Equivalent Lengths of Pipe Fittings and Valves

Tables of Equivalent Lengths in Plastic and Steel Pipe

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1. Introduction

A previous article published by Katmar Software discussed the available methods (including the Equivalent Length Method) for calculating the pressure drops in pipe fittings and valves. The present article gives Equivalent Length values for a wide variety of pipe fittings and valves that can be used as described in that article.

The **definition of the Equivalent Length** of a pipe fitting is the length of pipe of the same size as the fitting that would give rise to the same pressure drop as the fitting. It has been found experimentally that for a given type of fitting (e.g. a long radius elbow) the Equivalent Length (L_e) is larger for larger fittings. **But** it is found that if L_e is divided by the inside diameter of the pipe (D) the ratio (L_e/D) that is obtained is virtually constant for that type of fitting. This has 2 advantages - it dramatically decreases the amount of information that is required and it also removes the problem of the units used to measure lengths and diameters since the ratio L_e/D is dimensionless. The tables of data in this article can therefore be used with any system of units, provided that the pipe inside diameter (D) and the Equivalent Length (L_e) are measured in the same units.

As an example, consider a 2" globe valve with L_e/D = 320 when installed in commercial steel pipe. If the valve is connected to 2" Sch 40 steel pipe with an inside diameter of 0.172 ft (or 52.5 mm) then the Equivalent Length of the globe valve in terms of the steel pipe is 320 x 0.172 = 55 ft (or 320 x 52.5 = 16800 mm).

It should be noted that the pressure drop across a fitting is determined mainly by how the geometry of the fitting causes changes in the direction and velocity of the fluid flow. On the other hand, the friction between the fluid and the fitting walls has a relatively minor effect on the pressure drop. This means that the material of construction of the fitting has very little effect on the pressure drop and (for example) a plastic globe valve will have the same pressure drop as a steel valve with the same geometry (and of course for the same flow of the same fluid).

However, the length of pipe that would give a pressure drop equivalent to the globe valve would depend strongly on the roughness of that pipe. It is therefore important that Equivalent Lengths be expressed in terms of the actual pipe that is connected to the fitting. This concept is described in more detail in the previously mentioned article.

Although Equivalent Length Values for commercial steel pipe are easy to find, there is much less Equivalent Length data available for plastic materials such as PVC, CPVC, HDPE and GRP/FRP. The Tables given below cover a comprehensive range of pipe fittings and also cover the range of pipe surface roughnesses that are encountered in typical industrial applications. This will allow engineers to apply the Equivalent Length Method more confidently to estimate the pressure drops across pipe fittings.

2. Equivalent Length Values for Bends, Tees and Valves

When the pressure drop across a fitting is expressed in terms of Resistance Coefficients (K values) it is found that the K value varies with the size of the fitting and the Reynolds Number. The best method available at present to model these variations is the

Darby 3-K Method. Unfortunately it requires the engineer to have 3 constants for every type of fitting, and the calculations involved are beyond what can be done without a spreadsheet or dedicated computer program.

Fortunately it is found that changes in fitting size and Reynolds Number result in much smaller variations in the Equivalent Length / Diameter ratio than in the K value. If less accuracy is required, the pressure drops can be calculated using only a single constant for each type of fitting (i.e. the Equivalent Length / Diameter ratio) that covers **all sizes and all Reynolds Numbers**. This makes the Equivalent Length Method suitable for preliminary manual calculations.

For the final, accurate design calculations it is preferable to use a specialist computer program like AioFlo, which uses the rigorous 3-K Method. In fact AioFlo makes rigorous calculations easier and quicker to do than doing them by hand using the Equivalent Length Method, and you get full accuracy as well. But there are times when the Equivalent Length Method is useful, so it is worth having access to these Tables of Equivalent Lengths.

The values in the Table below were generated from Resistance Coefficients (K values) calculated by the AioFlo Piping Hydraulics program, using the pipe surface roughnesses given in the Table. Because Equivalent Length / Diameter ratios are not truly constant for changes in fitting size and Reynolds Number you should **expect errors of up to 30% when used for Turbulent Flow and up to 50% in Laminar Flow**. Of course there are significant variations in pressure drop between proprietary devices like valves made by different manufacturers, but at the stage when you are doing preliminary calculations the final supplier choices may not have been made and you have to rely on generic data. The pressure drops across the fittings are usually a minor part of the overall pressure drop and these errors are "diluted" by the pressure drops that you can calculate accurately - such as the straight pipe and the static head.

Note that the values in the table below are L_e/D ratios. Many published tables give actual lengths for each size of fitting, rather than a single ratio as here. Please be aware of this distinction when comparing various data sources. Also, please be aware that some authors (myself included!) sometimes refer to the L_e/D ratio simply as the Equivalent Length instead of the more correct Equivalent Length / Diameter Ratio.

