losses in pipes

Types of losses

① Friction losses : This type of losses exists for any flow as a result of fluid viscosity and velocity difference between fluid layers. As a result of friction, part of the fluid's mechanical energy is converted into heat energy (decipated into atmosphere) and is considered as an energy loss.

② Eddy losses : occurs due to any change in the velocity vector (magnitude or direction). This change causes some of energy to be transfered from main flow to the eddies formed at corners. This part of energy is considered as energy losses.

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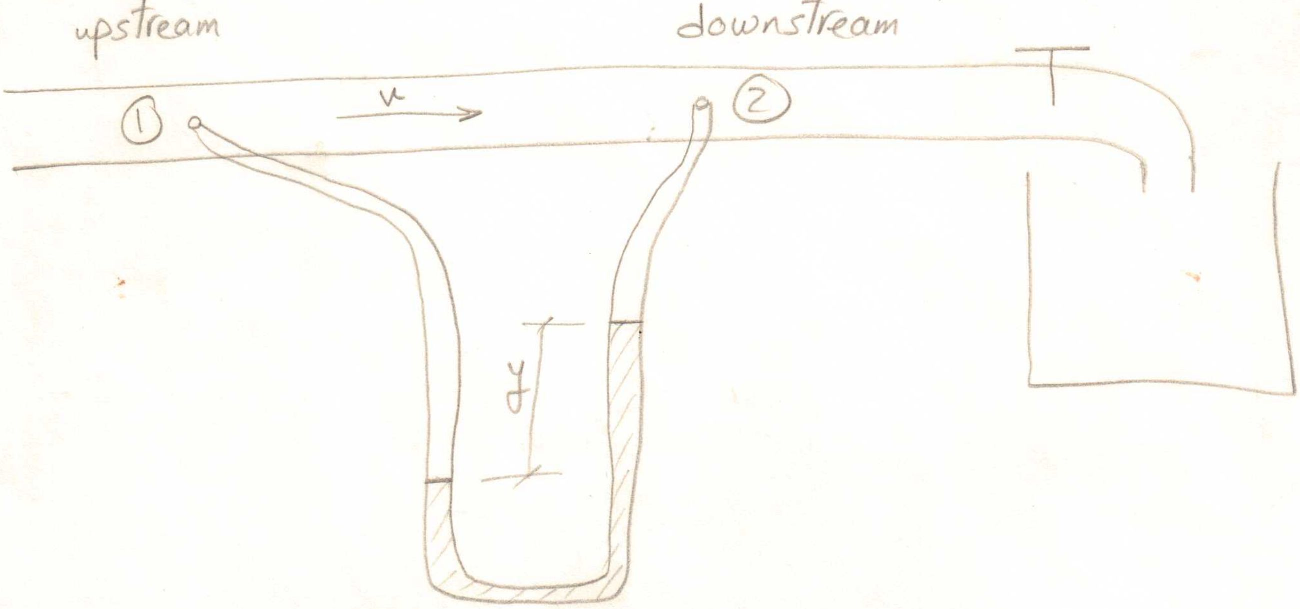
* Friction losses ⟸ ماسورة ليس بها تغيير بالمساحة لحساب

$\boxed{\text{تجربة بالمعمل}}$



$$E_1 = E_2 + h_{loss_{1\to 2}}$$

$$\frac{P_1}{w} + \cancel{Z_1} + \cancel{\frac{V_1^2}{2g}} = \frac{P_2}{w} + \cancel{Z_2} + \cancel{\frac{V_2^2}{2g}} + h_{loss_{1\to 2}}$$

same horizontal level.

