Irrigation and Drainage Engineering

(Soil Water Regime Management)

(ENV-549, A.Y. 2024-25)

4ETCS, Master option

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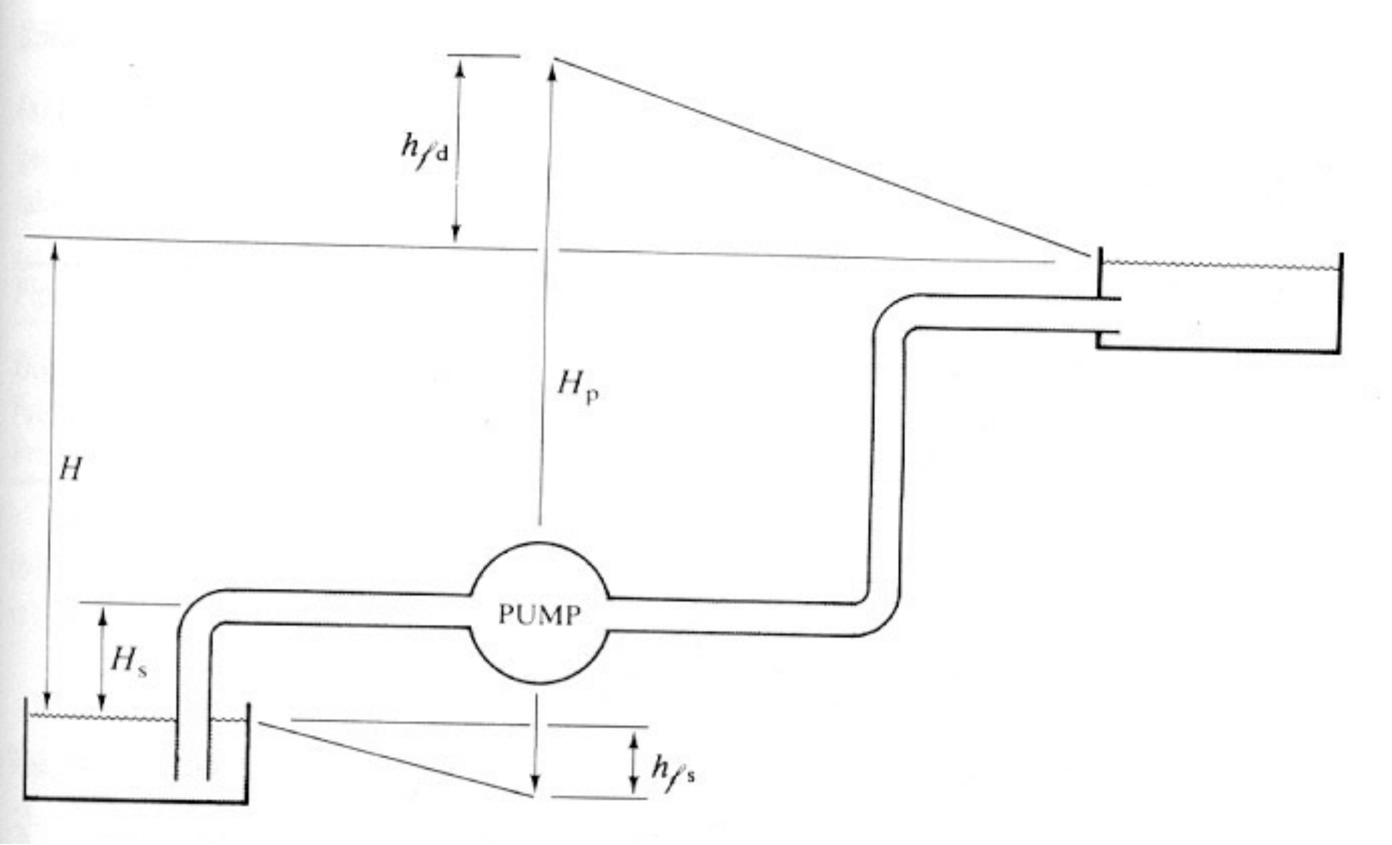
Platform of Hydraulic Constructions

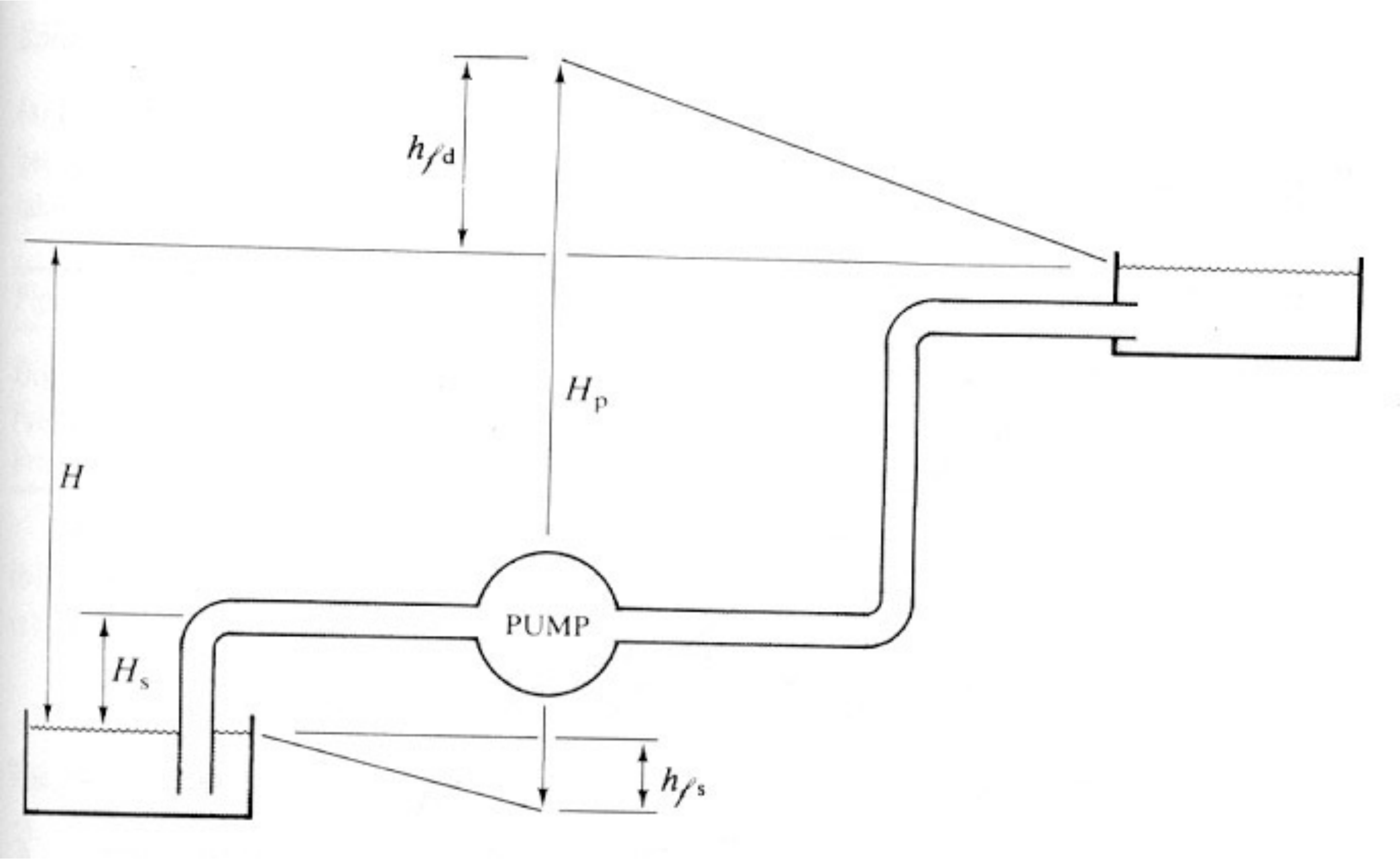
Lecture 6-2. Sprinkler irrigation: hydraulic design of pipes and conduits; pumped systems

