

- "R. D. Tutt: Modern trends in air distribution (*Refrigerating Engineering*, May 1953, p. 509).
- "W. W. Kennedy: Design factors in high velocity air distribution (*Heating and Ventilating*, January 1954, p. 83).
- "J. W. Kreutner: Can air conditioning be simplified in large buildings? (*Heating, Piping and Air Conditioning*, August 1954, p. 94).
- "Gardner Savage: Air conditioning an operating hotel (*Heating and Ventilating*, September 1954, p. 100).
- "C. M. Wilson: Handbook on high velocity air distribution (*Heating, Piping and Air Conditioning*, November 1954, p. 94). Discussions (*Heating, Piping and Air Conditioning*, December 1954, p. 73; February 1955, p. 69; March 1955, p. 99; June 1955, p. 82).
- "R. W. Waterfall: Air conditioning of multi-room buildings (*ASHAE Transactions*, Vol. 61, 1955, p. 233).
- "P. B. Gordon: Air conditioning multi-story buildings (*Heating, Piping and Air Conditioning*, April 1955, p. 112). Discussion (*Heating, Piping and Air Conditioning*, May 1955, p. 103).
- "N. S. Shataloff: Elements of dual duct design and performance (*ASHAE Transactions*, Vol. 62, 1956, p. 257).
- "N. J. Janisse: How to control high velocity double duct air systems (*Heating, Piping and Air Conditioning*, November 1955, p. 122 and December 1955, p. 100).
- "E. F. Snyder, Jr.: Self-actuated room control from high speed air (*ASHAE Transactions*, Vol. 62, 1956, p. 295).
- "High-velocity Air Distribution (collected papers read at Symposium at ASHAE 62nd Annual Meeting, January 25, 1956).
- "C. M. Ashley, S. F. Gilman, and R. A. Church: Branch-fitting performance at high velocity (*ASHAE Transactions*, Vol. 62, 1956, p. 279).
- "National Board of Fire Underwriters Standards (NBFU Pamphlet No. 90, p. 21).

BIBLIOGRAPHY

Fluid Flow (See Chapter 4)

- Hunter Rouse: *Elementary Mechanics of Fluids* (John Wiley & Sons, Inc., New York, 1946).
- J. C. Hunsaker and B. G. Rightmire: *Engineering Applications of Fluid Mechanics* (McGraw-Hill Book Co., New York, 1947).
- Clifford McClain: *Fluid Flow in Pipes* (The Industrial Press, New York, 1952).
- H. C. Berry: *Flow and Fan—Principles of Moving Air Through Ducts* (The Industrial Press, New York, 1954).
- R. J. S. Pigott: The flow of fluids in closed conduits (*Mechanical Engineering*, Vol. 55, 1935, p. 497).
- E. Kemler: A study of the data on the flow of fluids in pipes (*ASME Transactions*, Vol. 55, 1933, p. 7).

Flow of Air in Ducts

- F. C. Houghten, J. B. Schmieler, J. A. Zaloveik, and N. Ivandovic: ASHVE Research Report No. 1105—Frictional resistance to the flow of air in straight ducts (*ASHVE Transactions*, Vol. 45, 1939, p. 35).
- J. B. Schmieler, F. C. Houghten, and H. T. Olson: ASHVE Research Report No. 1154—Analysis of factors affecting duct friction (*ASHVE Transactions*, Vol. 46, 1940, p. 193).
- G. R. Whitnah and J. V. Borry: Pressure loss characteristics of small diameter round duct systems (*ASHVE JOURNAL Section, Heating, Piping and Air Conditioning*, November 1952, p. 111).
- H. G. Conn, W. G. Colborne, and W. G. Brown: ASHVE Research Report No. 1470—Pressure losses in 4-inch diameter galvanized metal duct and fittings (*ASHVE Transactions*, Vol. 59, 1953, p. 139).

