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# Study of the Separated and Total Losses in Bends

Abubaker A. Salem, Saib A.Yousif & Yasser F. Nassar
Mech.Eng.Dept., Faculty of Eng. & Tech, Sabha University
**Contact Person:**
Abubaker Awidat Salem
P O Box 53808, Brack, LIBYA
Phone:+218 721 20163, Fax: +218 721 20163, E-mail :abubakerawidat@hotmail.com

***Abstract***

*An experimental study was conducted on the total and separated head losses in five smoothed , one segmental copper right angle bends having different curvatures and 13.7 mm in a diameter. Turbulent flow with Reynolds number of value $3*10^3$-$3*10^4$ was covered. Results indicate that frictional (major) loss has significant effect on total head loss when relative bend curvature is more than 0.92, and is predominant for high relative curvature.*

***Keywords:*** *head losses, bends, error persentage, turbulent flow*

**Symbols**

D: bend diameter.
$f$ : Darcy friction factor.
$g$ : acceleration gravity.
$h_L$ : total head loss.
$h_m$ : separated head loss.
$h_f$ : frictional head loss.
$h_t$ : total bend head loss.
$k$ : loss coefficient.
$L$ : length of straight pipe with bend.
$L_e$ : equivalent bend length of straight pipe.
$p_1$ : pressure at section 1.
$p_2$ : pressure at section 2.
$p$ : air pressure in piezometer.
$r$ : bend curvature radius.
$u_1$ : water velocity at section 1.
$u_2$: water velocity at section 2.
z: height from datum.

$$\varepsilon\% : \text{error percent} = \frac{\left(\frac{L_e}{D}\right)_{total} - \left(\frac{L_e}{D}\right)_{separated}}{\left(\frac{L_e}{D}\right)_{separated}} \times 100$$

## 1 INTRODUCTION

Whenever the uniform cross-section of a pipeline is interrupted by the inclusion of a pipe fitting; such as a bend, valve, junction or flowmeter, then a pressure loss will be incurred. The value of these losses have to be included in a pipeline' s total resistance, if errors in pump and system matching or flow calculations for a given pressure differential are to be avoided. Generally, the flow separates from the pipe walls as it passes through the obstructing pipe fitting, resulting in the generation of eddies and swirls in the flow, with consequent pressure drop which called separation loss. For small, complex pipe networks such as those found in some chemical process plants, aircraft fuel and hydraulic systems and in ventilation systems, the total effect of separation losses is considered to be the predominant factor in the system pressure loss calculations[1]. Little work had been done on the contribution of the friction on overall head loss in bends . Present study is concentrated on examining the frictional effect on these fittings.

## 2 THEORY

### 2.1 Separated head loss

For a bend shown in figure 1 , the separated head loss is calculated from the following equation:

$$h_m = k\frac{u^2}{2g} = f\frac{Le}{D}\frac{u^2}{2g} \tag{1}$$

### 2.2 Total head loss

Total head loss (frictional and separated) is given as followed:

$$h_t = \frac{p_1 - p_2}{2g} - [L - \frac{\pi\, r/2}{L}]h_f \tag{2}$$

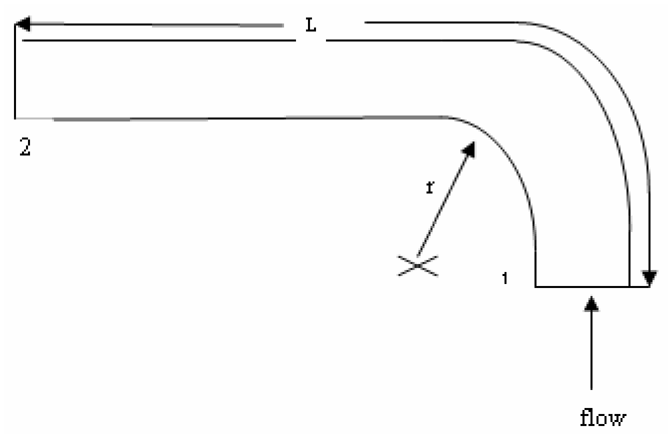


Figure 1. Bend Layout

**2.3 Principles of Pressure Loss Measurements**

For an incompressible fluid flowing through a pipe with a bend as shown in figure 2 , the following energy equation applies:

