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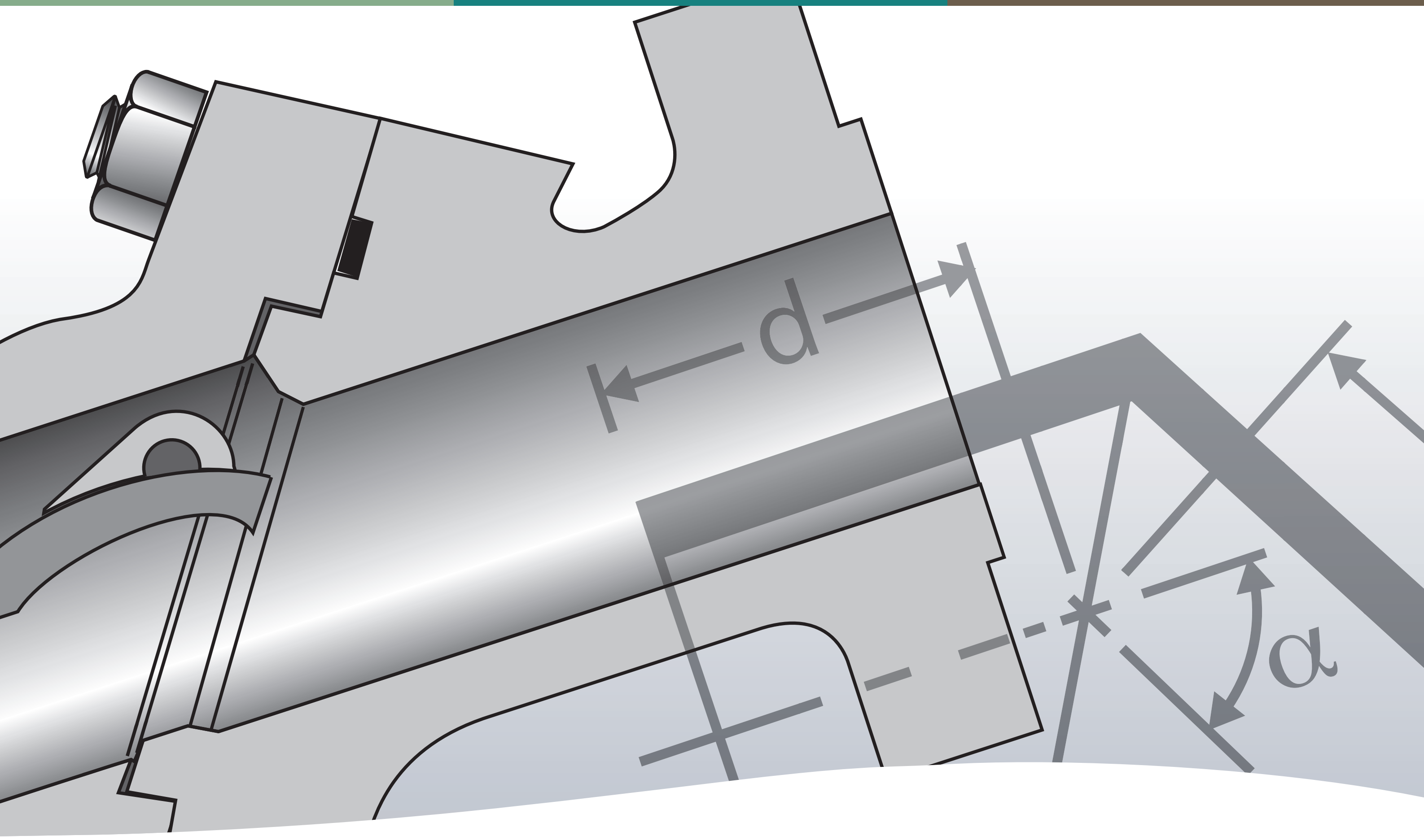

General Engineering Data

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Resistance Coefficient *K*, Equivalent Length L/D, and Flow Coefficient C_V

Pressure loss test data for a wide variety of valves and fittings are available from the work of numerous investigators. Extensive studies in this field have been conducted by Crane Laboratories. However, due to the time-consuming and costly nature of such testing, it is virtually impossible to obtain test data for every size and type of valve and fitting. It is therefore desirable to provide a means of reliably extrapolating available test information to envelope those items which have not been or cannot readily be tested. Commonly used concepts for accomplishing this are the "equivalent length **L/D**", "resistance coefficient ***K***", and "flow coefficient $\mathbf{C_V}$".

