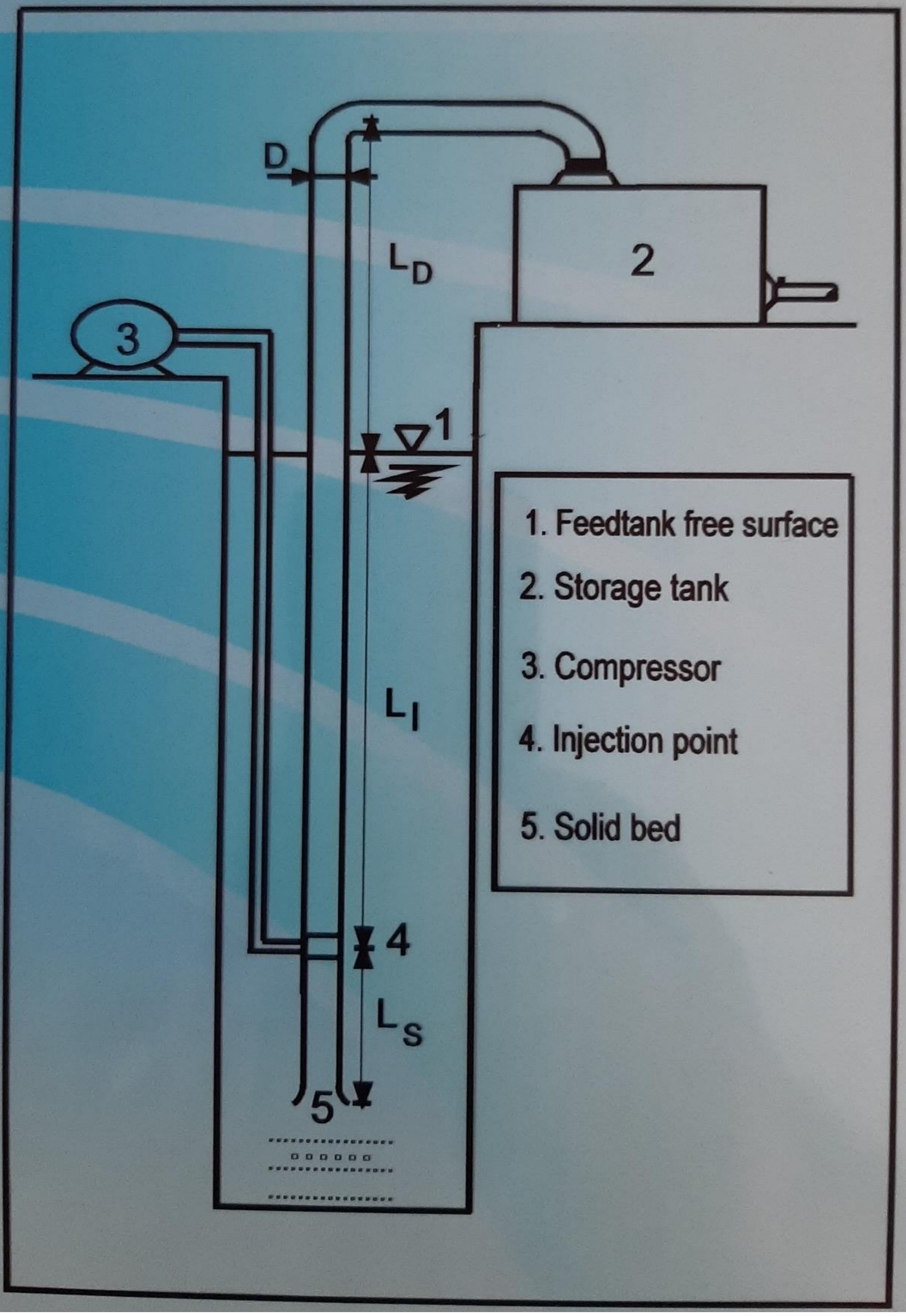
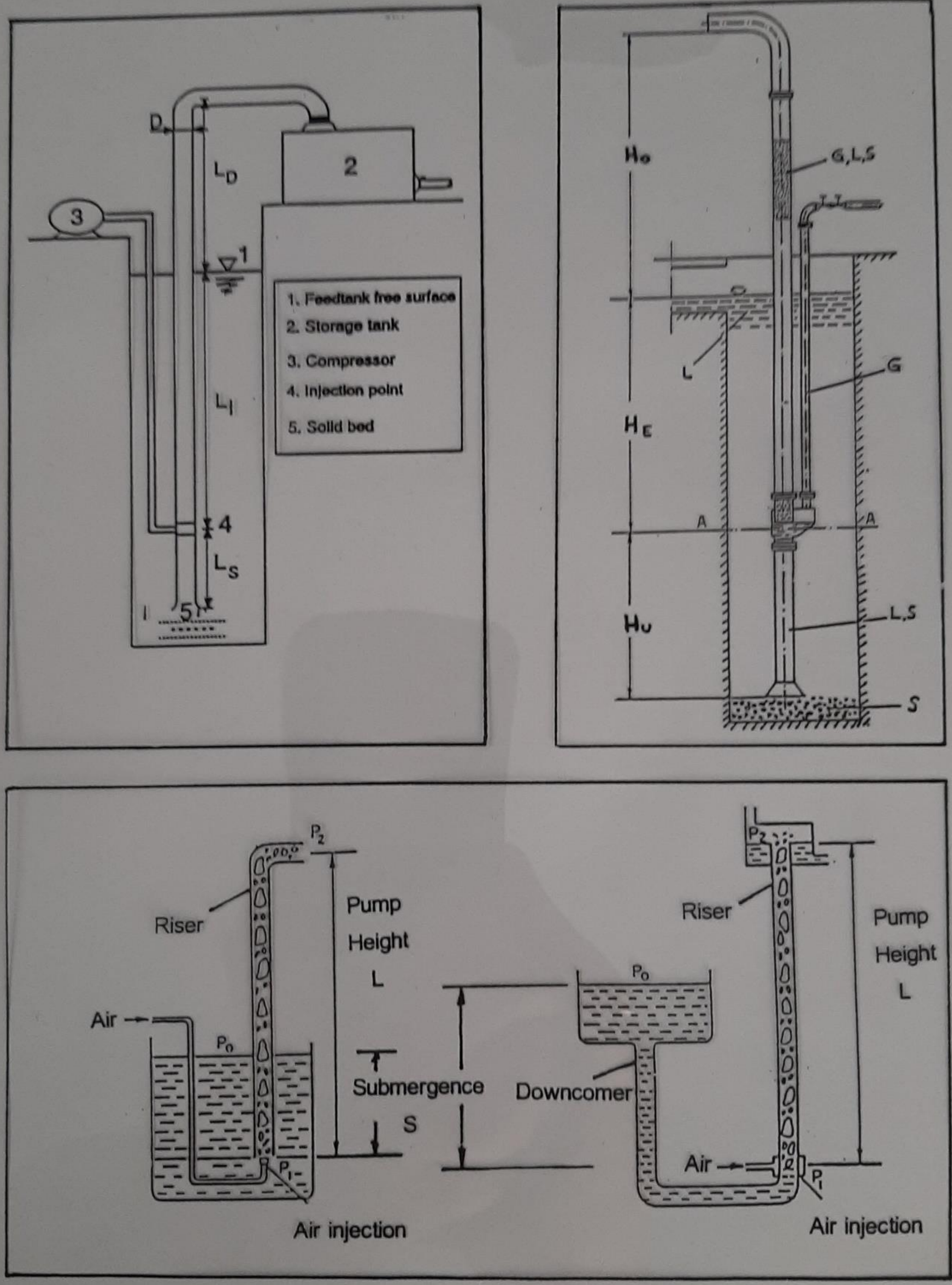
Airlift pump installation

