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EXPERIMENTAL OBTENTION OF THE HYDRODYNAMICS OF A PACKED COLUMN IN AN UNIT OPERATIONS LABORATORY

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ABSTRACT

In the laboratory of Unit Operations of the Faculty of Chemistry of the UNAM in the city of Mexico the students obtained experimentally the hydrodynamics of an absorption column. In the present article we show the experiments carried out by the students to determine experimentally the stable operating region in a packed column .

KEY WORDS: *Hydrodynamic of packed columns, region stable of points of operation, region of points of load, region of points of flooding.*

1. INTRODUCTION

The hydrodynamic effects caused by pressure drops of a gas flowing in countercurrent with a liquid in a packed tower are of great importance for the design of equipment used in the Chemical industry. Lacking the date of theoretical mathematical basis which apply the principles of transport phenomena. However when seeking explanations of the hydrodynamic behaviors observed in packed columns, we can give satisfactory answers using generalized experimental correlations of pressure drops and flood [1, 2,3,4,6,7,8,9].

1.1 Fundamentals

The gas flow through a packed tower is frequently turbulent. The pressure drop for a constant mass velocity of gas G', without feeding the stream of a liquid induces a linear behavior as you can see in the profile of the line C .Fig. (1):

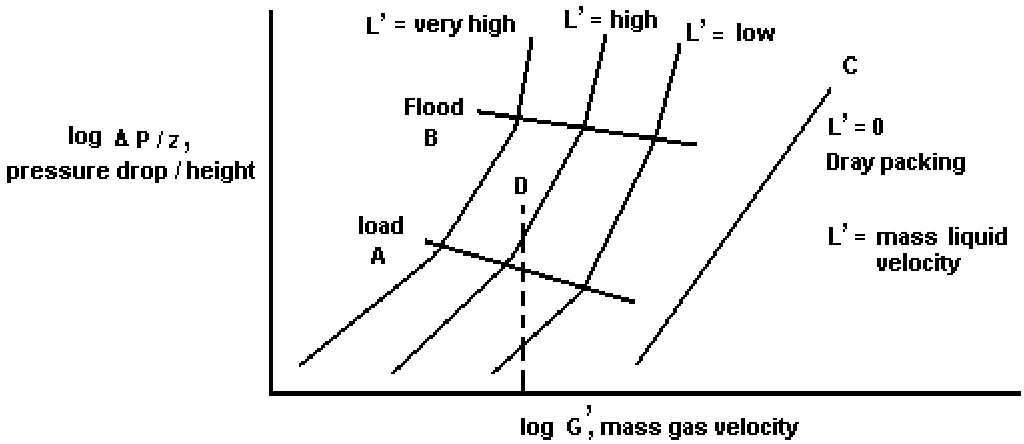


Fig. (1)

But for a constant mass velocity G´ of the gas, the fall of pressure along the tower increases with the increase in the mass velocity of the liquid L´ as can see in the dotted line D. Each type of packaging material has a void volume fixed for the passage of the liquid, so as we increase the mass velocity of the liquid, this liquid fills the holes, thus reducing the available cross-sectional area for the gas flow. When the tower operates with a fixed mass velocity of liquid L' below the marked region A, the amount of fluid retained in the packed bed will remain reasonably constant . But as the gas flow-rate increases while maintaining constant L' it generates a hydrodynamic instability since the column retains a greater quantity of fluid this is known as a *charge region in A*. Finally, at some value of the mass velocity of the gas, G´, the retention is so high that the tower starts to fill up with liquid. In that point the tower may not work causing other instability, called *point of flooding in the region B*. It is not practical to operate a tower in these instabilities, since they cause a decrease of the contact between the interfaces of fluids reducing considerably the transfer of mass in absorbers and desorbers. Because of this the towers must be operated just below the region of the point of load, in the region of stable points of operation to obtain behaviors in a permanent regime.

2. DESCRIPTION OF THE EQUIPMENT USED

The equipment used in the laboratory of engineering chemistry of the Faculty of Chemistry of the Universidad Nacional Autónoma de México (UNAM) is an absortion tower from the french company Pignat Fig. (2), (3). This equipment allows the students to obtain experimentally the values of pressure drops between the base and the dome of the column packed using an u-shape manometer by varying flows of liquid and gas.

