Chapter 4:

DYNAMICS OF REAL INCOMPRESSIBLE FLUIDS

1/ INTRODUCTION

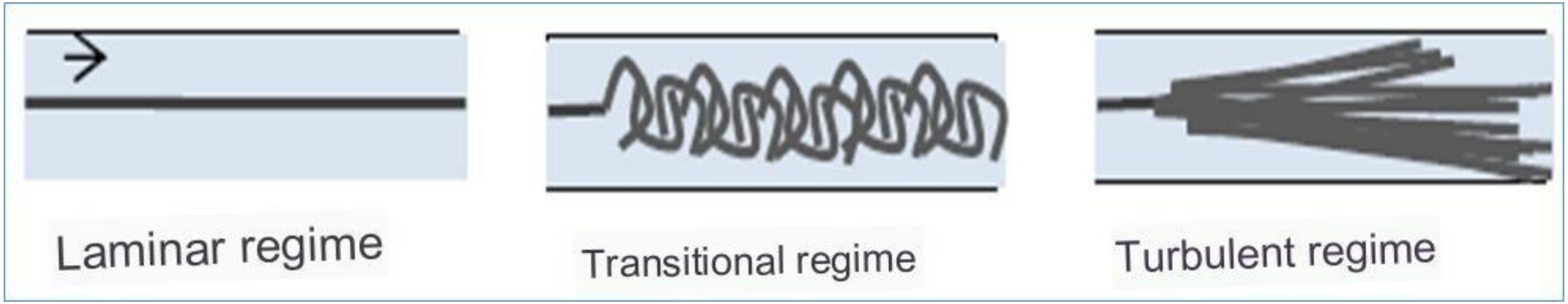
- In the previous chapter we assumed that the fluid was perfect to apply the energy conservation equation.
- In the case of the flow of a **real fluid,** it There are frictional forces , due to the viscosity of the fluid, which act between the fluid particles and the walls, as well as between the particles themselves .

2/ REAL FLUID

A fluid is said to be real if, during its motion, the contact forces are not perpendicular to the surface elements on which they are exerted . This resistance is characterized by the viscosity.

3. FLOW REGIMES - REYNOLDS NUMBER

Reynolds (1883) varied the flow rate, viscosity and diameter of the pipe, and If a small volume of dye is injected into the axis of a horizontal pipe through which water flows, the following phenomena are observed according to the flow rate of the liquid:



Re < 2000 **2000< Re <3000** **Re > 3000**

Reynolds number: is a dimensionless number used to determine the flow regime.

$$Re = vD/\nu \quad \text{or} \quad Re = \frac{\rho v D}{\mu}$$

v : Average speed

υ: kinematic viscosity

μ: dynamic viscosity

D: Pipe diameter

ρ:density

If Re <2000 the regime is laminar

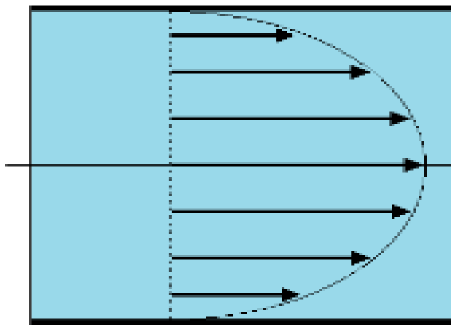
If 2000< Re <3000 the regime is transient

If Re >3000 the regime is turbulent

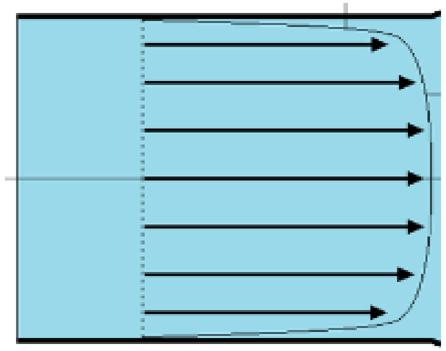
All calculation done, the total flow is: $Q = \frac{\pi D^4}{128\mu} \cdot \frac{\Delta p^*}{L}$