Pumped systems

- Pumps as hydraulic machines – concepts
- Volumetric pumps, irregularity
- Volumetric pumps with helicoidally screw
- Centrifugal pumps
- Start/stop problems in pumped systems
- Pumped systems

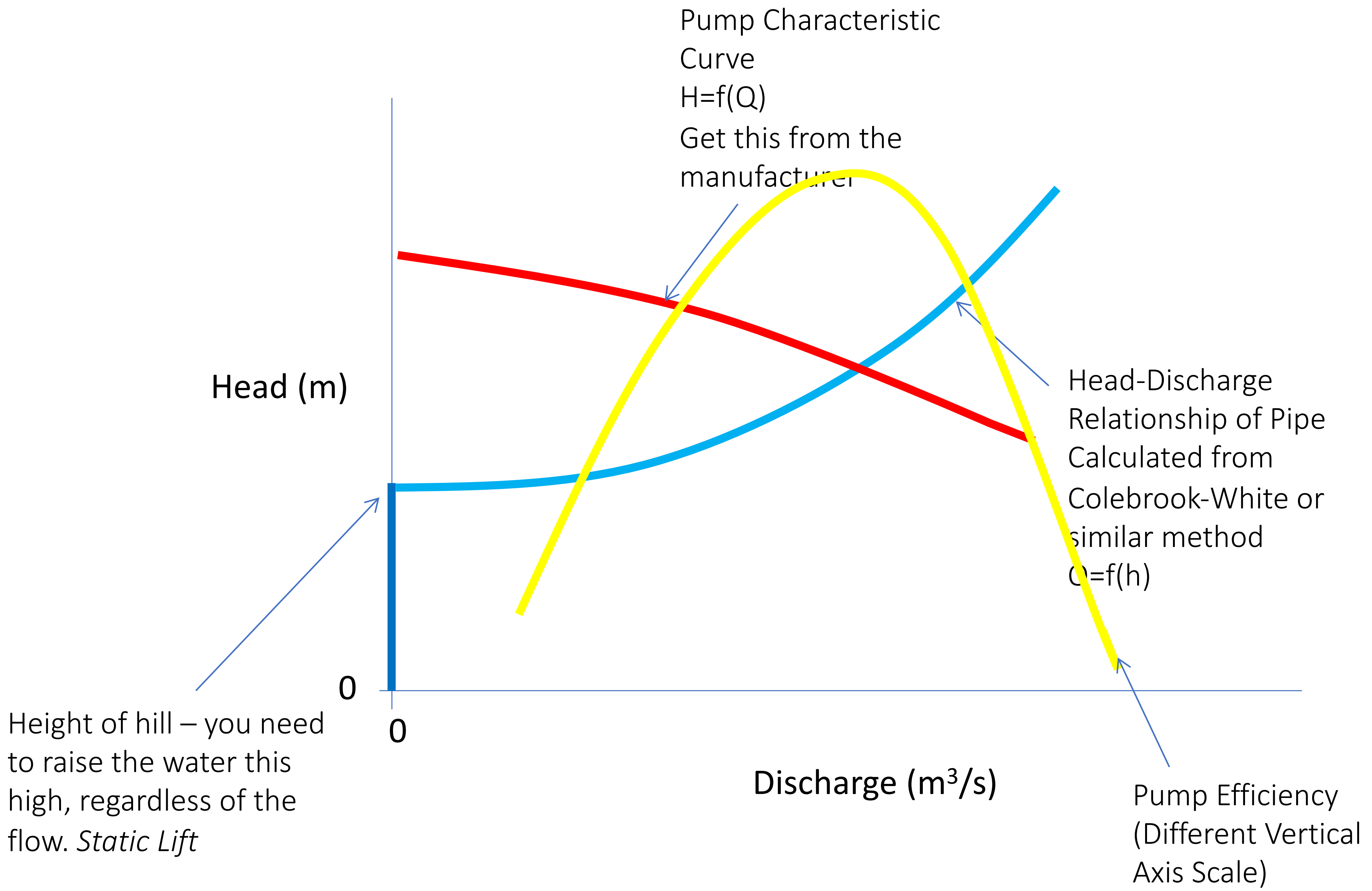


- Pumping adds head to the system. Hence:
- $H_p = H + h_{fs} + h_{fd}$
- s=suction, d=delivery



- Pumps in Series:
  - The head increases for a given discharge:
- H_{np} = nH_p $Q_{np} = Q_p$
- Pumps in Parallel:
  - The discharge increases for a given head:
- $H_{np} = H_p$ $Q_{np} = nQ_p$

