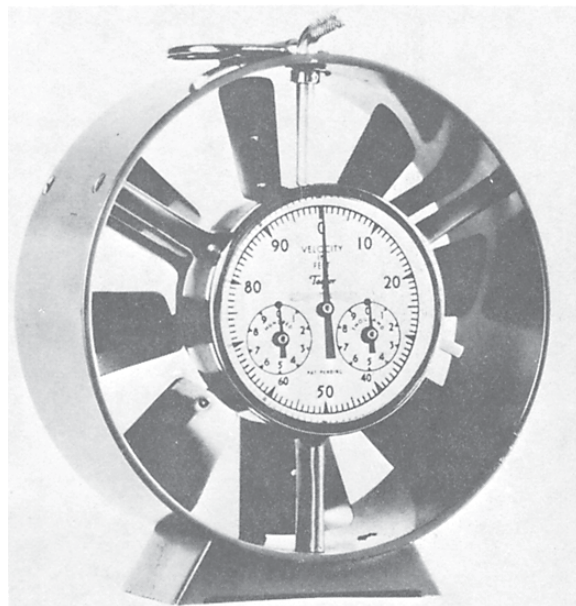
### Miscellaneous Instruments

In addition to the air balancing instruments, there are other miscellaneous devices required. Thermometers are necessary for making temperature measurements at various duct and room locations; a tachometer is needed to determine fan speeds; and a multimeter is needed to check fan motors for proper operation.

### PREPARATION FOR BALANCING

The following preliminary procedure is necessary before proper balancing can begin. These steps are general in nature and should apply to most situations.

1. Review applicable mechanical drawings and job specifications. This review will provide necessary data on the ducts, air handlers, and outlets. Information pertaining to design airflow can also be taken from these drawings.
2. Prepare a simple working sketch of the entire duct system showing dimensions, airflow volumes and velocities, and the location of all components such as dampers, fans, coils, and filters. Duct outlets should be numbered on the sketch starting at the farthest one from the fan



87.178

Figure 13-11.—Rotating vane anemometer.

and working back toward the fan. (See fig. 13-12.) The type of diffuser and the air delivery design of each outlet should be noted.

3. Obtain data pertinent to motors, fans, diffusers, and grilles that are not given on drawings. This can usually be taken from the manufacturer's identification plate located on the component. This information is useful during the balancing process for comparing measured results with design conditions.

4. Make a visual check of the system to ascertain that all fans are rotating correctly. Also, that air filters are clean and properly installed.

5. Place all dampers in the open position. This includes volume balancing dampers, splitter dampers, outlet dampers, and fire dampers.

6. Check all necessary instruments *prior* to starting the balancing procedure. Always follow the manufacturer's recommendations for checking the calibration of instruments.

## PROCEDURES FOR BALANCING

The procedures required for balancing most systems are similar. Balancing is a rigorous technique that, if properly done, yields excellent results. As with any set of procedures, each operation is necessary and must be performed in the correct sequence. The following procedures are general in nature and apply to most systems.

## Determine Fan Performance

The first step of the procedure is to determine fan performance. The purpose for this is to ensure that there is sufficient static pressure and air volume being handled at the fan before balancing is started. The fan's revolutions per minute (rpm), the voltage and amperage of the fan motor, the fan static pressure, and the system's total airflow are indications of fan performance.

The fan rpm can be measured by a tachometer as shown in figure 13-13. You should take several readings to ensure an accurate reading. The results can be compared with the design conditions to determine performance.

You should use a multimeter to determine if the operating voltage and amperage of the fan motor are within the range of rated voltage and amperage indicated on the motor nameplate. The measured results can either be compared or used to calculate the brake horsepower. Use the manufacturer's recommended calculation to determine the brake horsepower.