same Q , Area

$$\frac{P_1}{w} = \frac{P_2}{w} + h_{loss_{1\to 2}}$$

$$h_{f.L} = \frac{P_1 - P_2}{w} \longrightarrow (1)$$

تم تسميتها $h_{f.L.}$ لأنها كلها Friction losses وليس بها eddy losses

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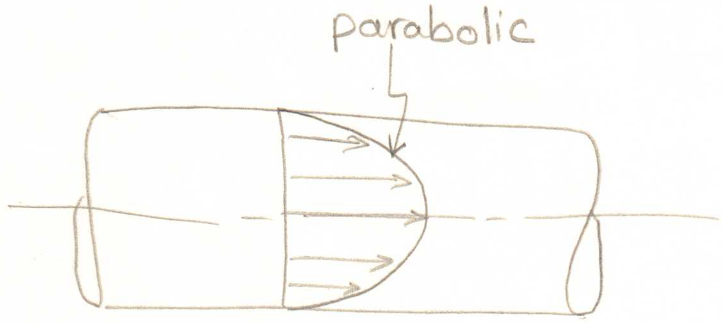
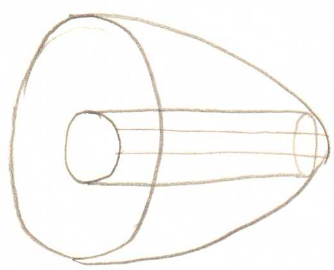
* Friction losses in laminar flow $\quad R_e < 2000$





velocity distribution
for laminar flow

$$F_{vis} = \mu A \frac{dV}{dy} \longrightarrow (2)$$

from (1) & (2)

$$\boxed{h_{f.L.} = \frac{32 \mu V l}{w\, d^2}}$$

where l is the pipe length

$$h_{f.L.} \propto V \qquad \text{(linear)}$$

$$h_{f.L.} = 32 * \frac{\mu V l}{\rho g d^2} * \frac{V}{V} * \frac{2}{2}$$

$$= 32*2* \frac{\mu}{\rho V d} * \frac{l}{d} \frac{V^2}{2g}$$

$$= \frac{64}{R_e} * \frac{l}{d} \frac{V^2}{2g}$$

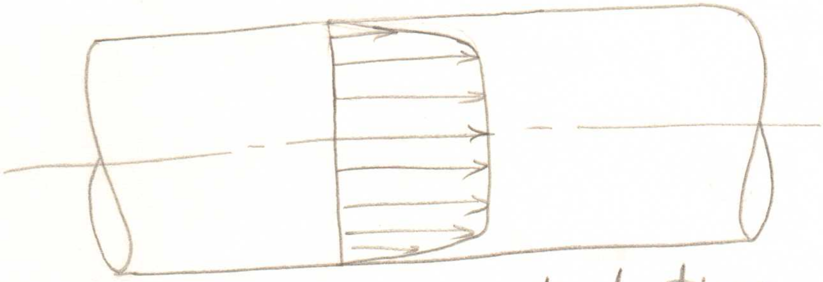
$$\boxed{h_{f.L.} = f \frac{l}{d} \frac{V^2}{2g}} \longrightarrow \text{Another form}$$

$$f = \frac{64}{R_e}$$

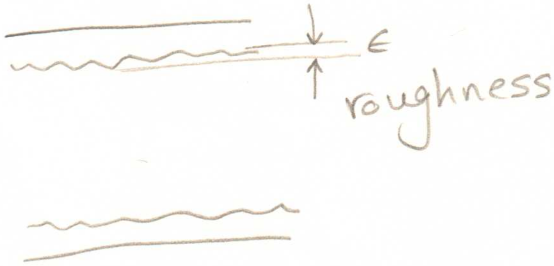
where f : Coefficient of friction

__Note:__ for laminar flow, the pipe roughness has no effect on friction losses because the velocity of the fluid layer beside the pipe wall is very small and almost stationary.