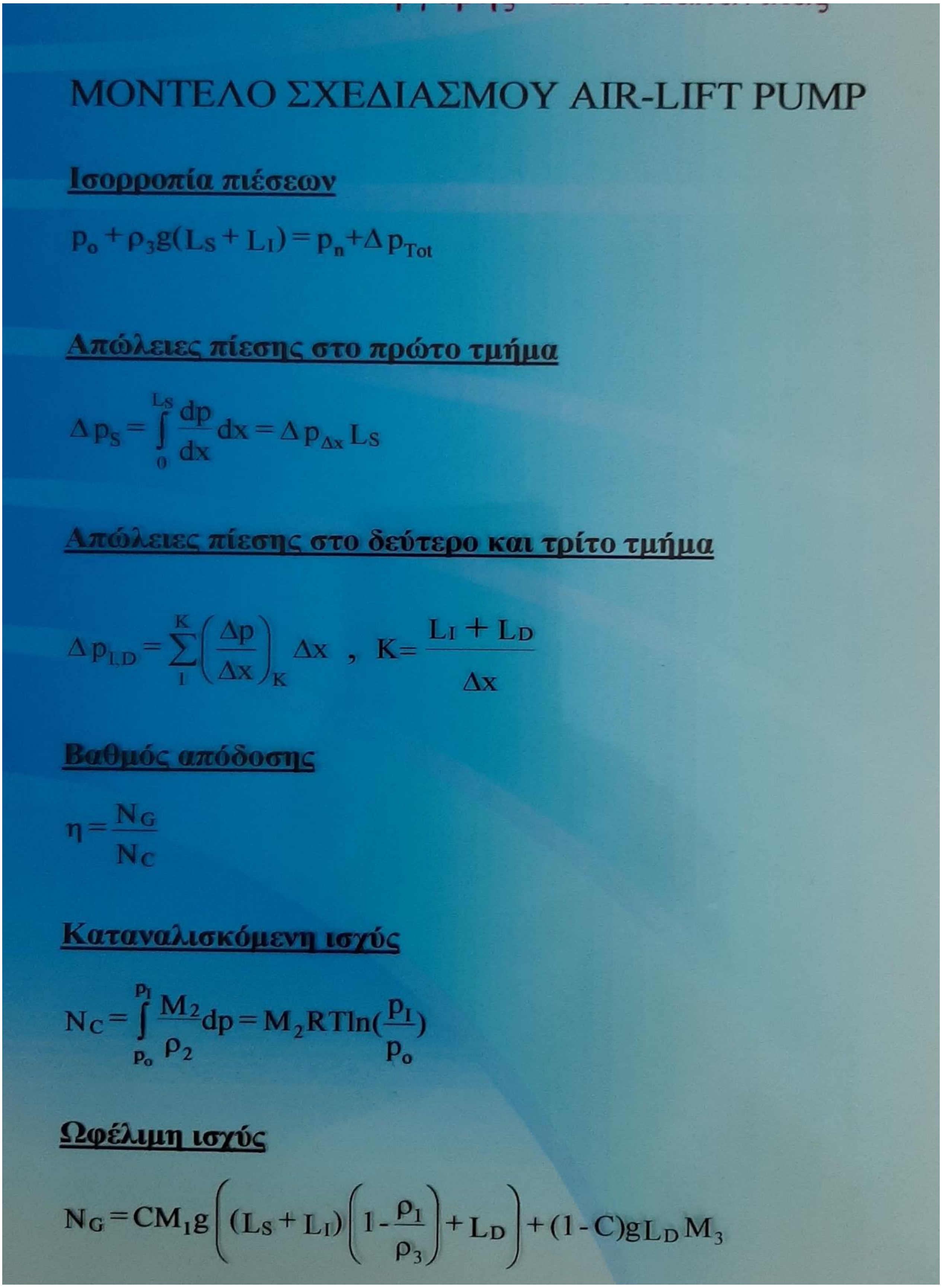


1. Feedtank free surface
2. Storage tank
3. Compressor
4. Injection point
5. Solid bed

AIR - LIFT PUMP



Εγκαταστάσεις Air-Lift Pump



ΜΟΝΤΕΛΟ ΣΧΕΔΙΑΣΜΟΥ AIR-LIFT PUMP

Ισορροπία πιέσεων

$$p_o + \rho_3 g(L_S + L_I) = p_n + \Delta p_{Tot}$$

Απώλειες πίεσης στο πρώτο τμήμα

$$\Delta p_S = \int_0^{L_S} \frac{dp}{dx} dx = \Delta p_{\Delta x} L_S$$

Απώλειες πίεσης στο δεύτερο και τρίτο τμήμα

$$\Delta p_{I,D} = \sum_1^K \left(\frac{\Delta p}{\Delta x}\right)_K \Delta x \quad , \quad K = \frac{L_I + L_D}{\Delta x}$$