Fig. (2) Absorption Tower

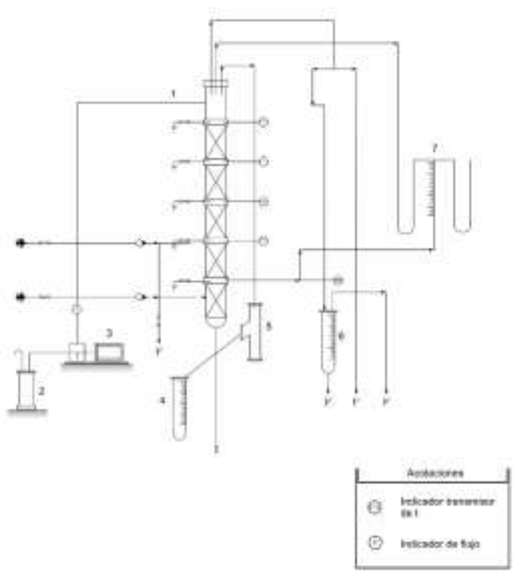


Fig. (3)
Diagram of the absorption tower equipment

The equipment has the following specifications:

KEY	TEAM	SPECIFICATIONS
1	Packed column	Service: absorption or desorption Operation: backwash Inner diameter: 5.08 cm Packaged height: 106 cm Building material: glass Packing: glass Raschig Rings 0.703 cm external diameter, 0.545 cm internal diameter and 0.854 cm length Support plate: stainless steel
2	Feed Tank	Capacity: 30 litres Side: 30 cm Height: 50 cm Building material: polyethylene
3	Positive displacement pump	Type: dosing Actuator: 110 Volts Electric Motor Building material: PTFE (teflon)
4	Receiver tank	Service: Receive diluted solution Capacity: 1 liter Diameter: 8 cm Height: 45 cm Mat. construction: glass, stainless steel.
5	Barometric leg	Service: Matching level
6	Receiver tank	Service: download of product Capacity: 3 liters Diameter: 13 cm Height: 50 cm Building material: glass, stainless steel
7	Differential manometer	Service: Indicator of the difference of pressure of the column Manometer liquid: water Material of construction: glass
		Packed cross-sectional area of flow: 0.001419 m^2
		Specific surface area of filling: = 2100.87 m^2/m^3

3. EXPERIMENTAL WORK

1. So the students can obtain points in the stable regions of operation they must:

a) Consult the manual of the hydrodynamics of a packed column [5] published on the website https//sites.google.com/site/liqfqunqm/ .

b) To turn on the compressor Fig. (4) and visually follow the air line to the column inlet valve.

c) Purge the air coming from the compressor before entering the column. Open the valve discharging air to the atmosphere. Then attach a pressure of 1 bar in the air column air with the regulator valve .

d) Turn on the pump of the liquid.

e) Verify that the feed tank water is colored with fluorescein.

f) f) Feed the water to recommended workflows.

g) Feed the air and control the flow with the rotameter. For each of the values given in the tables of experimental data, take your temperature and pressure drop.

h) Calculate the flows of air G´ in (kg / m^{2}h) in the laboratory conditions. Enter them in the tables of experimental data

i) For each flow of water find the drop of pressure of the air ΔP between the dome P_d and the bottom column P_b. Stop increasing the flows of air when visually declared the conditions of load point of liquid . Write down in the tables the experimental data including the loading point.

j) (j) Calculate the ratios of the falls of pressure between the length packed ΔP / Z point values in the tables of experimental data

Fig. (4) Centrifugal compressor

3.1. Experiments and processing of data

In an experiment the students obtained the following data:

water temperature = 17 ° C , packaged length Z = 106 cm air temperature = 19 ° C

Water flow = 0 (L / h)

% air		G´ (kg / m^2 h)	P dome (cm H_20)	P bottom (cm H_20)	ΔP (cm H_20)	ΔP / Z (kgf / m2 m)
10		782.07	65.75	65.56	0.19	1.7925
20		1564.14	65.80	65.25	0.55	5.1887
30		2346.21	66.00	65.10	0.90	8.4906
40		3128.28	66.25	64.85	1.4	13.2075
50		3910.35	66.60	64.50	2.1	19.8113
60		4692.419	66.90	64.14	2.76	26.0377
70		5474.489	67.45	63.75	3.70	34.9057
80		6256.559	68.00	63.2	4.80	45.283

Water flow = 5 (L / h)

% air		G´ (kg / m^2 h)	P dome (cm H_20)	P bottom (cm H_20)	ΔP (cm H_20)	ΔP / Z (kgf / m2 m)
10		782.07	65.90	65.45	0.45	4.2
20		1564.14	66.40	64.95	1.45	13.7
30		2346.21	67.10	64.30	2.80	26.4
40		3128.28	68.10	63.10	5.0	47.2
50		3910.35	69.80	61.80	8.00	75.5
60		4692.419	77.50	55.25	2225	209.9
70		5474.489	84.75	43.00	41.75	393.9
80						

Note-a percentage of 70% of air, manifested a point of load fully developed.