$$z + \frac{p_1}{\rho g} + \frac{u_1^2}{2g} = \frac{p_2}{\rho g} + \frac{u_2^2}{2g} + h_l \qquad (3)$$

but for constant diameter: $v_1 = v_2$ (continuity equation)

therefore:
$$h_l = z + \frac{(p_1 - p_2)}{\rho g} \qquad (4)$$

consider piezometer tubes:
$$p = p_1 + \rho g[z - (x - y)] \qquad (5)$$

also:
$$p = p_2 - \rho g y \qquad (6)$$

giving:
$$x = z + \frac{(p_1 - p_2)}{\rho g} \qquad (7)$$

comparing equation 4 and 7 gives:
$$h_l = x \qquad (8)$$

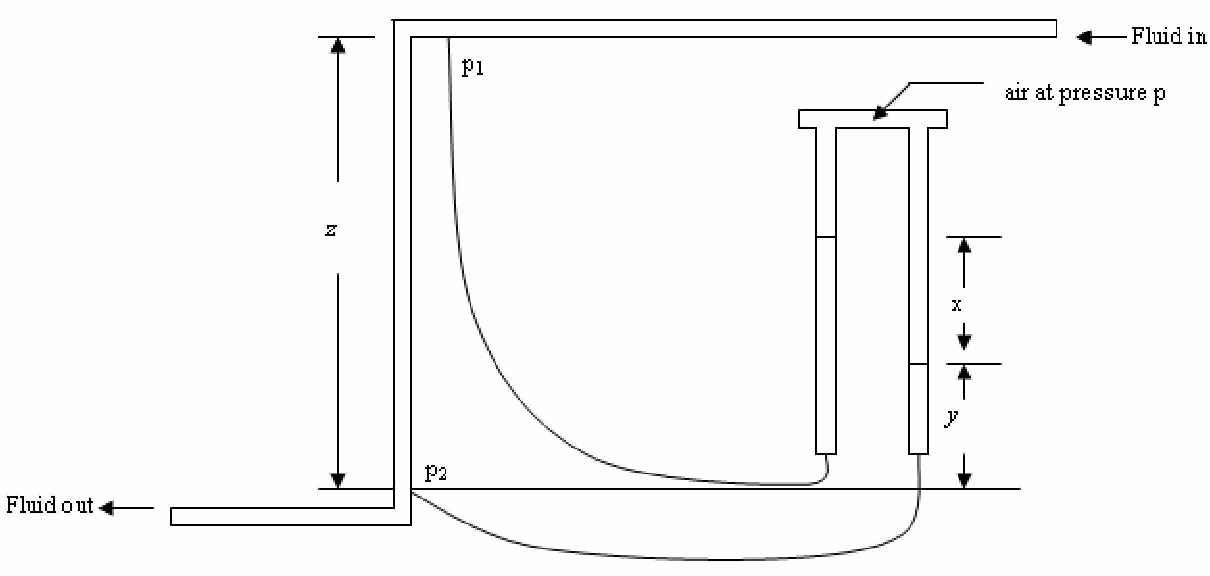


Figure 2. Scheme of Pressure Loss Measurement

## 3 EXPERIMENTAL STUDY

The apparatus shown diagrammatically in Figure 3 consists of two separate hydraulic circuits. First circuit contains a sharp bend (mitre) with r=0 and proprietary $90^0$ elbow 12.7 mm radius, the other circuit contains $90^0$ bend 52 mm radius, $90^0$ bend 102 mm radius and $90^0$ bend 152 mm radius with a valve in each circuit . Both circuits were supplied with water from the same hydraulic bench. In all cases, the pressure change across each of the components is measured by a pair of pressurized piezometer tubes with the downstream pressure tapping 50 pipe diameters away from the bend[2] to have fully developed turbulent flow. The piping is made up from proprietary standard (BS 659) light gauge copper tubing. Measurement of actual flowrate and pressure on each component in one circuit is carried out separately from the other circuit.