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

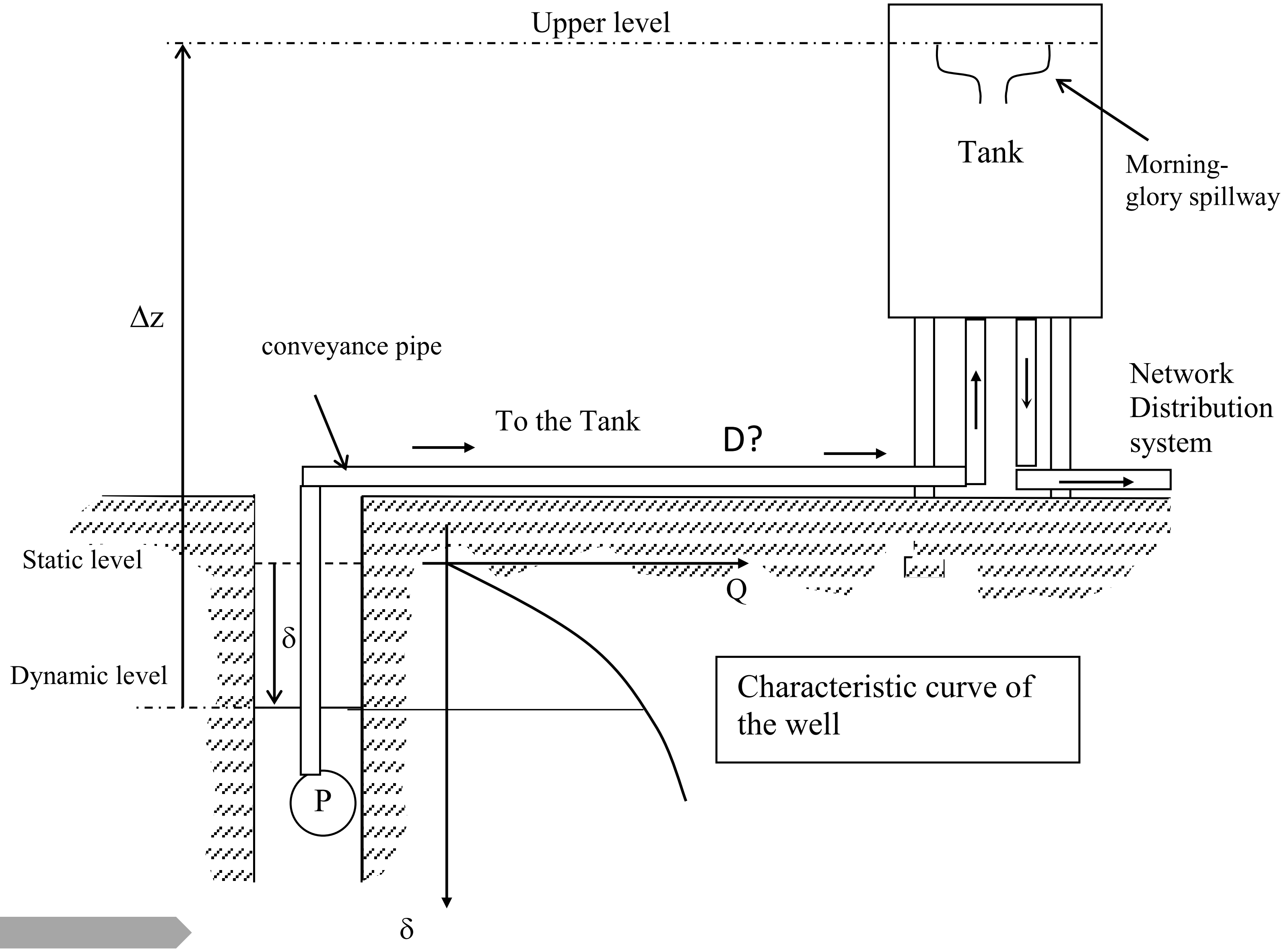


EPFL

Optimal design of pumped systems (hydraulics+economy)

AIM: design of the best diameter D of the conveyance pipe that allows to pump the requested flow rate Q from the well to the elevated tank respecting the minimum cost condition

Tool: the pure hydraulic design is an indetermined problem (infinite solutions). → use both hydraulic and economic criteria



$$H = \Delta z + iL = \Delta z + \beta \frac{Q^2}{D^n} L .$$

The requested power to pump the flow rate Q is therefore

$$W = \frac{\gamma Q H}{1000 \ \eta} \qquad \text{[KW]}$$

$$\Downarrow$$

$$W = \frac{\gamma Q}{1000 \ \eta} \left(\Delta z + \beta \frac{Q^2}{D^n} L \right)$$

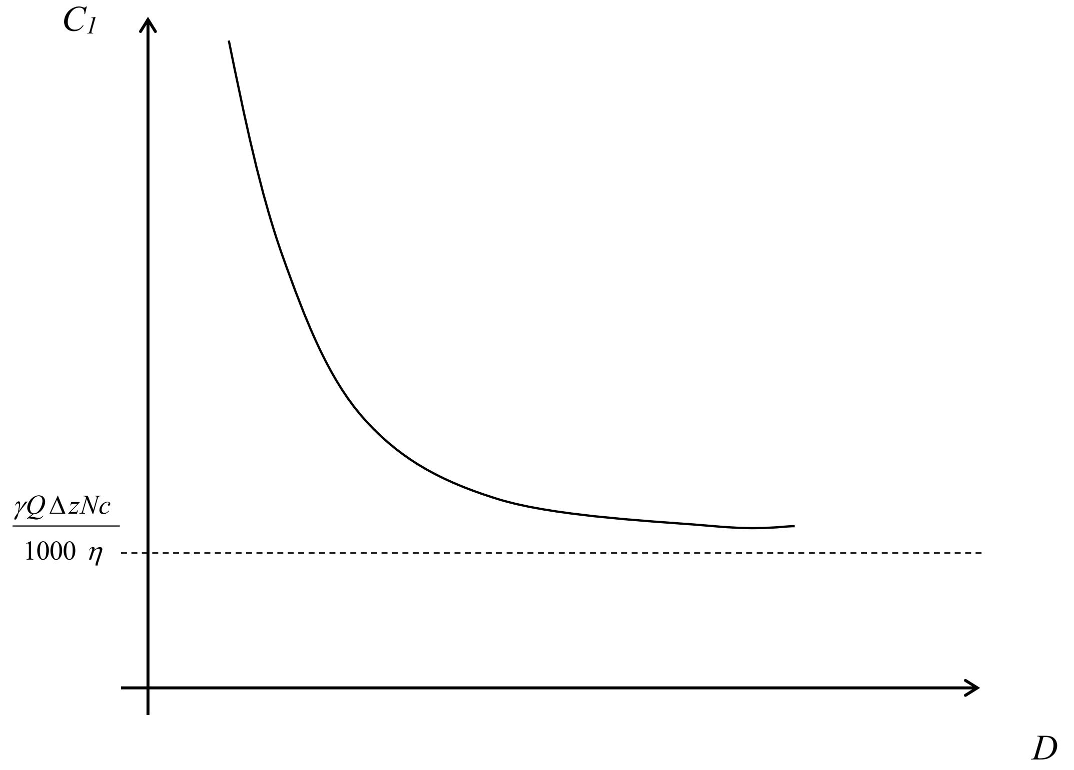
Pump Power

$$E = \frac{\gamma Q}{1000\ \eta}\left(\Delta z + \beta \frac{Q^{2}}{D^{n}} L\right) N$$

Pump Energy over *N* hours

$$C_1 = \frac{\gamma Q}{1000\ \eta}\left(\Delta z + \beta \frac{Q^{2}}{D^{n}} L\right) N\bar{c}$$

Cost for pumping for N hours



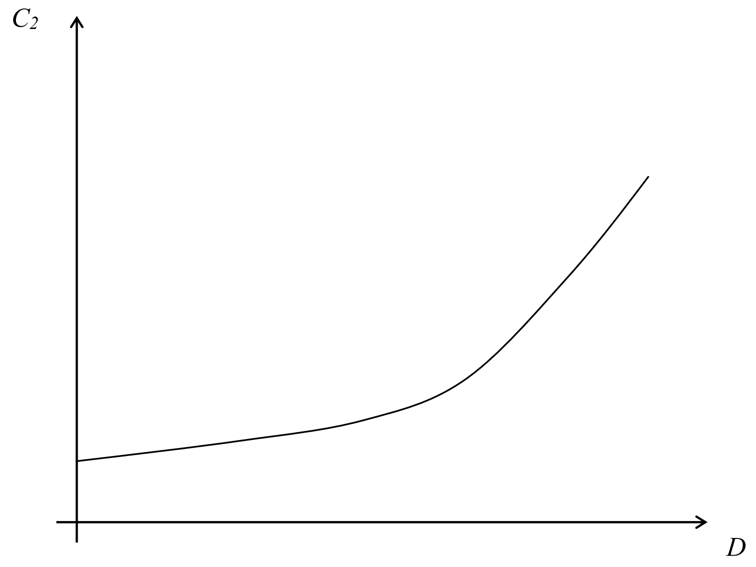
The cost for pumping is clearly a function of the unknown diameter *D*

Other costs:

1) land purchasing, excavation, transporting, laying, installing and filling. We indicate this cost as *R*.

