PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

Irrigation and Drainage Engineering

(Soil Water Regime Management)

(ENV-549, A.Y. 2025-26)

4ETCS, Master option

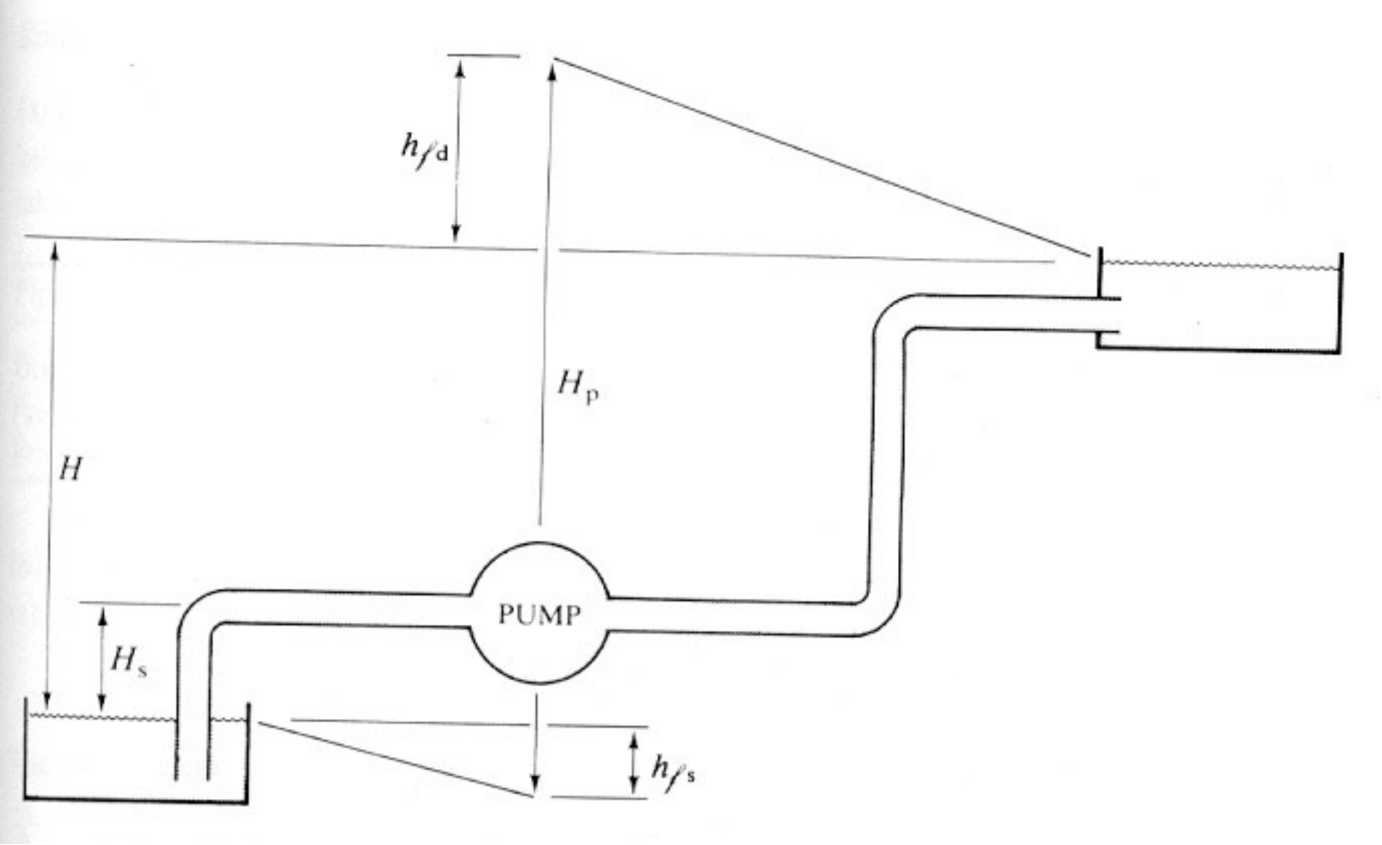
Prof. Paolo Perona
Platform of Hydraulic Constructions

