

Hydraulics of a Packed Column

Introduction

Packed beds are widely used in industry to contact two or more fluid phases at relatively low pressure drops. For process design purposes, it is essential that pressure drop be estimated for its proper operation. Physical design characteristics of columns - particularly packing type, size, and column dimensions - can greatly impact neighbouring process units and the load induced upon compressors and pumps.

The advantage of using a packed column rather than just a tank or other reaction vessel is that the packing affords a larger surface area per unit volume for mass transfer. They are readily used in industry for catalytic reactions, combustion, gas absorption, distillation, drying, and separation processes. One example where packed beds are employed is in a sulfuric acid plant. Water vapour or sulfur trioxide is absorbed from the gas phase by a counter-current stream of concentrated sulfuric acid. The columns shown in figure 1 are made of aluminum (stainless steel, fibreglass or polyethylene can also be used), and are robust and durable.

Packed columns are also used extensively for pollution control. Figure 2 shows a WMT packed column that is used to scrub H_2S gases from a waste stream. This process strips the H_2S using a counter-current liquid-gas flow, and prevents the



1: Industrial Packed Columns



2: Packed columns used for H_2S scrubbing

harmful gas from reaching the atmosphere.

To predict the behaviour of physical and chemical processes, it is convenient for the design engineer to use mathematical models. In this experiment, mathematical models are tested against experimental data using water and air as the working fluids in the column. Trials involving dry packing, wet packing, and irrigated packing will be explored.

Objectives:

- to design experiments to test mathematical models pertaining to packed columns
- to understand the concept of pressure drop over the packed column under different fluid flow conditions.
- to interpret the values obtained experimentally and theoretically.
- to apply the concepts to industrial applications.

Theory

Several empirical correlations exist in theory to predict how packed beds will operate, relating pressure drop to fluid velocity, fluid physical properties, bed porosity, bed geometry, particle size, and particle size distribution. One of the most useful is the *Ergun Equation*. It is unique among many models because it covers any flow condition (turbulent, laminar, or transitional). It can be expressed as:

$$\frac{-\Delta P}{H} = 150 \frac{\mu U (1-e)^2}{x^2 e^3} + 1.75 \frac{\rho_f U^2 (1-e)}{x e^3} \quad (1)$$

where x = particle diameter
 ϵ = bed voidage

U = gas velocity
H = bed height
 r_f = fluid density
 μ = fluid viscosity

The first term on the right side of the equation represents the laminar component of the flow while the left side deals with turbulent flow.

Another model commonly used when dealing with packed columns is one developed by *Leva*. It is expressed as:

$$\Delta P = C_2 10^{C_3 U_t} r_2 U_t^2 \quad - \textit{irrigated} \quad (2)$$

$$\Delta P = C_2 r_g U_t^2 \quad - \textit{wetted} \quad (3)$$

where C_1, C_2 = packing coefficients (Perry's [1])

The two equations shown apply in different situations based on the fluid flow through the bed. Since the water and air flow rates will vary a great deal in this experiment, it is appropriate to use these equations because of their versatility. It is also useful in this experiment because the three varying terms (density, pressure, and velocity) can all be easily controlled and thus the equation can easily be manipulated. (**Note:** these are but two references of many that may be applied. Students are encouraged to find the “best” to describe the behavior witnessed in the lab data)

Apparatus:

The existing apparatus in the lab is illustrated in the Process & Instrumentation Diagram attached. The arrangement of the pellets in the column is known as *dump* or *random* packing, which simply means that the pellets were not placed in any specific pattern.

For pressure measurements, there are several points along the line where the gas pressure is measured. There are three manometers on the panel that represent the orifice (mm H₂O),

column (mm H₂O), and the blower (mm Hg). There are also thermometers located after the blower, after the heater, and at the water inlet and outlet points.

Column Specs:

ID:	6"
Packing:	3/4" ceramic Raschig Rings
Packing Height:	5.9 ft

Air Supply Pipe:

ID:	2.91"
Orifice Plate:	0.875"

Motor:	General Electric 3 HP Induction Motor
	1745 rpm
	208 V, 9.5 A

Water Flow - variable:

Max Flow	1.96 USGPM
----------	------------

Air Flow - variable using bypass valve

- measured using orifice plate
- blower supply pressure given by manometer

Air Temperature - variable using rheostat

References:

- [1] Perry, Robert H. Perry's Chemical Engineer's Handbook McGraw Hill, Toronto. 1984
- [2] Geankoplis, Christie J. Transport Processes and Unit Operations - Third Edition. Prentice Hall. Englewood Cliffs, NJ. 1993
- [3] Mills, A. F. Heat Transfer - Second Edition. Prentice Hall. Upper Saddle River, NJ. 1999