2) Cost for the pipe $T = cLD^{\alpha}$

Total building costs:



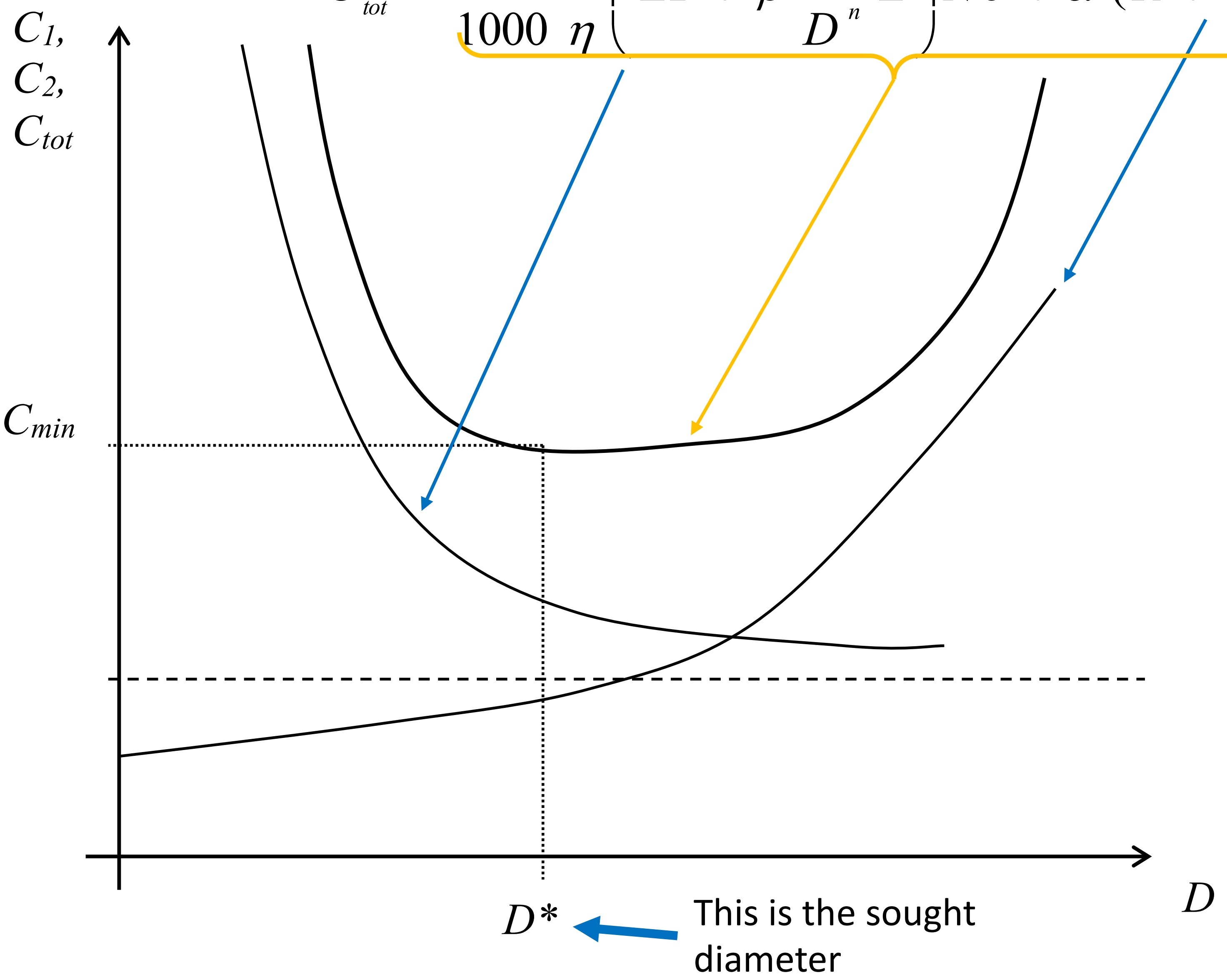
$$C_2 = R + T$$

$$C_2 = \bar{\alpha} C = \bar{\alpha} (R + cLD^{\alpha})$$

Total cost

$$C_{tot} = C_1 + C_2,$$

$$C_{tot} = \frac{\gamma Q}{1000\,\eta}\left(\Delta z + \beta \frac{Q^2}{D^n} L\right) N\bar{c} + \bar{\alpha}\left(R + cLD^a\right)$$



$$\frac{dC_{tot}}{dD} = 0\,,$$

$$D^{*(\alpha+n)} = \frac{n\gamma\beta N\bar{c}Q^3}{\alpha\bar{\alpha}c1000\,\eta} = AQ^3\,.$$

Imposing for sake of simplicity that α=1 and n=5,

$$\boxed{D^* = K\sqrt{Q}}$$

Irrigation pipes and ancillary elements

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

Pipes and conduits

➔ **buried:** large diameters (plastic, cast iron, steel, etc.)

➔ **on the ground:** fixed or mobile (galvanised steel, aluminium, plastic, etc.)

➔ **aerial** (fixed)

Laying depth of buried pipes

Diameter (mm)	Prof. min. above pipe* (cm)
70 – 100	60
> 100	75

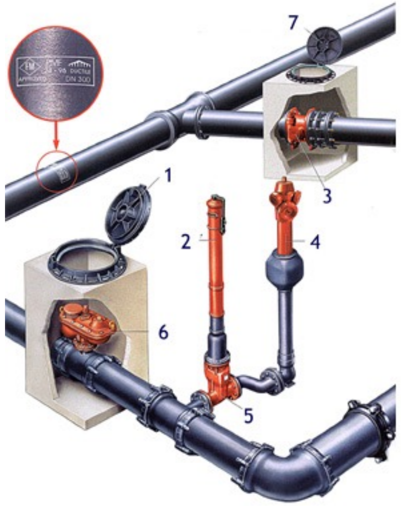
*In the case of rolling loads (heavy machines), at least 75 cm