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

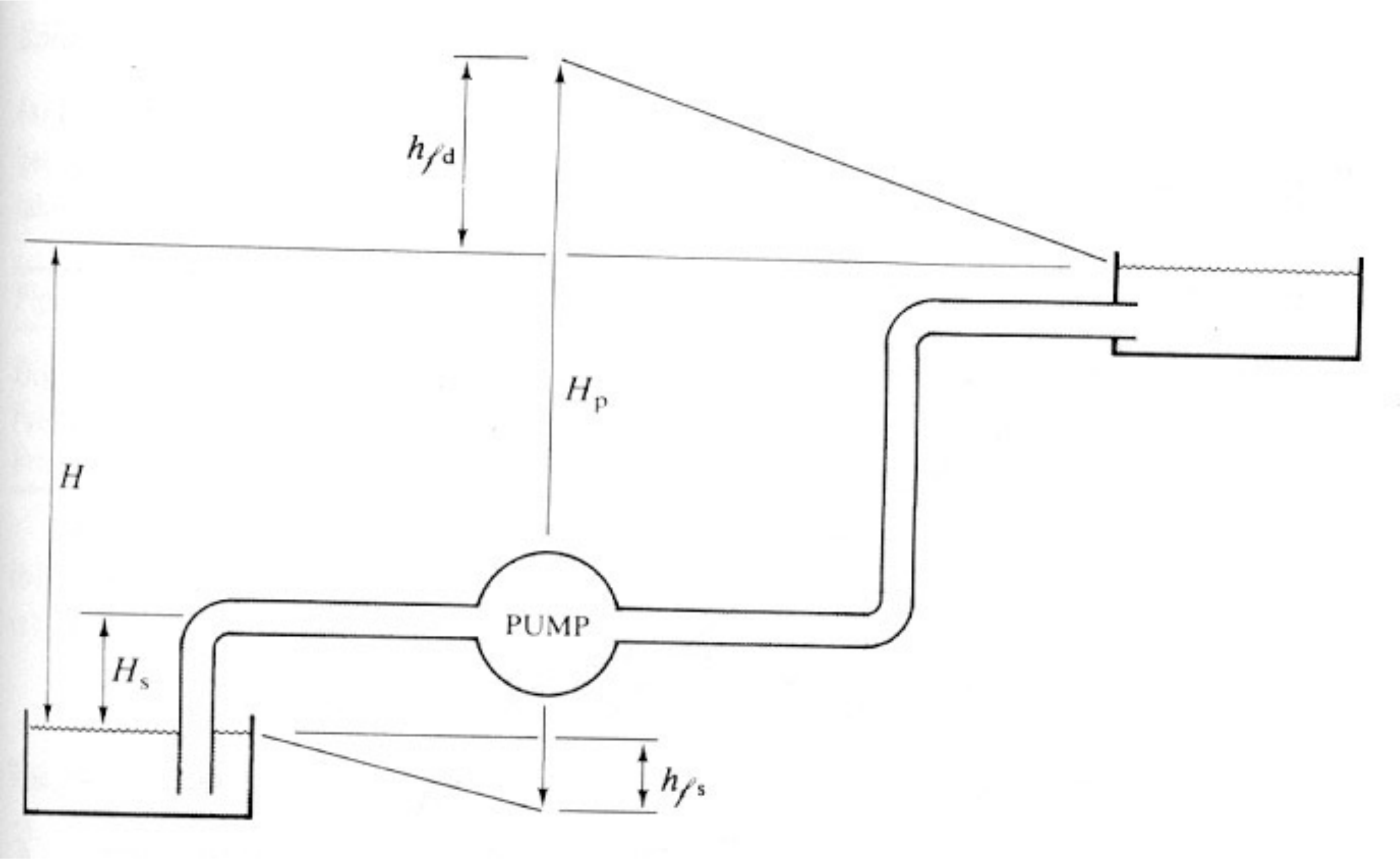
EPFL

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

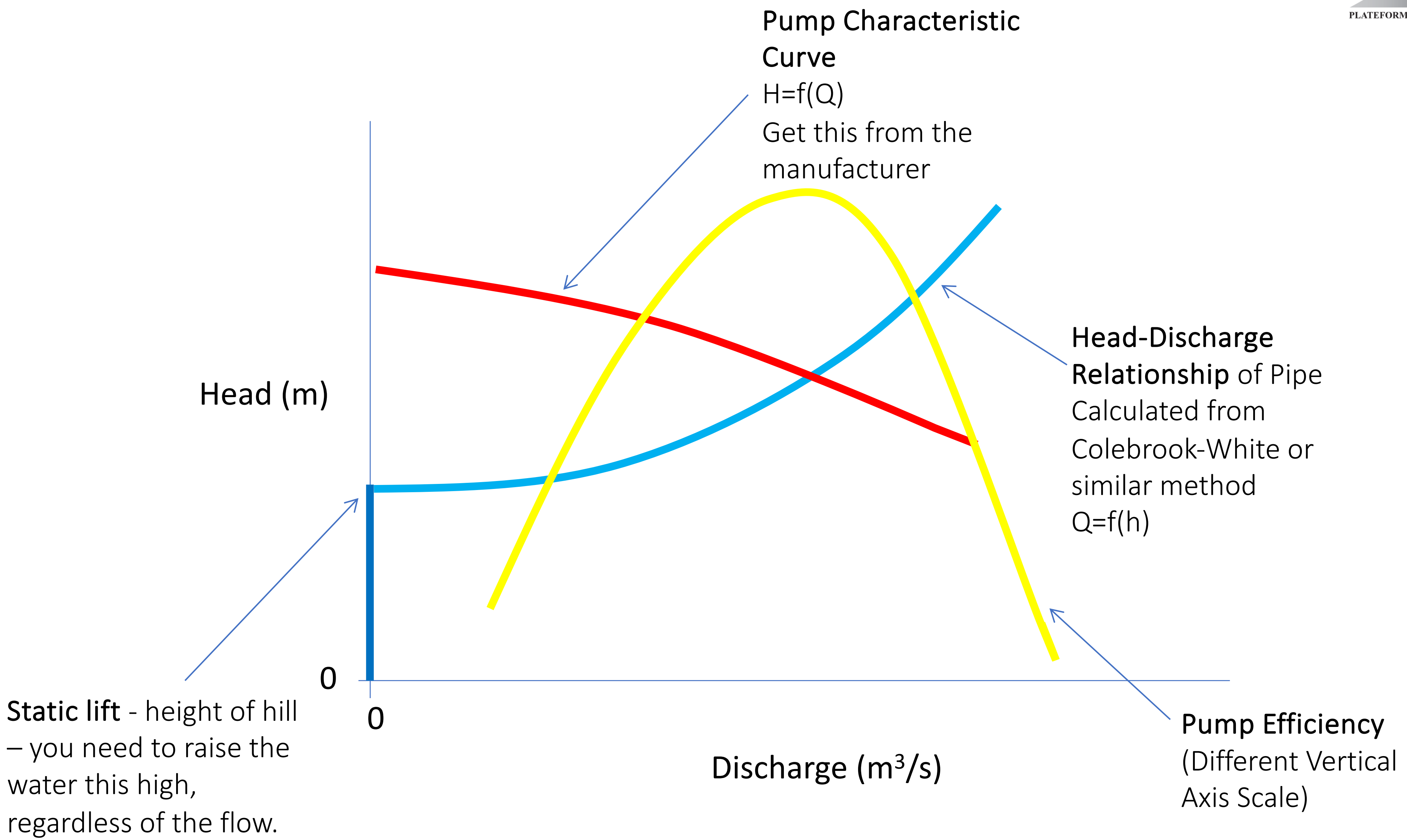


- Pumps in Series:
  - The head increases for a given discharge:
- H_{np} = nH_p $\qquad$ $Q_{np} = Q_p$

- Pumps in Parallel:
  - The discharge increases for a given head:

- $H_{np} = H_p$ $\qquad$ $Q_{np} = nQ_p$

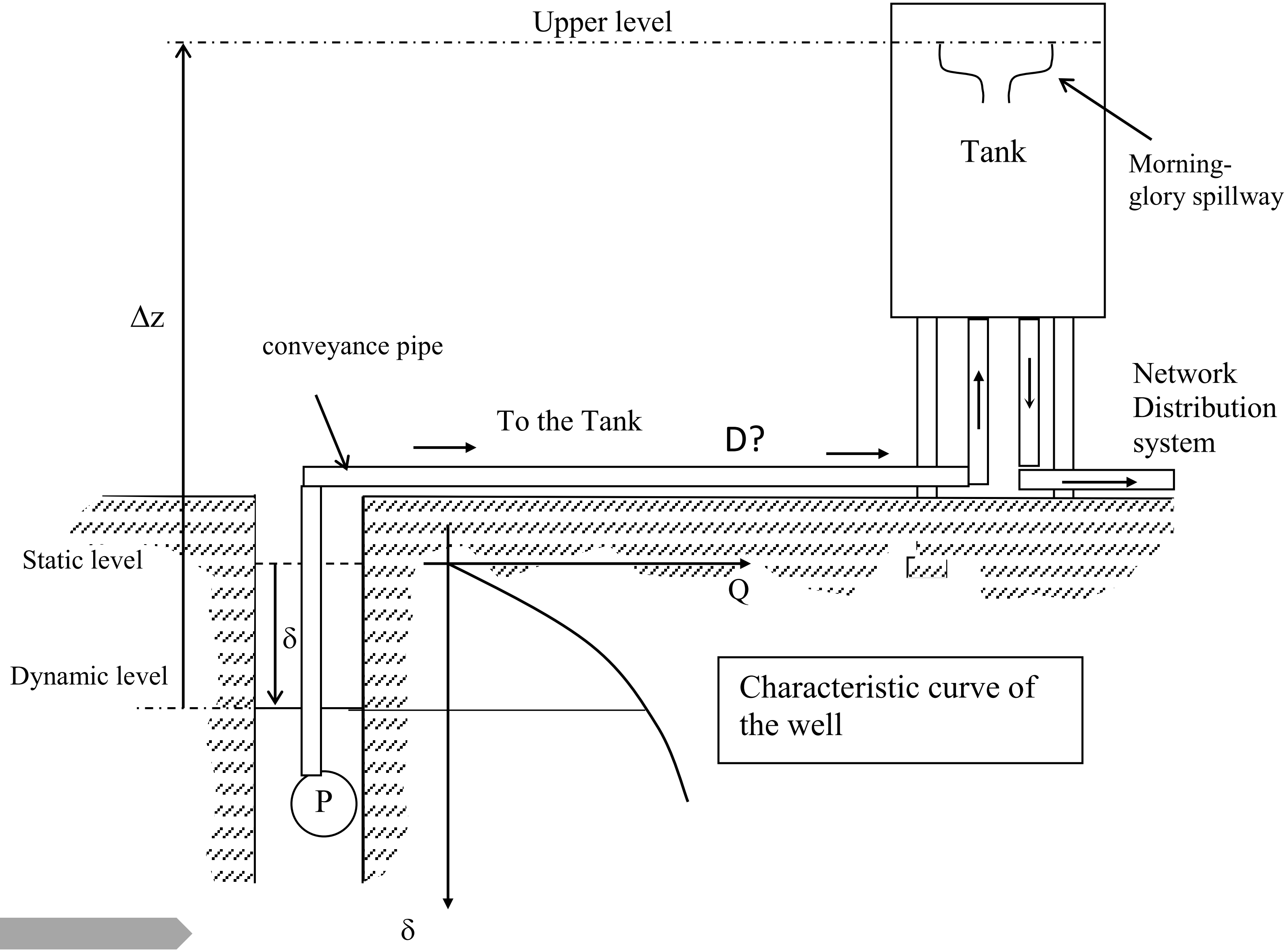
Pump functioning curves



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

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

↓

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

Pump Power

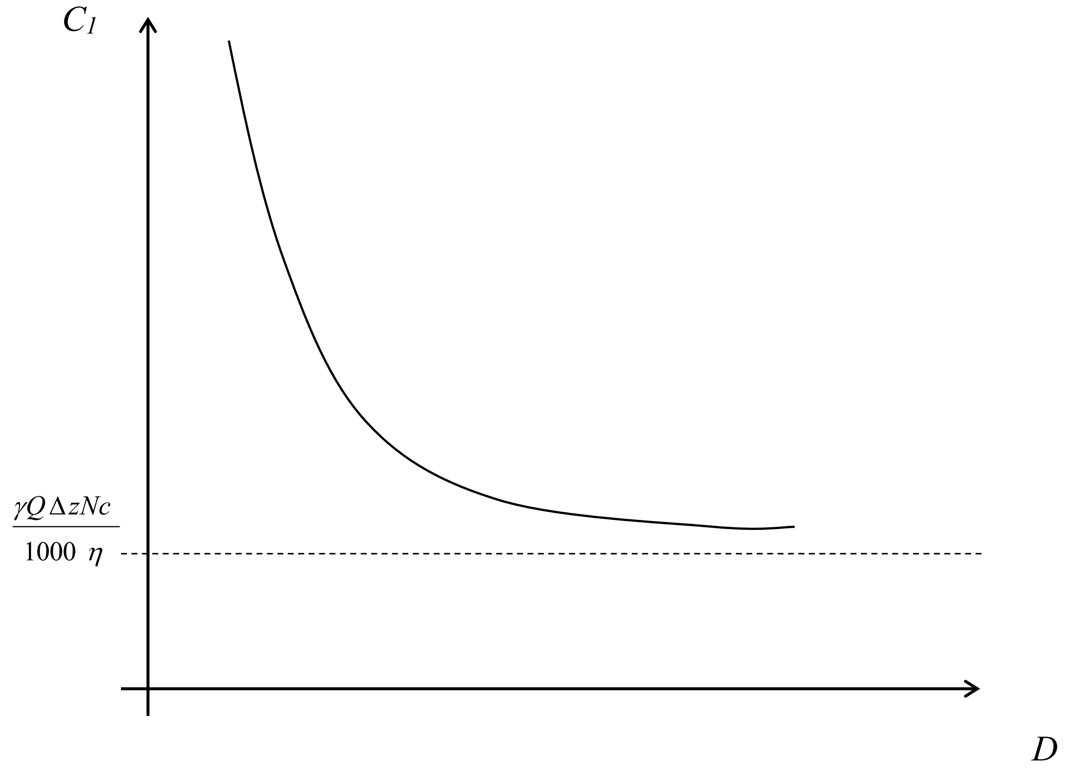
$$E = \frac{\gamma Q}{1000\ \eta}\left(\Delta z + \beta \frac{Q^2}{D^n} L\right) N$$

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:

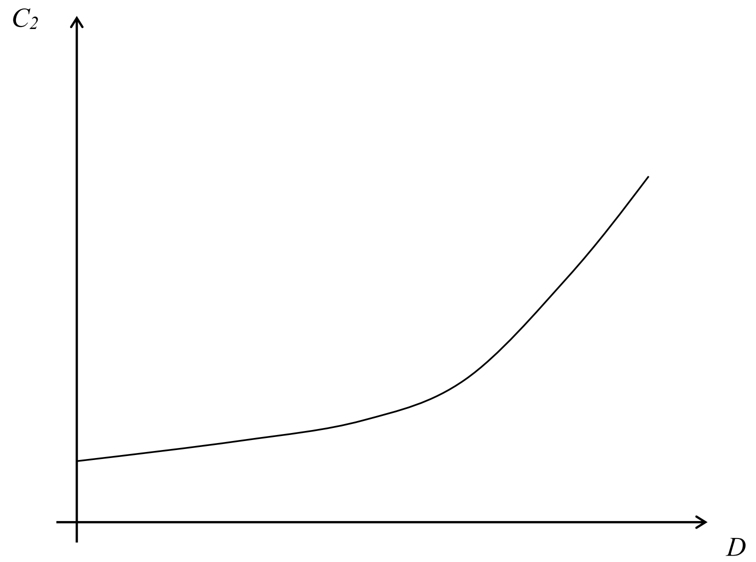
1) land purchasing, excavation, transporting, laying, installing and filling. We indicate this cost as *R*.