Pressure losses in a piping system result from a number of system characteristics, which may be categorized as follows:

1. Pipe friction, which is a function of the surface roughness of the interior pipe wall, the inside diameter of the pipe, and the fluid velocity, density and viscosity. For friction data, see page 4.
2. Changes in direction of flow path.
3. Obstructions in flow path.
4. Sudden or gradual changes in the cross-section and shape of flow path.

Velocity in a pipe is obtained at the expense of static head, and decrease in static head due to velocity is,

$$h_L = \frac{v^2}{2g}$$ **Equation 1**

which is defined as "velocity head". The resistance coefficient K in the equation,

$$h_L = K\frac{v^2}{2g}$$ **Equation 2**

therefore, is defined as the number of velocity heads lost due to a valve or fitting. It is always associated with the diameter in which the velocity occurs. In most valves or fittings, the losses due to friction (Category 1 above) resulting from actual length of flow path are minor compared to those due to one or more of the other three categories listed.

The resistance coefficient ***K*** is therefore considered as being independent of friction factor or Reynolds number, and may be treated as a constant for any given obstruction (i.e., valve or fitting) in a piping system under all conditions of flow, including laminar flow.

The same loss in straight pipe is expressed by the Darcy equation,

$$h_L = \left(f\frac{L}{D}\right)\frac{v^2}{2g}$$ **Equation 3**

It follows that,

$$K = \left(f\frac{L}{D}\right)$$ **Equation 4**

The ratio L/D is the equivalent length, in pipe diameters of straight pipe, that will cause the same pressure drop as the obstruction under the same flow conditions. Since the resistance coefficient ***K*** is constant for all conditions of flow, the value of **L/D** for any given valve or fitting must necessarily vary inversely with the change in friction factor for different flow conditions.

Equation 2 may be written in many forms depending upon the units In which flow conditions are expressed. Some of the more common and useful forms are,

$$h_L = 522\frac{Kq^2}{d^4} = 2.59 \times 10^{-3}\frac{KQ^2}{d^4}$$

$$\Delta P = 1.078 \times 10^{-4} K_{pv^2} = 3.62\frac{Kpq^2}{d^4}$$

$$\Delta P = 18 \times 10^{-6}\frac{KpQ^2}{d^4}$$

$$\Delta P = 28 \times 10^{-8}\frac{KW^2\overline{V}}{d^4}$$

$$\Delta P = 6.05 \times 10^{-10}\frac{K(q'h)^2 TS_g}{d^4 P'}$$

$$\Delta P = 16.33 \times 10^{-10}\frac{K(q'h)^2 S_{g^2}}{d^4 p}$$

For compressible flow with $\mathbf{h_L}$ or **ΔP** greater than 10% of the inlet absolute pressure, refer to Crane Technical Paper No. 410 —"Flow of Fluids Through Valves, Fittings, and Pipe".

Analysis of flow test data for different sizes of the same items indicates that the resistance coefficient K for any given line of valves and fittings tends to vary with size, in the same manner as does the friction factor for straight pipe at flow conditions resulting in Reynolds numbers falling in the zone of complete turbulence.

As previously stated, the resistance coefficient ***K*** is always associated with the diameter In which the velocity in the term **v²/2g** occurs. The values in the "***K***" Factor Table (pages 4 to 7) are associated with the Internal diameter of the following pipe schedule numbers for the various ANSI Classes of valves and fittings.

Class 300 and lower	Schedule 40
Class 400 and 600	Schedule 80
Class 900	Schedule 120
Class 1500	Schedule 160
Class 2500 (sizes ½ to 6")	Schedule 160
Class 2500 (sizes 8" and up)	XXS

When the resistance coefficient ***K*** is used in flow equation 2, or any of its equivalent forms, the velocity and internal diameter dimensions used in the equation must be based on the dimensions of these schedule numbers regardless of the pipe with which the valve may be installed.

An alternate procedure which yields identical results for Equation 2 is to adjust ***K*** in proportion to the fourth power of the diameter ratio, and to base values of velocity or diameter on the internal diameter of the connecting pipe.

$$K_a = K_b\left(\frac{d_a}{d_b}\right)^4$$ **Equation 5**

Subscript ***"a"*** defines ***K*** and ***d*** with reference to the internal diameter of the connecting pipe.