You can determine the fan static pressure by attaching a velometer and static pressure probe to test tap holes located on the inlet and discharge duct of the fan, as shown in figure 13-14. Fan static pressure is the static pressure at the outlet minus the total pressure in the fan inlet. This

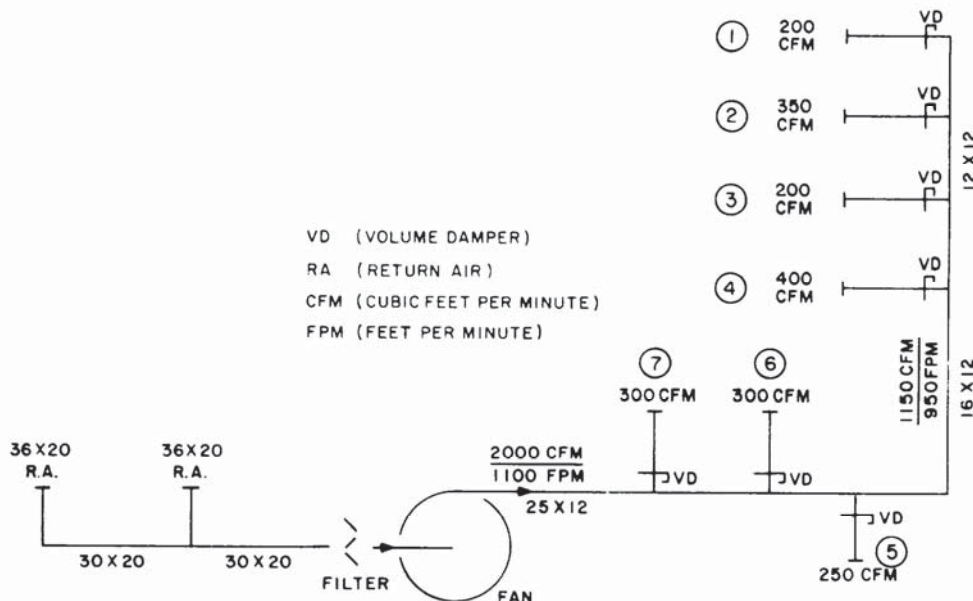


Figure 13-12.—Duct system working sketch.



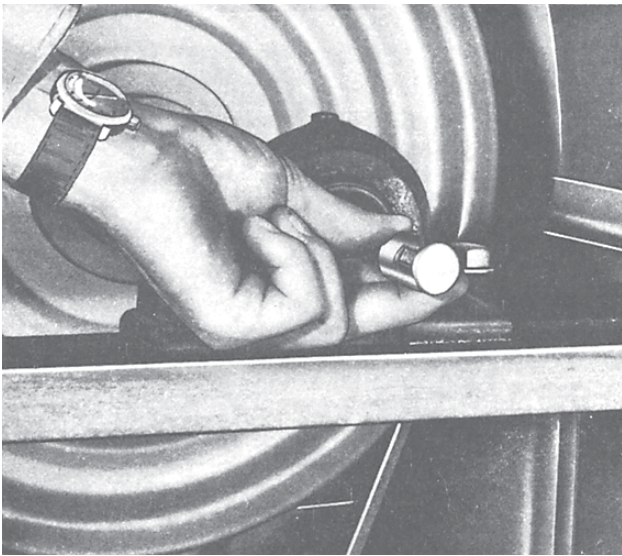


Figure 13-13.—Measuring fan rpm.

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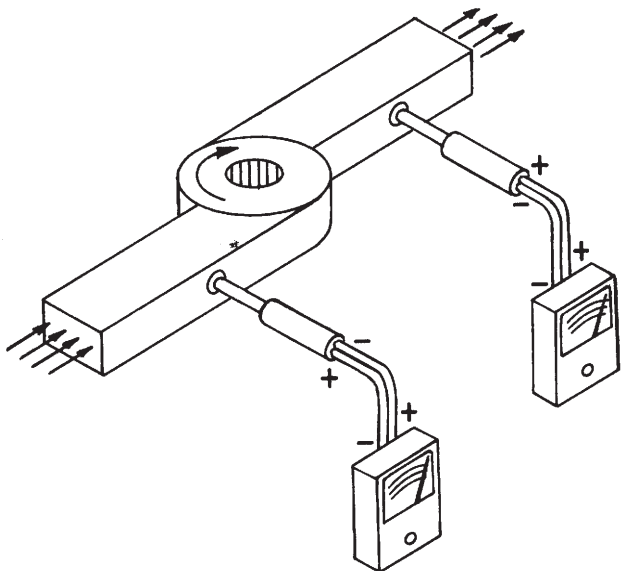


Figure 13-14.—Fan static pressure measurement.