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

Total building costs:

$C_2 = R + T$

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



Total cost

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

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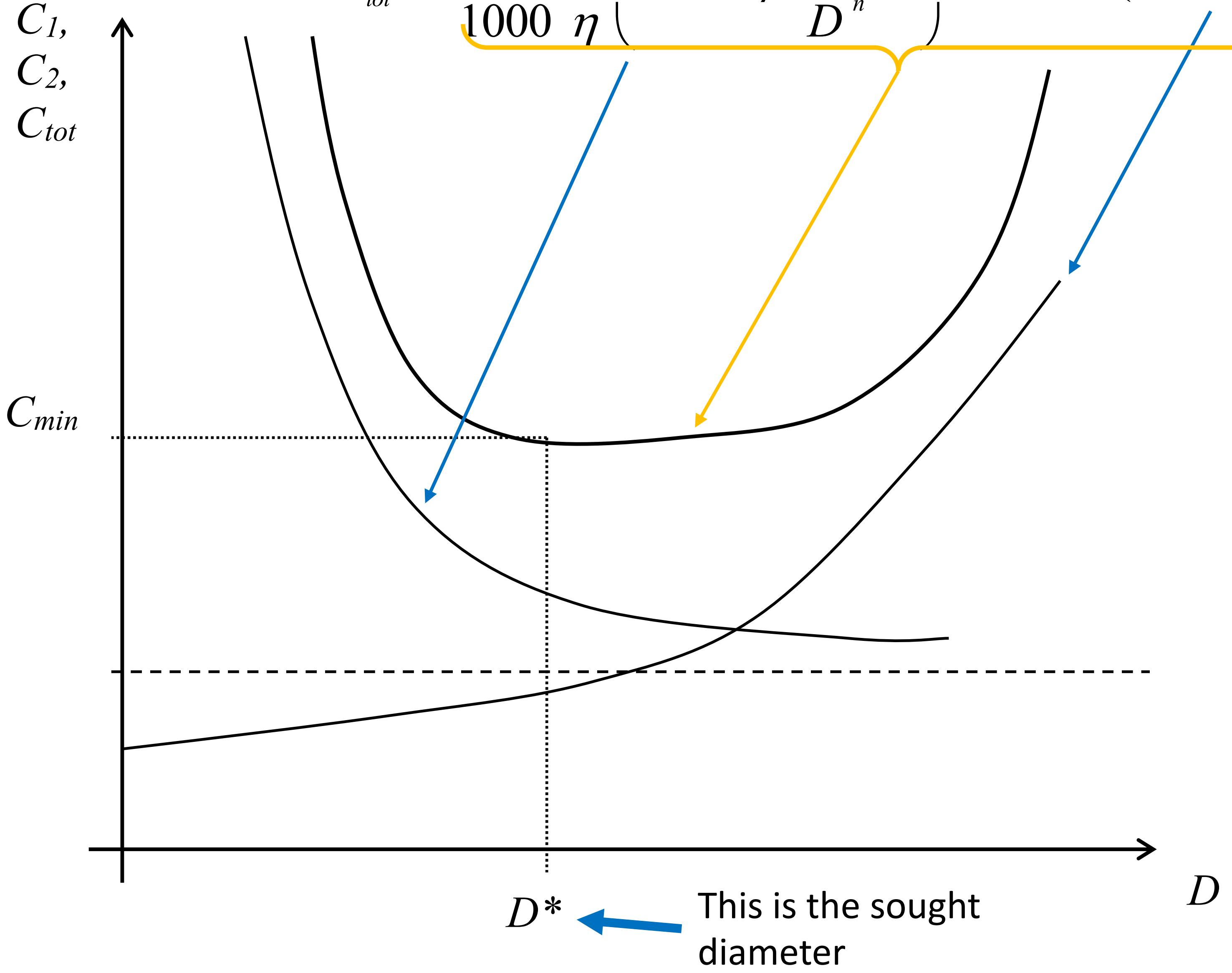
$$C_{tot} = \frac{\gamma Q}{1000\,\eta}\left(\Delta z + \beta\frac{Q^{2}}{D^{n}}L\right)N\bar{c} + \bar{\alpha}\left(R + cLD^{a}\right)$$



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

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

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

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

Irrigation pipes and ancillary elements

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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

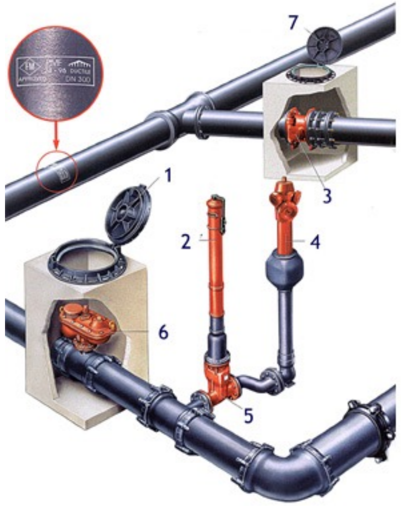
*In the case of rolling loads (heavy machines), at least 75 cm