Pressure Loss in Elbows

- F. L. Busby: Loss of pressure due to elbows in the transmission of air through pipes or ducts (*ASHVE Transactions*, Vol. 19, 1913, p. 366).
- Loring Wirt: New data for the design of elbows in duct systems (*General Electric Review*, Vol. 30, June 1927, p. 286).
- O. E. Parker: An investigation of pressure losses in air duct elbows (Northeastern University thesis, May 28, 1934).
- C. H. McLellan and W. A. Bartlett, Jr.: *Investigation of Air Flow in Right Angle Elbows in a Rectangular Duct* (National Advisory Committee for Aeronautics, *Advanced Restricted Report* L-328, October 1941).
- M. C. Stuart, C. F. Warner, and W. C. Roberts: ASHVE Research Report No. 1211—Pressure loss caused by elbows in eight-inch round ventilating duct (*ASHVE Transactions*, Vol. 48, 1942, p. 335).
- J. R. Weske: *Experimental Investigation of Velocity Distributions Downstream of Single Duct Bends* (National Advisory Committee for Aeronautics Technical Note 1471, January 1948).
- J. R. Weske: Investigations of the flow in curved ducts at large Reynolds numbers (*Applied Mechanics Journal*, December 1948, p. 344).
- R. K. Guthrie: How much pressure loss in round elbows? (*Heating, Piping and Air Conditioning*, March 1955, p. 130).
- R. D. Madison and R. M. Conner: Discussion (*Heating, Piping and Air Conditioning*, April 1955, p. 89).
- R. K. Guthrie: Discussion (*Heating, Piping and Air Conditioning*, June 1955, p. 81).

Pressure Loss in Divided-Flow Fittings

- H. H. Korst, H. A. Buckley, S. Konso, and R. W. Roose: ASHVE Research Report No. 1392—Fitting losses for extended-plenum forced air systems (*ASHVE Transactions*, Vol. 56, 1950, p. 259).
- J. W. Holl, S. F. Gilman, R. J. Martin, and S. Konso: ASHVE Research Report No. 1430—Pressure losses of take-offs for extended-plenum duct systems (*ASHVE Transactions*, Vol. 57, 1951, p. 419).
- L. G. Miller, C. H. Pesterfield, and R. J. Waalkes: Resistance of rectangular divided-flow fittings (*ASHAE Transactions*, Vol. 62, 1956, p. 145).

Duct Design

- L. G. Miller: ASHVE Research Report No. 1050—A rational method of duct design (*ASHVE Transactions*, Vol. 43, 1937, p. 71).
- Kirby Walker: Modern thinking applied to duct design (*Heating, Piping and Air Conditioning*, March 1949, p. 85; April 1949, p. 104; May 1949, p. 91; July 1949, p. 95; September 1949, p. 96; November 1949, p. 97; March 1950, p. 97; May 1950, p. 94).
- Pointers on air conditioning duct design and installation (*Reference Section, Heating and Ventilating*, October 1951).
- Peter Franck: Economical duct layouts (*Heating, Piping and Air Conditioning*, December 1952, p. 100).
- F. W. Hutchinson: *The Design of Aluminum Duct Systems* (Kaiser Aluminum & Chemical Sales, Inc., Oakland, California, 1954).
- R. W. Ruppert: Nomograph simplifies duct design (*HPAC Data Sheet, Heating, Piping and Air Conditioning*, July 1955, p. 127).
- V. J. Turecamo: To size ducts adequately select the right pressure drop (*Heating, Piping and Air Conditioning*, April 1956, p. 110).
- Miscellaneous
- R. H. Heilman and R. A. McArthur: Performance tests of asbestos insulating air ducts (*ASHVE Transactions*, Vol. 44, 1938, p. 197).