Water flow = 7 (L / h)

% air		G´ (kg / m^2 h)	P dome (cm H_20)	P bottom (cm H_20)	ΔP (cm H_20)	ΔP / Z (kgf / m^2 m)
10		782.07	65.55	65.00	0.55	5.189
20		1564.14	66.40	64.60	1.80	16.981
30		2346.21	66.90	63.05	3.85	36.321
40		3128.28	68.30	61.20	7.10	66.981
50		3910.35	71.30	54.90	16.40	154.717
60		4692.419	85.75	56.50	29.25	275.943
70						
80						

Note-a percentage of 60% of air, manifested a point of load fully developed.

Water flow = 9 (L / h)

% air		G´ (kg / m² h)	P dome (cm H_20)	P bottom (cm H_20)	ΔP (cm H_20)	ΔP / Z (kgf / m² m)
10		782.07	65.60	64.90	0.70	6.6
20		1564.14	66.80	64.50	2.30	21.7
30		2346.21	67.70	62.50	5.20	49.1
40		3128.28	69.20	59.10	10.10	95.3
50		3910.35	73.50	49.50	24.00	226.4
60		4692.419	80.25	40.23	40.02	377.5
70						
80						

Note-to a percentage of the 60% of air, there was a point of load fully developed.

Water flow = 12 (L / h)

% air		G´ (kg / m² h)	P dome (cm H_20)	P bottom (cm H_20)	ΔP (cm H_20)	ΔP / Z (kgf / m² m)
10		782.07	66.40	65.52	0.88	8.3
20		1564.14	66.80	63,14	3.66	34.5
30		2346.21	67.80	60.70	7.10	67
40		3128.28	70.20	57.90	12.30	182.1
50		3910.35	85.00	51.75	33.25	313.7
60						
70						
80						

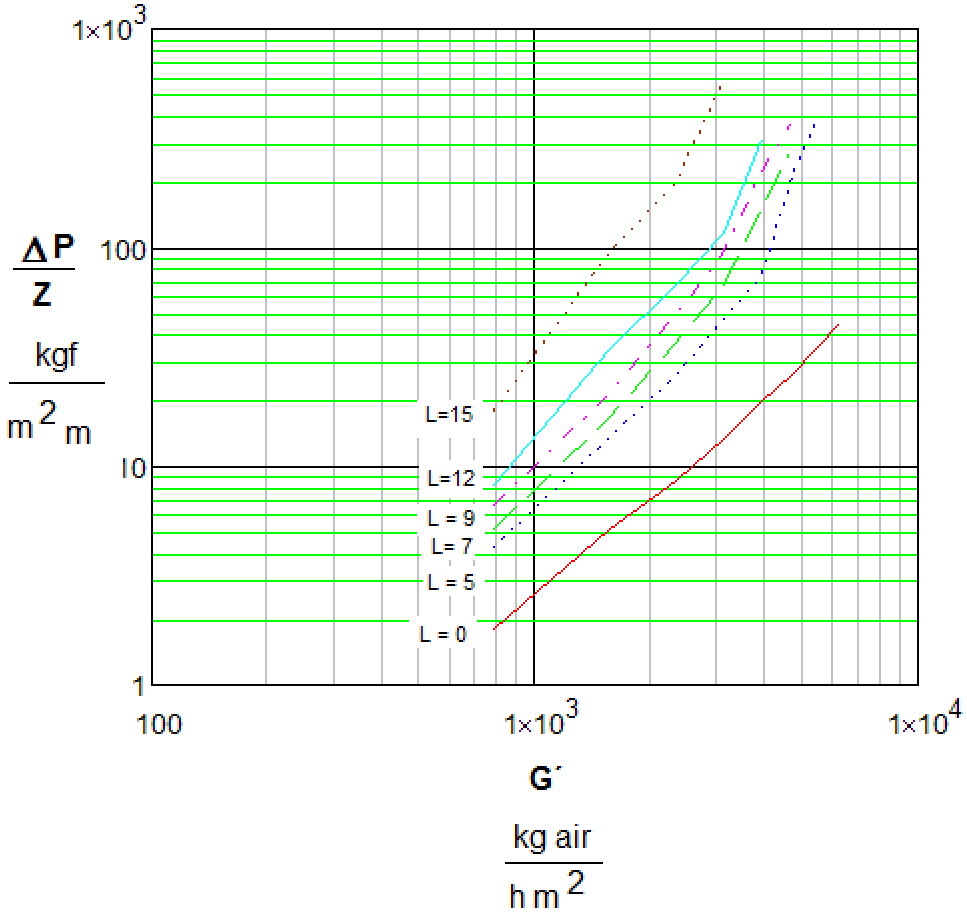
Note-a percentage of 50% of air, manifested a point of load fully developed.