Βαθμός απόδοσης

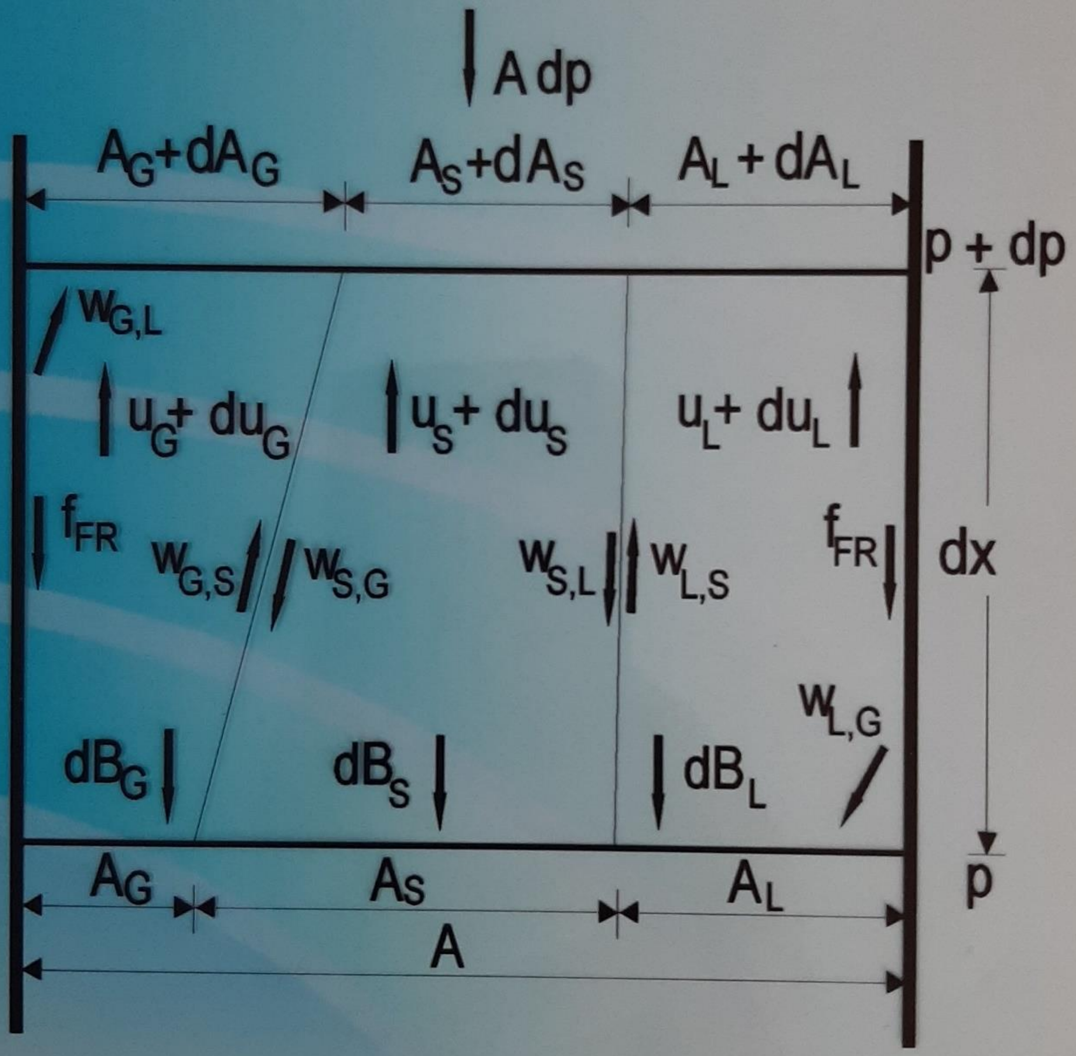
$$\eta = \frac{N_G}{N_C}$$

Καταναλισκόμενη ισχύς

$$N_C = \int_{p_o}^{p_I} \frac{M_2}{\rho_2} dp = M_2 RT \ln\left(\frac{p_I}{p_o}\right)$$

Ωφέλιμη ισχύς

$$N_G = CM_1 g\left((L_S + L_I)\left(1 - \frac{\rho_1}{\rho_3}\right) + L_D\right) + (1 - C) g L_D M_3$$



Δυνάμεις που επενεργούν στον όγκο ελέγχου

ΦΥΣΙΚΟΜΑΘΗΜΑΤΙΚΟ ΜΟΝΤΕΛΟ

Εξισώσεις διατήρησης Χωριστής Τριφασικής Ροής

Εξίσωση συνέχειας

$$M_t = \sum_{i=1}^{3} M_i = \sum_{i=1}^{3} \rho_i\, u_i\, A_i = \sum_{i=1}^{3} \rho_i\, u_i\, a_i\, A = \text{const.} \qquad \text{με} \qquad \sum_{i=1}^{3} a_i = 1$$

Εξίσωση ορμής

$$\sum F = \sum_{i=1}^{3}\left(\underbrace{-\rho_i a_i A dx g}_{\text{Gravitational forces}} \underbrace{- \rho_i a_i A dx \frac{du_i}{dt}}_{\text{Accelerational forces}} \underbrace{- a_i A dp}_{\text{Pressure forces}} \underbrace{- a_i A dp_{FR,i}}_{\text{Friction forces}} + \underbrace{\sum_{j=1}^{3} \delta_{i,j}\, w_{i,j}}_{\text{Interaction forces}} \right) = 0$$

$$-\frac{dp}{dx} = \sum_{i=1}^{3}\left(\rho_i a_i g + \rho_i a_i u_i \frac{du_i}{dx} + \left(\frac{dp}{dx}\right)_{FR,i} \right)$$

Απόλυτες και Σχετικές Ταχύτητες

$$u_i = u_3 + (-1)^i u_{i,r} \qquad u_{i,r} = \left(\frac{4}{3} \frac{d_i a_3 g}{C_{D,i}} \left| 1 - \frac{\rho_i}{\rho_3} \right| \right)^{\frac{1}{2}}$$

Συντελεστής αντίστασης

$$C_{D,i} = \sum_{j=1}^{2} B_{i,j} Re_i^{b_{i,j}} \qquad \Big|\ i = 1,2$$

Αριθμός Reynolds

$$Re_i = \frac{\rho_3 \left| u_i - u_3 \right| d_i}{\mu_3}$$

Συντελεστής συμπιεστότητας

$$\frac{p}{Z\rho_2} = RT = \text{const.} \qquad Z(p) = 1 - 5.8198 \cdot 10^{-4} \left(\frac{p_1}{p_n} \right) + 2.809 \cdot 10^{-6} \left(\frac{p_1}{p_n} \right)^2$$

ΜΟΝΤΕΛΟ ΨΕΥΔΟ-ΥΓΡΟΥ

$\rho_{PS}=\left(\frac{a_1}{a_{PS}}\right)\rho_1+\left(\frac{a_3}{a_{PS}}\right)\rho_3=\alpha_1^*\rho_1+\alpha_3^*\rho_3$ με $a_{PS}=a_1+a_3$

$\mu_{PS}=(1-c_m)\nu_3\rho_{PS}$ όπου $c_m=\frac{\rho_1}{\rho_{PS}}\left(\frac{a_1}{a_{PS}}\right)$

$M_{PS}=M_1+M_2=u_{PS}\,\rho_{PS}\,a_{PS}\,A$

$$\left(\frac{dp}{dx}\right)_{FR}=\Phi_{PSO}^2\left[\left(\frac{dp}{dx}\right)_{FR}\right]_{PSO}$$

$$\Phi^2{}_{PSO}=E+\frac{3.24FH}{Fr^{0.045}+We^{0.035}}$$

$E=(1-x)^2+x^2\frac{\rho_{PS}f_{2O}}{\rho_2 f_{PSO}}$ $F=x^{0.78}(1-x)^{0.24}$

$H=\left(\frac{\rho_{PS}}{\rho_2}\right)^{0.91}\left(\frac{\mu_2}{\mu_{PS}}\right)^{0.19}\left(1-\frac{\mu_2}{\mu_{PS}}\right)^{0.7}$

$Fr=\frac{m^2}{gD\rho_{PST}^2}$ $We=\frac{m^2D}{\sigma\rho_{PST}}$ $\rho_{PST}=\left(\frac{x}{\rho_2}+\frac{1-x}{\rho_{PS}}\right)^{-1}$

ΠΙΝΑΚΑΣ 1 Σταθερές για τον υπολογισμό του συντελεστή αντίστασης σφαιρικών σωματιδίων ή φυσαλίδων

Re_i	B_{11}	b_{11}	B_{12}	b_{12}	B_{21}	b_{21}	B_{22}	b_{22}
< 0.2	24	-1	0	0	24	-1	0	0
$0.2 - 989$	26	0.8	0.4	0	3.6	-0.313	24	-1
$989 - 10^4$					0.44	0	0	0
$10^4 - 2x10^5$	0.4	0	0	0				
$> 2x10^5$	-	-	-	-	0.1	0	0	0

ΠΙΝΑΚΑΣ 2 Σταθερές για υπολογισμό του συντελεστή αντίστασης σωματιδίων διαφόρων σχημάτων ή σφαιρικών φυσαλίδων

Constants			***Reynolds range***	***Characteristic dimension***	***Shape of particle***	***Reference***
B_1	B_2	B_3				
24	0	0	$Re_1 < 0.1$	diameter	sphere	Stokes
24	4	0.4	$Re_1 < 10^4$	diameter	sphere	Molerus
21.5	6.5	0.23	$0.5 < Re_1 < 10^3$	diameter	sphere	Muschelk.
24	6	0.35	$0.5 < Re_1 < 800$	1.5 x a a=larg. dimen.	Polyhed.	Muschelk.
23	6	0.5	$0.5 < Re_1 < 600$	1.08 x dz dz=base diam.	cylinder l/dz = 1	Muschelk.
27	4.5	0.65	$0.5 < Re_1 < 400$	1.24 x a a = edge	cube	Muschelk.

