Pipe Material	**k_s (mm)**
Brass, copper, glass, Perspex	0.003
Asbestos cement	0.03
Wrought iron	0.06
Galvanised iron	0.15
Plastic	0.03
Bitumen-lined ductile iron	0.03
Spun concrete lined ductile iron	0.03
Slimed concrete sewer	6.0

Table 1: Typical k_s values

1.5 Local Head Losses

In addition to head loss due to friction there are always head losses in pipe lines due to bends, junctions, valves etc. (See notes from Level 1, Section 4 - Real Fluids for a discussion of energy losses in flowing fluids.) For completeness of analysis these should be taken into account. In practice, in long pipe lines of several kilometres their effect may be negligible for short pipeline the losses may be greater than those for friction.

A general theory for local losses is not possible, however rough turbulent flow is usually assumed which gives the simple formula

$$h_L = k_L \frac{u^2}{2g}$$

Equation 14

Where h_L is the local head loss and k_L is a constant for a particular fitting (valve or junction etc.)

For the cases of sudden contraction (e.g. flowing out of a tank into a pipe) of a sudden enlargement (e.g. flowing from a pipe into a tank) then a theoretical value of k_L can be derived. For junctions bend etc. k_L must be obtained experimentally.

1.5.1 Losses at Sudden Enlargement

Consider the flow in the sudden enlargement, shown in figure 6 below, fluid flows from section 1 to section 2. The velocity must reduce and so the pressure increases (this follows from Bernoulli). At position 1' turbulent eddies occur which give rise to the local head loss.

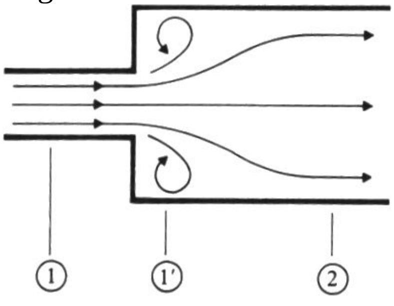

Figure 6: Sudden Expansion

Apply the momentum equation between positions 1 and 2 to give:

$$p_1 A_1 - p_2 A_2 = \rho Q(u_2 - u_1)$$

Now use the continuity equation to remove Q. (i.e. substitute $Q = A_2 u_2$)

$$p_1 A_1 - p_2 A_2 = \rho A_2 u_2 (u_2 - u_1)$$

Rearranging gives

$$\frac{p_2 - p_1}{\rho g} = \frac{u_2}{g}(u_1 - u_2)$$

Equation 17

Now apply the Bernoulli equation from point 1 to 2, with the head loss term h_L

$$\frac{p_1}{\rho g} + \frac{u_1^2}{2g} = \frac{p_2}{\rho g} + \frac{u_2^2}{2g} + h_L$$

And rearranging gives

$$h_L = \frac{u_1^2 - u_2^2}{2g} - \frac{p_2 - p_1}{\rho g}$$

Equation 18

Combining Equations 17 and 18 gives

$$h_L = \frac{u_1^2 - u_2^2}{2g} - \frac{u_2}{g}(u_1 - u_2)$$

$$h_L = \frac{(u_1 - u_2)^2}{2g}$$

Equation 19

Substituting again for the continuity equation to get an expression involving the two areas, (i.e. $u_2 = u_1 A_1 / A_2$) gives

$$h_L = \left(1 - \frac{A_1}{A_2}\right)^2 \frac{u_1^2}{2g}$$

Equation 20

Comparing this with Equation 14 gives k_L

$$k_L = \left(1 - \frac{A_1}{A_2}\right)^2$$

Equation 21

When a pipe expands in to a large tank $A_1 << A_2$ i.e. $A_1/A_2 = 0$ so $k_L = 1$. That is, the head loss is equal to the velocity head just before the expansion into the tank.