Water flow = 15 (L / h)

% air		G´ (kg / m² h)	P dome (cm H_20)	P bottom (cm H_20)	ΔP (cm H_20)	ΔP / Z (kgf / m² m)
10		782.07	66.20	64.30	1.90	17.9
20		1564.14	66.80	56.50	10: 30 am	97.2
30		2346.21	67.50	46.70	20.80	196.2
40		3128.28	73.50	11.50	62.00	584.9
50						
60						
70						
80						

Note-to a percentage of the 40% of air, there is a point of load fully developed.

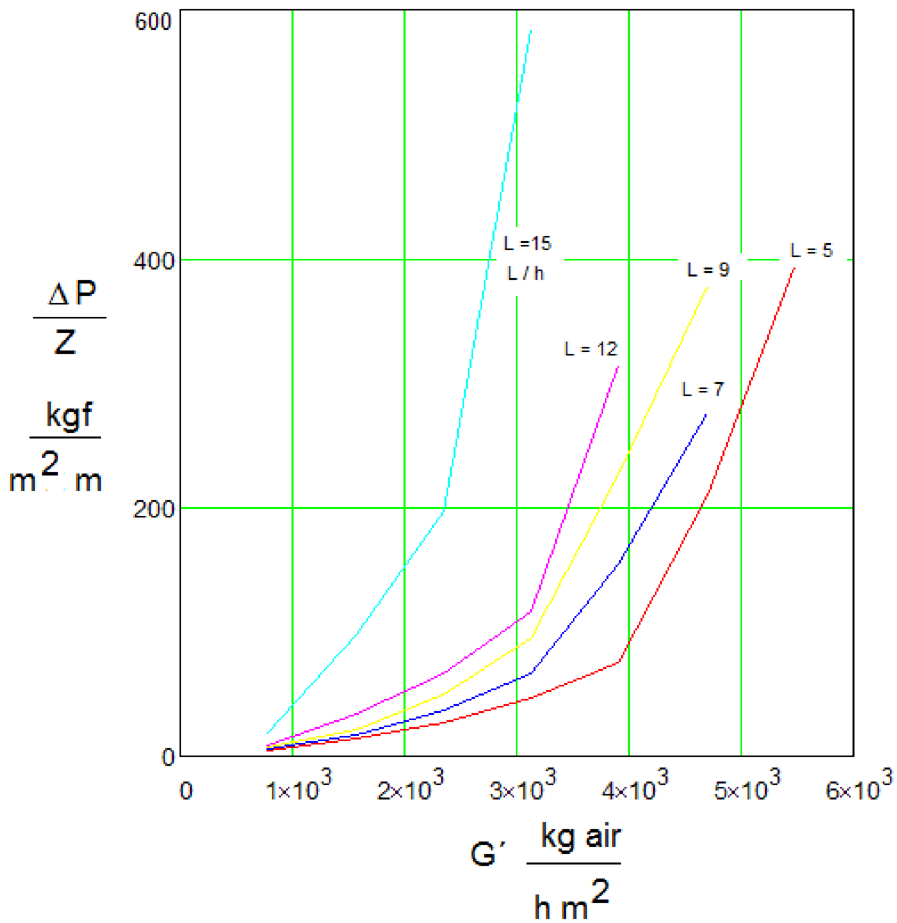
With the data from the previous tables the students built the graphics (1)



Graphics (1)

Representation of the experimental data in logarithmic coordinates

In the above graph the regions in which it is possible to operate the column without risk of flooding can not be perceived clearly, therefore we asked the students to make a graph in rectangular coordinates (graph 2).