ΑΡΙΘΜΗΤΙΚΗ ΛΥΣΗ

$$\frac{dp}{dx}=\sum_{i=1}^{3}\left(\rho_i a_i g+\rho_i a_i u_i\frac{du_i}{dx}+\left(\frac{dp}{dx}\right)_{FR,i}\right)$$

$$u_i\rho_i\frac{da_i}{dx}+u_i a_i\frac{d\rho_i}{dx}+\rho_i a_i\frac{du_i}{dx}=0$$

με $\dfrac{d\rho_1}{dx}=\dfrac{d\rho_3}{dx}=0$ και $\displaystyle\sum_{i=1}^{3}\frac{da_i}{dx}=0$

$$\frac{du_i}{dx}=\frac{du_3}{dx}+(-1)^i\frac{du_{i,r}}{dx} \qquad \frac{du_{1,r}}{dx}=\left(\frac{4}{3}\frac{d_1 g}{C_{D,1}}\left(\frac{\rho_1}{\rho_3}-1\right)\right)^{\frac{1}{2}}\frac{1}{2a_3^{\frac{1}{2}}}\frac{da_3}{dx}$$

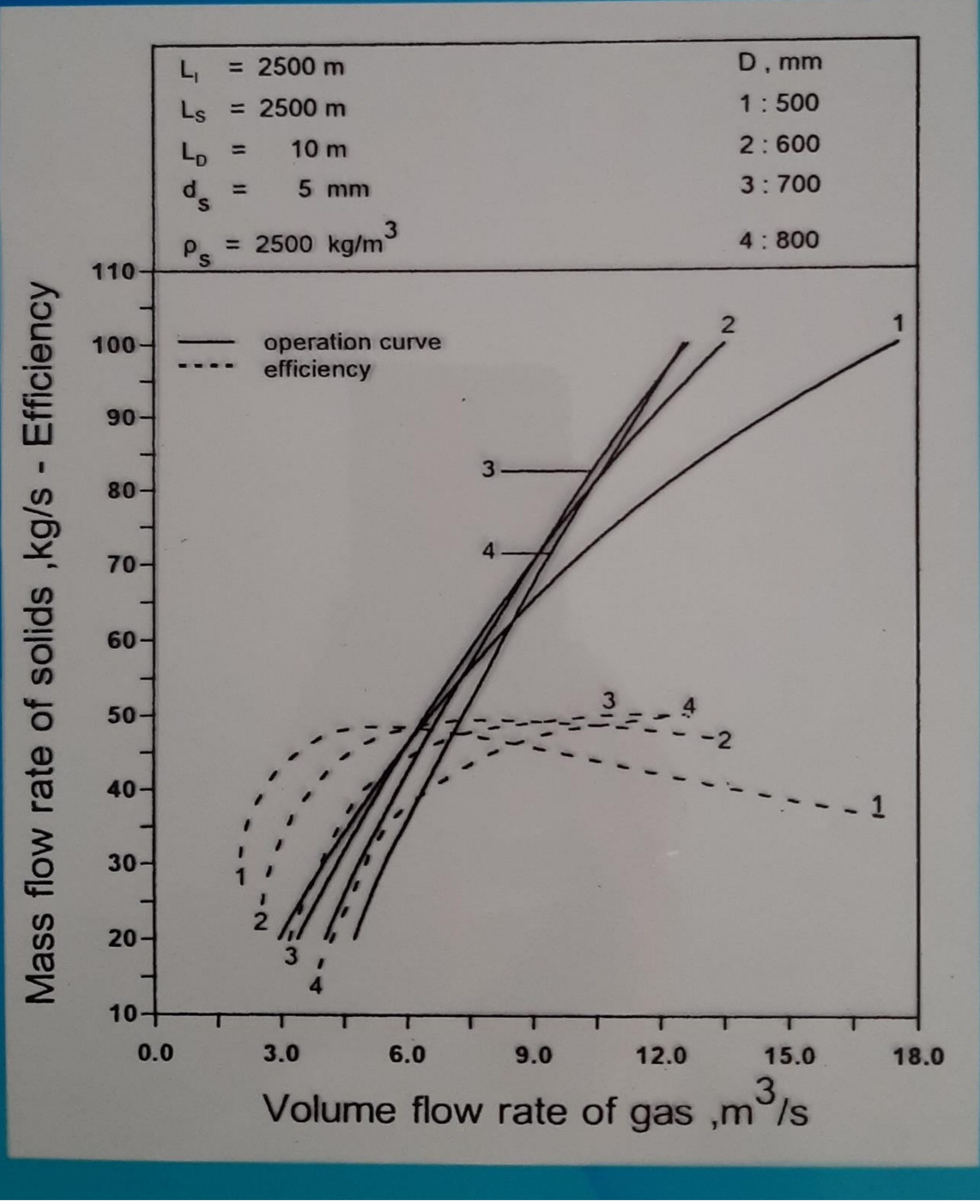
$$u_{2,r}=\left(\frac{4}{3}\frac{d_{2,0}a_3 g}{C_{D,2}}\left(\frac{p_0}{Z_0}\right)^{\frac{1}{3}}\right)^{\frac{1}{2}}\left(1-\frac{Z_0\rho_{2,0}p}{p_0\rho_3 Z}\right)^{\frac{1}{2}}\left(\frac{Z}{p}\right)^{\frac{1}{6}}$$

