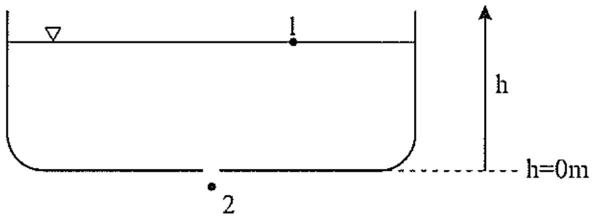
Free outflow from vessel

Velocity of outflow



Point 2 is somewhat lower than the hole, here the streamlines are already parallel, but this height difference can be neglected.

$$\frac{v_1^2\cdot\rho}{2}+h_1\cdot\rho\cdot g+p_1=\frac{v_2^2\cdot\rho}{2}+h_2\cdot\rho\cdot g+p_2+f\cdot\frac{L_{total}}{D_e}\cdot\frac{v_2^2\cdot\rho}{2}$$

$p_1 = p_2$ (the pressure difference of the air due to height can be neglected)

$v_1 \approx 0$ m/s because the vessel is much wider than the hole

$f = 0$, $L_{total} = 0$ m

$$h_1\cdot\rho\cdot g=\frac{v_2^2\cdot\rho}{2}+h_2\cdot\rho\cdot g$$

$$\frac{v_2^2\cdot\rho}{2}=(h_1-h_2)\cdot\rho\cdot g$$

$$v_2=\sqrt{2\cdot g\cdot(h_1-h_2)}=\sqrt{2\cdot g\cdot h}$$

Flow rate of outflow

$$\dot{V}=A_{hole}v_2=\frac{D_e^2\pi}{4}\sqrt{2\cdot g\cdot h}$$

Time of outflow

Differential equation of the change of volume in time

$$dV=-\dot{V}\cdot dt$$

$$A_{vessel}\cdot dh=-\alpha\cdot A_{hole}\cdot v\cdot dt$$

$$A_{vessel}\cdot dh=-\alpha\cdot A_{hole}\cdot\sqrt{2\cdot g\cdot h}\cdot dt$$

$$\frac{A_{vessel}}{-\alpha\cdot A_{hole}\cdot\sqrt{2\cdot g}}\cdot\frac{1}{\sqrt{h}}dh=dt$$

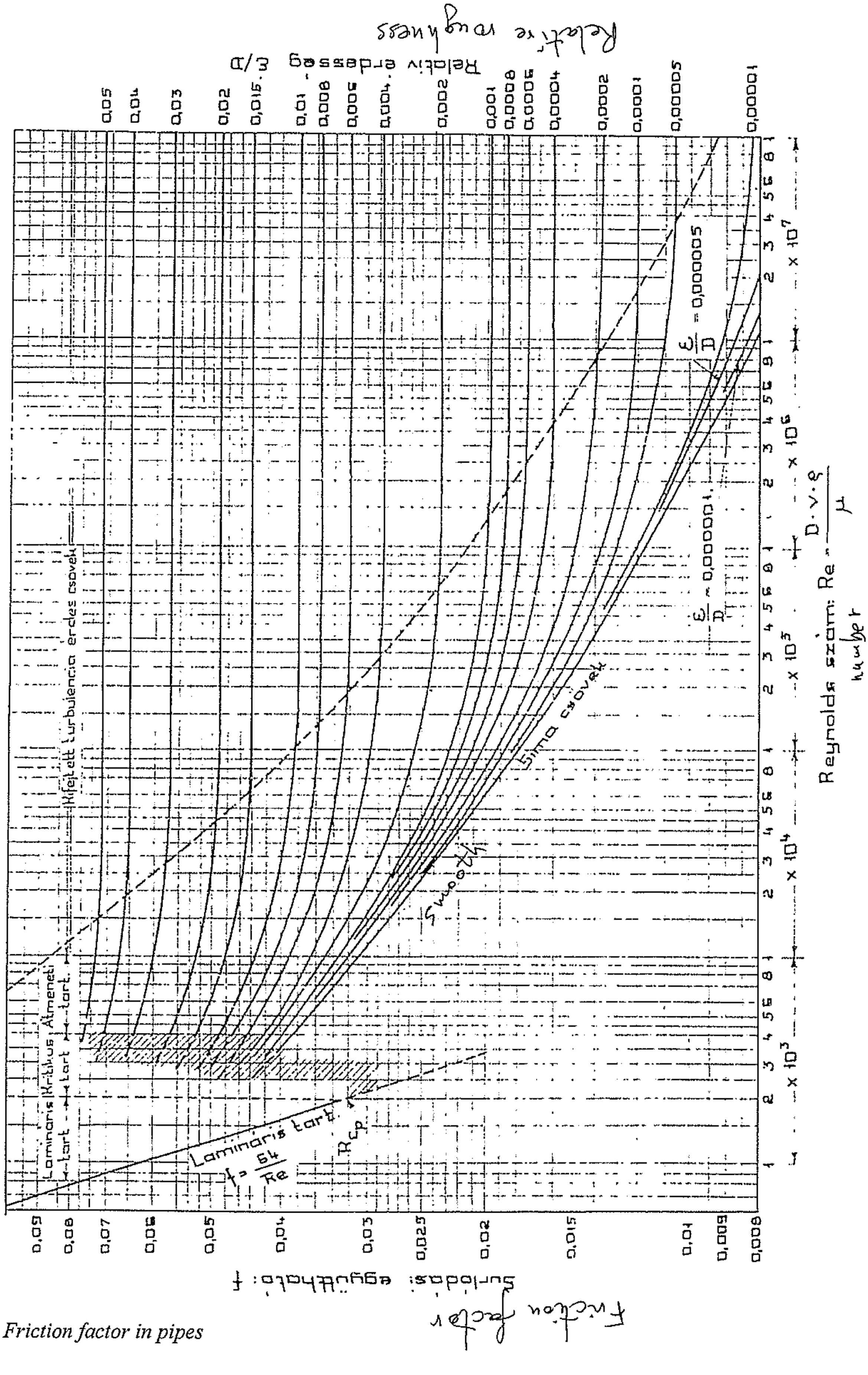
where α is a so-called outflow factor expressing what fraction is utilized due to turbulence.