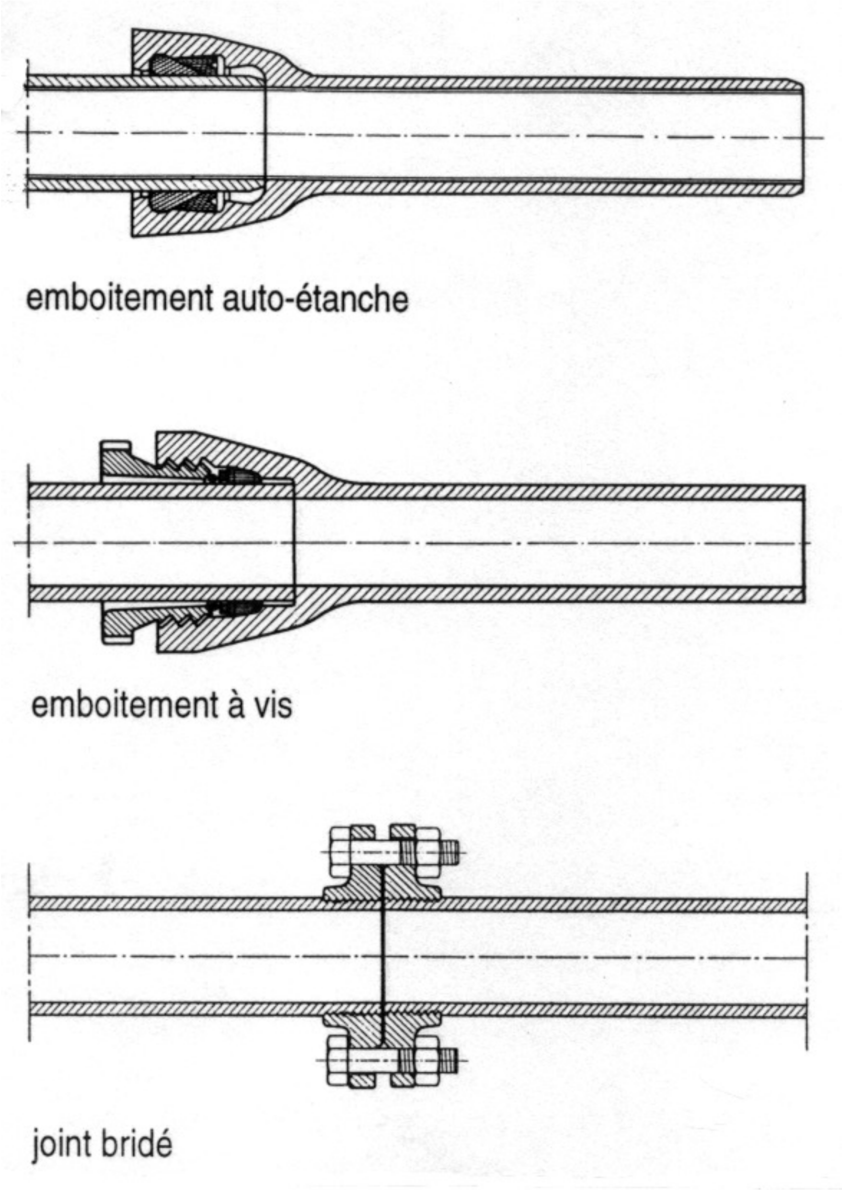
Materials

➔ 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

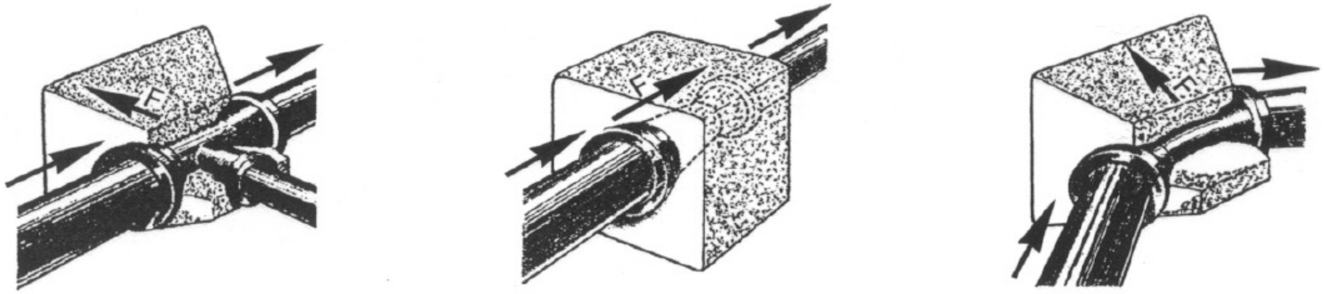
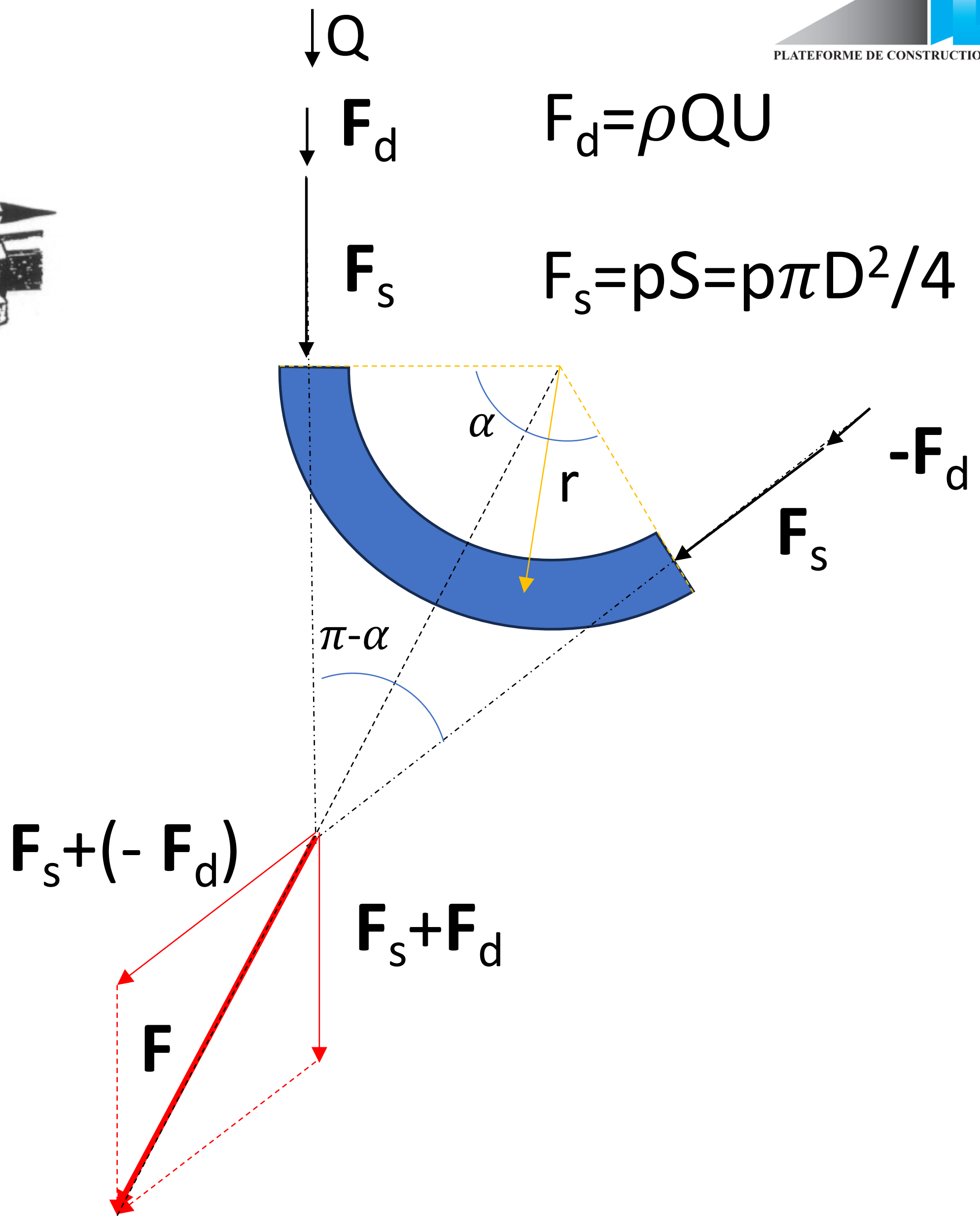