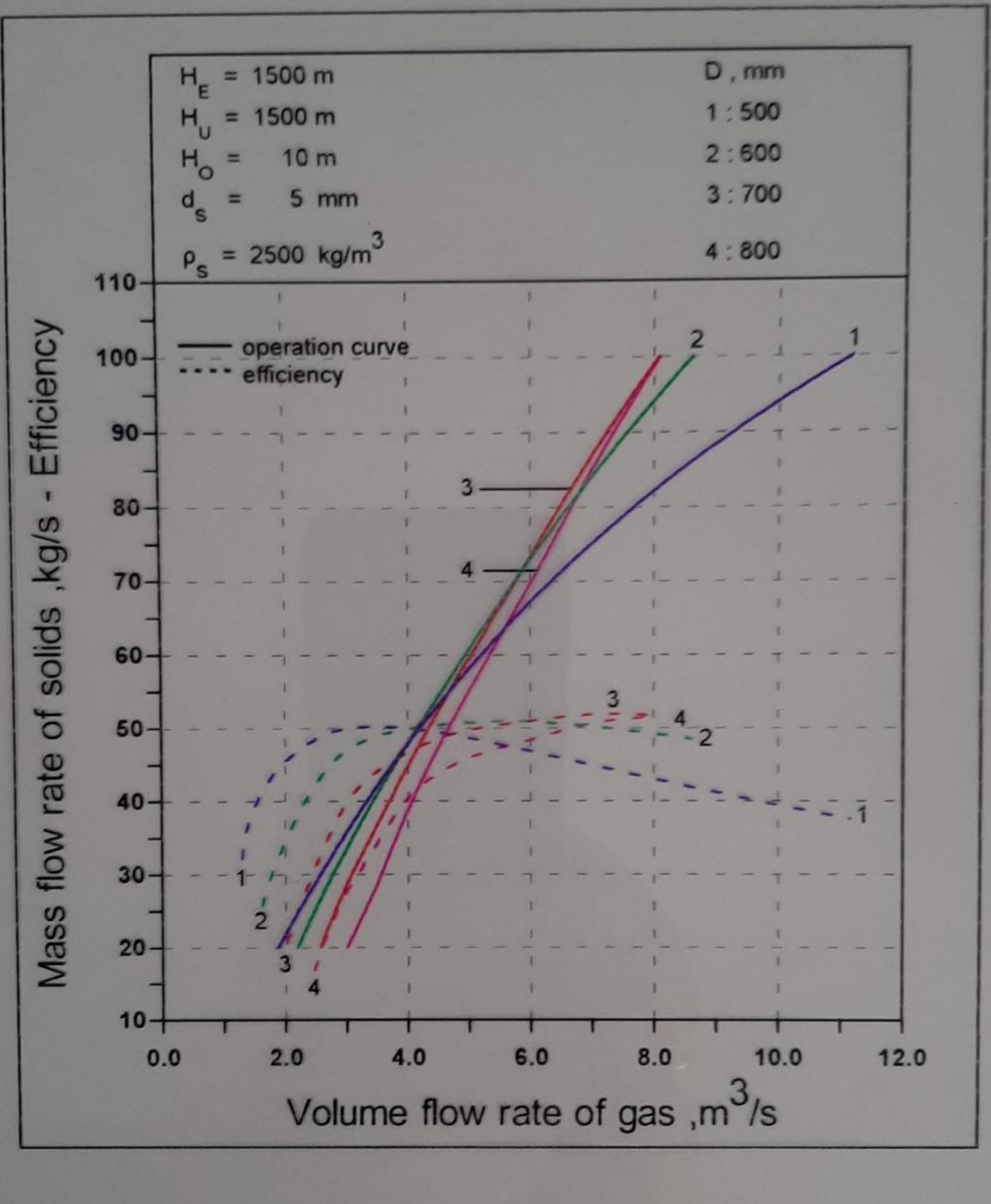
$$\frac{du_{2,r}}{dx}=C_1\left(C_2\left(Z^{-1}\frac{dZ}{dp}-p^{-1}\right)\right)\frac{dp}{dx}+\left(\frac{\rho_3-\rho_2}{4\rho_3 a_3^2}\right)^{\frac{1}{2}}\frac{da_3}{dx}$$

$$C_1=\left(\frac{4}{3}\frac{d_{2,0}ga_3}{C_{D,2}}\right)^{\frac{1}{2}}\left(\frac{p_0}{p}\frac{Z}{Z_0}\right)^{\frac{1}{6}} \qquad \text{και} \qquad C_2=\frac{1}{6}\frac{\rho_3+2\rho_2}{(2\rho_3-\rho_2)^{\frac{1}{2}}}$$

$$\frac{dZ}{dx}=\left(\frac{dp}{dx}-\frac{p}{\rho_2}\frac{d\rho_2}{dx}\right)\frac{Z}{p}$$

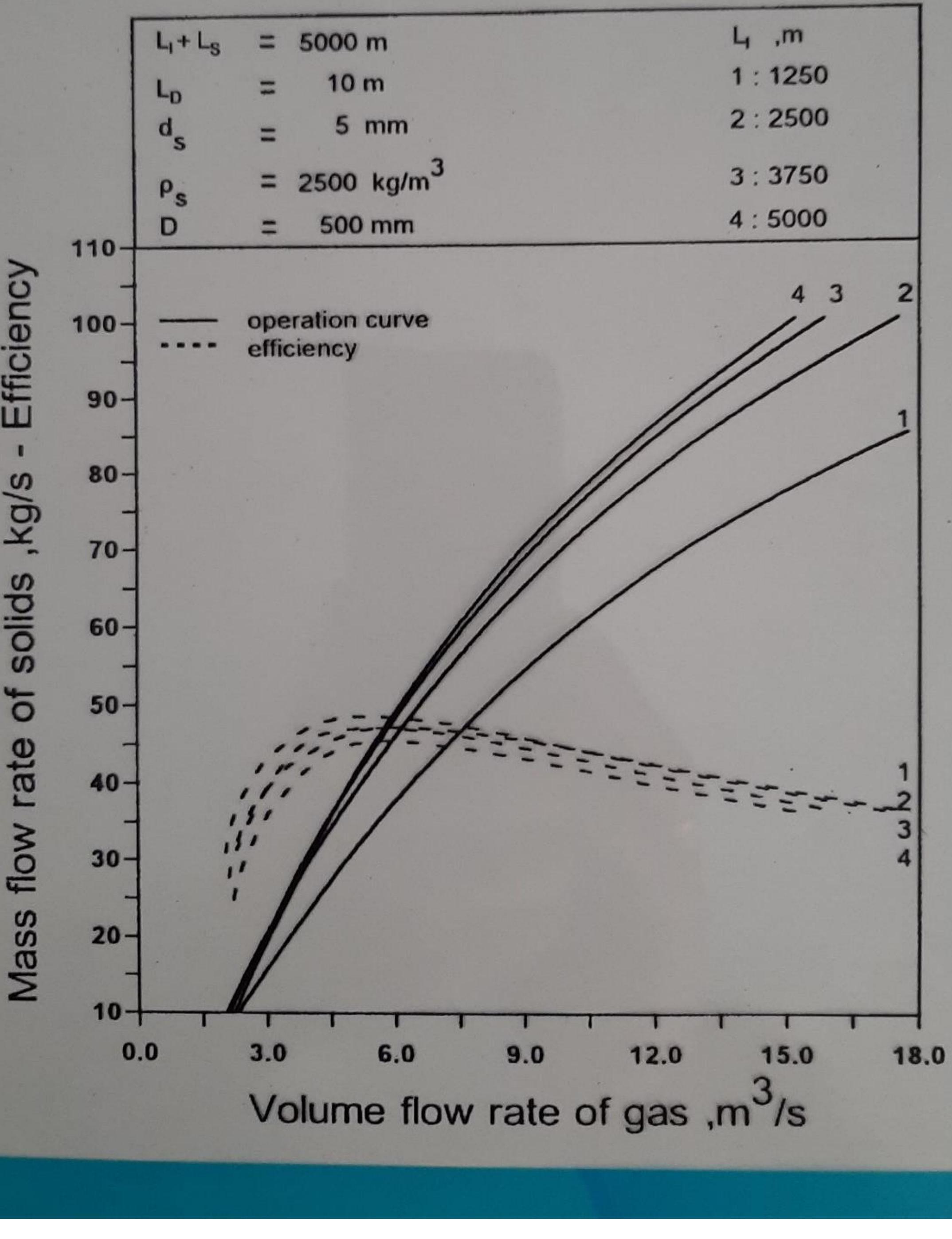
Pipe diameter influence on the airlift pump efficiency