(b) Friction losses in turbulent flow $R_e > 4000$

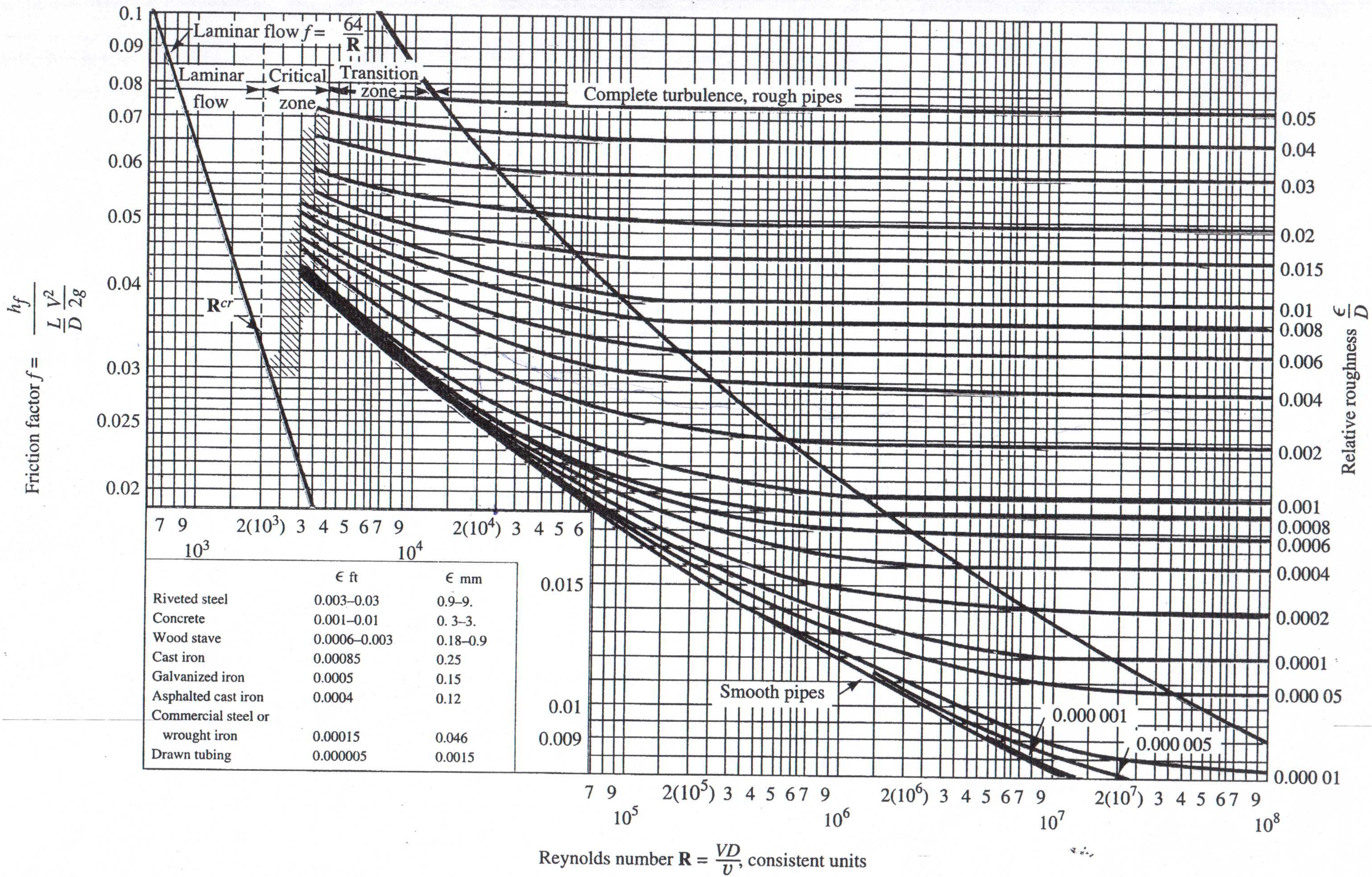


velocity distribution in turbulent flow



* All the following results are experimental results written as empirical formula.