Subscript ***"b"*** defines ***K*** and ***d*** with reference to the internal diameter of the pipe for which the values of ***K*** were established, as given in the foregoing list of pipe schedule numbers.

General Engineering Data

Resistance Coefficient K, Equivalent Length L/D, and Flow Coefficient C_V — cont.

When a piping system contains more than one size of pipe, valves, or fittings, Equation 5 may be used to express all resistances in terms of one size. For this case, subscript "a" relates to the size with reference to which all resistances are to be expressed, and subscript "b" relates to any other size in the system.

It has been found convenient in some branches of the valve industry, particularly in connection with control valves, to express the valve capacity and the valve flow characteristics in terms of the flow coefficient Cv.

The Cv coefficient of a valve is defined as the flow of water at 60 F, in gallons per minute, at a pressure drop of one pound per square inch across the valve.

By the substitution of appropriate equivalent units in the Darcy equation, it can be shown that,

$$C_v = \frac{29.9d^2}{\sqrt{K}}$$

Equation 6

Also, the quantity (gpm) of liquids of low viscosity that will flow through the valve can be determined from:

$$Q = C_v\sqrt{\Delta P\left(\frac{62.4}{P}\right)} = 7.9\,C_v\sqrt{\frac{\Delta P}{P}}$$

Equation 7

Laminar Flow Conditions

In the usual piping installation, the flow will change from laminar to turbulent in the range of Reynolds numbers from 2000 to 4000, defined in the Friction Factor Chart (page 4) as the critical zone. The lower critical Reynolds number of 2000 is usually recognized as the upper limit for the application of Poiseuille's law for laminar flow in straight pipes,

$$h_L = 0.0962\left(\frac{\mu L v}{d^2 \rho}\right)$$

Equation 8

which is identical to Equation 3 when the value of the friction factor for laminar flow, $f = 64/R_e$, is factored into it. Laminar flow at Reynolds numbers above 2000 is unstable, and in the critical zone and lower range of the transition zone, turbulent mixing and laminar motion may alternate unpredictably.

Equation 2 (**$h_L = Kv^2/2g$**) is valid for computing head loss due to valves and fittings for all conditions of flow, including laminar flow, using resistance coefficient K as given in the "***K***" Factor Table (pages 4 to 7).

When Equation 2 is used to determine the losses in straight pipe, it is necessary to compute the Reynolds number in order to establish the friction factor f, to be used to determine the value of the resistance coefficient ***K*** for the pipe in accordance with Equation 4 (***K=fL/D***).

Reduced Seat Valves

Valves are often designed with reduced seats, and the transition from seat to valve ends may be either abrupt or gradual. Straight-through types such as gate and ball valves so designed with gradual transition are sometimes referred to as venturi valves. Formulas (page 4) for computing resistance coefficient K for several types of reduced seat valves have been found to yield results that have excellent correlation with test results. It will be noted that these computed K values are a function of the ratio β (beta) of the seat diameter to the internal diameter of the connecting pipe.

Procedure for determining K for reduced seat globe and angle valves is also applicable to throttled globe and angle valves. For this case the value of β must be based upon the square root of the ratio of areas,

$$\beta = \sqrt{\frac{a_1}{a_2}}$$

where:

a_1 defines area at most restricted point in flow path

a_2 defines internal area of connecting pipe.

*The use of β as a factor is purely empirical based on test information and it has no theoretical basis.

Proper Sizing of Check and Foot Valves

Many difficulties encountered with check valves, both lift and swing types, or with foot valves, are due to oversizing which results in noisy operation and premature wear of moving parts. The minimum velocity required to lift the disc to the full-open and stable position has been determined by test for numerous types of check and foot valves, and is given on pages 5 and 6 expressed in terms of a constant times the square root of the specific volume of the fluid being handled, making it applicable for use with any fluid.

Sizing check and foot valves on the basis of the specified minimum velocity for full disc lift will often result in valves smaller in size than the pipe in which they are installed, but the pressure drop will be little, if any, higher than if a full size valve is used with the disc not fully open. The losses due to sudden or gradual contraction and expansion which will occur in such installations with bushings, reducing flanges or tapered reducers can be readily calculated from the data given on page 5.