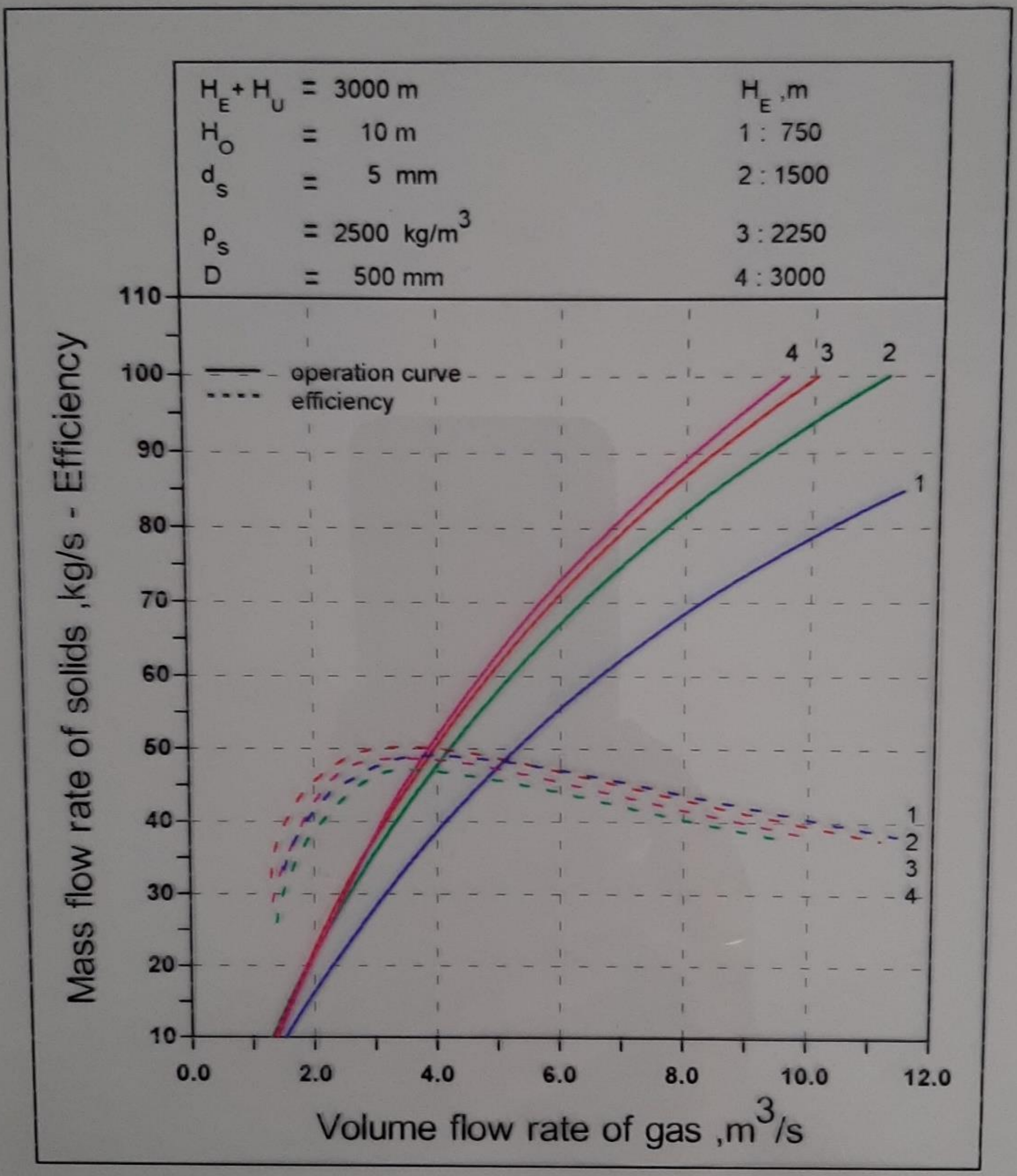




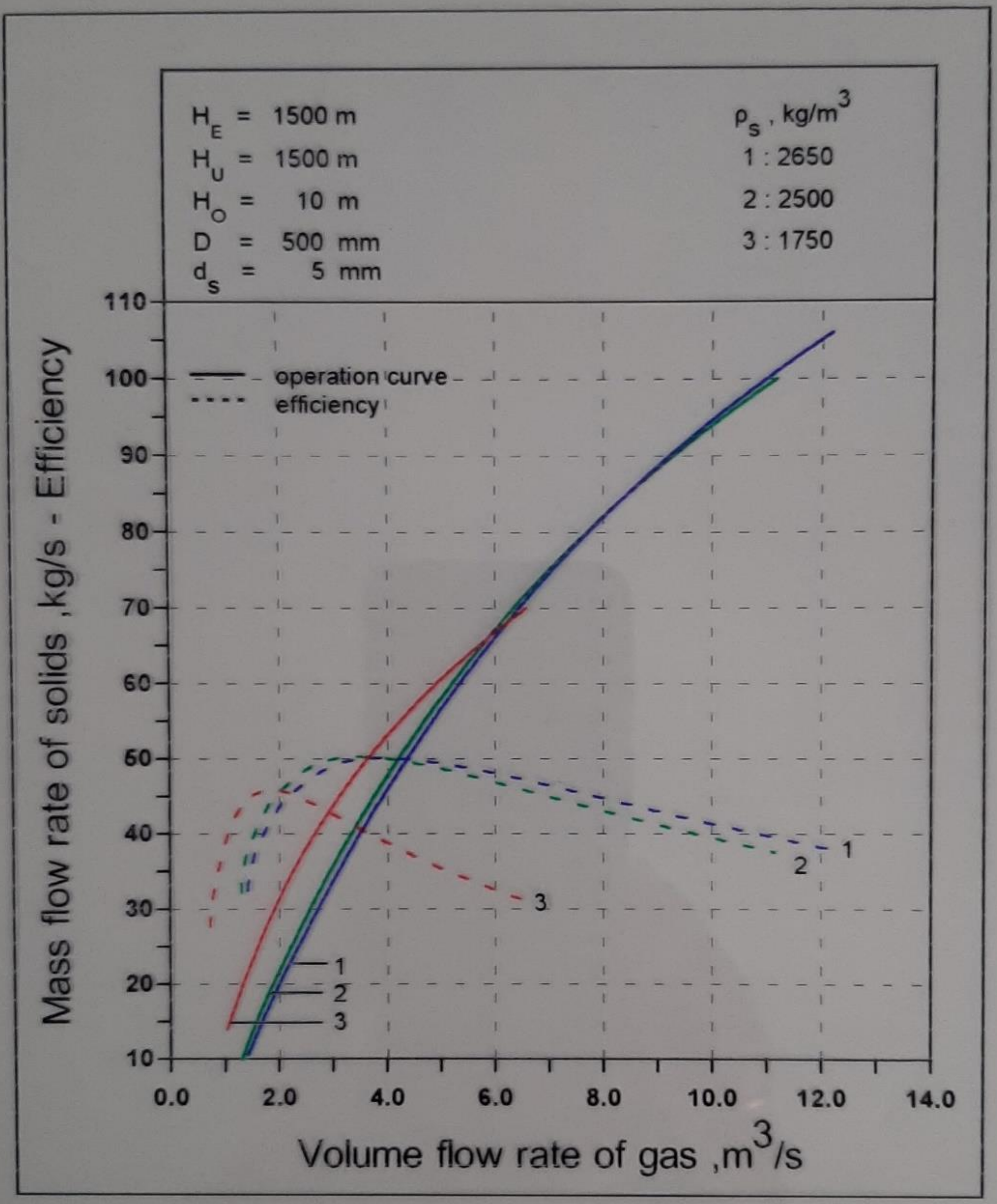
Influence of pipe diameter
on Air - Lift pump operation