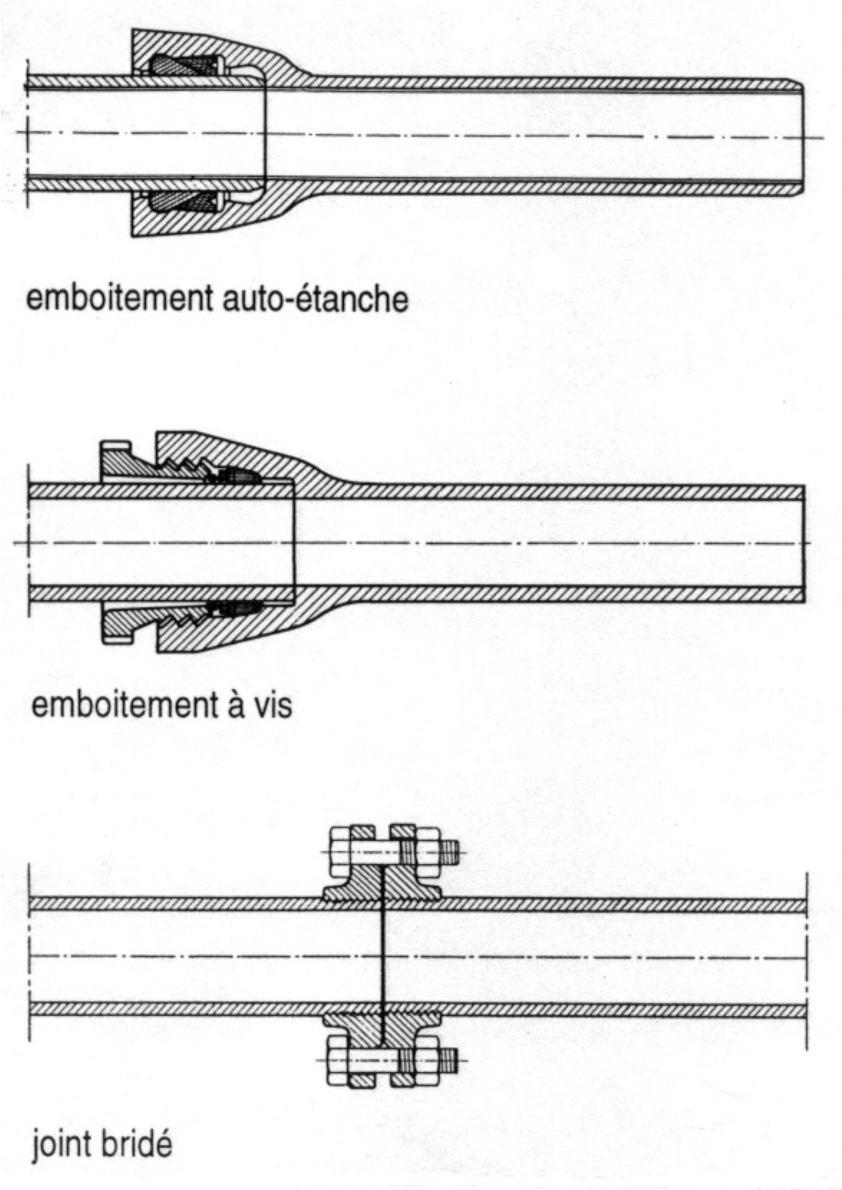
Materials

- Plastics: lightweight, easy to lay and assemble, low roughness, not very sensitive to soil chemicals, durable, reasonable cost. Joints: mechanical, welding or gluing

- steel : Easy to lay and assemble, high resistance to pressure and external stresses. Joints: welded, interlocking, flanged or other joints. Weight (7800 kg/m3) and susceptibility to corrosion

- Cast iron: high resistance to pressure, external stresses and corrosion; high durability. Joints: self-sealing, screwed, flanged. Weight (7000 kg/m3), price and difficulty of installation (need for appropriate joints).





Different cast iron pipe assembly systems

Anchoring systems

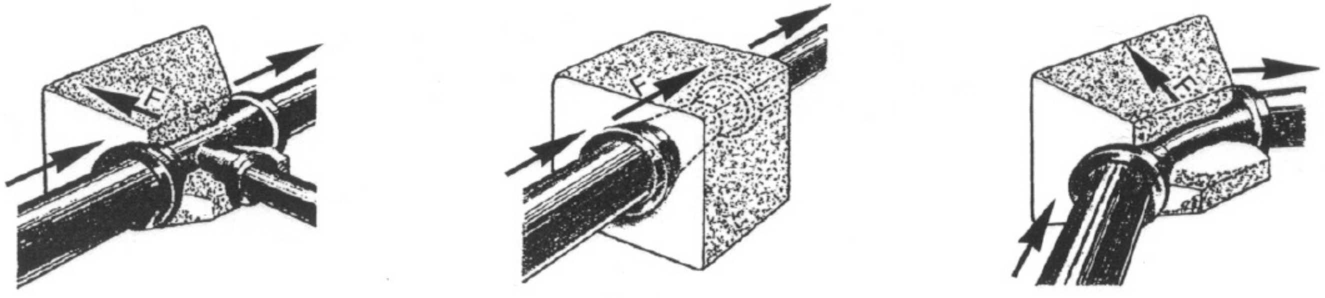
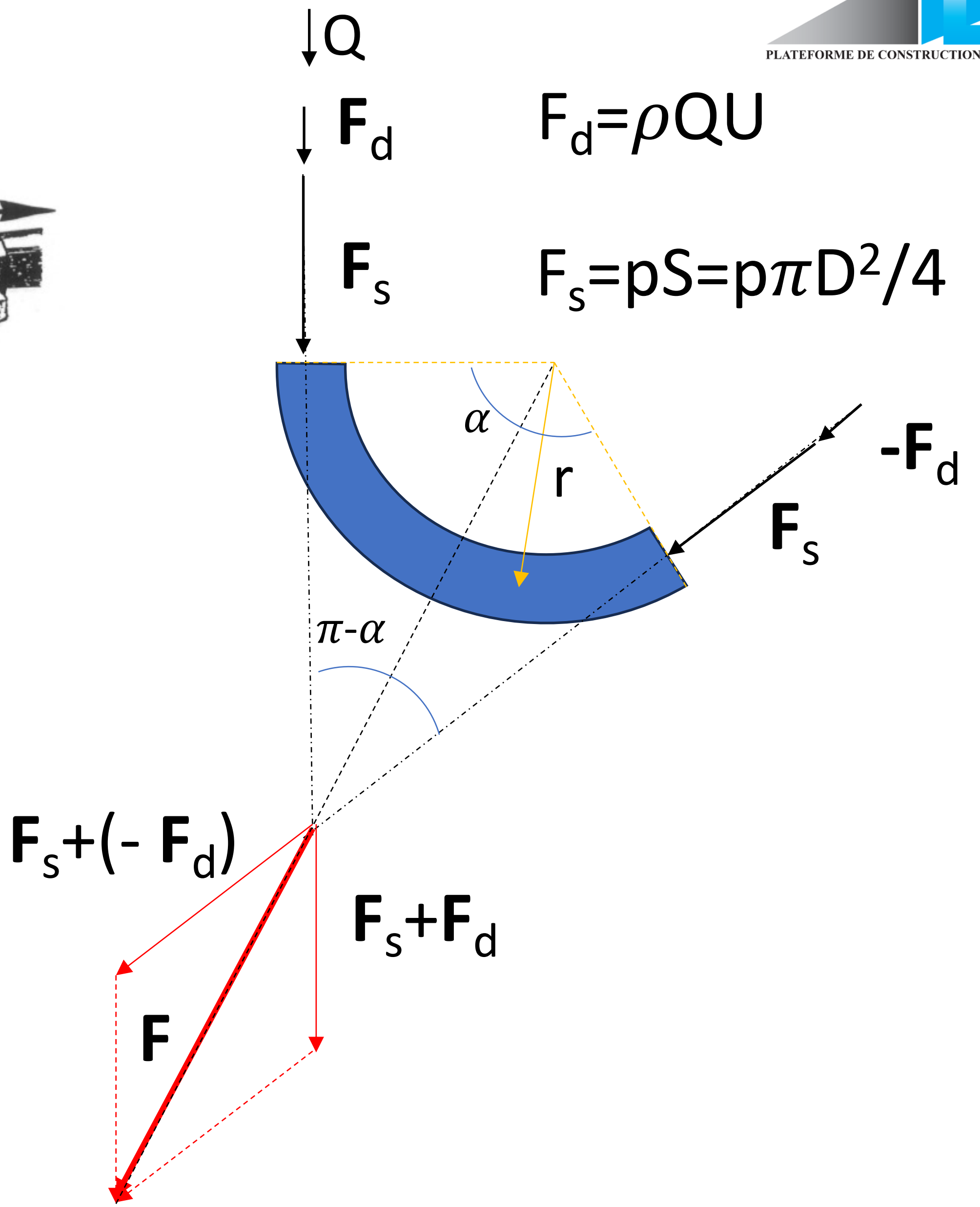