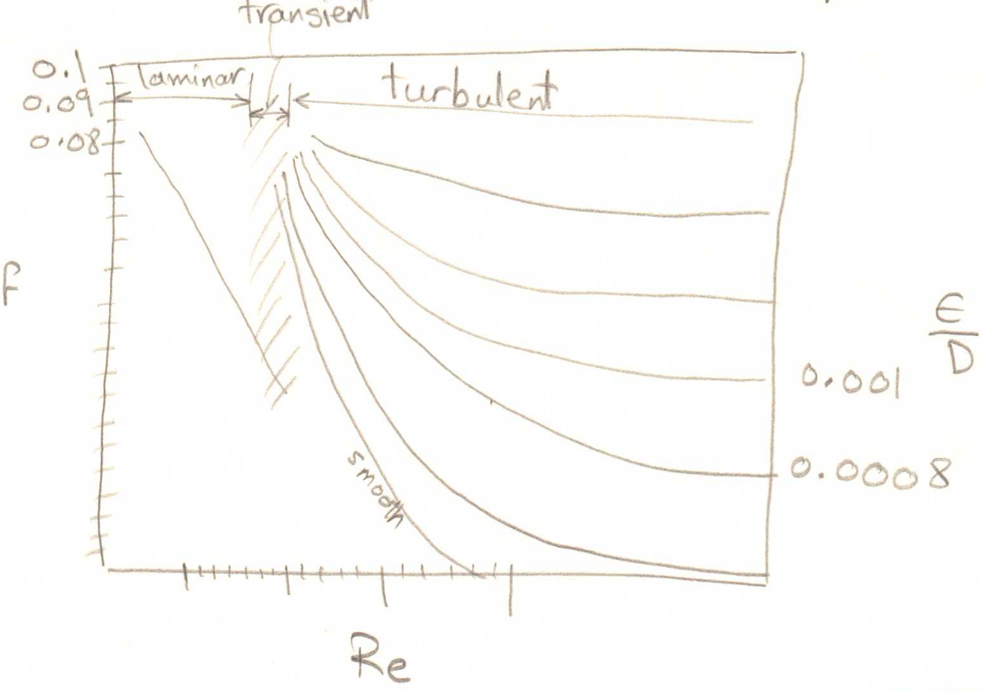
$$\boxed{h_{f.L.} = f \frac{l}{d} \frac{V^2}{2g}} \longrightarrow h_{f.L.} \propto V^2$$



	ϵ ft	ϵ mm
Riveted steel	0.003–0.03	0.9–9.
Concrete	0.001–0.01	0. 3–3.
Wood stave	0.0006–0.003	0.18–0.9
Cast iron	0.00085	0.25
Galvanized iron	0.0005	0.15
Asphalted cast iron	0.0004	0.12
Commercial steel or wrought iron	0.00015	0.046
Drawn tubing	0.000005	0.0015

$$f \begin{cases} \rightarrow R_e = \dfrac{\rho V d}{\mu} \\ \rightarrow \dfrac{\epsilon}{d} : \text{relative roughness of pipe} \end{cases}$$

الخشونة النسبية

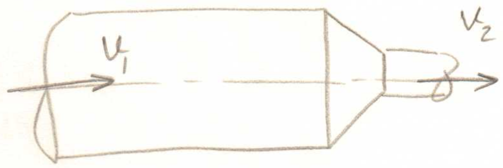


* Eddy losses

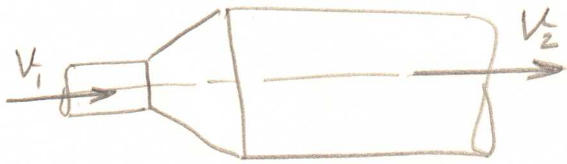
أي تغيير في السرعة مقدار أو اتجاه

All eddy losses depend only on Kinetic energy $\left(\frac{V^2}{2g}\right)$ of flow (not type of flow).