Representative Resistance Coefficient K for Valves and Fittings

K is based on use of schedule pipe as listed on page 2.

Pipe Friction Data for Schedule 40 Clean Commercial Steel Pipe with Flow in Zone of Complete Turbulence

Nominal Size	½″	¾″	1″	1¼″	1½″	2″	2½″	3″	4″	5 , 6″	8″	10-14″	16-22″	24-36″
Friction Factor (f_T)	.026	.024	.022	.021	.020	.019	.018	.017	.016	.015	.014	.013	.012	.011

Formulas For Calculating K Factor For Valves and Fittings with Reduced Port*

$$f_T = \frac{0.25}{\left[\log\left(\frac{\varepsilon/D}{3.7}\right)\right]^2}$$

Formula 1

$$K_2 = \frac{0.8\left(\sin\frac{\theta}{2}\right)\left(1-\beta^2\right)}{\beta^4} = \frac{K_1}{\beta^4}$$

Formula 2

$$K_2 = \frac{0.5\left(1-\beta^2\right)\sqrt{\sin\frac{\theta}{2}}}{\beta^4} = \frac{K_1}{\beta^4}$$

Formula 3

$$K_2 = \frac{2.6\left(\sin\frac{\theta}{2}\right)\left(1-\beta^2\right)^2}{\beta^4} = \frac{K_1}{\beta^4}$$

Formula 4

$$K_2 = \frac{\left(1-\beta^2\right)^2}{\beta^4} = \frac{K_1}{\beta^4}$$

Formula 5

$$K_2 = \frac{K_1}{\beta^4} + \text{Formula 1} + \text{Formula 3}$$

$$K_2 = \frac{K_1 + \sin\frac{\theta}{2}\left[0.8\left(1-\beta^2\right) + 2.6\left(1-\beta^2\right)^2\right]}{\beta^4}$$

- Use K furnished by valve or fitting supplier when available

Formula 6

$$K_2 = \frac{K_1}{\beta^4} + \text{Formula 2} + \text{Formula 4}$$

$$K_2 = \frac{K_1 + 0.5\sqrt{\sin\frac{\theta}{2}}\left(1-\beta^2\right) + \left(1-\beta^2\right)^2}{\beta^4}$$

Formula 7

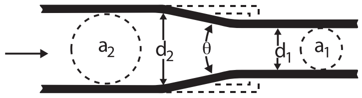
$$K_2 = \frac{K_1}{\beta^4} + \beta\ (\text{Formula 2} + \text{Formula 4}) \qquad \text{When } \theta = 180^{o}$$

$$K_2 = \frac{K_1 + \beta\left[0.5\left(1-\beta^2\right) + \left(1-\beta^2\right)^2\right]}{\beta^4}$$

$$\beta = \frac{d_1}{d_2} \qquad \beta^2 = \left(\frac{d_1}{d_2}\right)^2 = \frac{a_1}{a_2}$$

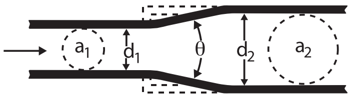
- Subscript 1 defines dimensions and coefficients with reference to the smaller diameter.
- Subscript 2 refers to the larger diameter.

Sudden and Gradual Contraction



if $\theta \lesssim 45°$ . . . . .K_2 = Formula 1
$45° \lesssim \theta \lesssim 180°$ . . . . .K_2 = Formula 2

Sudden and Gradual Enlargement



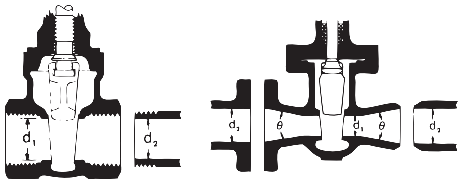
if $\theta \lesssim 45°$ . . . . .K_2 = Formula 3
$45° \lesssim \theta \lesssim 180°$ . . . . .K_2 = Formula 4

Representative Resistance Coefficient K for Valves and Fittings

K is based on use of schedule pipe as listed on page 2.