Fig. 11 : Poussées dans différentes situations ([12])



The total force acting on the bed has two origins:

- Hydrodynamic (change direction of flow momentum), F_d;
- Hydrostatic (dure to pressure forces originated at the bend section), F_s

The two forces are not co-axial, but this can be approximated so

Usually $F_d << F_s$ and can be neglected

Anchoring system (see also discussion)

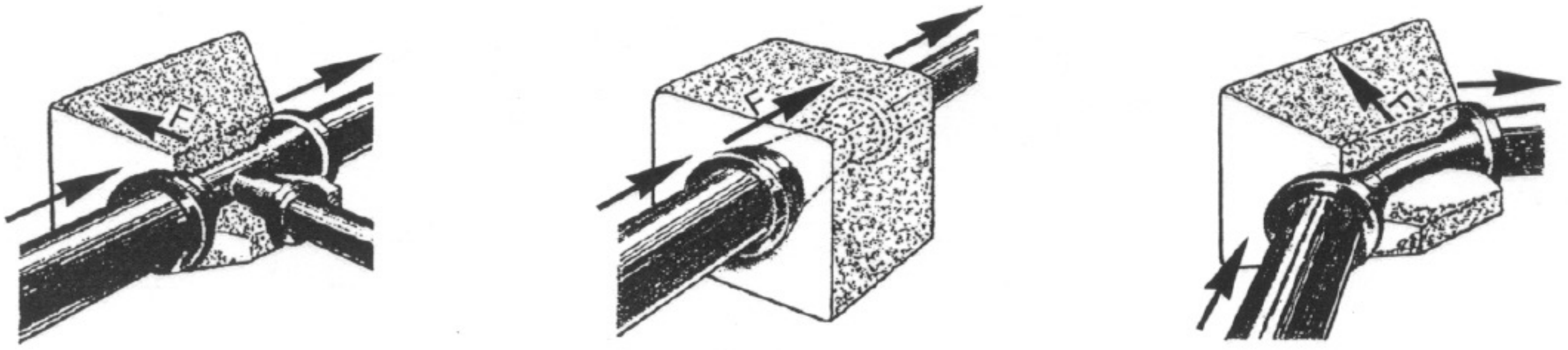


Fig. 11 : Poussées dans différentes situations ([12])

$$F = K\,P\,S$$

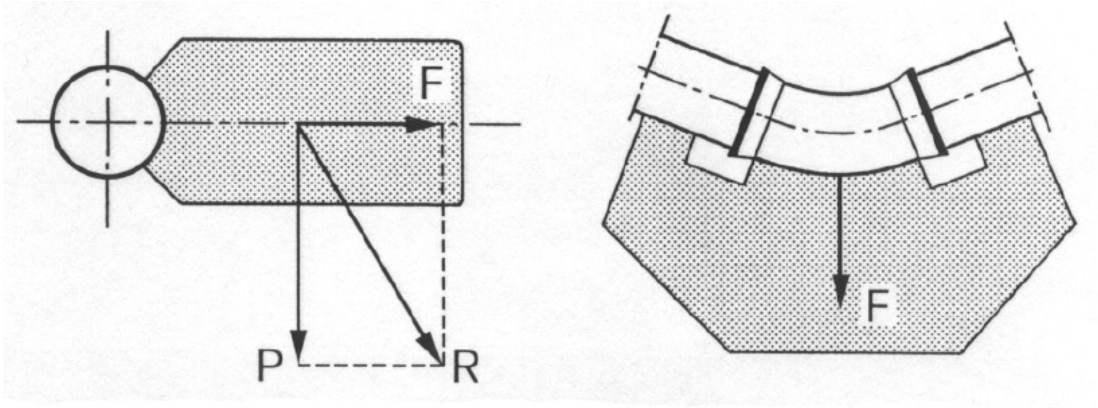
K : coefficient fonction du type de singularités

~ pour les extrémités de conduites, réductions et tés : K = 1

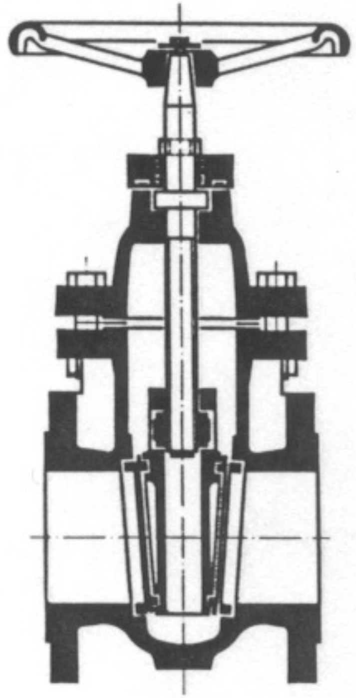
~ pour les coudes d'angle α : $K = 2 \sin \frac{\alpha}{2}$

(ex. $\alpha = 90^{o}$, K = 1.414; $\alpha = 45^{o}$, K = 0.766)