Solution:

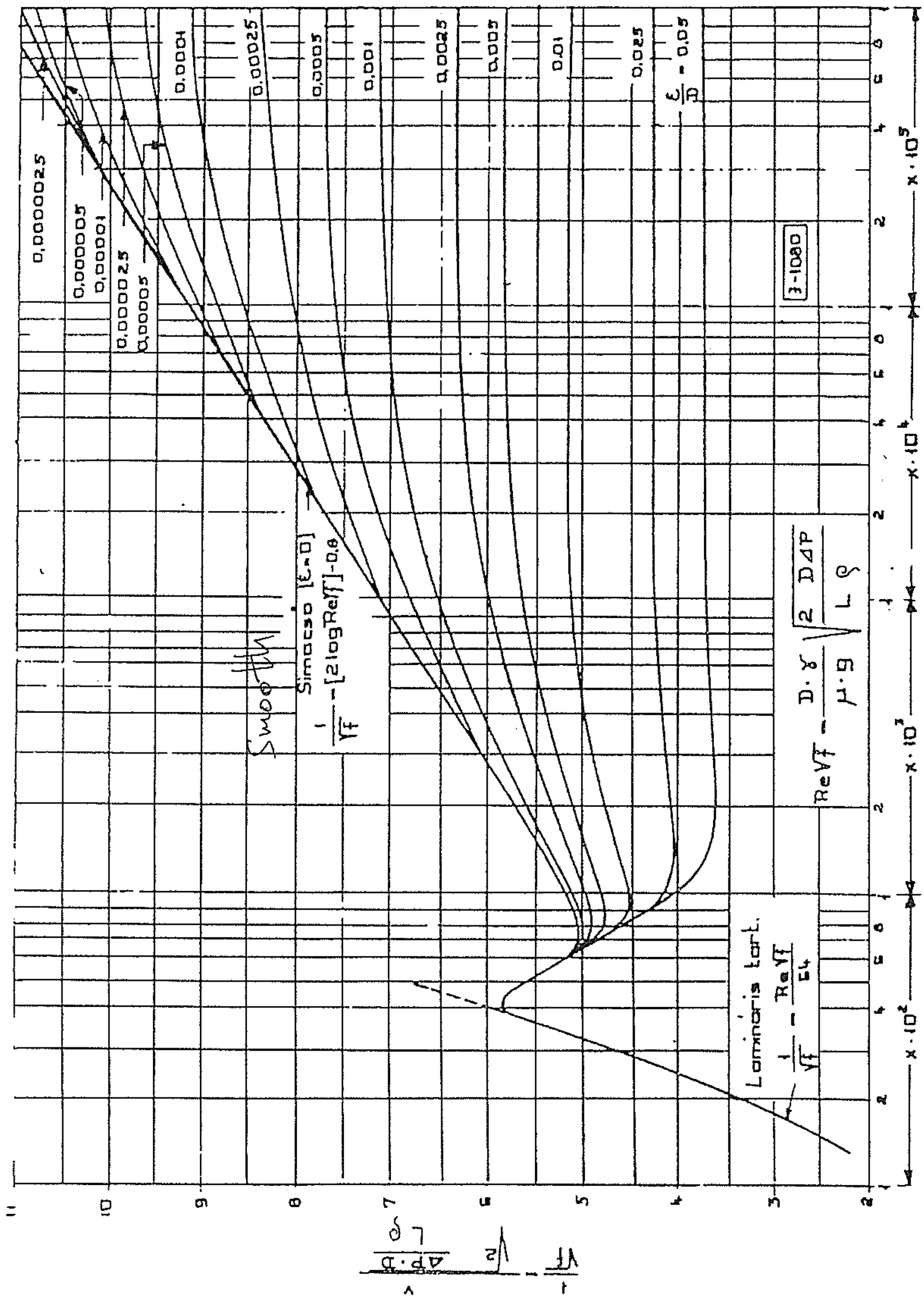
$$t=\frac{2\cdot A_{vessel}}{\alpha\cdot A_{hole}\cdot\sqrt{2\cdot g}}\cdot\left(\sqrt{h_0}-\sqrt{h_1}\right)\quad h_0>h_1$$