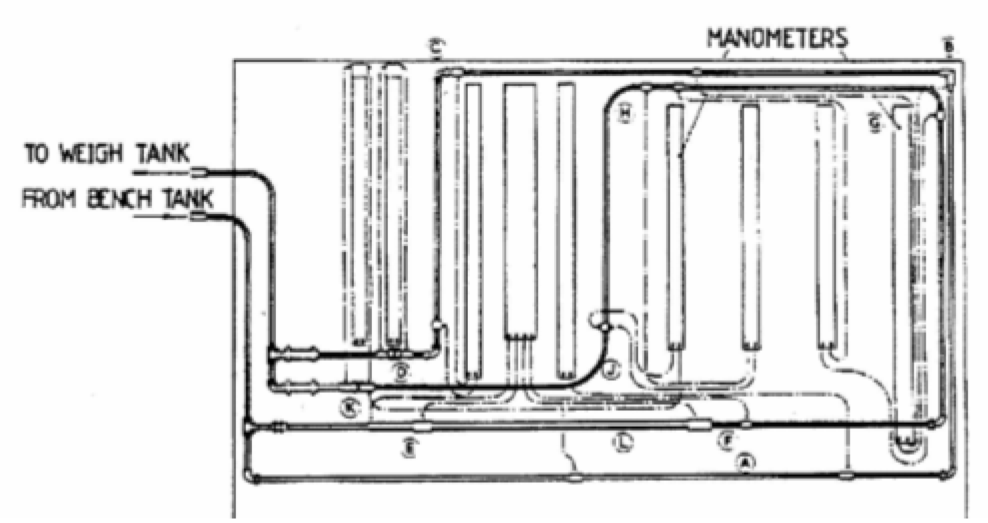


Figure 3 Diagrammatic Arrangement of Apparatus
A: Straight Pipe 13.7 mm Bore; B: $90^0$ Sharp Bend (Mitre); C: Proprietary $90^0$ Elbow; D: Gate Valve; G: Smooth $90^0$ Bend 52 mm Radius; H: Smooth $90^0$ Bend 102 mm Radius; J: Smooth $90^0$ 152 mm Radius; K: Globe Valve

## 4 RESULTS AND DISCUSSION

Figure 4 confirms the linear relationship of separated head loss with velocity head. Clearly, the separated loss increased with decreasing bend curvature, due to distortion in flow resulting in separation and swirls, nonuniform velocity distribution and secondary flow generation[3] in bends. The metre bend has the highest loss because of sharp change in flow direction and zero curvature radius.

Figure 5 , relating total head loss with velocity head, shows the same trends as in former figure but with higher head losses resulting from additional resistance due to friction of bend length. When the total and the separated equivalent lengths were plotted in figure 6 and compared with published results of Crane Co.[4], it is obvious that higher values of losses were reported. This is expected because of relatively small physical scale of the pipework. All published data have been obtained using much larger bore tubing (76 mm and above), and considering each component in isolation and not in a compound circuit[4,5,6]. The maximum Reynolds Number obtained is $3*10^4$ which is lower than $1*10^5$ and above, obtained by all previous work[4,5,6]. Although there is a divergence even amongst published data, it is clear that all curves seem to show a minimum value of the equivalent length where the ratio r/D is between 2 and 4. One can deduce from figure 6 that the difference between both types of losses increases progressively.Thus, when frictional effect is neglected, significant error ($\varepsilon$%) will produce. For r/D > 0.92, which represents all bends except the mitre and elbow, error percent $\varepsilon\% > 5$ % as shown in figure 7.