(i) change in magnitude

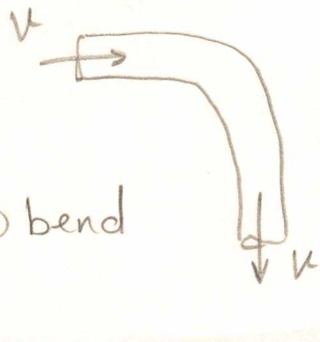


⊛ Contraction

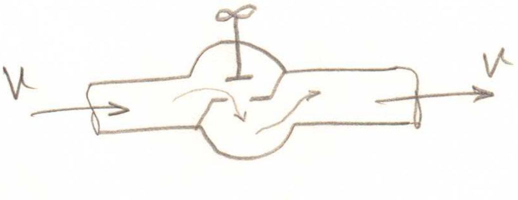


⊛ Enlargement

(ii) change in direction



⊛ bend



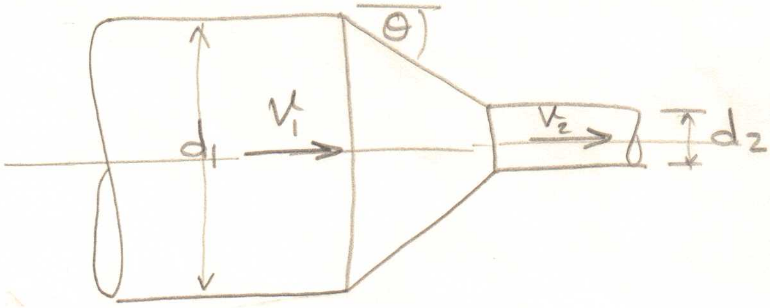
⊛ valve

* Contraction

$$h_\ell = K \frac{V_2^2}{2g}$$

K: Coefficient of eddy loss

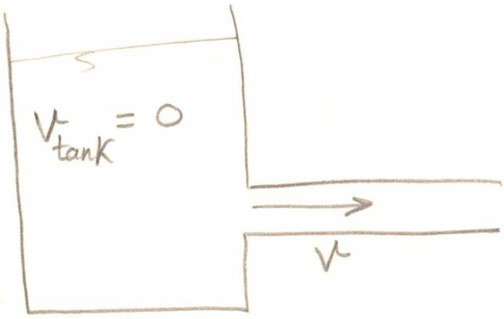
Kinetic energy



$$K = fn\left(\frac{d_1}{d_2}, \theta\right)$$

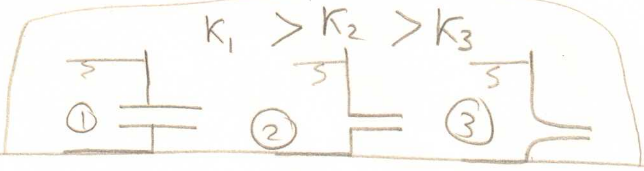
أسوأ حال من tank الى pipe

K_{max} for Contraction at $\frac{d_1}{d_2} = \infty$ & $\theta = 90°$



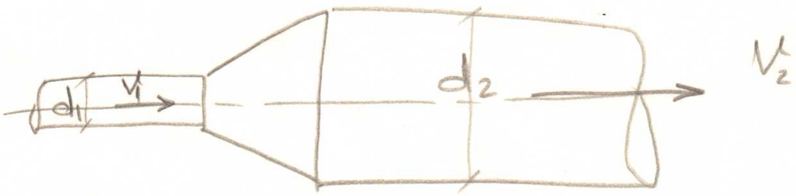
$$K_{max} = 0.5$$

$$h_\ell = 0.5 \frac{V^2}{2g}$$



* Enlargement

$$h_\ell = K \frac{(V_1 - V_2)^2}{2g}$$



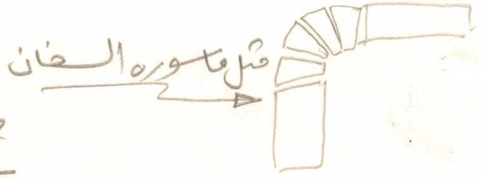
$K = fn(\theta)$. The effect of $\frac{d_2}{d_1}$ is presented in $(V_1 - V_2)$