Fittings	**Rigid PVC/HDPE e = 0.005 mm**	**GRP/FRP e = 0.02 mm**	**Commercial Steel e = 0.05 mm**	**Spiral Weld Steel e = 0.1 mm**
Threaded bends				
90ï¿½ elbow, r/d=1	37	34	30	26
45ï¿½ elbow, r/d=1	20	18	16	14
Welded bends				
90ï¿½ elbow, sharp bend	69	63	55	49
90ï¿½ elbow, r/d=1	23	21	19	16
90ï¿½ elbow, r/d=1.5	17	15	13	12
90ï¿½ elbow, r/d=2	14	13	11	10
45ï¿½ elbow, sharp bend	22	20	18	16
45ï¿½ elbow, r/d=1	17	16	14	12
45ï¿½ elbow, r/d=1.5	12	11	9.4	8.3
Threaded tees				
Tee, straight through	25	23	20	18
Tee, through branch	75	68	60	53
Welded tees				
Tee, square, straight through	0	0	0	0
Tee, square, through branch	87	79	70	61
Tee, radiused, straight through	13	12	10	9
Tee, radiused, through branch	72	65	57	50
Valves / Strainers				
Globe valve, full open	400	370	320	280
Gate valve, full open	9	8.5	7.5	6.6
Ball valve, full bore	3.3	3.0	2.6	2.3
Ball valve, reduced bore	31	28	25	22
Plug valve, 2-way	21	19	17	15

Fittings	Rigid PVC/HDPE e = 0.005 mm	GRP/FRP e = 0.02 mm	Commercial Steel e = 0.05 mm	Spiral Weld Steel e = 0.1 mm
Plug valve, 3-way, straight through	36	32	29	25
Plug valve, 3-way, through branch	100	95	84	74
Diaphragm valve, weir type	200	190	160	140
Butterfly valve	46	42	37	32
Lift check valve	700	640	560	490
Swing check valve	120	110	95	85
Wafer disk check valve	530	480	420	370
Y-strainer, clean	300	280	250	220

Table of Equivalent Lengths (Le/D) for Fittings in Plastic and Steel Pipe

3. Equivalent Length Values for Reducers (Turbulent Flow Only)

The pressure drop across a reducer is not often modeled using the Equivalent Length Method because reducers have 2 characteristic diameters. Also, the Equivalent Lengths for reducers are not as constant across changes in size and Reynolds Numbers as they are for the fittings listed in section 2 above. And of course the pressure drop through a reducer is different when the flow is from the large end to the small than it is with reverse flow.

Nevertheless, reducers are commonly used fittings and it is necessary to be able to model their pressure losses to some degree if we are going to use the Equivalent Length Method at all. We can do this if we use the ratio of the downstream diameter to the upstream diameter to specify a reducer as a particular fitting with its own Equivalent Length. Although the fittings in Section 2 above each had only one Equivalent Length we will have to accept that reducers will have 2 Equivalent Lengths - one for each flow direction.

The Equivalent Lengths in the Tables below can be expected to give accuracies of 50% or better. While this may sound extremely poor, it does at least give an indication of whether the pressure drop across the reducer is a significant portion of the overall pressure drop. This will give the engineer a basis on which to decide whether or not further work is justified or required to be able to come to a sufficiently accurate result. If better accuracy is required the more sophisticated methods as implemented in AioFlo should be considered. The Equivalent Length Method for reducers can **only be used for turbulent flow** (Reynolds Number > 4000).

Steel pipe reducers are made with well rounded transitions between the straight and tapered portions. This significantly decreases the pressure drop when the reducer is used in the converging mode - i.e. with flow from the larger diameter towards the smaller diameter. Commonly available plastic reducers are not made this way. Plastic reducers generally have sharp corners between the straight and tapered portions, and the tapers are usually very steep. The Equivalent Lengths given below for plastic reducers are based on a sudden contraction. This may be a bit conservative, but in the absence of better data this gives a "safe" estimate. Equivalent Lengths are also given for sudden contractions in steel pipe and for smoothly rounded steel pipe reducers. The Equivalent Lengths in the Table below are based on the **upstream diameter** of the reducers.

Note that the pressure losses that are modeled with this method are only those due to the friction and form losses in the fitting and do not include any consideration of the changes in pressure brought about by the net change in velocity. The change in pressure with a change in velocity is described by the Bernoulli Equation and is a completely different effect from what is being considered here, although of course the Bernoulli Effect has to be taken into account in the overall design of the pipeline. This is discussed in a bit more detail in this AioFlo Example Calculation.