87.264

test may not be necessary in the field; however, if it is, the results can be compared with the manufacturer's fan curve and system specifications to determine fan performance.

You can quickly locate problems caused by blockages in duct systems by performing static pressure readings. The total air volume in cubic

feet per minute (cfm) for a fan can be determined by the following procedures:

1. Downstream of the air handler, establish a point along the duct that has the longest straight run and drill test holes into the duct. Holes should be far enough downstream from any elbows or from the fan discharge to minimize the effect of turbulence. The holes must be closed and sealed after the test is completed.
2. Take velocity pressure readings using a pitot probe and manometer or velometer. For rectangular ducts, velocity readings are taken at the center of equally divided areas. On round ducts, readings are taken across each of two diameters on lines at right angles to each other. (See fig. 13-15.)
3. Calculate the cubic feet of air per minute by multiplying the average velocity pressure in feet per minute found in the above reading by the cross-sectional area of the duct in square feet. Total airflow in cfm = Average velocity in fpm x duct cross-sectional area in square feet.

The results are compared with design conditions to determine performance. Measured cfm should be approximately equal to design cfm plus 10 percent to allow for leakage.

In the event that fan performance is not consistent with design conditions, the necessary adjustments or repairs should be made at this point in the balancing procedure. For example,

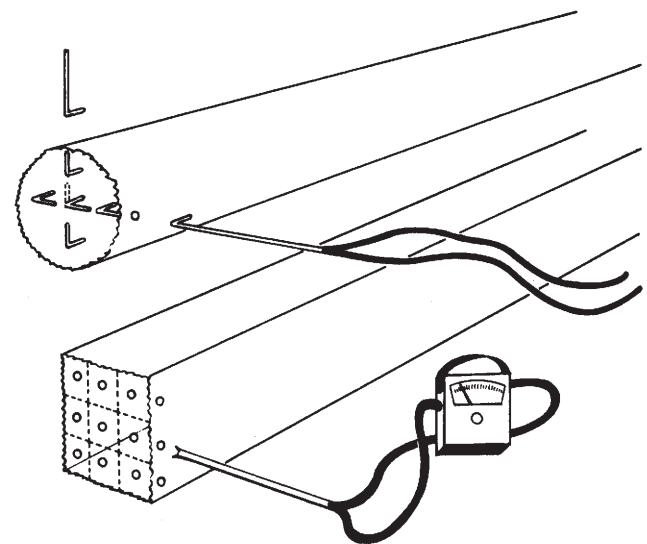


Figure 13-15.—Velocity pressure measurement.

87.265



the fan speed can be changed by adjusting the variable diameter motor pulley. Be careful to avoid operating the fan at a speed that overloads the motor. After adjustments or repairs, tests should be repeated to verify that the design conditions have been attained. Total air volume measurements should be repeated for all air-handling units on branch, return, and exhaust duct systems.

### **Duct and Outlet Adjustments**

You should use the same procedure for measuring total air volume to set the main splitter dampers on systems containing branch ducts. When main ducts, zone ducts, and branches are set for design air, the tests necessary for adjusting individual outlets can begin. When available, always follow the manufacturer's recommended procedure.

The final balancing procedure involves the adjustment of individual outlets to correspond with the manufacturer's design flow and system specifications. Begin with the last outlet on the branch farthest from the fan discharge and measure the velocity (or cfm). You can use either a velometer with the diffuser probe or an anemometer. If the cfm is below design, leave the damper open and proceed to the next outlet. If the cfm is greater than design, close the damper to obtain the desired results. In the same branch go to the next closest outlet, repeat the procedure, then continue the process with each outlet until you reach the main duct.

If applicable, you should complete the same procedure on the remaining branch ducts. Finally, total cfm of all outlets should agree with total cfm of all branches, and this grand total should agree with the air volume for the fan or fans. These figures should be within 3 to 7 percent of design conditions. You should check fan outputs and motor amperages to ensure that the motor is not in an overloaded condition. At this point, fan speed and horsepower, fan total air by velocity measurement, and total air by outlet volume measurements have been established for the specific operating condition of the system during the procedure. The system should be balanced for those conditions.