This is the time decreasing the level from h_0 to h_1.

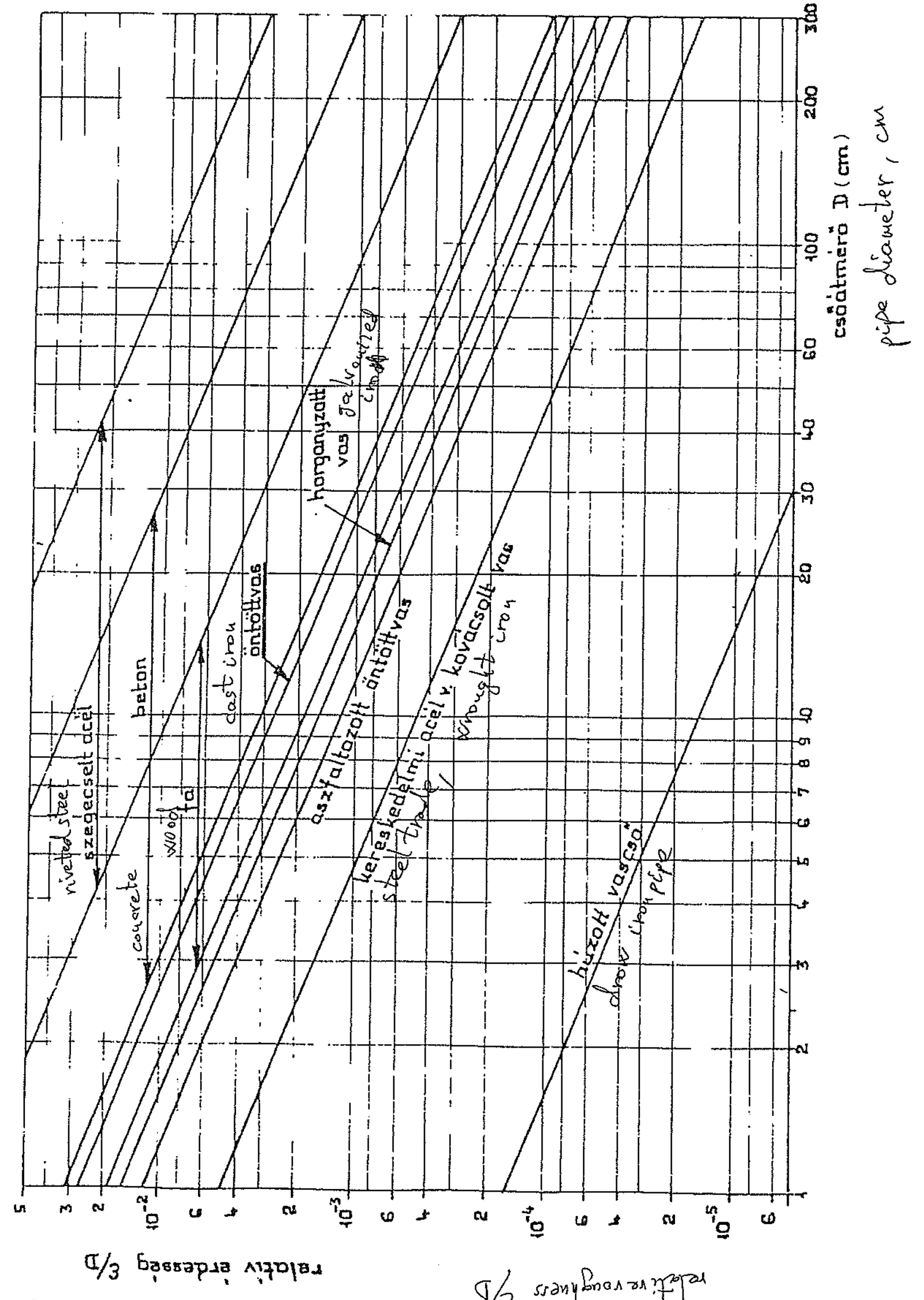
h = 0 m must be the height where the level can decrease to (perhaps during infinite time).



