

PRESSURE DROP ACROSS A PERFORATED-PLATE DISTRIBUTOR IN A GAS-FLUIDIZED BED

CHIEN-SONG CHYANG AND CHENG-CHUNG HUANG

*Department of Chemical Engineering, Chung Yuan Christian University,
Chung Li, Taiwan, R.O.C.*

Key Words: Fluidized Bed, Gas Distributor, Pressure Drop

Pressure drops across a perforated-plate distributor, with and without a bed present, were investigated and a disagreement was found. A "real minimum uniform fluidization velocity", U_{rmuf} , was defined at which the distributor pressure drop was consistent with that in an empty bed. An approach for modifying the orifice equation when the gas velocity was smaller than U_{rmuf} was proposed.

Introduction

The critical ratio of the distributor-to-bed pressure drop, $\Delta P_d/\Delta P_b$, at a specific superficial gas velocity has usually been used as the criterion for multiorifice gas distributor design. Providing that an appropriate value of such a ratio is chosen, then the distributor pressure drop can be determined. Based on this pressure drop and the specific superficial gas velocity, the open area ratio can be determined by using the orifice theory.

Differences between the distributor pressure drops measured in the absence and presence of a bed have been found by several investigators.^{1-5,7,9)} Except for the theoretical prediction by Sutherland⁸⁾ for a porous plate, it was usually found that the presence of the bed increased the distributor pressure drop. The previous investigators have attributed this phenomenon to the obstruction of orifices by fine particles³⁾, formation of a dead zone⁵⁾, inactive orifices⁴⁾, and

backflow of particles into the orifices²⁾. On the other hand, the effect of the venturi-type expansion regions formed by the solids surrounding the gas jets has been regarded as reducing the pressure drop across a perforated plate.^{5,6)}

In this study the discrepancies between the pressure drops across a perforated-plate distributor measured in the absence and presence of a bed were investigated. An attempt was made to find an approach for modifying the orifice equation.

1. Experimental

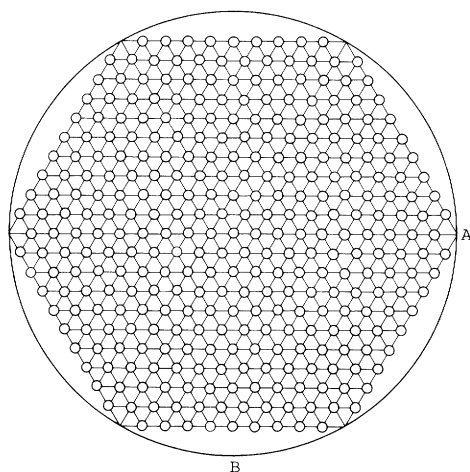
All the experiments were conducted in a 0.3-m-diameter fluidized bed which was fabricated from an acrylic column. Acrylic plates drilled on a triangular pitch, as shown in **Fig. 1**, were used as the distributors. Their characteristics are shown in **Table 1**. River sand with a narrow size distribution was used as the bed material and the density, average particle size and U_{mf} were 2580 kg/m³, 0.650 mm and 0.3 m/s, respectively.

Two pairs of pressure taps were installed vertically along the acrylic column and were 90 degrees angularly

* Received August 6, 1990. Correspondence concerning this article should be addressed to C. S. Chyang.

