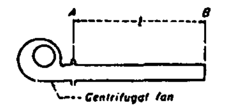
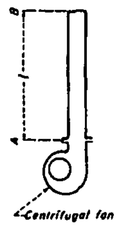
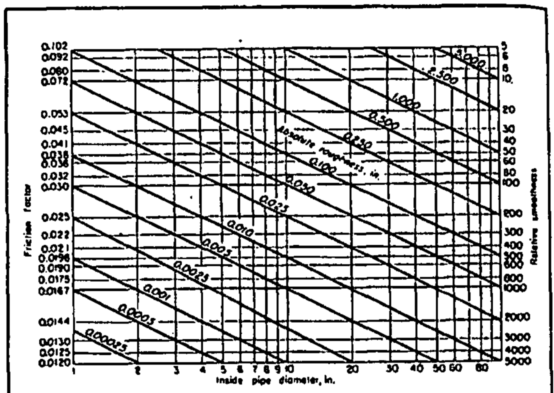


1 With zero air flow, pressure difference in horizontal duct between A and B equals zero

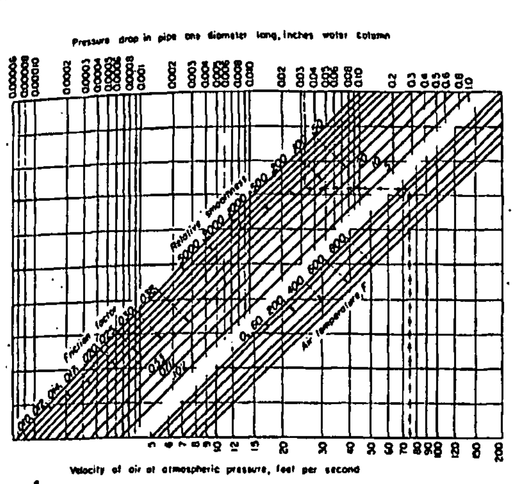


2 With zero air flow, pressure difference in vertical duct from A to B equals air weight



3 For fluids with high Reynolds numbers the friction factor depends only on pipe or duct diameter and absolute roughness as correlated in this air chart

4 Calculating chart for air-pressure drops in piping. Example: For air at atmospheric pressure and 60 F, flowing at a 75-fps velocity through a duct with a relative smoothness of 200, follow the trace and find a pressure drop of 0.031-in. water through distance equivalent to that of one-pipe diameter



NOMENCLATURE

a	pipe inclination angle, deg
d	fluid density, lb per cu ft
d_w	water density, lb per cu ft
D	pipe diameter, ft
f	friction factor
g	gravitational acceleration, ft per sec per sec
h	pressure drop, in. water
k	pipe roughness, ft
p	absolute pressure, psfa
Δp	pressure drop, psi
R	gas constant
R_e	Reynolds number
r	pipe radius, ft
s	pipe length, ft
t	fluid temperature, F
u	fluid velocity, fps
v	fluid viscosity, lb sec per sq ft

TABLE II—RANGE OF ABSOLUTE ROUGHNESS

Calculated From Test Data

Kind of pipe	Absolute roughness, k, in.
Cold-drawn pipe, brass, copper, lead	0.0005 to 0.0020
New steel pipe	0.003 to 0.018
New cast-iron pipe	0.007 to 0.042

How to Determine Reliable Air-Flow Data for Design of Duct Systems

To overcome wide disagreements between air-pressure drops as found on test and as predicted in handbooks, Arthur H Korn here describes method for finding data rationally that may be used with confidence in specifying both duct and fan sizes

▶ DESIGNERS with no experience in laying out specifications for air systems find themselves at a serious disadvantage trying to find reliable basic data. Charts, giving pressure drops for air flow through galvanized pipe and round sheet-metal ducts given in various reference hand-books, differ by enormous amounts. Data on air flow through metal ducts, riveted and lock-seamed, are apparently nonexistent since none have been published.