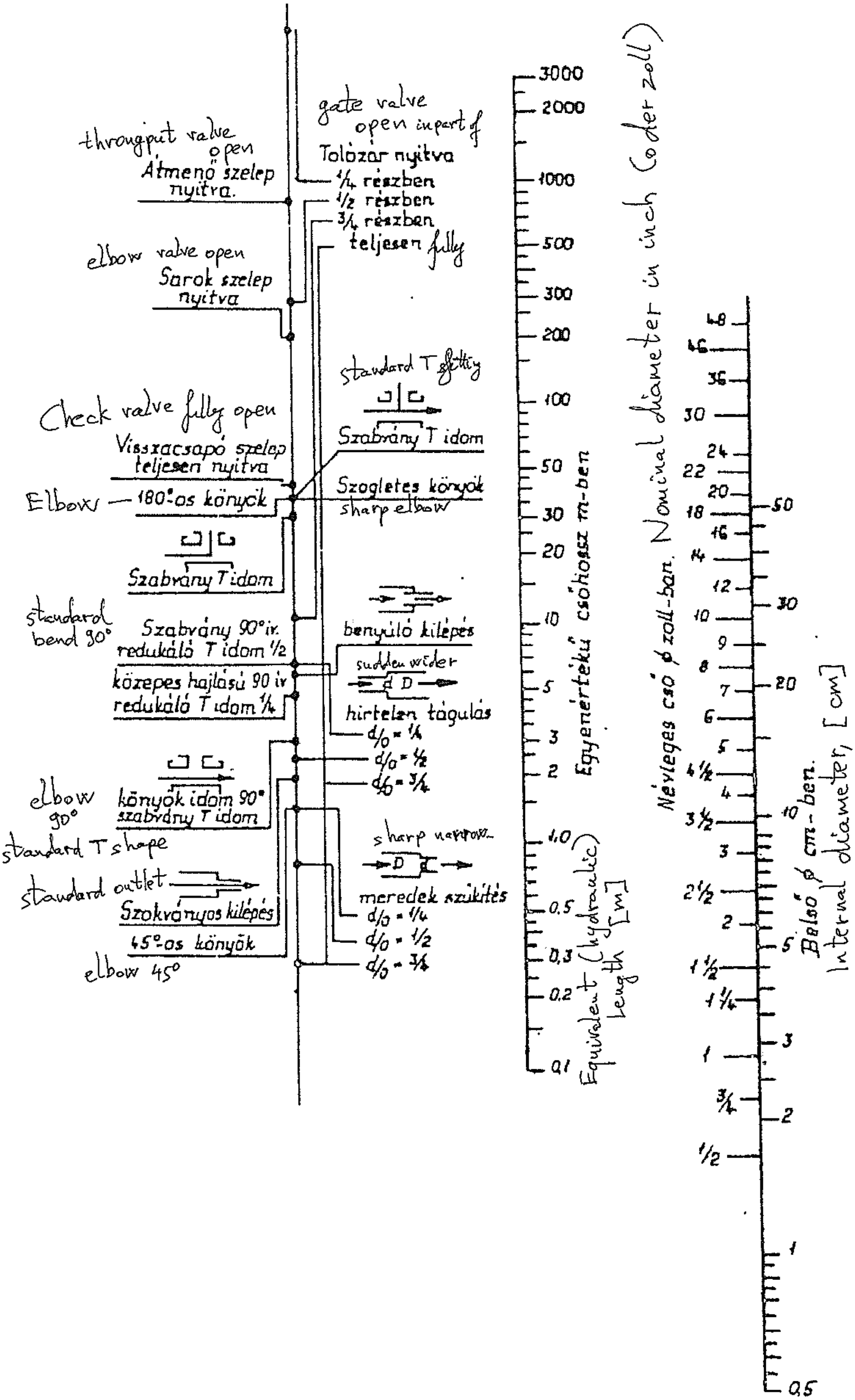
Friction factor in pipes



$Re \cdot \sqrt{f} - \frac{1}{\sqrt{f}}$ *plot*



Relative roughness of pipes



Equivalent pipe length nomogram