Table 1. Characteristics of perforated-plate gas distributors

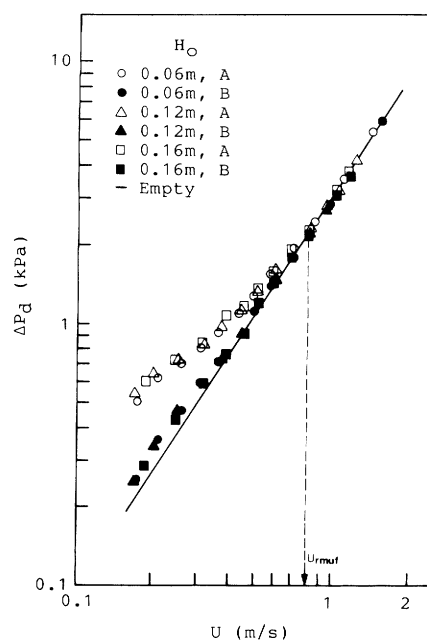
Plate No.	Thickness (mm)	Orifice size (mm)	Number of orifices (—)	Orifice pitch (mm)	Open area (%)
1	13.5	2.3	187	20	1.10
2	13.5	3.1	187	20	2.00
3	13.5	1.5	769	10	1.92
4	13.5	2.3	745	10	4.38
5	9.5	3.1	325	15	3.47
6	9.5	1.6	879	9	2.50
7	9.5	1.6	241	18	0.69
8	9.5	2.2	241	18	1.42
9	9.5	3.1	241	18	2.57
10	9.5	3.9	241	18	4.07
11	8.0	3.1	187	20	2.00
12	8.0	3.1	745	10	7.95
13	8.0	2.3	325	15	1.91
14	4.8	4.0	73	32	1.30
15	4.8	4.0	301	16	5.35
16	4.8	2.3	757	10	4.45

**Fig. 1.** Configuration of orifices with triangular pitch on perforated plates 5 and 13

apart at the locations denoted A and B in Fig. 1. Each pair consisted of two taps, one immediately above and the other 40 mm below the distributor. The inside opening of each tap was covered with 200-mesh screen to prevent solid blockage. The fluidizing air was supplied by a blower. An orifice meter coupled with a Taylor 3403T Model B pressure transmitter and a Chessell Model 4001 recorder were used to measure the gas flow rate. The accuracy of measurement of the gas flow rate was 3%. A manometer was used to measure the pressure drops across the perforated plate.

2. Results and Discussion

Figure 2 indicates that the distributor pressure drop measured in the presence of the bed strongly depends on the locations of pressure taps when the superficial gas velocity is below a certain value. Similar results were obtained for all the perforated plates used in this study. The distributor pressure drop measured at

**Fig. 2.** Variation of pressure drop of perforated-plate distributor (plate 8) with static bed height and superficial gas velocity. A and B identify locations

location A is much higher, while that measured at location B is just slightly higher, than that measured in the empty column. It should be noted that in an empty column the data measured from taps A and B were the same, proving that no maldistribution of air in the windbox occurred. In the presence of bed material, the total pressure drops across the distributor and the bed measured from taps A and B were also the same. While the superficial gas velocity was smaller than U_{mf} , the flow resistance of gas across the plate was so low that the gas could not rearrange itself properly before flowing through the orifices of the plate. This resulted in a nonequal flow of gas through

the orifices and the maldistribution of gas immediately above the perforated plate. Consequently, a discrepancy between the distributor pressure drops measured at different locations was found. While the superficial gas velocity was higher than U_{mf} , the dead zones in the area near the location A were less extensive than those near location B. The bubble flow would be more significant near location A, and this would increase the bed voidage and decrease the bed pressure drop in this region. Under the condition of the same total pressure drop, this resulted in the fact that the distributor pressure drop measured from taps A was higher than that measured from taps B.

The data obtained with a perforated plate of 1.3% open area ratio (plate 14) was used to check the explanations suggested by previous investigators for this phenomenon. Spouting above each orifice was observed when the static bed height was lower than the dead zone height even at low gas velocities. Therefore each orifice could be regarded active and no obstruction occurred because of the steady spouting. The results shown in Fig. 3 indicate that the distributor pressure drop measured from taps A is still much higher than that in the empty column. It seems that the explanations suggested by Grohse³⁾ and Ho *et al.*⁴⁾ are inadequate for this case. When the static bed height was 0.1 m or higher, fluidization of particles could be induced and spouting above each orifice was no longer observed. A different effect from that at a static bed height of 0.06 m was found, as shown in Fig. 3. Obviously, whether the static bed height is higher or lower than the dead-zone height can be identified from the difference in effects of the presence of the bed on the distributor pressure drop. Neither obstructions nor inactiveness of orifices could well explain the results. Thus we can infer that the hydrodynamics of the grid region is the main factor in the increase of distributor pressure drop in the presence of bed material. The solids flow toward the orifice could increase the resistance of gas flow during the formation of a pulsating jet and the detachment of an initial bubble.