Fig. 11 : Poussées dans différentes situations ([12])



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 is a good approximation

Usually F_d << F_s and can be neglected

Anchoring system (see also discussion)

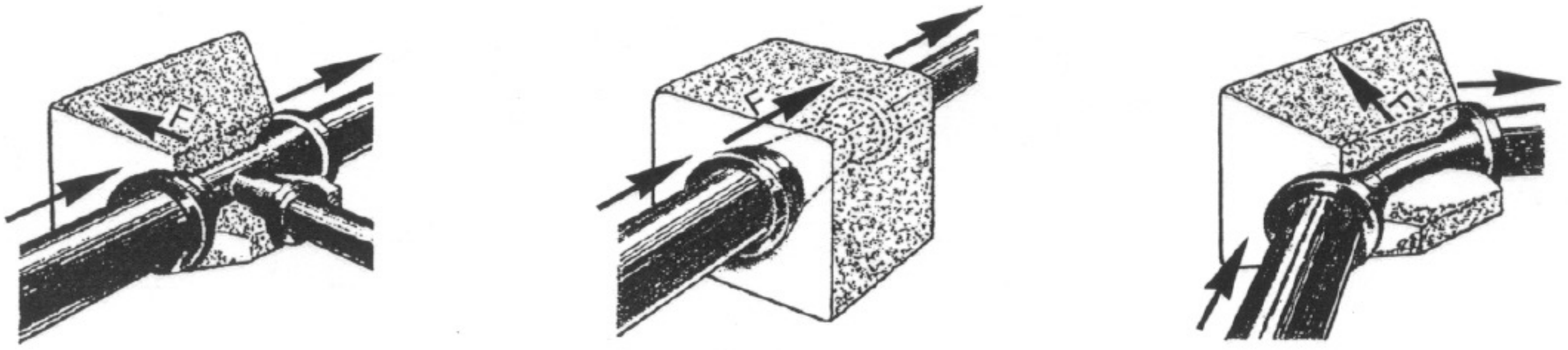


Fig. 11 : Poussées dans différentes situations ([12])

$$F = K P S$$

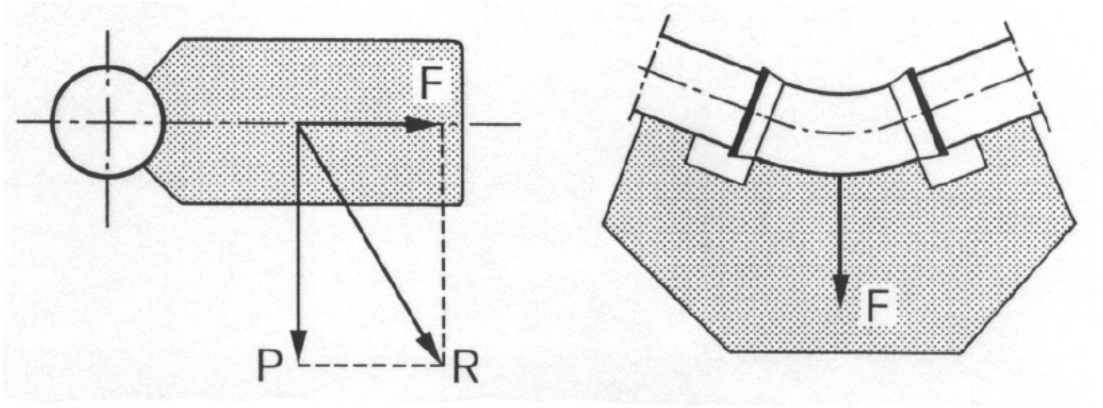
K : coefficient fonction du type de singularités

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

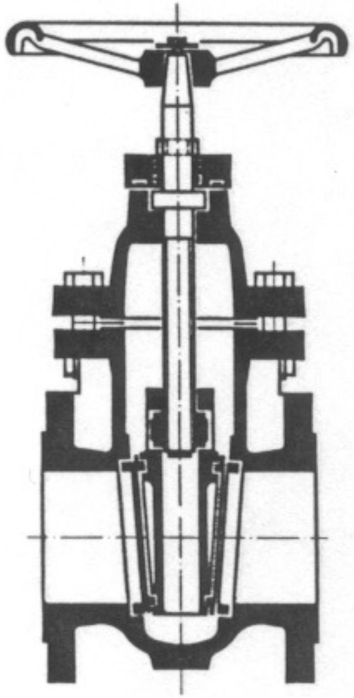
~ pour les coudes d'angle α : $K = 2 \sin\frac{\alpha}{2}$

(ex. α = 90°, K = 1.414; α = 45°, K = 0.766)

