Experiment (10)

Reynolds Number & Pressure Loss in Pipe

Fluid Mechanics Lab.
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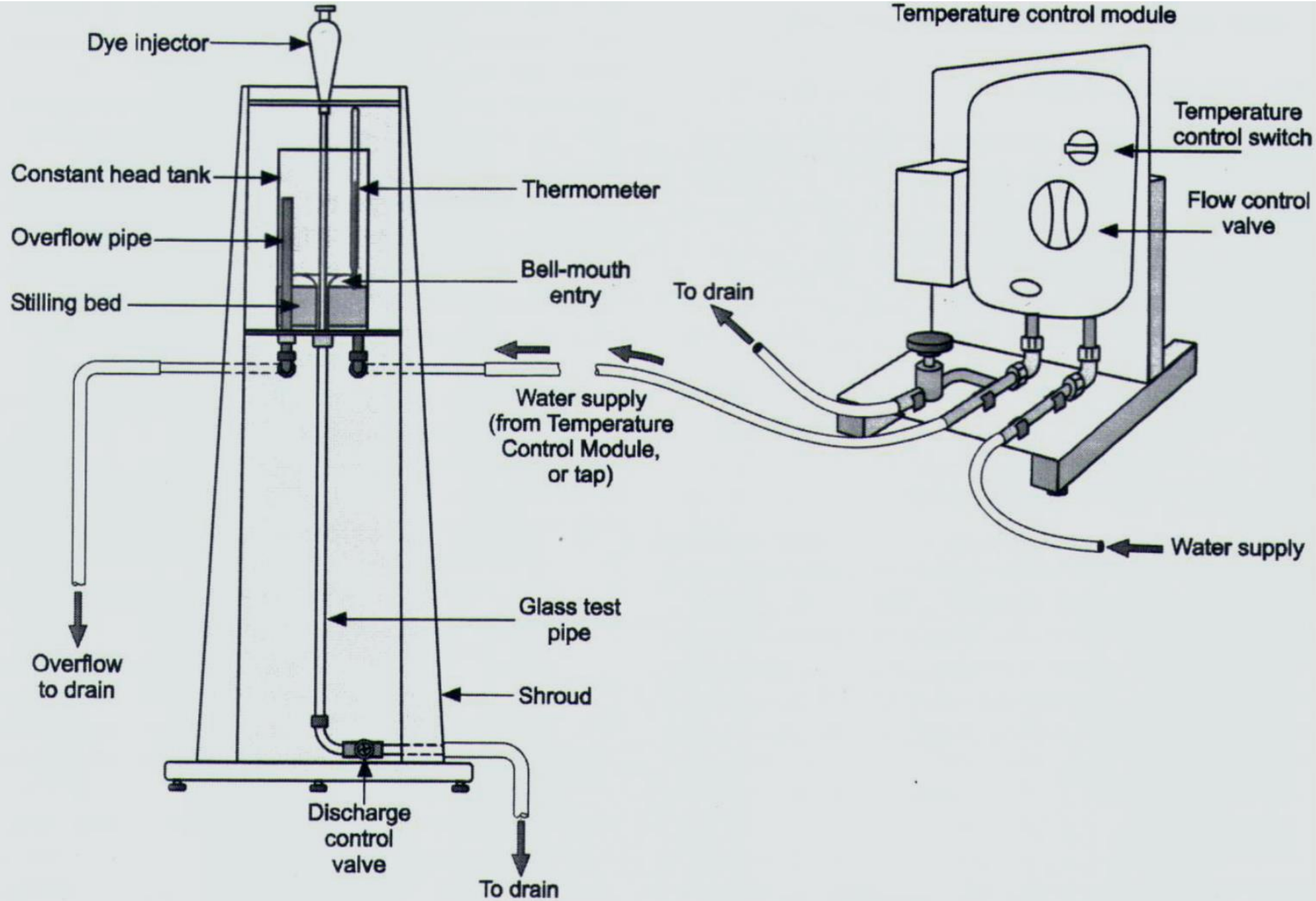
Introduction