3.1. Speed profile

Perfect



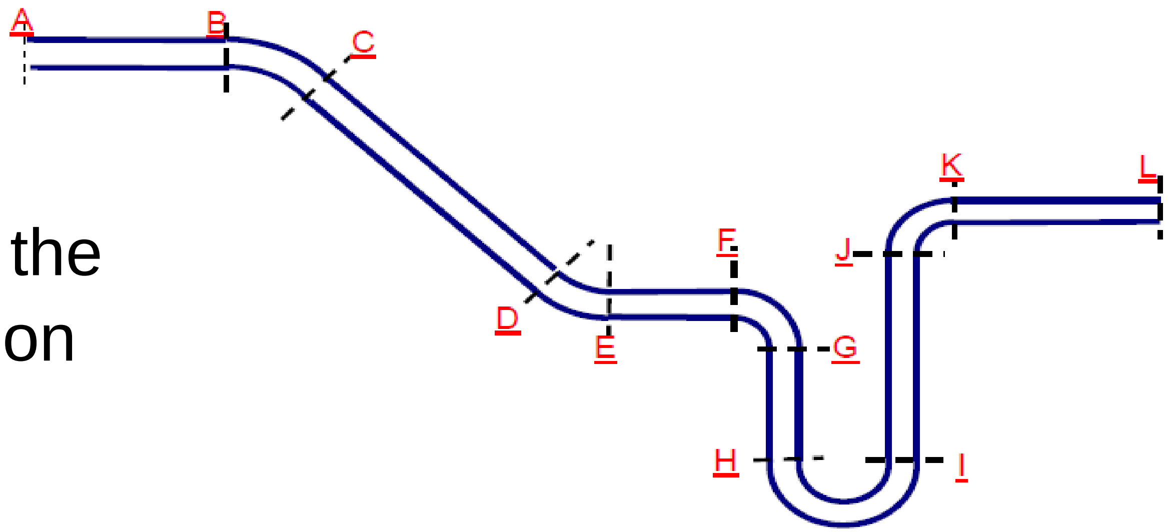
laminar



Turbulent

4. Load losses

4.1. Singular pressure drops



The existence of head losses results in the sudden change in direction and/or section (fitting, T, valves, etc.) .

$$\Delta Hs = K \cdot \frac{V^2}{2g}$$

K **:** Head loss coefficient (unitless). It depends on nature and geometry.

The values of ***K*** are given by the manufacturers in their catalogues.

4.2 Linear head losses:

They then correspond to the flow along the pipes due to the roughness of the pipe.

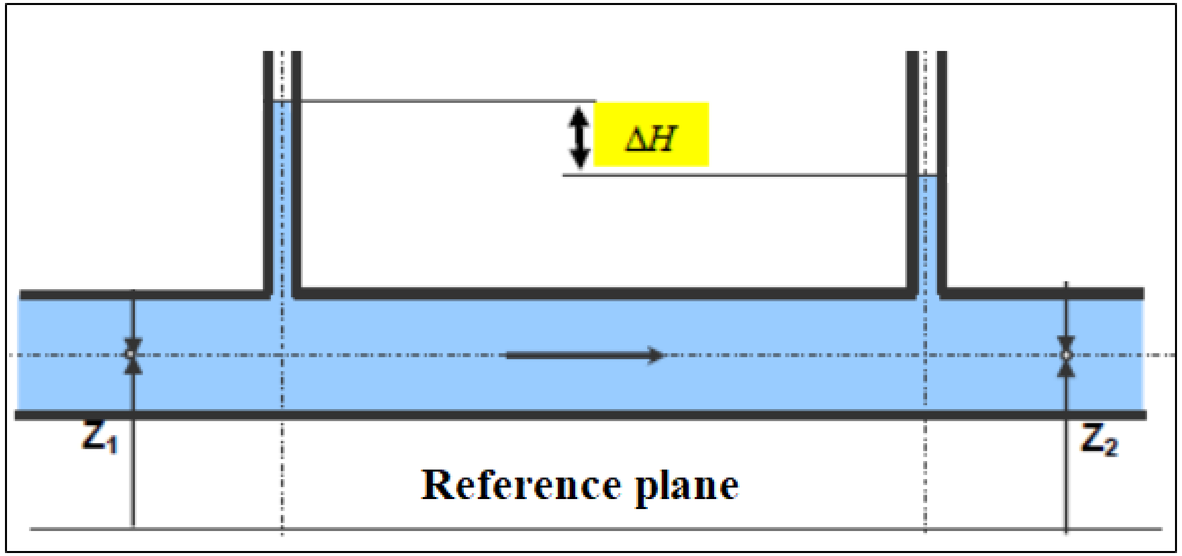
The absolute roughness represents the average thickness of the surface asperities of the material making up the pipe. It is noted Ɛ, and it is most often expressed in millimeters.

For a pipe of a given diameter D, the relative roughness is the ratio ε/D .

4.2 Linear head losses:

They then correspond to the flow along pipes due to the roughness of the pipe.

$$\Delta H_l = \lambda . \frac{V^2}{2g} . \left(\frac{L}{d} \right)$$



- V: average flow velocity in the pipe (m/s)
- L: length of the pipe (m)
- d: pipe diameter (m)
- λ : linear pressure drop coefficient (is the coefficient of friction). It depends on the flow regime and in particular on the Reynolds number Re .

$$\Delta H_l = \lambda . \frac{V^2}{2g} . \left(\frac{L}{d} \right)$$

In a laminar flow regime: $R_e < 2000$

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

(Poiseuille formula)

In a smooth turbulent flow regime: $2000 < R_e < 10^5$

$$\lambda = 0{,}316 / R_e^{\ 0{,}25}$$

(Blasius formula)