Graph (2)

Representation of the experimental data in rectangular coordinates

3.2. Comparison with the data of other authors.

The flow limit, is the flood. The phase gas not can have a flow greater that the mass velocity of flood. The engineers must take into account this fact because working at flows extremely high can cause a flood in the column. Because of that, the engineers always choose a flow lower than the 50% of the flow that causes the flood.

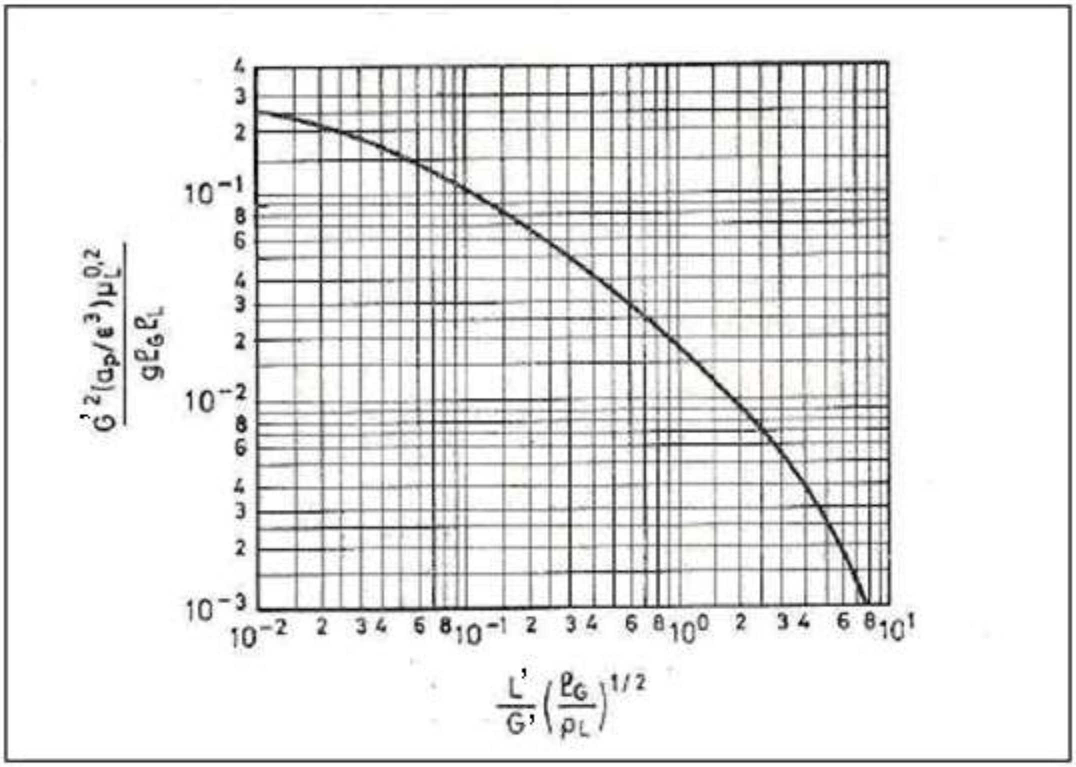
Mass velocities of the gas and the liquid influences the required height of packing. For this reason a column should work with maximum flows provided economic spending that produced losses of pressure is not a major problem. There is no expression fully generalized to calculate the point of load, but yes there are semi-empirical correlations for flood point.

The calculation of the point of the flood can be predicted [8,9] from the Lobo graph (3), on the axis of abscissas is represented:

$$\frac{L'}{G'} = \sqrt{\frac{\rho_G}{\rho_L}}$$

And in the axis of ordinates:

$$\frac{G'^2\ a_V\ \mu_L^{0.2}}{g\ \ \varepsilon^3\ \rho_G\ \ \rho_L} = \frac{V^2\ a_V\ \ \rho_G\ \ \mu_L^{0.2}}{g\ \varepsilon^3\ \rho_L}$$



Graphics (3)
Graphic of Lobo to predict the flood

From the experimental data, students built a graph of load points using the same ordinate and abscissa of Eckert works[7] and Lobo[8.9]. Consult the chart (4).