## 5 CONCLUSION

It is convenient and necessary to establish total loss coefficient or total equivalent length rather than minor (separated) loss, when dealing with design calculations of bends because of pronounced effect of major (frictional) losses though the bores are small. No effect on $90^0$ sharp bend (mitre), and negligible for $90^0$ elbow.

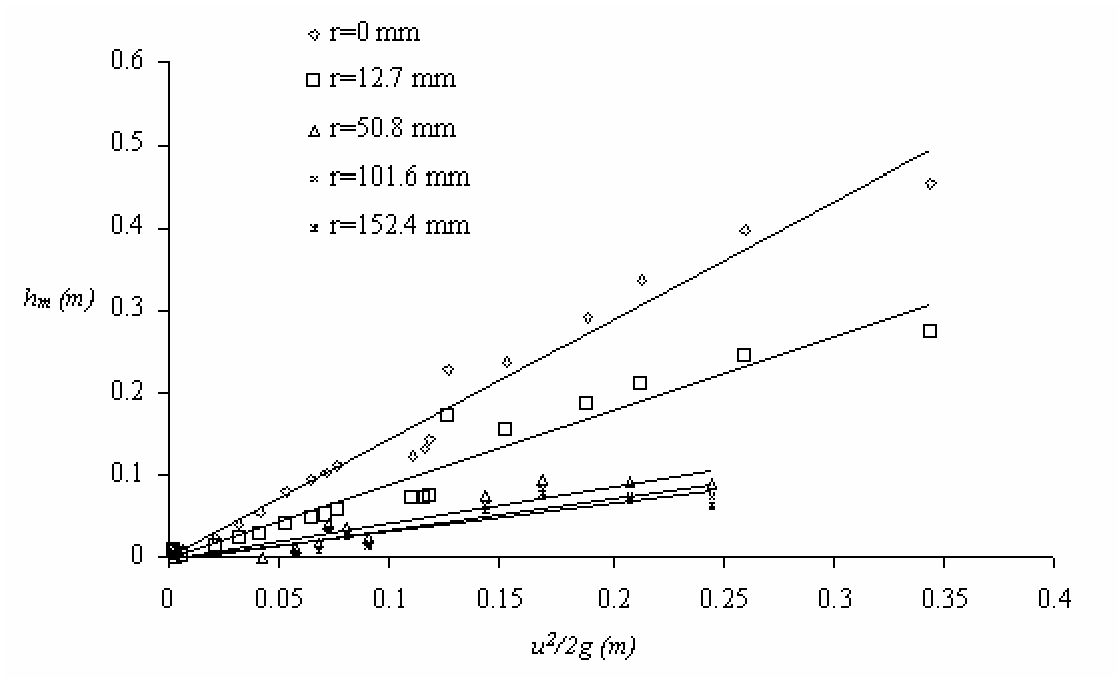