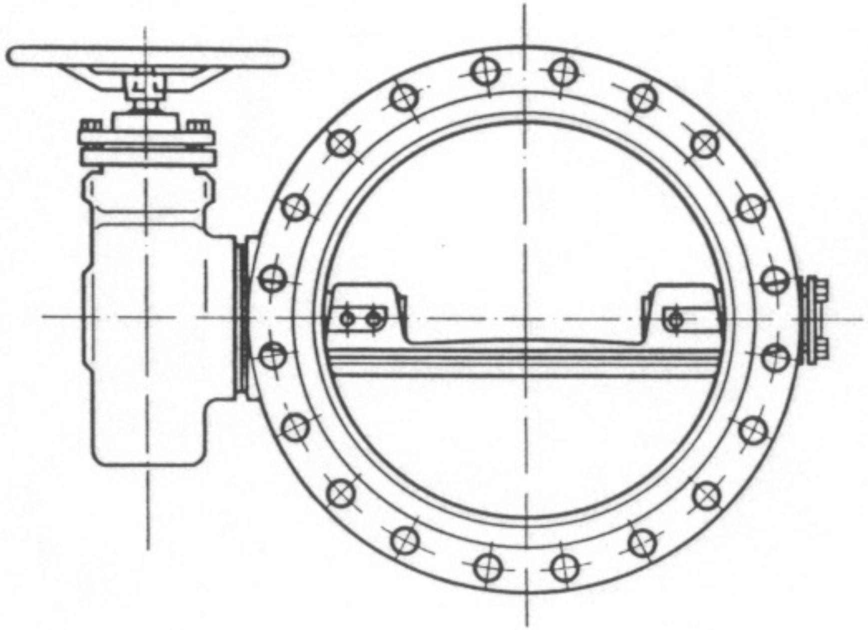
$$\frac{F}{P} < \mathrm{tg}\,\varphi < 0.577$$



Valves and gates



vanne à coin

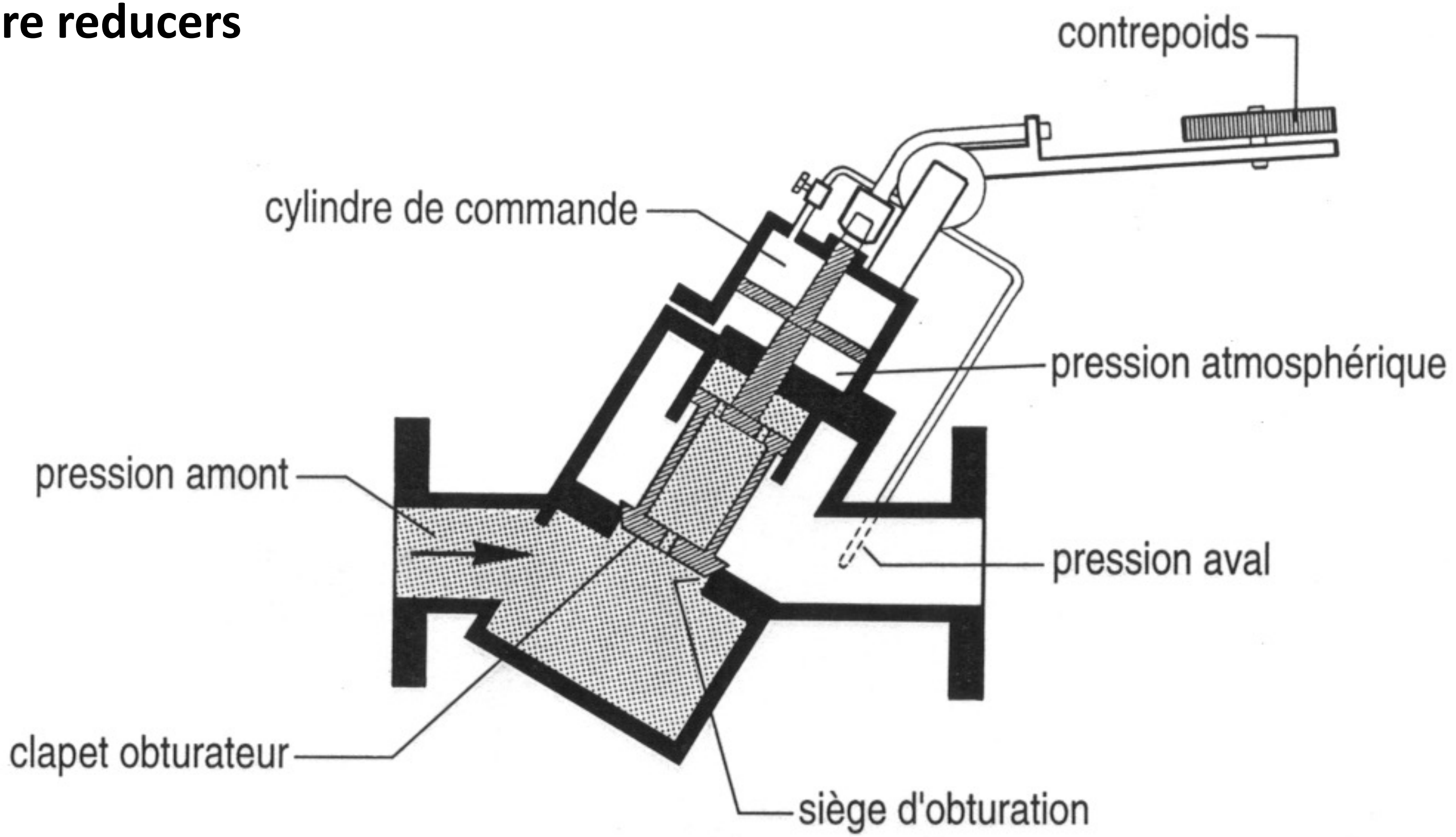


vanne - papillon

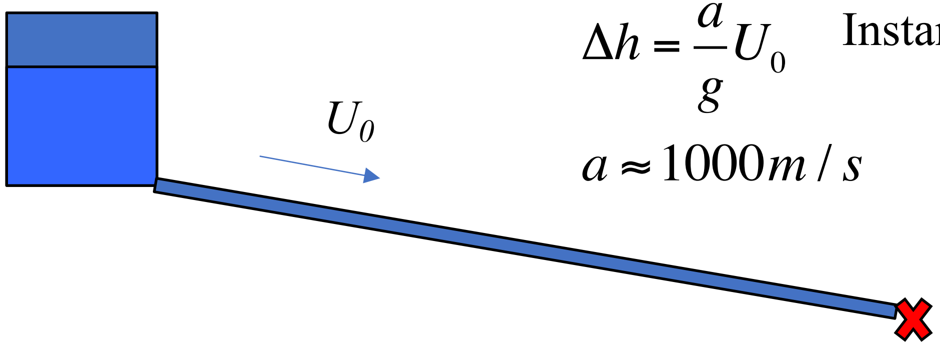
Positioning :