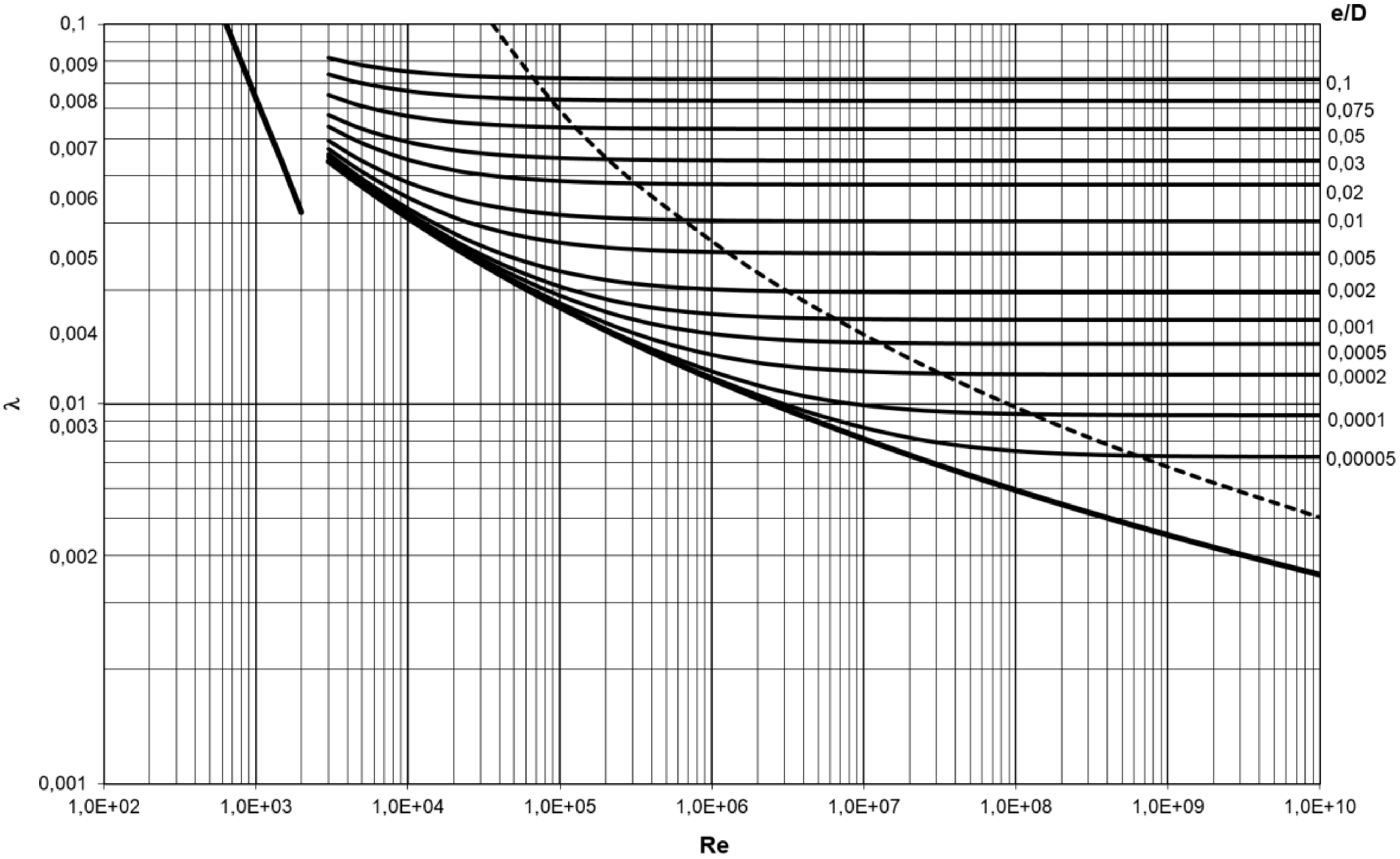
In a rough turbulent flow regime: $R_e > 10^5$

$$\lambda = 0{,}79 . \sqrt{\frac{\varepsilon}{d}}$$

(Blench Formula)

Sometimes, we read the value of λ on an abacus established by Moody.

$$\Delta H_l = \lambda \cdot \frac{V^2}{2g} \cdot \left(\frac{L}{d}\right)$$



5. BERNOULLI'S THEOREM APPLIED TO A REAL FLUID

Δ H 1.2 : Sum of all head losses, singular and linear between sections 1 and 2.

P: Mechanical power exchanged between the fluid and the machines placed between (1) and (2).

Bernoulli's Theorem takes the following general form:

$$\frac{v_1^2}{2g} + Z_1 + \frac{P_1}{\rho g} + \frac{P}{\rho g Q_V} = \frac{v_2^2}{2g} + Z_2 + \frac{P_2}{\rho g} + \Delta H_{1,2}$$