As shown in Fig. 2 and Fig. 3, the velocity at which the distributor pressure drops measured at locations A and B are the same and are consistent with those measured in the empty column is defined as the real minimum uniform fluidization velocity, U_{rmuf} . It indicates that U_{rmuf} is a unique value because the static bed height has a constant effect on the distributor pressure drop as long as it is higher than the dead-zone height. It is the velocity at which the hydrodynamic behaviour near locations A and B have no effect on the pressure drop across a perforated plate; therefore, the fluidization behavior can be regarded as uniform. As shown in Fig. 4, U_{rmuf}/U_{mf} decreases with the distributor pressure drop evaluated at U_{mf} . Figure 5

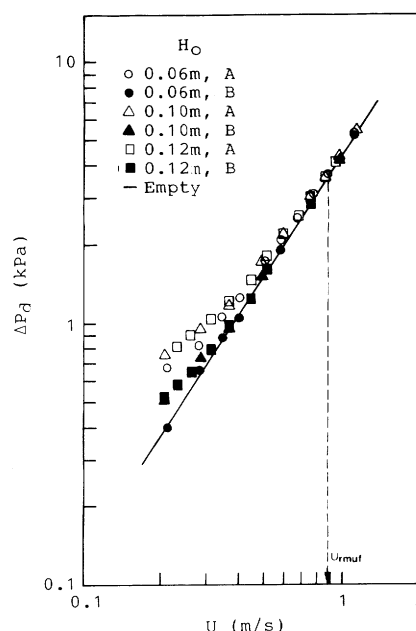


Fig. 3. Variation of pressure drop of perforated-plate distributor (plate 14) with static bed height and superficial gas velocity. A and B identify locations

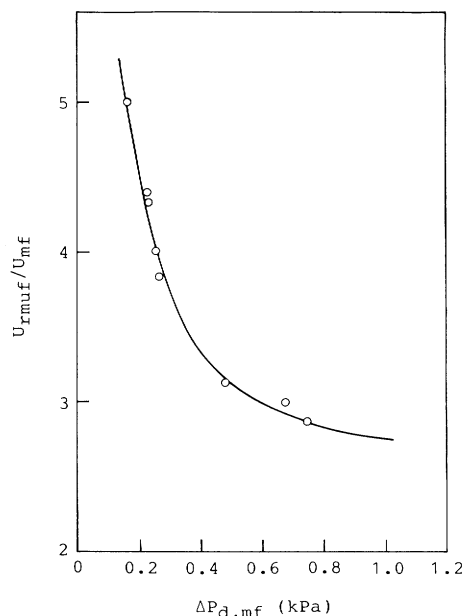


Fig. 4. Effect of pressure drop of perforated-plate distributor at $U = U_{mf}$ on real minimum uniform fluidization velocity. $H_o = 0.12$ m

shows the degree of increase of the distributor pressure drop in the presence of the bed. Obviously, the orifice equation should be modified when the orifice theory is applied to multiorifice distributor design. A procedure was proposed and is illustrated in the following example.

Example: 0.650 mm river sand is used as the bed material in a 0.3 m-diameter gas-fluidized bed. The static bed height is 0.15 m. If a perforated-plate

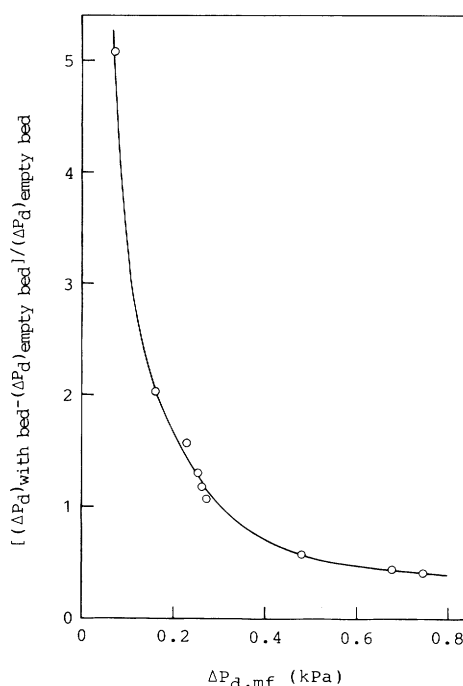


Fig. 5. Degree of increase of perforated-plate pressure drop at $U = U_{mf}$ while static-bed height was greater than dead-zone height

distributor is designed on the basis of $\Delta P_{d,mf}/\Delta P_b = 0.2$ at U_{mf} , how can the orifice equation be modified?