CHAPTER 22

FANS

Types, Fan Performance, Fan Laws, Fan Performance Curves, System Characteristics, Fan Arrangements, Fan Control, Motive Power, Fan Selection, Fan Installation, Fan Applications

IN HEATING, ventilating and air-conditioning practice, the devices used to produce air flow are variously known as fans, blowers, exhausters or propellers. The ASME Test Code¹ limits fans to those in which the fluid density change does not exceed 7 percent (one psi at atmospheric pressure) and labels as compressors those devices operating beyond that pressure range. Since air conditioning rarely requires pressures of over 1/4 psi, all such devices will be known as fans and the air will be considered non-compressible.

TYPES

Fans are divided into two general classifications: (1) *centrifugal or radial flow* in which the air flows radially through the impeller within a scroll type housing, and (2) *axial flow* in which the air flows axially through the impeller within a cylinder or ring.

Centrifugal fans are further subdivided into types denoted by the curvature or slope of the impeller blades, the angle of which largely determines the operating characteristics. For a given output, a forward inclination of blade indicates a relatively low speed of operation, and a backward inclination, a relatively high speed of operation. Many intermediate forms are also found.

Axial-flow fans are subdivided into types differentiated mainly by their enclosures and refinements of impellers and appurtenances. All types vary in shape, number and angles of blades; ratios of hub diameter to impeller diameter; materials and methods of fabrication, depending upon design and preference of manufacturer. *Tubeaxial* and *vaneaxial* fans, usually used against appreciable resistance, commonly have relatively large hubs and helical blades (the angle varies radially along the blade). The blades may be of uniform thickness, either flat or cambered, and either cast or made of plates; or they may be of air-foil sections, either cast or of double thickness sheet. Streamlining of both impeller and enclosure is common practice. *Vaneaxial* fans incorporate guide vanes to modify performance and increase efficiency. *Propeller* fans customarily used for free delivery, or against low resistance, also are found with a variety of blade configurations, but are simple in construction. They are merely mounted within a plate or ring.

The fan nomenclature in Fig. 1 has been standardized by the Air Moving and Conditioning Association.²

FAN PERFORMANCE

Fan performance is a statement of volume, total pressures, static pressures, speed, power input, mechanical efficiency, and static efficiency, at a stated density. These terms are

defined by the Air Moving and Conditioning Association³ as follows:

1. *Volume handled* by a fan is the number of cubic feet of air per minute expressed at fan outlet conditions.
2. *Total pressure* of a fan is the rise of pressure from fan inlet to fan outlet.
3. *Velocity pressure* of a fan is the pressure corresponding to the average velocity determination from the volume of air flow at the fan outlet area.
4. *Static pressure* of a fan is the total pressure diminished by the fan velocity pressure.
5. *Power output* of a fan is expressed in horsepower and is based on fan volume and the fan total pressure.
6. *Power input* to a fan is expressed in horsepower and is measured horsepower delivered to the fan shaft.
7. *Mechanical efficiency* of a fan is the ratio of power output to power input.
8. *Static efficiency* of a fan is the mechanical efficiency multiplied by the ratio of static pressure to the total pressure.
9. *Fan outlet area* is the inside area of the fan outlet.
10. *Fan inlet area* is the inside area of the inlet collar.

While the total pressure truly represents the actual pressure developed by the fan, the static pressure may best represent the useful pressure for overcoming resistance. In many installations, since the outlet velocity of the fan is greater than the duct velocity, some of the velocity pressure may be utilized by conversion to static pressure within the system. However, due to the uncertainty of the flow at the points of velocity change, the amount of conversion is seldom known and therefore, most fan tables list only the static pressure as available to overcome the system resistance.

According to the Standard Test Code⁴ the efficiencies may be determined by the formulas:

Mechanical (total) Efficiency =

$$\frac{0.0001573 \times (\text{cfm}) \times \text{total pressure (inches water)}}{\text{horsepower input}}$$

Static Efficiency =

$$\frac{0.0001573 \times (\text{cfm}) \times \text{static pressure (inches water)}}{\text{horsepower input}}$$

As the static pressure is often more useful than total pressure, static efficiency is likewise many times more useful than