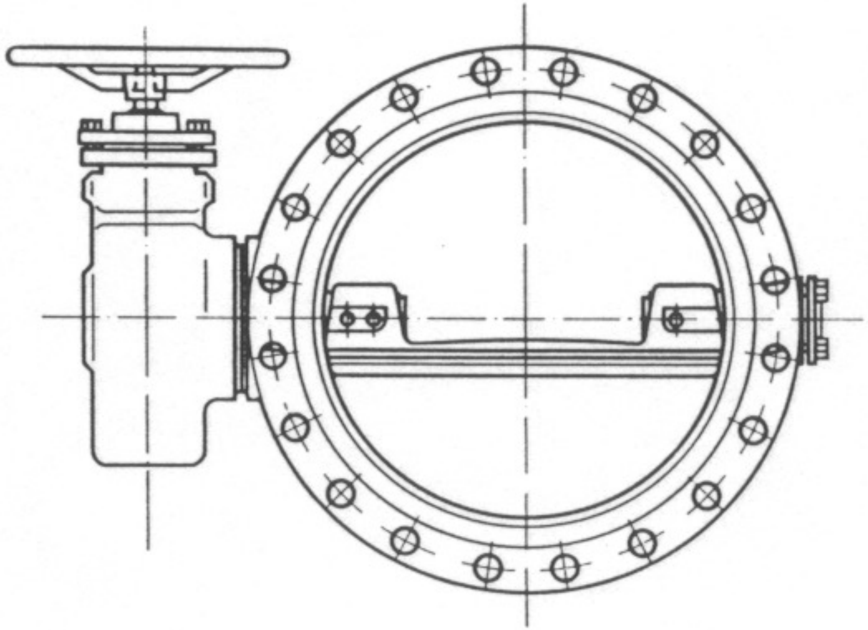
$$\frac{F}{P} < tg\,\varphi < 0.577$$



Valves and gates



vanne à coin

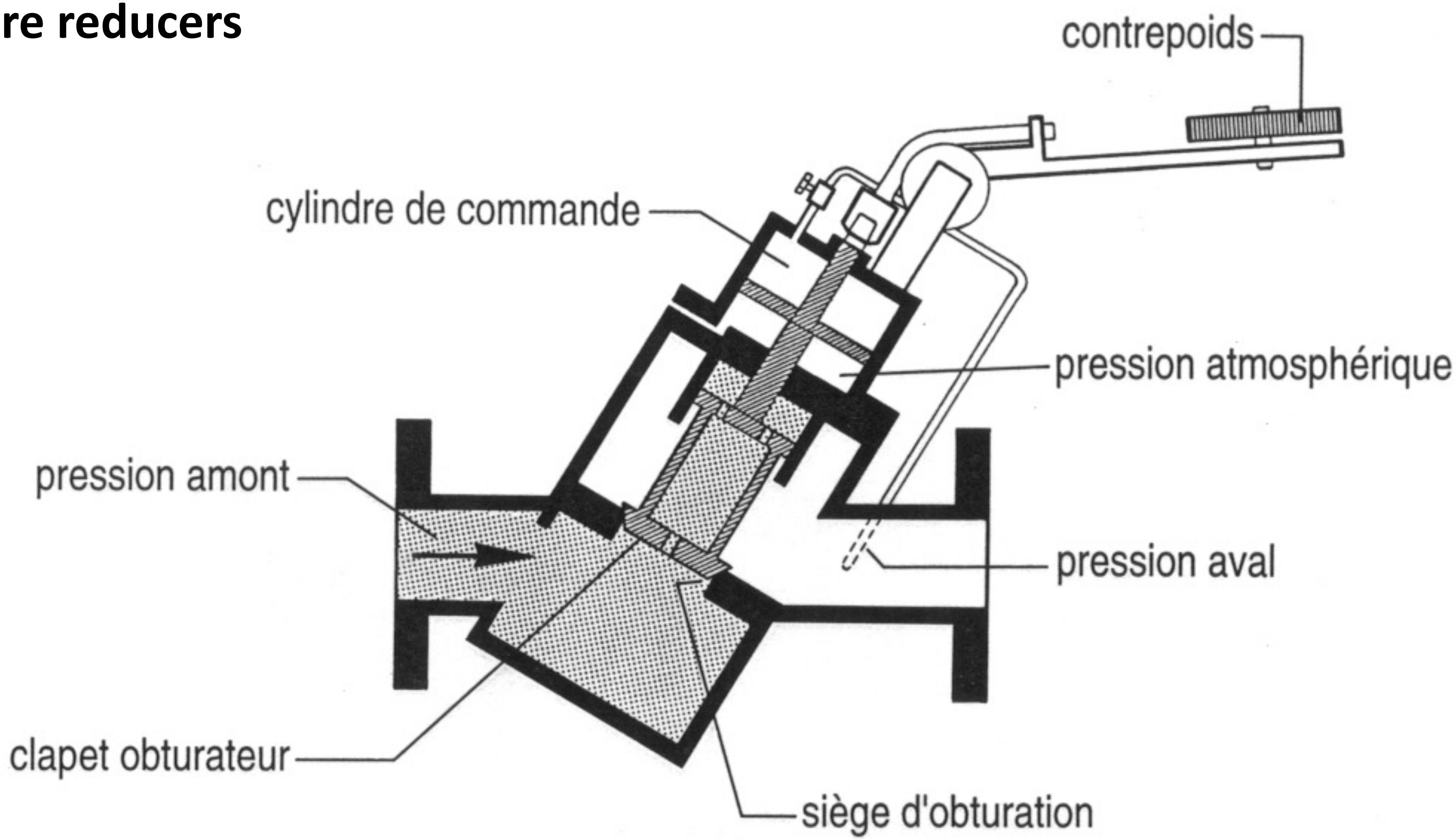


vanne - papillon

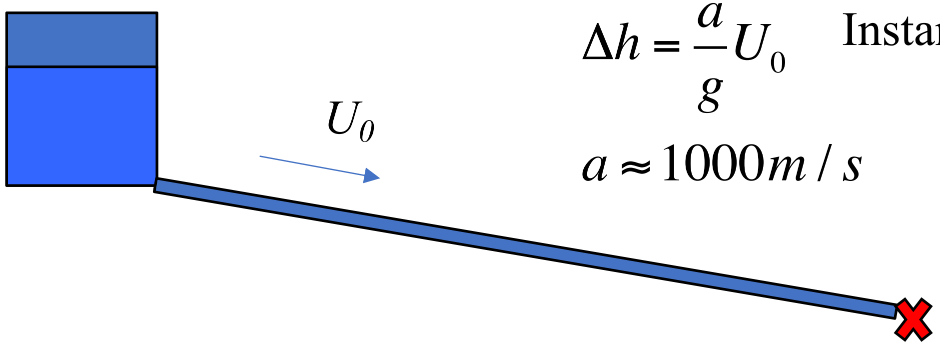
Positioning :