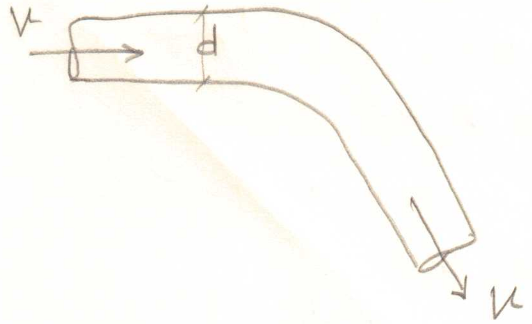
* K_{max} for enlargement at $\theta = 90°$ (sudden enlargement)

$$K_{max} = 1$$

$$h_\ell = \frac{(V_1 - V_2)^2}{2g}$$

* Bend or Elbow



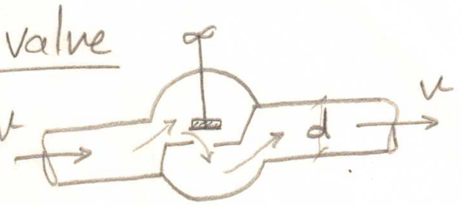


$$h_l = K \frac{v^2}{2g}$$

$$K = fn\ (\theta\ , d, \text{ type of bend})$$

* valves

Globe valve



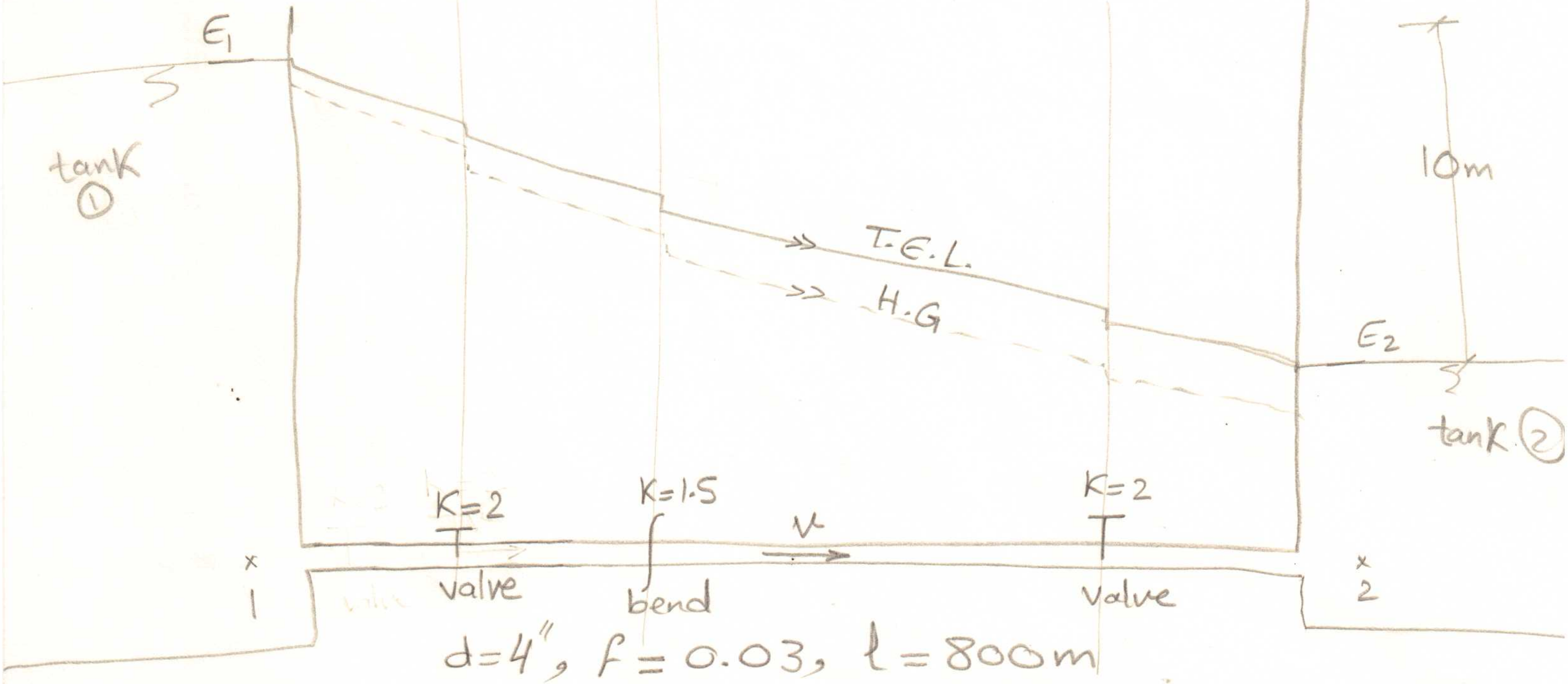
$$h_l = K \frac{V^2}{2g}$$

$$K = fn\,(d, \text{ type of valve})$$

* only for fully opened valves

- عند غلق المحابس نصف يكون هناك فاقد أكبر في الطاقة
- لذلك الاستخدام الأمثل لها أن تكون مفتوحة بالكامل أو مغلقة بالكامل.

Example



$d = 4''$, $f = 0.03$, $l = 800\,m$

a) Calculate the discharge between the two tanks.

b) one of valves is partially closed. The discharge reduced by 50%. Calculate the losses in the value in this Case.

c) draw T.E.L. & H.G.

ⓐ $Q = AV$ $\qquad d = \frac{4'' * 2.54}{100} = 0.1 \text{ m}$