Figure 4. Separated head loss vs. velocity head in bends

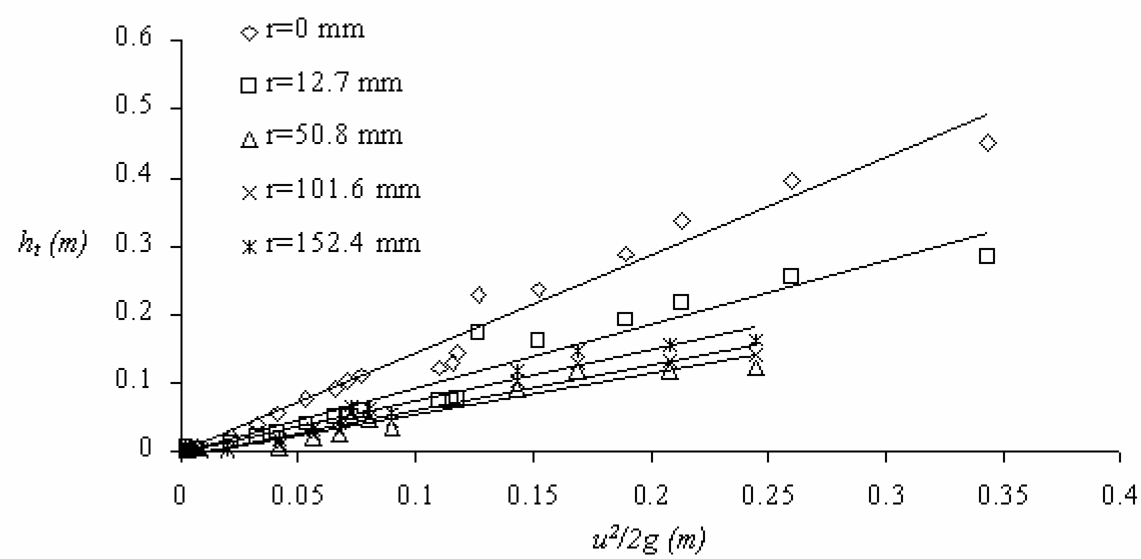


Figure 5. Total head loss vs.velocity head in bends

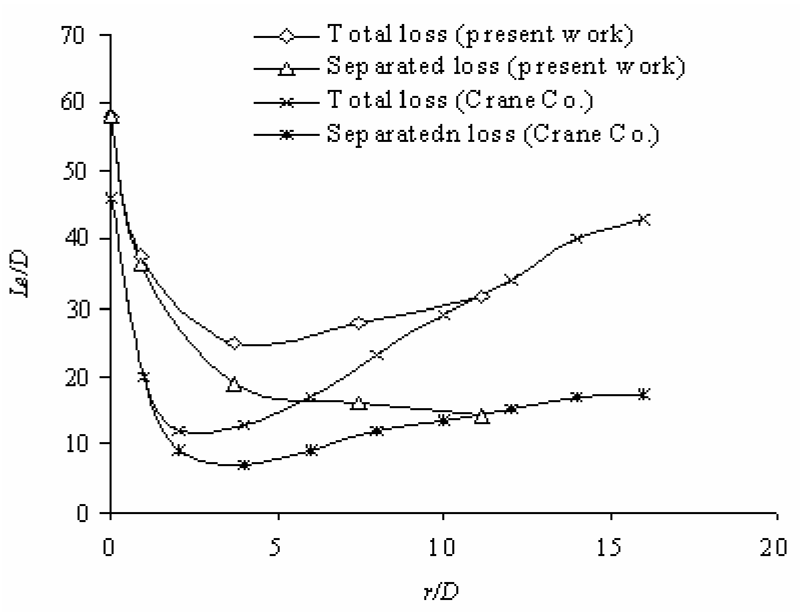


Figure 6. Equivalent lenght vs. relative radius of bend curvature

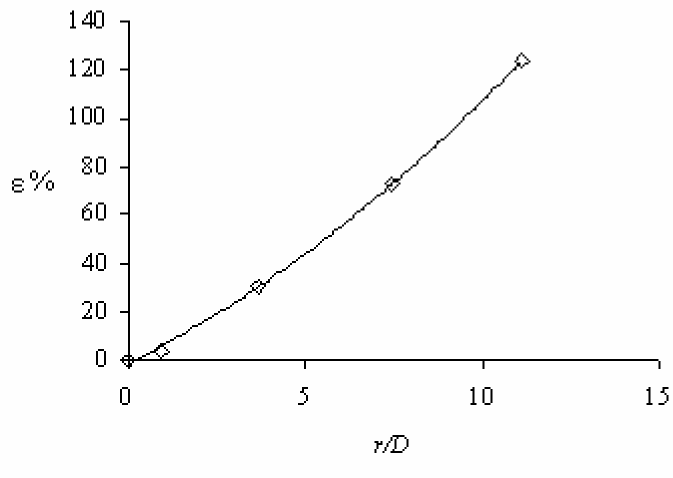


Figure 7. Error percent vs relative bend curvature

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