- strategic locations
- sector entrances
- to isolate certain equipment

Pressure reducers



The “Water hammer” phenomenon



$$\Delta h = \frac{a}{g} U_0$$ Instantaneous stop

$$a \approx 1000 m/s$$

Gradual stop (Allievi-Michaud)

$$\Delta h \leq \frac{2LU_0}{g\tau}$$

$$\tau = 2\frac{L}{a}$$

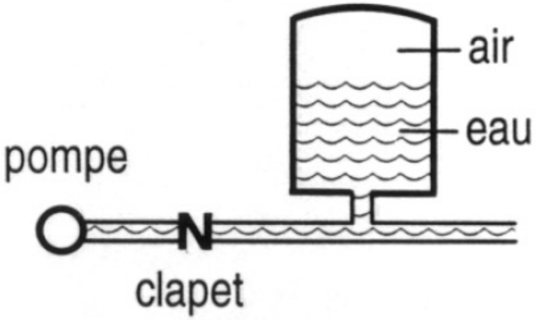


Fig. 9 : Réservoir anti-bélier

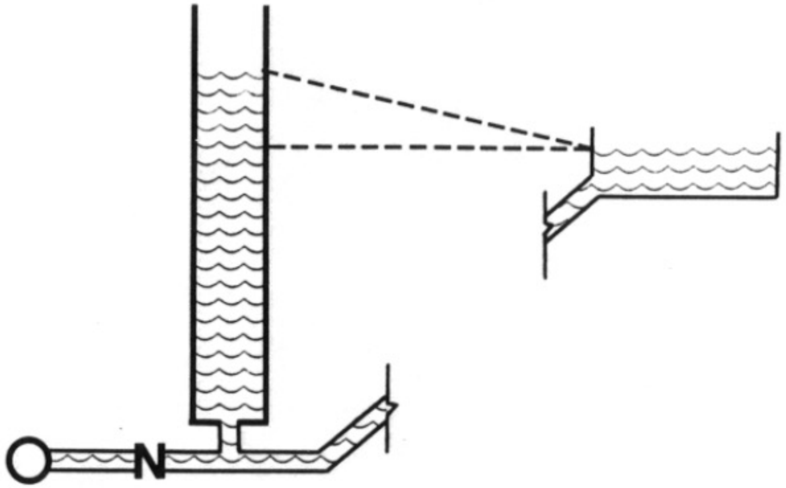
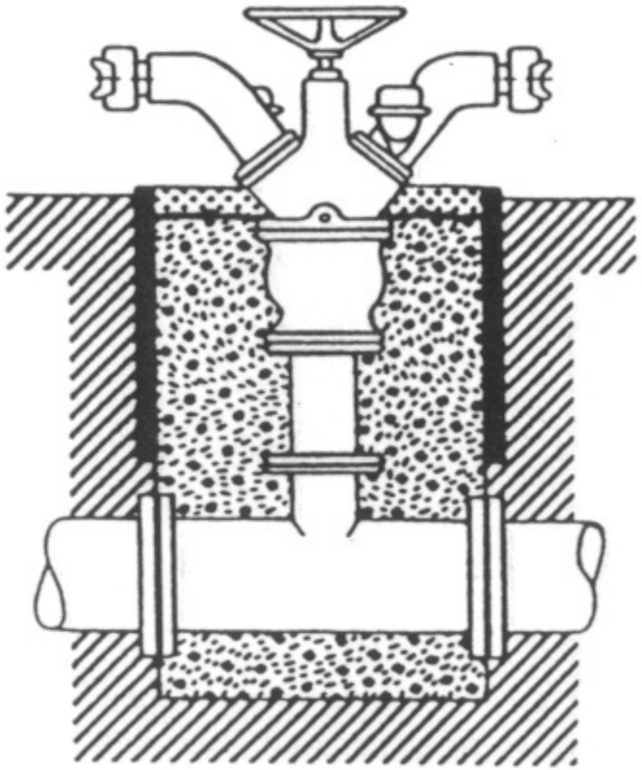


Fig. 10 : Cheminée d'équilibre

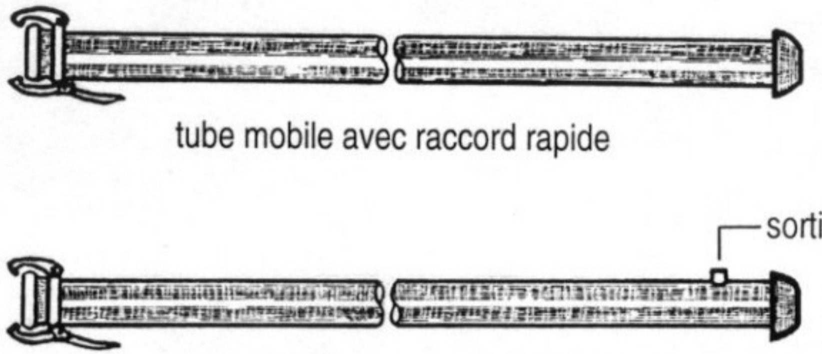
Similar solutions are adopted in pumped and hydropower systems (see discussion)

Irrigation hydrants (or terminals)



Mobile canalisations

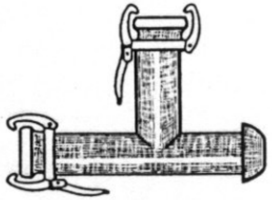
Canalisations mobiles



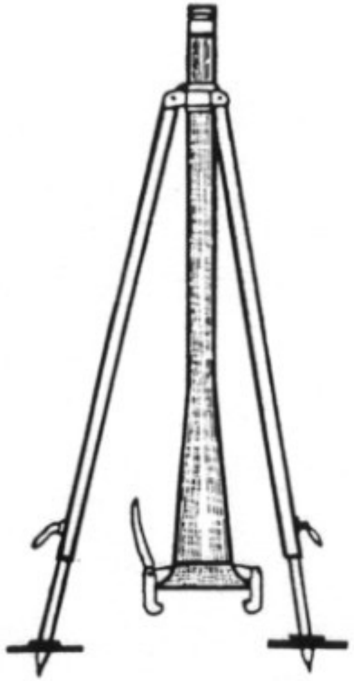
tube mobile avec raccord rapide

tube mobile avec sortie filetée

coude 90°



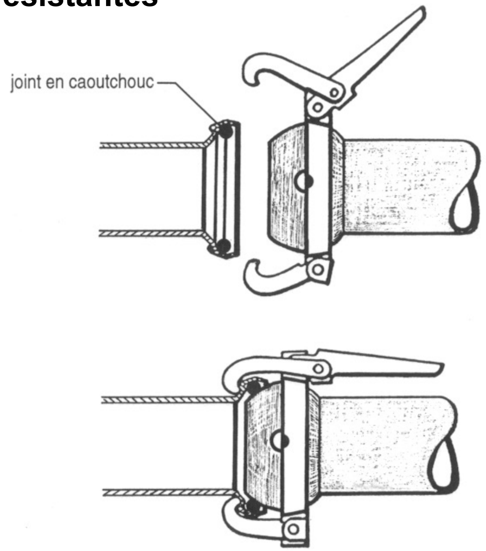
té à 2 accouplements



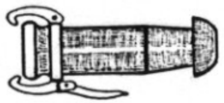
pied stabilisateur

Qualités requises :

- **faciles à déplacer et à assembler**
- **étanches**
- **résistantes**



Accouplement rapide



réduction