$E_1 = E_2 + h_{loss_{1\to2}}$

$h_{loss_{1\to2}} = E_1 - E_2 = 10 \text{ m}$

$$10 = f\frac{l}{d}\frac{V^2}{2g} + K_{\substack{ent.\\ Cont.\\ max}}\frac{V^2}{2g} + K_V\frac{V^2}{2g} + K_b\frac{V^2}{2g} + K_V\frac{V^2}{2g} + K_{\substack{enl.\\ max}}\frac{(V-0)^2}{2g}$$

$$10 = \frac{V^2}{2*9.8}\left(0.03*\frac{800}{0.1} + 0.5 + 2 + 1.5 + 2 + 1\right)$$

$V = 0.89 \text{ m/s}$

$Q = \frac{\pi}{4}(0.1)^2 * V = 7*10^{-3} \text{ m}^3/\text{sec} = 7 \text{ lit/sec}$

ⓑ $Q_1 = 0.5Q = A V_1$

$\therefore 10^{-3}*3.5 = \frac{\pi}{4}(0.1)^2 V_1$

$V_1 = 0.445 \text{ m/s}$

$\boxed{\begin{array}{l} Q_1 = 0.5Q \\ V_1 = 0.5V \end{array}}$

$E_1 - E_2 = h_{loss_{1\to2}} = 10$

$$10 = f\frac{l}{d}\frac{V_1^2}{2g} + K_{\substack{ent\\ Cont.\\ max.}}\frac{V_1^2}{2g} + h_{\substack{loss\\ Value}} + K_b\frac{V_1^2}{2g} + K_V\frac{V_1^2}{2g} + K_{\substack{enl.\\ max}}\frac{V_1^2}{2g}$$