Injection depth influence on the airlift pump efficiency

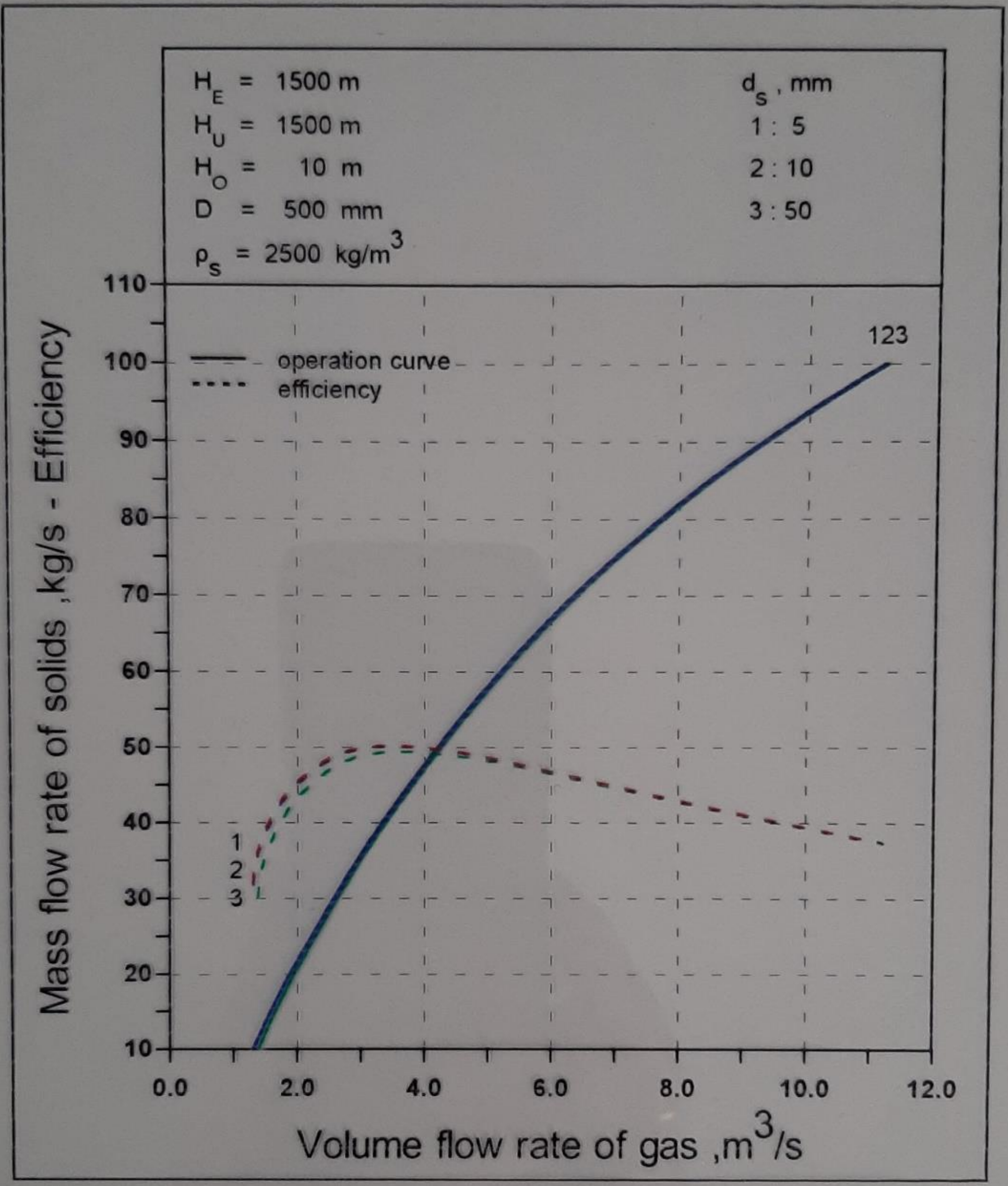




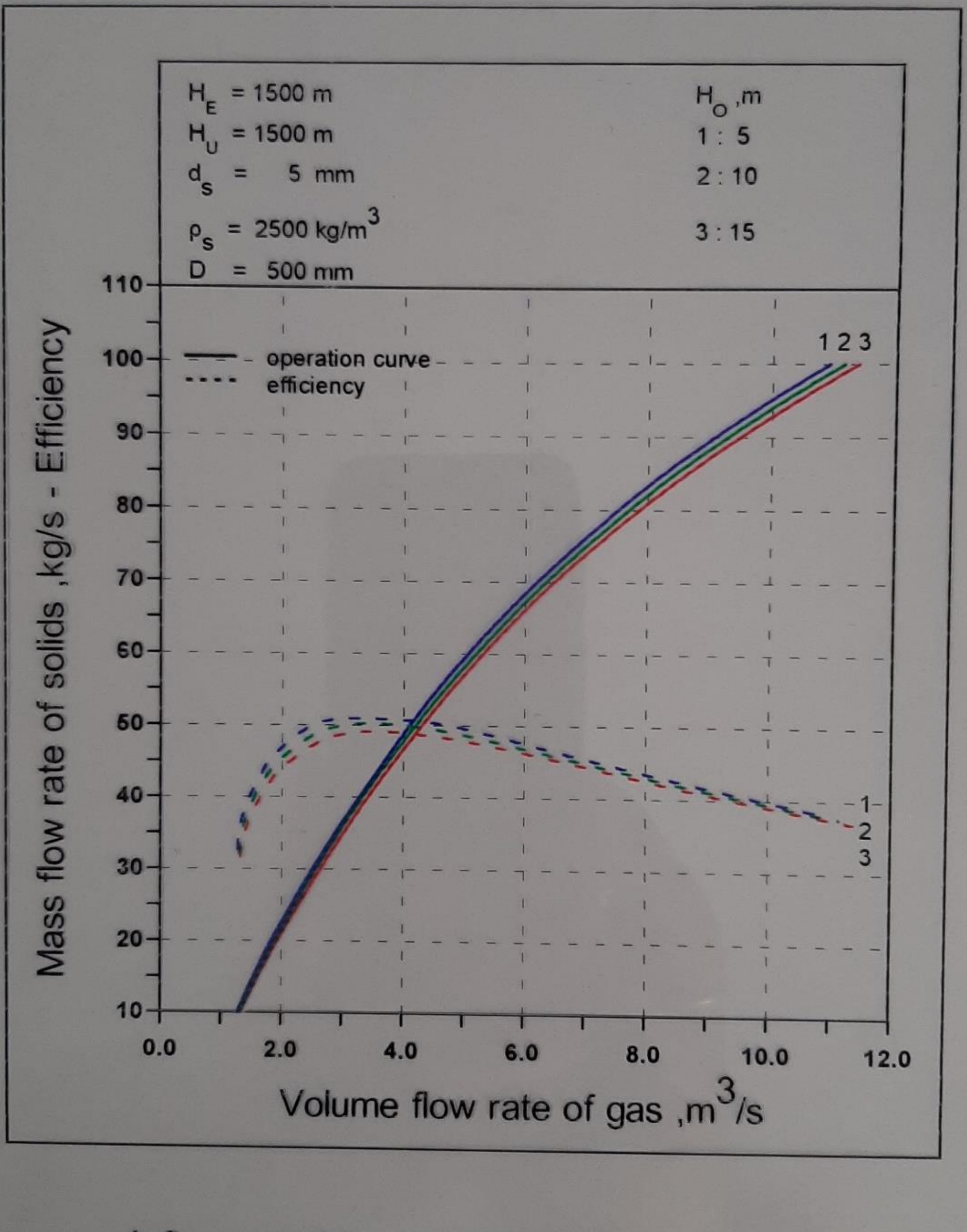
Influence of injection depth
on Air - Lift pump operation