Gate Valves

Wedge Disc, Double Disc, or Plug Type

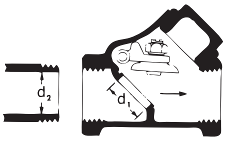


If: $\beta = 1, \theta = 0$ . . . . $K_1 = 8\, f_T$

$\beta < 1$ and $\theta \lesssim 45°$ . . . . K_2 = Formula 5

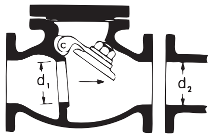
$\beta < 1$ and $45° < \theta \lesssim 180°$. . . . . K_2 = Formula 6

Swing Check Valves



$K_1 = 100 f_T$

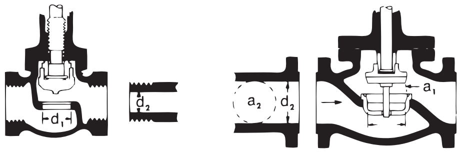
Minimum pipe velocity
(fps) for full disc lift
$= 35\sqrt{\bar{V}}$



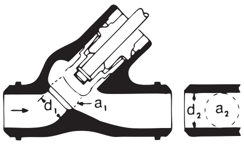
$K_1 = 50 f_T$

Minimum pipe velocity
(fps) for full disc lift
$= 60\sqrt{\bar{V}}$ except
U/L listed $= 100\sqrt{\bar{V}}$

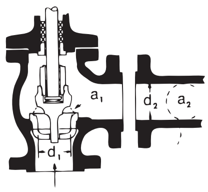
Globe And Angle Valves



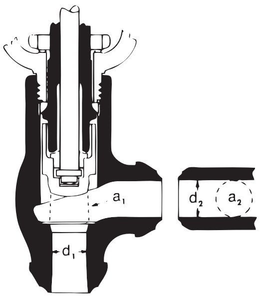
if: $\beta = 1 \ldots K_1 = 340 f_T$



if: $\beta = 1 \ldots K_1 = 55 f_T$



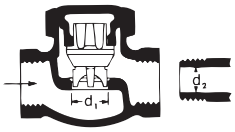
if: $\beta = 1 \ldots K_1 = 150 f_T$



if: $\beta = 1 \ldots K_1 = 55 f_T$

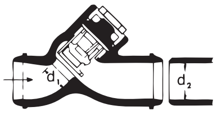
All globe and angle valves,
whether reduced seat or throttled,
If: $\beta < 1 \ldots K_2$ = Formula 7

Lift Check Valves



if: $\beta = 1 \ldots K_1 = 600 f_T$ if: $\beta < 1 \ldots K_2$ = Formula 7

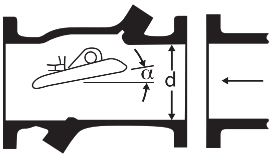
Minimum pipe velocity (fps) for full disc lift
$= 40\beta^2\sqrt{\bar{V}}$



if: $\beta = 1 \ldots K_1 = 55 f_T$ if: $\beta < 1 \ldots K_2$ = Formula 7

Minimum pipe velocity (fps) for full disc lift
$= 140\beta^2\sqrt{\bar{V}}$

Tilting Disc Check Valves



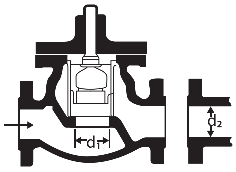
	$\alpha = 5°$	$\alpha = 15°$
Sizes 2 to 8″ … $K =$	$40 f_T$	$120 f_T$
Sizes 10 to 14″ … $K =$	$30 f_T$	$90 f_T$
Sizes 16 to 48″ … $K =$	$20 f_T$	$60 f_T$
Minimum pipe velocity (fps) for full disc lift =	$80\sqrt{\bar{V}}$	$30\sqrt{\bar{V}}$

Representative Resistance Coefficient K for Valves and Fittings

K is based on use of schedule pipe as listed on page 2.

Stop Check Valves

Globe and Angle Type



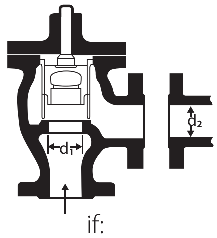
if:

$\beta = 1 \ldots K_1 = 400\, f_T$

$\beta < 1 \ldots K_2 =$ Formula 7

Minimum pipe velocity (fps) for full disc lift

$= 55\, \beta^2 \sqrt{\bar{V}}$



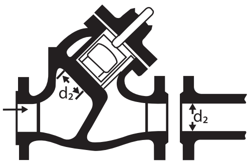
if:

$\beta = 1 \ldots K_1 = 200\, f_T$

$\beta < 1 \ldots K_2 =$ Formula 7

Minimum pipe velocity (fps) for full disc lift

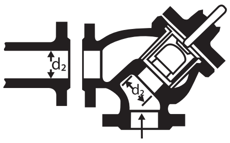
$= 75\, \beta^2 \sqrt{\bar{V}}$



if:

$\beta = 1 \ldots K_1 = 300\, f_T$

$\beta < 1 \ldots K_2 =$ Formula 7



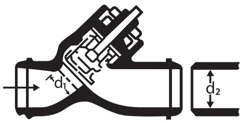
if:

$\beta = 1 \ldots K_1 = 350\, f_T$

$\beta < 1 \ldots K_2 =$ Formula 7

Minimum pipe velocity (fps) for full disc lift

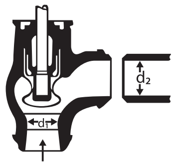
$= 60\, \beta^2 \sqrt{\bar{V}}$



if:

$\beta = 1 \ldots K_1 = 55\, f_T$

$\beta < 1 \ldots K_2 =$ Formula 7



if:

$\beta = 1 \ldots K_1 = 55\, f_T$

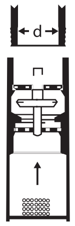
$\beta < 1 \ldots K_2 =$ Formula 7

Minimum pipe velocity (fps) for full disc lift

$= 140\, \beta^2 \sqrt{\bar{V}}$

Foot Valves with Strainer

Poppet Disc

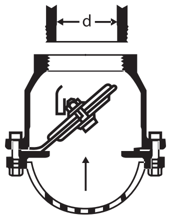


$K = 420\, f_T$

Minimum pipe velocity (fps) for full disc lift

$= 15 \sqrt{\bar{V}}$

Hinged Disc

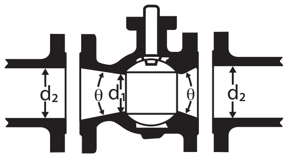


$K = 75\, f_T$

Minimum pipe velocity (fps) for full disc lift

$= 35 \sqrt{\bar{V}}$

Ball Valves

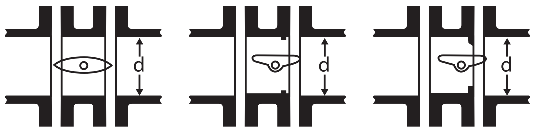


If: $\beta = 1, \theta = 0 \ldots\ldots\ldots\ldots K_1 = 3\, f_T$

$\beta < 1$ and $\theta \lesssim 45° \ldots\ldots\ldots\ldots K_2 =$ Formula 5

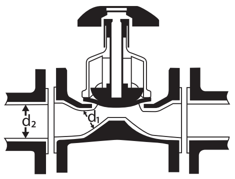
$\beta < 1$ and $45° < \theta \lesssim 180° \ldots\ldots\ldots K_2 =$ Formula 6

Butterfly Valves



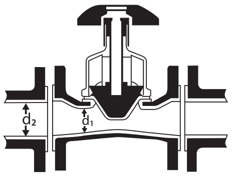
Size Range	Centric	Double Offset	Triple Offset
2″ – 8″	$K = 45 f_T$	$K = 74 f_T$	$K = 218 f_T$
10″ – 14″	$K = 35 f_T$	$K = 52 f_T$	$K = 96 f_T$
16″ – 24″	$K = 25 f_T$	$K = 43 f_T$	$K = 55 f_T$

Diaphragm Valves



Weir:

$\beta = 1 \ldots K_1 = 149\, f_T$



Straight Through

$\beta = 1 \ldots K_1 = 39\, f_T$

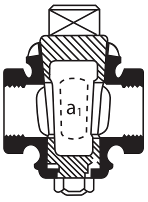
General Engineering Data

Representative Resistance Coefficient K for Valves and Fittings

K is based on use of schedule pipe as listed on page 2.