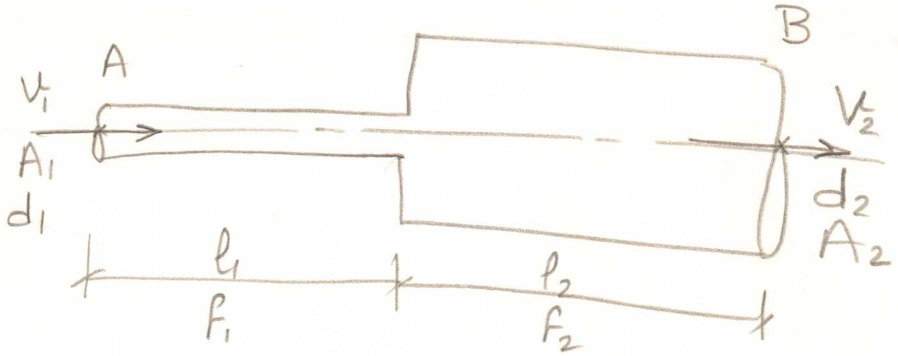
$$10 = 0.03*\frac{800}{0.1}*\frac{(0.445)^2}{2*9.8} + 0.5\frac{(0.445)^2}{2*9.8} + h_{\substack{loss\\ value}} + 1.5*\frac{(0.445)^2}{2*9.8} + 2*\frac{(0.445)^2}{2*9.8} + 1*\frac{(0.445-0)^2}{2*9.8}$$

$h_{\substack{loss\\ value}} = 7.5$ m of liquid.

ⓒ from figure it can be seen that the eddy losses occure as a sudden drop in T.E.L. & H.G. while friction losses occure as a gradual drop in T.E.L. & H.G. (both lines).

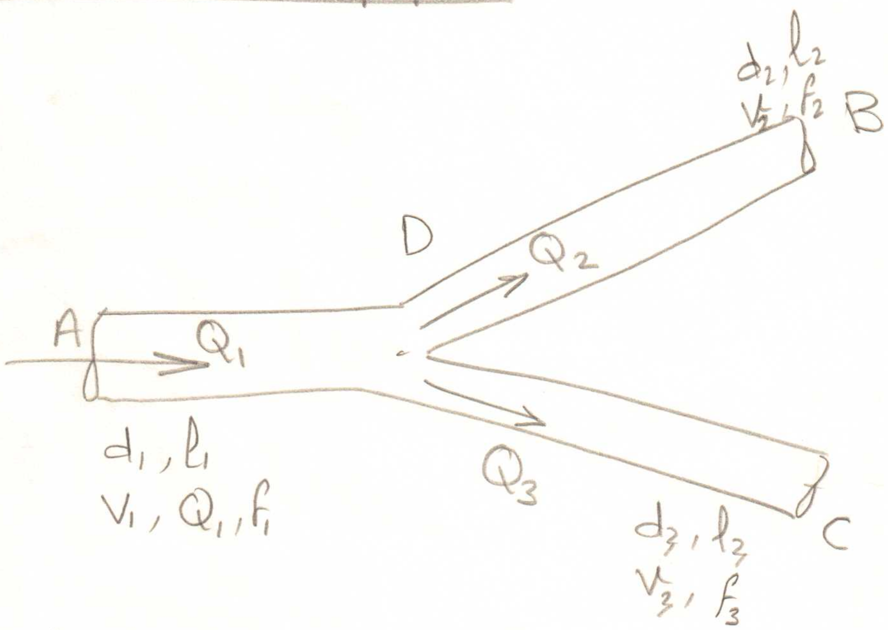
H.G. & T.E.L متوازيين وبينهم نفس المسافات

* losses in series pipes



$$h_{\ell_{A\to B}} = f_1 \frac{l_1}{d_1}\frac{V_1^2}{2g} + \frac{K(V_1 - V_2)^2}{2g} + f_2 \frac{l_2}{d_2}\frac{V_2^2}{2g}$$

losses in parallel pipes



$$h_{\ell_{A\to B}} = f_1 \frac{l_1}{d_1}\frac{V_1^2}{2g} + h_{\ell_{\text{branching}}} + f_2 \frac{l_2}{d_2}\frac{V_2^2}{2g}$$

$$h_{\ell_{A\to C}} = f_1 \frac{l_1}{d_1}\frac{V_1^2}{2g} + h_{\ell_{\text{branching}}} + f_3 \frac{l_3}{d_3}\frac{V_3^2}{2g}$$

$$Q_1 = Q_2 + Q_3$$

$$A_1 V_1 = A_2 V_2 + A_3 V_3$$