Absolute roughnesses, Table II, have been calculated from test data compiled by Kemler, but they show too great a range to be really useful. In Kent's *Mechanical Engineer's Handbook—Power*, a diagram for pressure drop in heating and ventilating ducts assumes a constant relative smoothness of 200 regardless of pipe diameter. Mark's *Mechanical Engineer's Handbook* gives a similar chart for velocities between 1200 and 2400 fpm and a constant absolute roughness of about k = 0.006, also regardless of diameter. This seems low since it is at the low end for new steel pipe, Table II. The number of joints generally determines the resistance, and sheet-metal-duct sections are usually only 2½ ft long. The absolute roughness is probably greater than the mean value for the new-steel-pipe range in Table II.

Friction factors, given in *Design of Industrial Exhaust Systems* by Alden, yield pressure drops of only one-fifth to one-seventh of those given by the previous references. These wide discrepancies call for development of a rational approach to the problem.

RATIONAL DESIGN BASIS

Pressure loss of a fluid, caused by friction with the pipe or duct through which it is moving, is generally small compared with the fluid's absolute pressure. The general case for a fluid flowing upward in an inclined pipe, forming an angle *a* with the horizontal, has a pressure drop* of:

$$\Delta p = \frac{dfu^2s}{D2g} + ds \sin a \qquad (1)$$

The last member of the equation represents the pressure caused by the weight of a column of fluid of the height, *s* sin *a*. It can be neglected for air at atmospheric conditions. Since this pressure difference in a vertical pipe already exists, Fig. 2, before air flow starts, it does not have to be overcome by the fan.

Since $\Delta p = d_w h/12$, equation (1) can be written for air flow as:

$$h = \frac{12dfu^2s}{2Dd_wg} \qquad (2)$$

Gas density depends on its pressure and temperature as given by the universal gas equation, $d = p/R(t + 460)$. Using this relation and transforming (2) to give the pressure drop in a pipe of a length equal to one diameter:

$$h\frac{D}{s} = \frac{6p}{gd_wR} \times \frac{fu^2}{t + 460} \qquad (3)$$

For atmospheric air, $p = 2117$ psf, and $R = 53.3$. Water density is 62.43 lb per cu ft, and $g = 32.17$ ft per sec per sec. Substituting these numerical values:

$$h\frac{D}{s} = 0.1188\frac{fu^2}{t + 460} \qquad (4)$$

Friction Factor. The friction factor *f* varies with air velocity, pipe size, air viscosity, air density and the pipe roughness. These quantities, excepting pipe roughness, are all related to the Reynolds number as in the following:

$$R_e = \frac{Dud}{gv} \qquad (5)$$

TABLE I—RANGE OF REYNOLDS NUMBERS AND VELOCITIES

For Accurate Use With Friction Factors at Atmospheric Pressure and Temperature

		Given values of f in second column are valid for Reynolds numbers greater than R_e and for fluid velocities greater than u, below.						If given values for f are used for Reynolds numbers as low as R'_e and for velocities as low as u' the greatest error will be less than E% above true value of friction factor.						
			Fluid velocity, u, fps.						Fluid velocity, u', fps.					
			Pipe diameter, in.						Pipe diameter, in.					
Relative smoothness r/k	Friction factor f*	Reynolds number R_e	3	6	12	24	48	Reynolds number R'_e	3	6	12	24	48	E %
15	0.0397	23,500	14	7	4	2	1	6,300	2	2	1	0.5	0.25	20
30	0.0433	53,800	33	16	8	4	2	6,300	4	2	1	0.5	0.25	18
60	0.0356	121,000	75	38	19	9	5	6,300	4	2	1	0.5	0.25	15
120	0.0287	271,000	168	84	42	21	10	16,200	10	5	2.5	1.0	0.5	14
240	0.0237	596,000	370	185	92	46	23	31,600	20	10	5.0	2.5	1.0	12
480	0.0198	1,303,000	808	404	202	101	50	63,000	40	20	10	5.0	2.5	11

* From equation (6)

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* For equation derivation see "Basic Equations For Fluid Motion And Pressure Drop In Pipes," by A H Korn, *Product Engineering*, May 1947, pp [illegible].