Plug Valves And Cocks

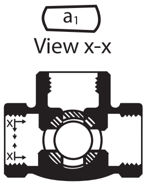
Straight Way



if: $\beta = 1$

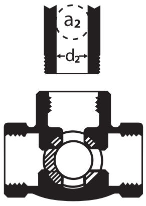
$K_1 = 18 f_T$

3-Way



if: $\beta = 1$

$K_1 = 30 f_T$

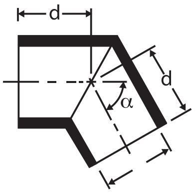


if: $\beta = 1$

$K_1 = 90 f_T$

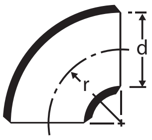
if: $\beta < 1$ ... K_2 = Formula 6

Mitre Bends



α	K
0°	$2 f_T$
15°	$4 f_T$
30°	$8 f_T$
45°	$15 f_T$
60°	$25 f_T$
75°	$40 f_T$
90°	$60 f_T$

90° Pipe Bends and Flanged or Butt-Welding 90° Elbows



r/d	K	r/d	K
1	$20 f_T$	8	$24 f_T$
1.5	$14 f_T$	10	$30 f_T$
2	$12 f_T$	12	$34 f_T$
3	$12 f_T$	14	$38 f_T$
4	$14 f_T$	16	$42 f_T$
6	$17 f_T$	20	$50 f_T$

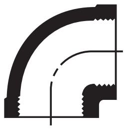
The resistance coefficient, K_B, for pipe bends other than 90° may be determined as follows:

$$K_B = (n - 1)\left(0.25\,\pi f_T \frac{r}{d} + 0.5K\right) + K$$

n = number of 90° bends
K = resistance coefficient for one 90° bend (per table)

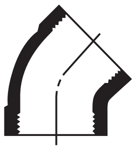
Standard Elbows

90°



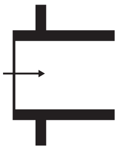
$K = 30 f_T$

45°



$K = 16 f_T$

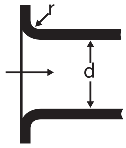
Pipe Entrance



$K = 0.78$

r/d	K
0.00*	0.5
0.02	0.28
0.04	0.24
0.06	0.15
0.10	0.09
0.15 & up	0.04

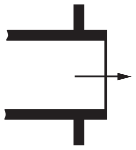
*Sharp-edged



For K = see table

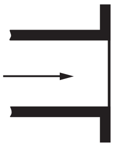
Pipe Exit

Projecting



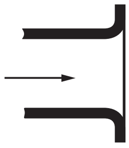
$K = 1.0$

Sharp-Edged



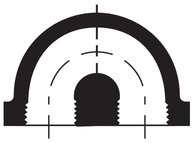
$K = 1.0$

Rounded



$K = 1.0$

Close Pattern Return Bends



$K = 50 f_T$

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Nomenclature

α = cross sectional area of pipe or orifice, or flow area in valve, in square inches

C_V = flow coefficient for valves: expresses flow rate in gallons per minute of 60 F water with 1.0 psi pressure drop across valve

D = internal diameter of pipe, in feet

d = internal diameter of pipe, in inches

f_T = friction factor in zone of complete turbulence

g = acceleration of gravity = 32.2 feet per second per second

H = total head, in feet of fluid

h = static pressure head existing at a point, in feet of fluid

h_L = loss of static pressure head due to fluid flow, in feet of fluid

K = resistance coefficient or velocity head loss in the formula, $h_L = KV^2/2g$

L = length of pipe, in feet

L/D= equivalent length of a resistance to flow, in pipe diameters

P = pressure, in pounds per square inch gauge

Q = rate of flow, in gallons per minute

q = rate of flow, in cubic feet per second at flowing conditions

q’ = rate of flow, in cubic feet per second at standard conditions (14.7 psia and 60F)

S = specific gravity of liquids at specified temperature relative to water at standard temperature (60 F)

S_g = specific gravity of a gas relative to air = the ratio of the molecular weight of the gas to that of air

T = absolute temperature, in degrees Rankine (460 + t)

t = temperature, in degrees Fahrenheit

V = specific volume of fluid, in cubic feet per pound

v = mean velocity of flow, in feet per second

W = rate of flow, in pounds per hour

β = ratio of small to large diameter in orifices and nozzles, and contractions or enlargements in pipes

Δ = differential between two points

p = weight density of fluid, pounds per cubic ft

p’ = density of fluid grams per cubic centimeter

θ = angle of convergence or divergence in enlargements or contractions in pipes

Subscripts for Diameter

(1) . . . defines smaller diameter

(2) . . . defines larger diameter

Subscripts for Fluid Property

(1) . . . defines inlet (upstream) condition

(2) . . . defines outlet (downstream) condition

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