Influence of particle density
on Air - Lift pump operation

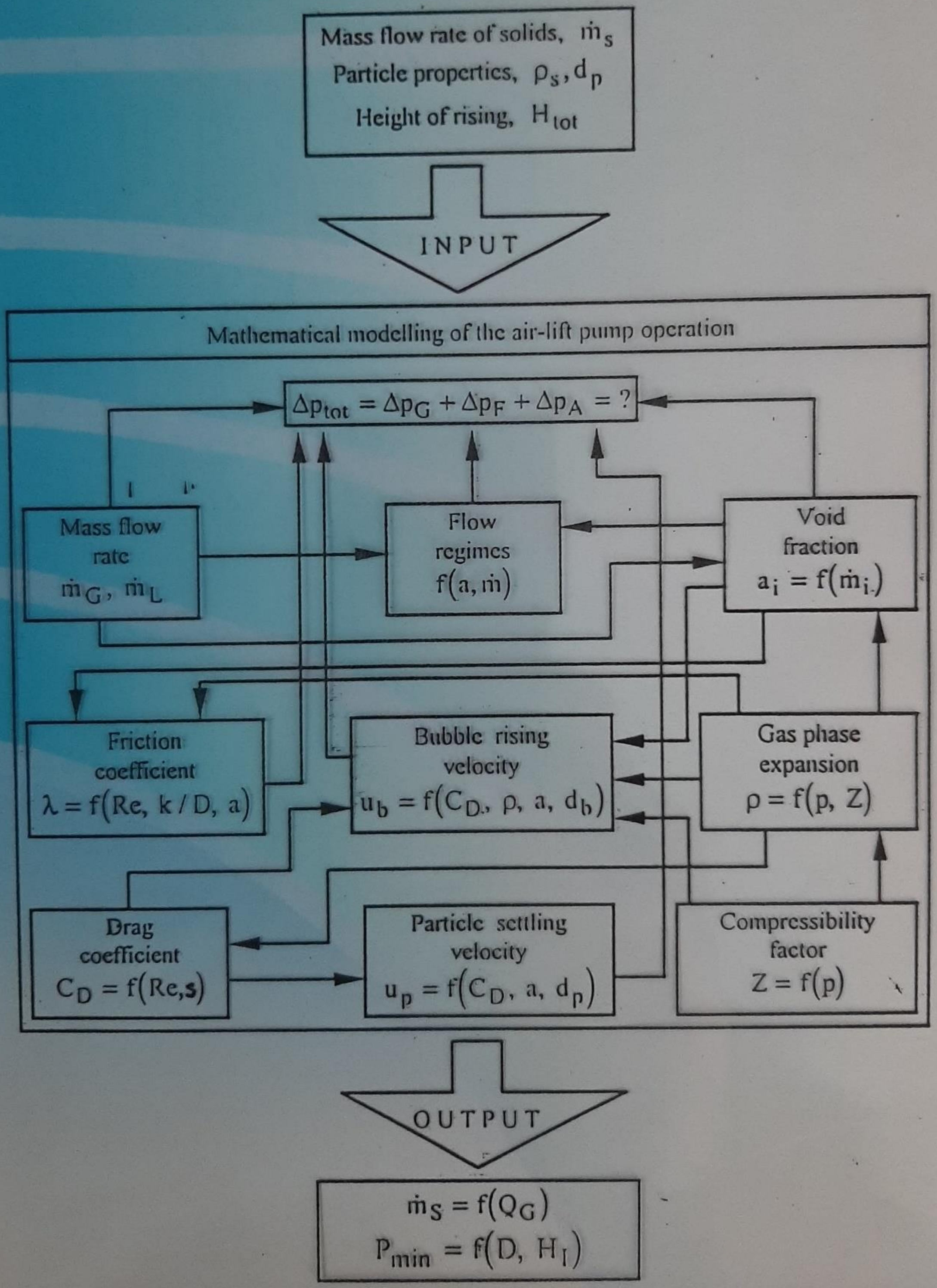


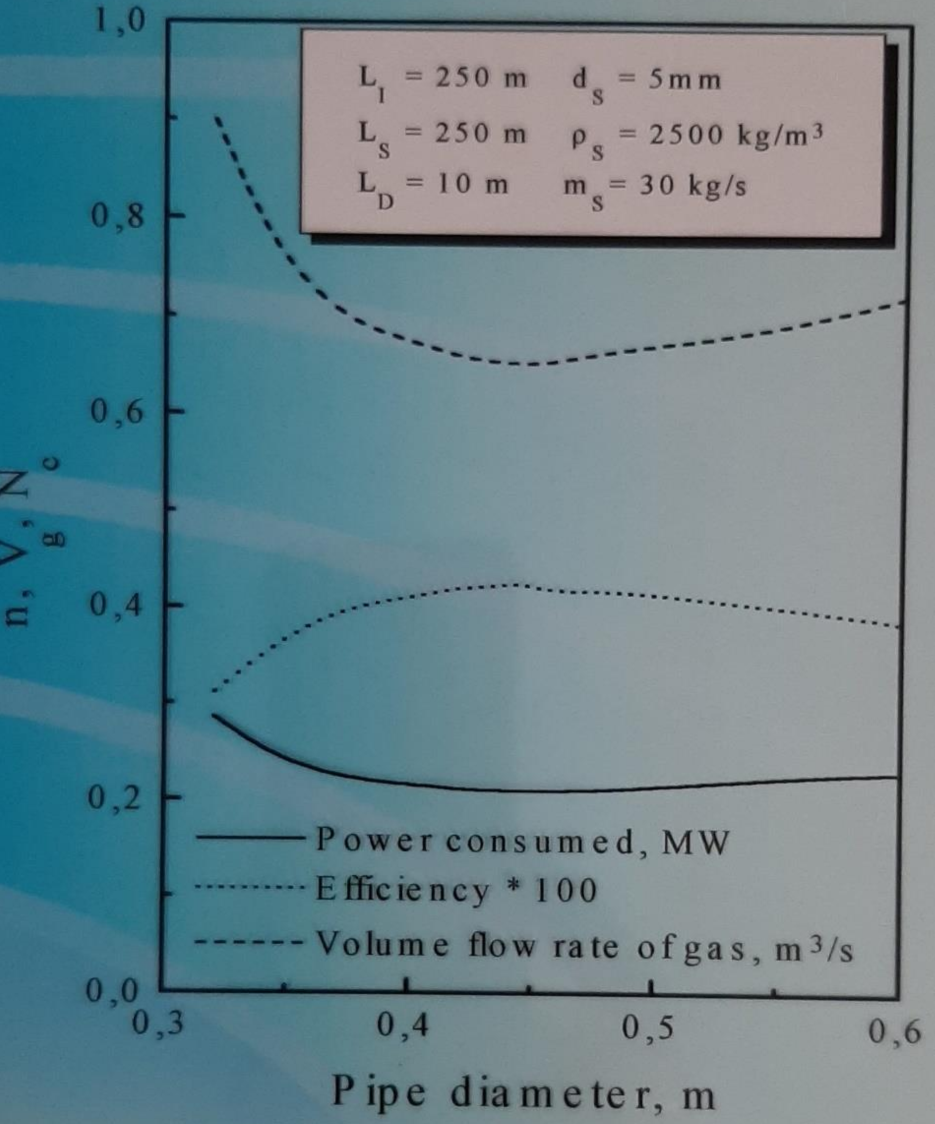
Influence of particle diameter
on Air - Lift pump operation



Influence of discharge height
on Air - Lift pump operation

DESIGN OF AN AIR-LIFT PUMP





Βελτιστοποίηση λειτουργίας υδροπνευματικής αντλίας