- 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)

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

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

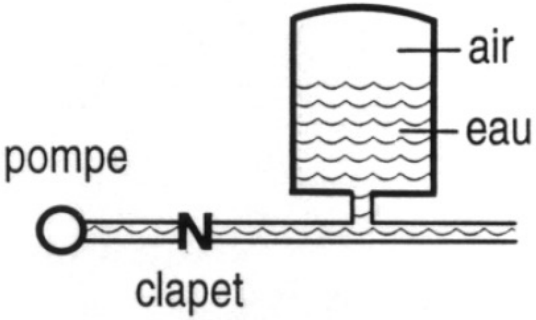


Fig. 9 : Réservoir anti-bélier

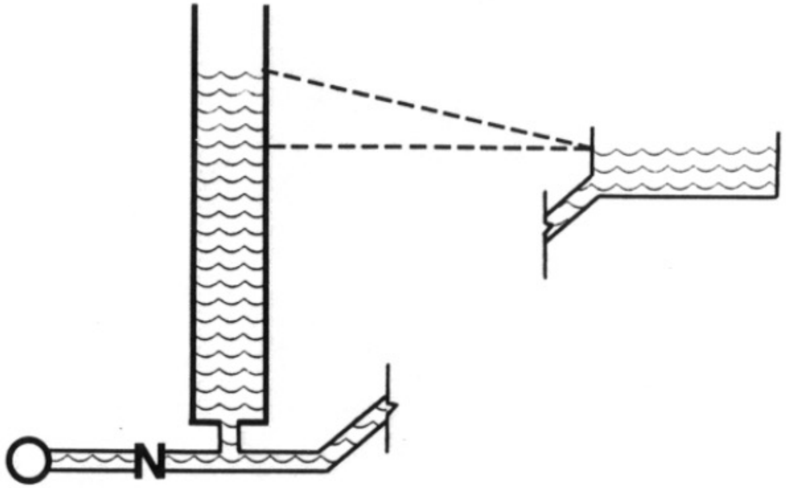
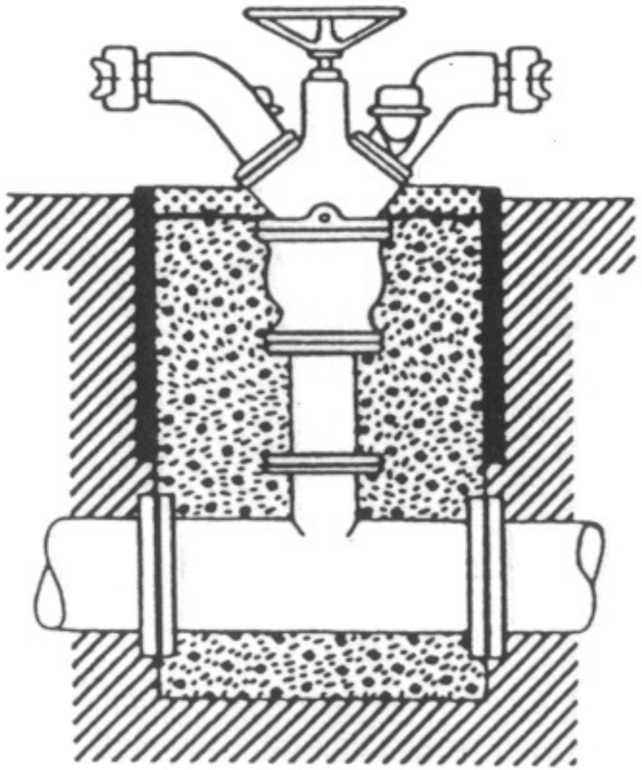


Fig. 10 : Cheminée d'équilibre

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

Irrigation hydrants (or terminals)



Mobile canalisations

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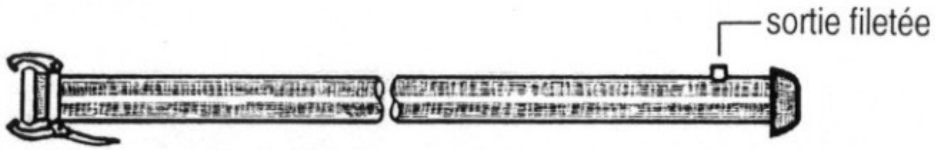
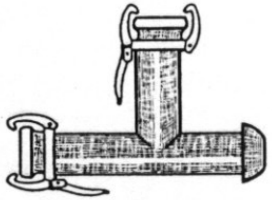
Canalisations mobiles

tube mobile avec raccord rapide

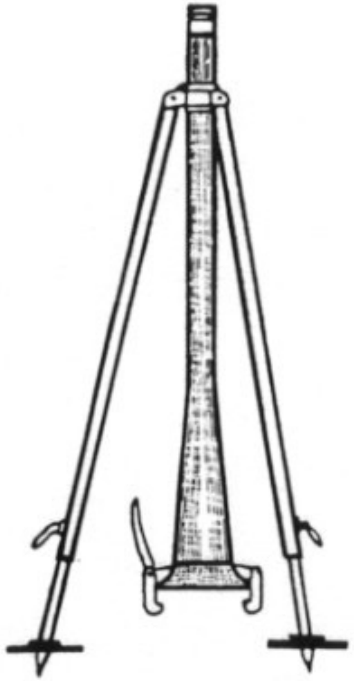


tube mobile avec sortie filetée

coude 90°



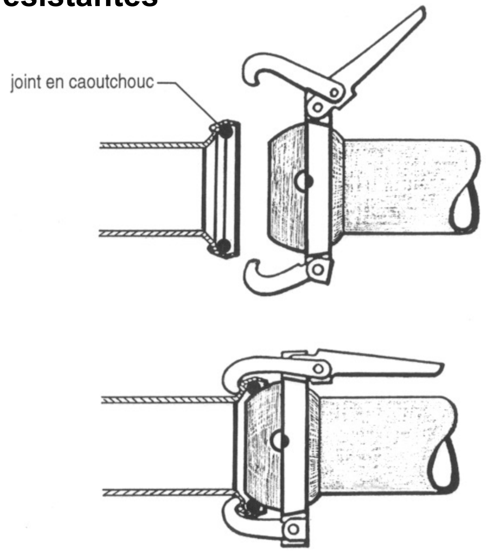
té à 2 accouplements



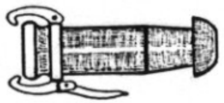
pied stabilisateur

Qualités requises :

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



Accouplement rapide



réduction