Illustration:

$$H_o = 0.15 \text{ m}$$

At U_{mf}

$$\Delta P_b = \rho_p g H_o (1 - \varepsilon_{mf}) = 1.96 \text{ kPa}$$

Then $\Delta P_{d,mf} = 0.2 \Delta P_b = 0.392 \text{ kPa}$

From Fig. 5, the degree of increase of the distributor pressure drop in the presence of 0.650 mm sand in the bed is 0.716. The orifice equation from orifice theory is

$$\Delta P_d = \rho_f U_o^2 / (2C_D^2) \quad (1)$$

Therefore, Eq. (1) is modified at U_{mf} as

$$\Delta P_{d,mf} = (1 + 0.716) \rho_f U_{o,mf}^2 / (2C_D^2) \quad (2)$$

To obtain sufficient information for modifying the orifice equation, it is recommended that the effect of particles of different size, density, and size distribution on the degree of increase of distributor pressure drop should be investigated.

Conclusions

The pressure drop across a perforated-plate dis-

tributor measured in the presence of bed material was higher than that measured in an empty column at low gas velocities and was significantly affected by the locations of pressure taps corresponding to the orifice layout on the perforated plate. A real minimum uniform fluidization velocity, U_{rmuf} , was defined at which the distributor pressure drop is consistent with that in an empty column. An approach was proposed to modify the orifice equation.

Acknowledgement

The authors wish to acknowledge the National Science Council, R.O.C. for financial support through grant No. NSC-76-0402-E033-02.

Nomenclature

C_D	= orifice discharge coefficient	[—]
g	= gravitational acceleration	[m/s ²]
H_o	= static bed height	[m]
ΔP_b	= bed pressure drop	[kPa]
ΔP_d	= distributor pressure drop	[kPa]
$\Delta P_{d,mf}$	= distributor pressure drop at minimum fluidization velocity	[kPa]
U	= superficial gas velocity	[m/s]
U_{mf}	= minimum fluidization velocity	[m/s]
U_o	= gas velocity through distributor orifices	[m/s]
$U_{o,mf}$	= gas velocity through distributor orifices at minimum fluidization velocity	[m/s]
U_{rmuf}	= real minimum uniform fluidization velocity	[m/s]
ρ_f	= density of gas	[kg/m ³]
ρ_p	= density of particles	[kg/m ³]
ε_{mf}	= void fraction in the bed at minimum fluidization velocity	[—]

Literature Cited

- Behie, L. A., B. E. Voegelin and M. A. Bergougnou: *Can. J. Chem. Eng.*, **56**, 404 (1978).
- Briens, C. L., A. K. Tyagi and M. A. Bergougnou: *Can. J. Chem. Eng.*, **66**, 740 (1988).
- Grohse, E. W.: *AIChE J.*, **1**, 358 (1955).
- Ho, T. C., T. K. Chen and J. R. Hopper: *AIChE Symp. Ser.*, **80**(241), 34 (1984).
- Kassim, W. M. S., Ph. D. Dissertation, University of Aston, Birmingham (1972).
- Qureshi, A. E. and D. E. Creasy: *Powder Technol.*, **22**, 113 (1979).
- Saxena, S. C., A. Chatterjee and R. C. Patel: *Powder Technol.*, **22**, 191 (1979).
- Sutherland, J. P.: *Chem. Eng. Sci.*, **19**, 839 (1964).
- Trivedi, R. C. and W. J. Rice: *Chem. Eng. Progr. Symp. Ser.*, **62**(67), 57 (1966).