When a fluid flows next to a solid boundary the nature of the flow depends on the velocity relative to that boundary. At low velocities the layers of fluid move smoothly over one another and this is termed 'laminar' flow. However, as the velocity is increased small disturbances cause eddies which 'mix-up' the layers of fluid and produces a different pattern of flow, which is termed 'turbulent'. This change has a marked effect on the forces acting between the fluid and the solid boundary and an understanding of the behaviour is of fundamental importance in the study of hydraulics and fluid mechanics. The nature of flow over an aircraft wing affects the drag and hence determines the power required to propel the aircraft forwards. Similarly, when fluid flows along a pipe the nature of the flow determines the pressure loss and hence the power required to pump the fluid along the pipe.

Reynolds Number Apparatus

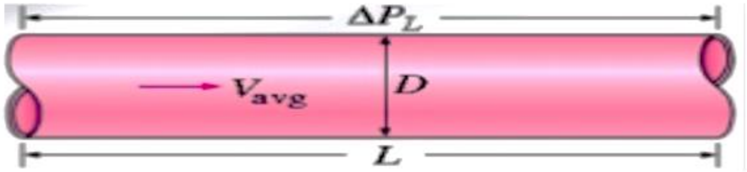


British physicist named Osborne Reynolds (1842 - 1912) who first identified the variables controlling the flow and produced a rational means of predicting the nature of flow.

Reynolds number

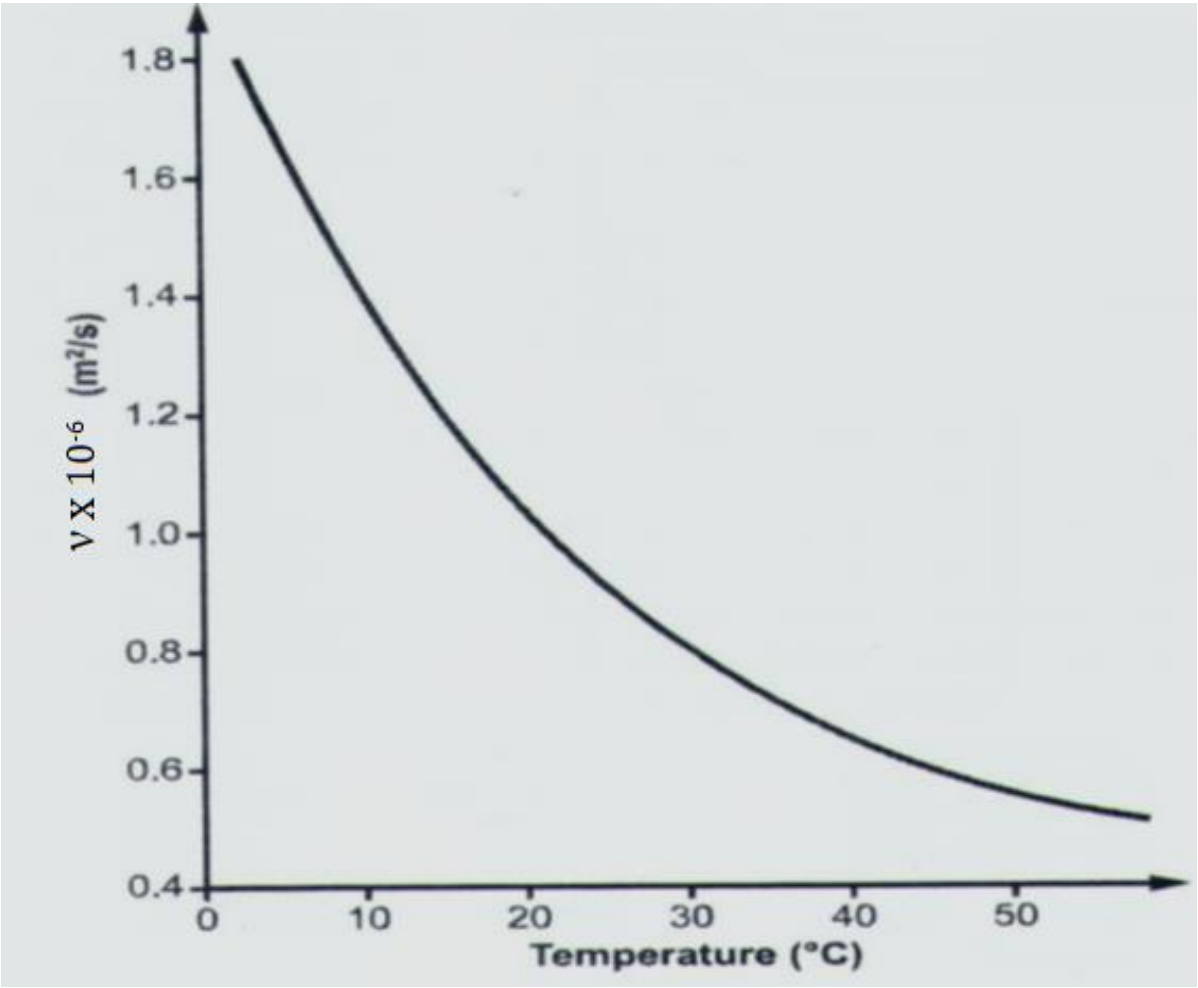
which expresses the ratio of inertia to viscous forces and can be used to identify the conditions under which the flow changes from laminar to turbulent. By experiment