Data of the used packaging

Specific surface area of packaging: = 2100.87 m^2/m^3

Area cross of flow: ACF = 0.001419 m^2

Properties of fluids:

T ° C H2O = 17 ° C

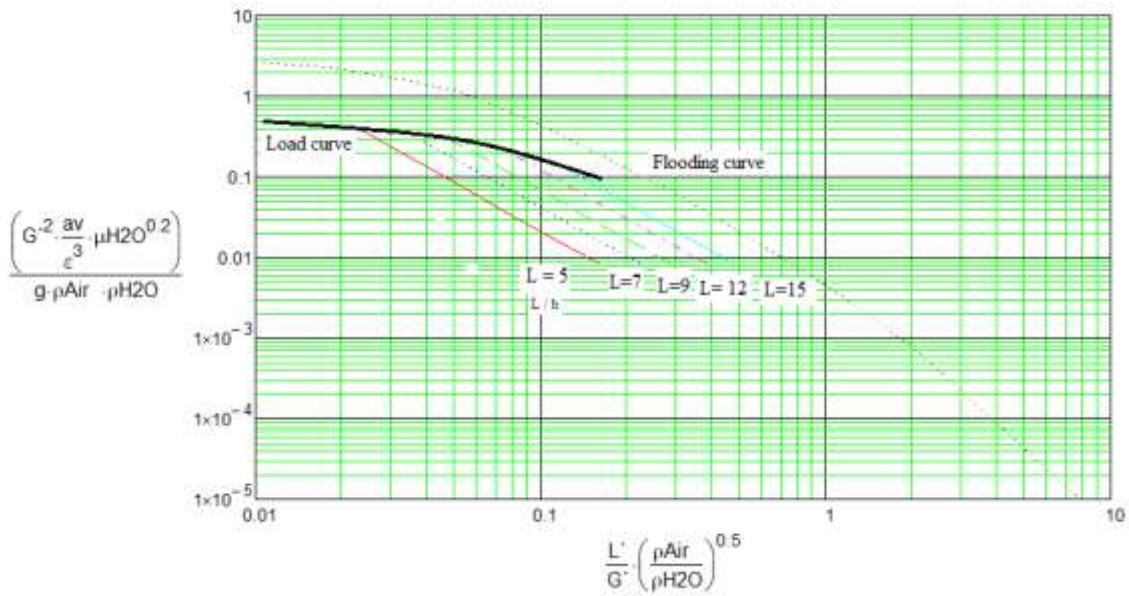
$$\rho_{air} = 1 \frac{kg}{m^3} \ , \ \rho_{H2O} = 1000 \frac{kg}{m^3}$$

Viscosity = 1 centipoise

Water flows:

L´ = 3646.47, L´ = 5105.058, L' = 6563.647, L´ = 8751.529, L´ = 10939.411

(kg water / h m^2)



Graphics (4)

The graph presents the coordinate axes of the generalized experimental correlations of flood[1,2,3,4,6,7,8.9] curve and the curve of points obtained by the students in the laboratory of unit operations.

CONCLUSIONS

Through a simple experiment the students were able to observe how behaves the hydrodynamics of a packed column and could see the points of operation and charging. The five tests began with a mass velocity of 782.07 kg air / h m^2 and with rising flows of water of 5, 7, 9, 12 and 15 L / h in countercurrent with air. When graphed the results as shown in chart (2) $\Delta P/Z$ versus G', the students observed the changes of slope in the so-called points of load. Before these points the tower could be operated in an stable form. After that the column began to manifest instabilities where it is not possible to reach the permanent regime in an operation of absorption or desorption.

NOMENCLATURE

L´: mass velocity of the liquid (kg / m^2 h).
G´: Mass velocity of the gas (kg / m^2 h).
ρ_G, ρ_L: gas and liquid density (kg /m^3).
μ_L: viscosity of the liquid (centipoises).
g: acceleration of gravity 12; 709,8720 (m^2 / h).
V: linear velocity of the gas (m/s).
a_V/ε^3 : Packing specific surface (m^2/m^3), their values are known based on the different types of packing.
Z: Height of the column (m)
Δ P: pressure drop on the package of the column (kgf / m^2)
Pb: pressure at the bottom of the section packed (kgf / m^2)
Pd: pressure in the dome of the section packed (kgf / m^2)

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