Do/Di (Note 1)	Plastic Sudden Contraction	Steel Sudden Contraction	Steel Pipe Reducer
0.9	10	9	3
0.8	30	27	8
0.7	75	65	18
0.6	175	150	38
0.5	420	370	85

Do/Di (Note 1)	Plastic Sudden Contraction	Steel Sudden Contraction	Steel Pipe Reducer
0.4	1150	1000	220

Table of Equivalent Lengths (Le/D) for Reducers in Converging Mode
Based on Upstream Diameter and Turbulent Flow

(Note 1 : Do/Di = downstream diameter / upstream diameter)

When a reducer is used in the diverging mode - i.e. with flow from the smaller diameter towards the larger diameter - the shape and angle of the reducer has little effect on the pressure drop and all reducers behave as sudden expansions. An exception to this is with very long reducers with very gradual tapers. These reducers are sometimes used to decrease the pressure drop when stepping up the pipe size from a control valve, but their design is a very specialized application that is beyond the scope of the estimates possible with the Equivalent Length Method.

As before, the Equivalent Lengths in the Table below are based on the **upstream diameter** of the reducers and ignore the Bernoulli Effect.

Do/Di (Note 2)	Plastic Sudden Expansion	Steel Sudden Expansion
1.1	1.7	1.5
1.3	9.6	8.5
1.5	18	16
1.7	25	22
2.0	32	28
2.5	41	35
3.0	46	40
4.0	51	44

Table of Equivalent Lengths (Le/D) for Reducers in Diverging Mode
Based on Upstream Diameter and Turbulent Flow

(Note 2 : Do/Di = downstream diameter / upstream diameter)

4. Equivalent Length of Pipe Represented as a Pipe of a Different Diameter

In the sections above we have looked at representing various pipe fittings by a length of pipe of the same diameter as the fittings. However, it is common to have a pipeline that includes sections of pipe of a different diameter from the principal section.

For example, you may have a line whose principal diameter is 100 mm (4 inch) and which includes a range of pipe fittings of that size but also includes a section of 80 mm (3 inch) pipe. It would be very convenient, and is indeed possible, to represent the section of 80 mm pipe by its equivalent length of 100 mm pipe. In effect, this allows you to treat the section of 80 mm pipe as just another fitting in the 100 mm line. This greatly simplifies calculations, especially when calculating the flowrate for a known pressure drop (which requires a trial and error solution). This procedure is known as the **"Equivalent Pipe Method"**.

This method takes advantage of the fact that the pressure drop in **turbulent flow** through pipes varies inversely with the 5th power of the diameter, provided that the diameters are not too different. If the pressure drop through a pipe of a given length and of inside diameter diam1 is dp1, then the same flow rate through a pipe of the same length and of inside diameter diam2 will result in a pressure drop dp2, i.e.

(dp2 / dp1) = (diam1 / diam2)^5, and

dp2 = dp1 x (diam1 / diam2)^5

Since the pressure drop is linear with pipe length, we can use this same ratio to calculate the equivalent length of the pipe of diameter diam1 that would have the same pressure drop as the original pipe section with diameter diam2.

equivalent length of pipe 2 in terms of diam1 = Actual length of pipe 2 x (diam1 / diam2)^5

The following example illustrates this method. A pipe roughness of 0.05 mm is assumed (i.e. commercial steel). The flow direction is from the 100 mm section, through the reducer, and then through the 80 mm section.

Principal pipe section	
Inside Diam :	100 mm
Straight Length :	20 m
Fittings :	3 x 90ï¿½ elbow, r/d=1.5
	1 x Globe valve, full open
	1 x 100 to 80 pipe reducer
Secondary pipe section	
Inside Diam :	80 mm
Straight Length :	10 m
Fittings :	1 x Diaphragm valve, weir type

The first step is to determine the total equivalent length of 80 mm pipe. The diaphragm valve has an L_e/D ratio of 160. This makes the equivalent length of the 80 mm section (as 80 mm pipe)

10 + (160 x 80 / 1000) = 22.8 m

Our goal is to represent this 22.8 m equivalent length of 80 mm pipe as its equivalent in 100 mm pipe. Using the equation given above

Equivalent length as 100 mm pipe = 22.8 x (100/80)^5 = 69.6 m

We can now add all the bits together to calculate the total equivalent length of 100 mm pipe as

20 + [((3 x 13) + 320 + 8) x 100 / 1000] + 69.6 = 20 + 36.7 + 69.6 = 126.3 m of 100 mm pipe

This approach can of course be generalized to handle any number of sections of different diameters in series in terms of a single pipe diameter for the entire line. **Other examples** of this method are available here and here (see post by Katmar).

In **laminar flow** the exponent used for calculating the ratio is 4 (in place of the 5 used above for turbulent flow).