$$Re = \frac{\rho v D}{\mu} = \frac{v D}{\nu}$$



$$Re = \frac{\rho v D}{\mu} = \frac{v D}{\nu}$$

- Dynamic viscosity (μ): can be defined as fluid resistance to flow when an external force is applied. (like when pump is used), so it is used for non-Newtonian fluids
- *Kinematic viscosity(v): can be defined as fluid resistance to flow when no external force is applied except the gravity acting on it.*



1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
V X 10-6 (m²/s)
0
10
20
30
40
50
Temperature (°C)

- Laminar flow (When Re < 2300)

$$f = \frac{64}{Re} \qquad (Hagen - Poiseuille\, equation)$$

- Transient flow (2300<Re<4000)
- Turbulent flow (Re>4000)

$$f = 0.316 Re^{-0.25} \qquad (Blasius \;\; equation)$$

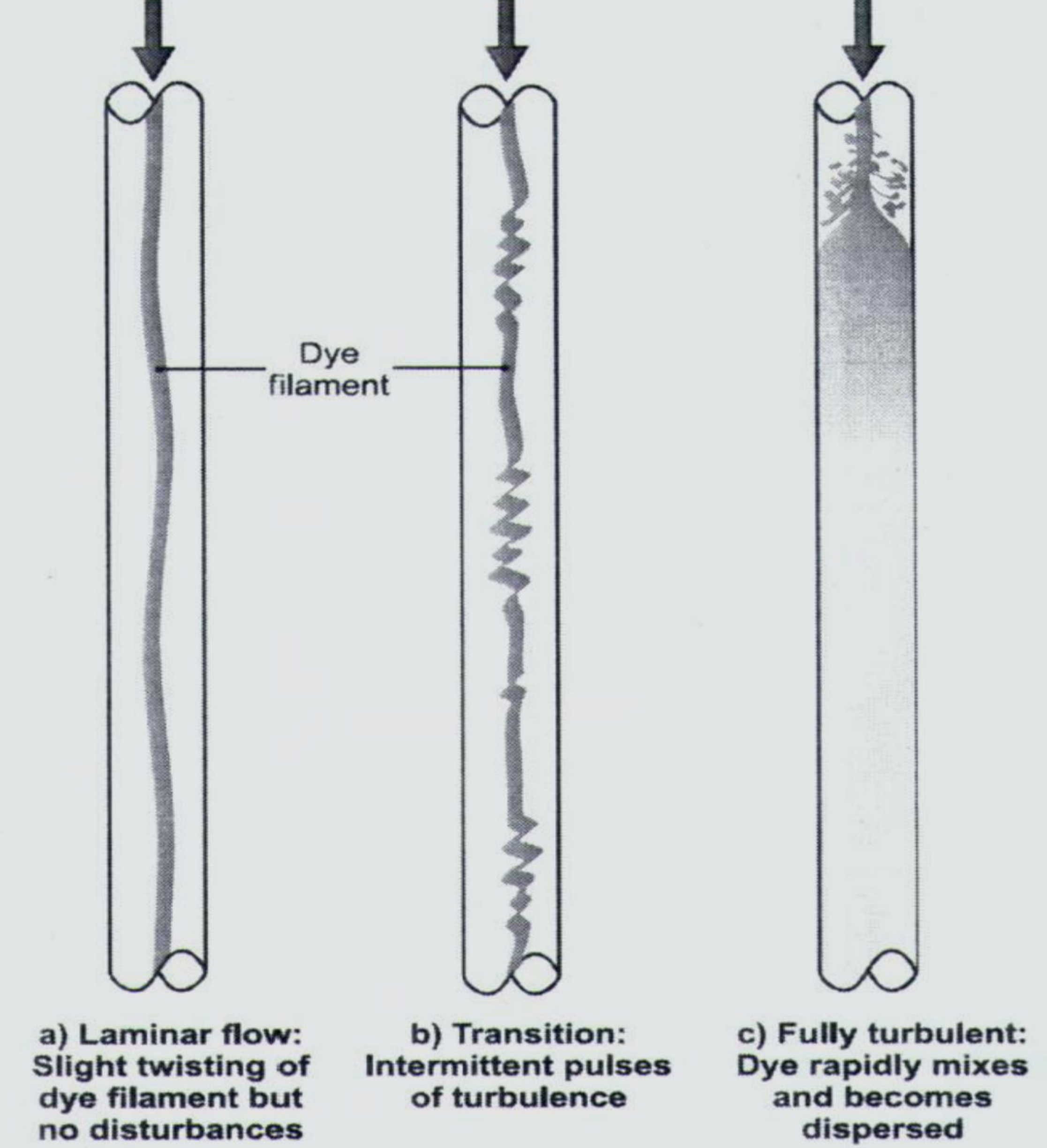
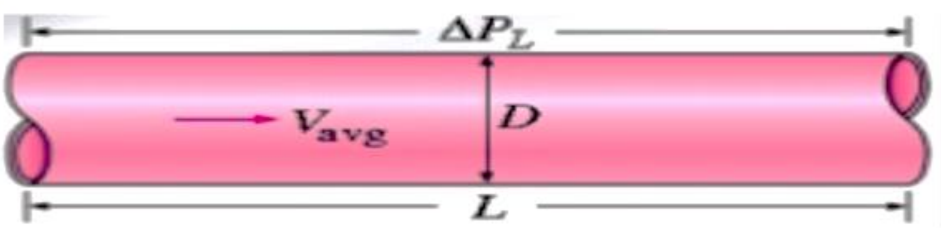


Figure 4 Typical flow patterns at various flow conditions

Pressure loss Calculation

- For calculation of pressure loss in circular pipe the following Darcy–Weisbach equation is used:

$$\frac{\Delta p}{L} = f_D \cdot \frac{\rho}{2} \cdot \frac{\langle v \rangle^2}{D}$$



Δp: pressure loss

ƒ: Darcy friction coefficient

L: pipe's length

D: pipe's diameter

v: average velocity

ρ: density of fluid

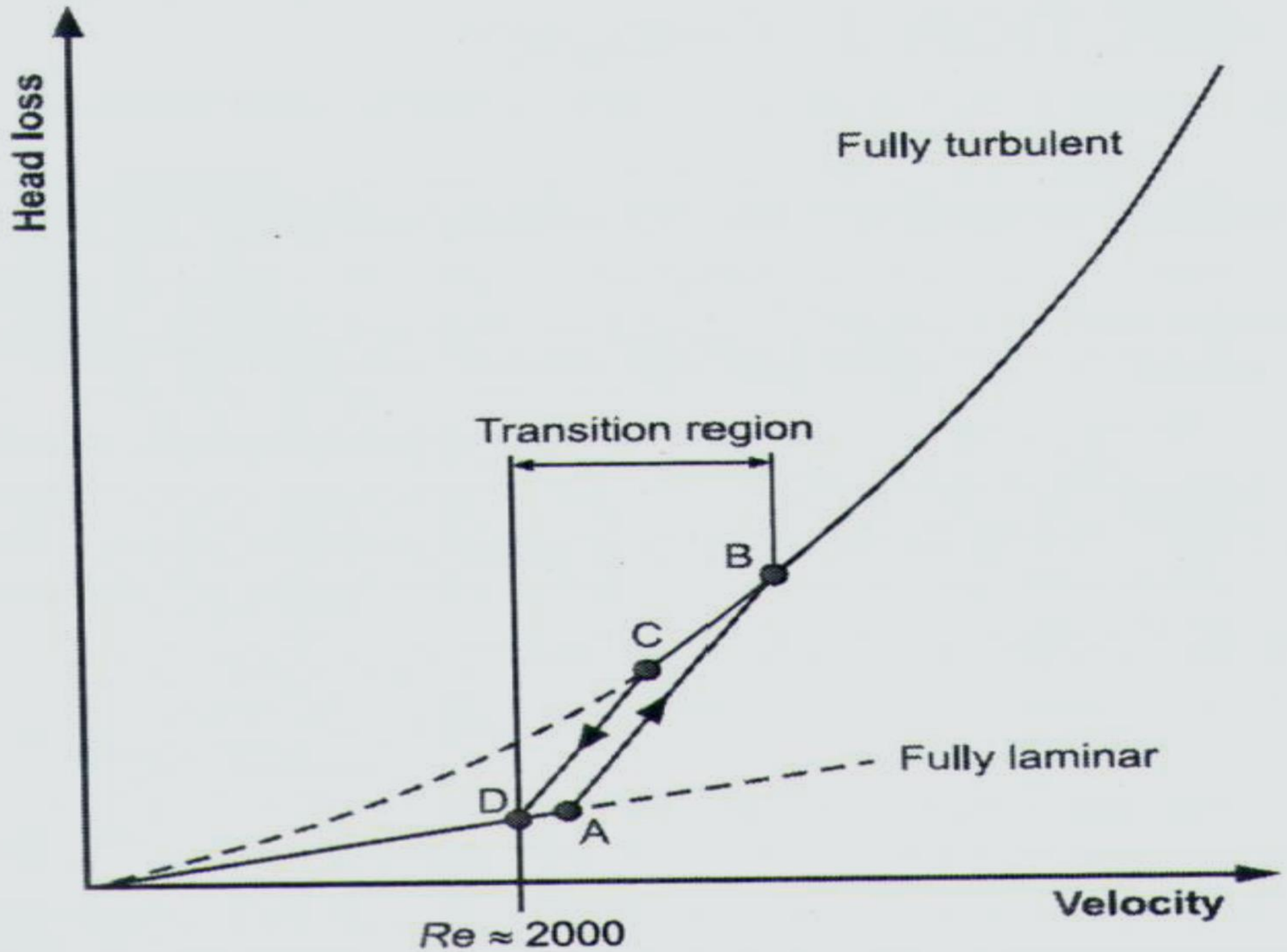
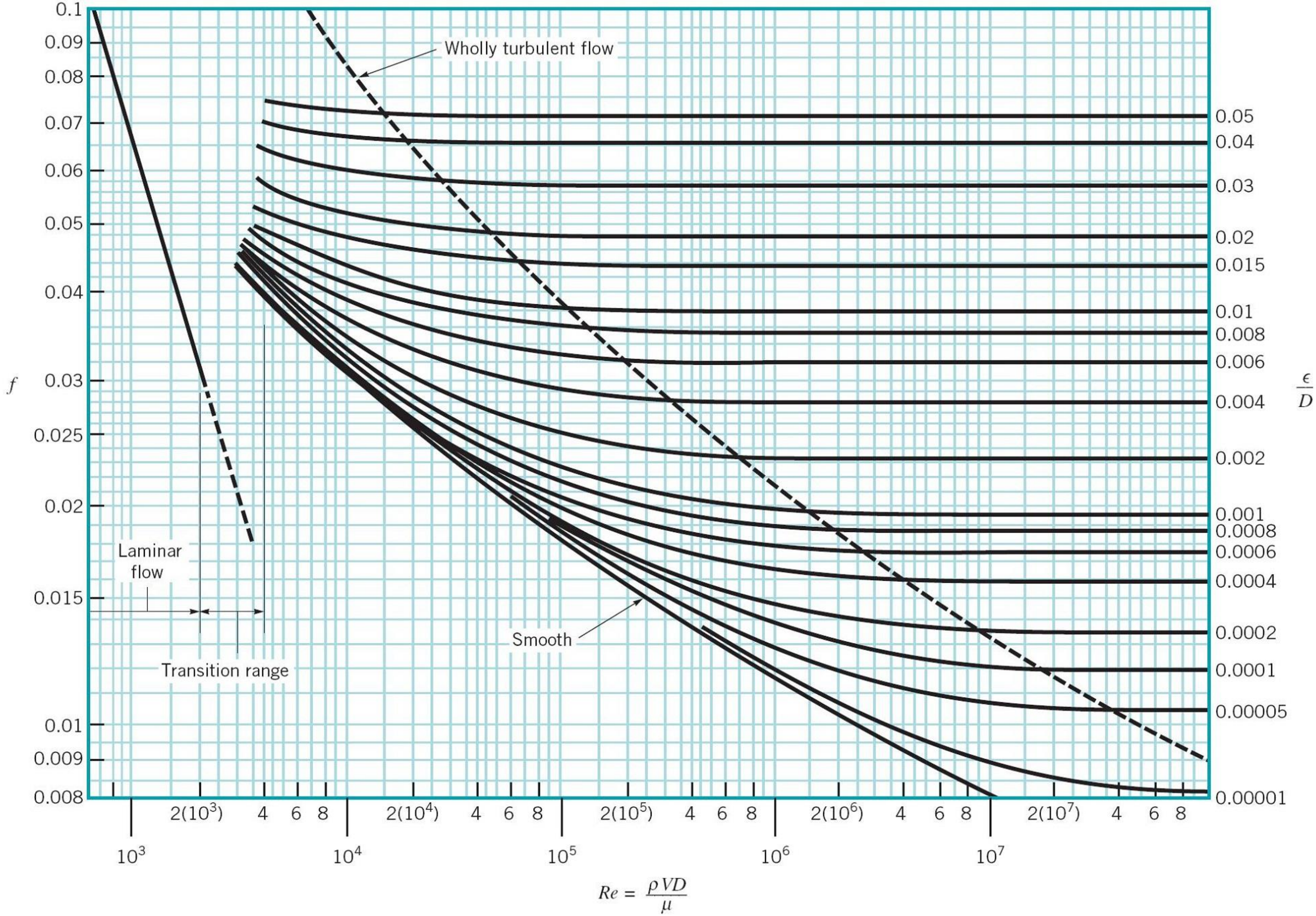


Figure 3 Variation of head loss with velocity for flow along a pipe


Wholly turbulent flow
f
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.025
0.02
0.015
0.01
0.009
0.008
ε/D
0.05
0.04
0.03
0.02
0.015
0.01
0.008
0.006
0.004
0.002
0.001
0.0008
0.0006
0.0004
0.0002
0.0001
0.00005
0.00001
Laminar flow
Transition range
Smooth
2(10^3) 4 6 8
2(10^4) 4 6 8
2(10^5) 4 6 8
2(10^6) 4 6 8
2(10^7) 4 6 8
10^3
10^4
10^5
10^6
10^7
Re = ρVD/μ