

# INTERCOMPANY MEMORANDUM

## CAL CHEM CORPORATION

**To:** CHE Seniors  
**From:** CHE faculty  
Laboratory Managers  
**Date:** Fall Quarter  
**File:** CHE 435  
**Subject:** COLUMN OPERATING CHARACTERISTICS

You are to study proprietary packings in the laboratory 2" ID glass tower test apparatus. We have had the lab technician set up three columns (a 2" column packed with 7mm Raschig rings, a 2" column packed with 1/4" Berl Saddles, and a 2" column fitted with sieve trays) for your study.

Run the same type of tests that we would run on a new packing. Be sure to consider the following items:

- Loading and flooding.
- Channeling.
- Pressure drop across column.
- Liquid holdup in column.
- Minimum liquid flow.
- Plot of pressure drop per unit height of packed bed, superficial gas and liquid mass flow rates on rectangular and log-log coordinates.
- Hysteresis effect once column is flooded.

You should explain why it is difficult to recover column operation once flooding takes place. It is probably best to use various water rates and vary the air flow for each water rate.

We have included an apparatus diagram and some information from the following references:

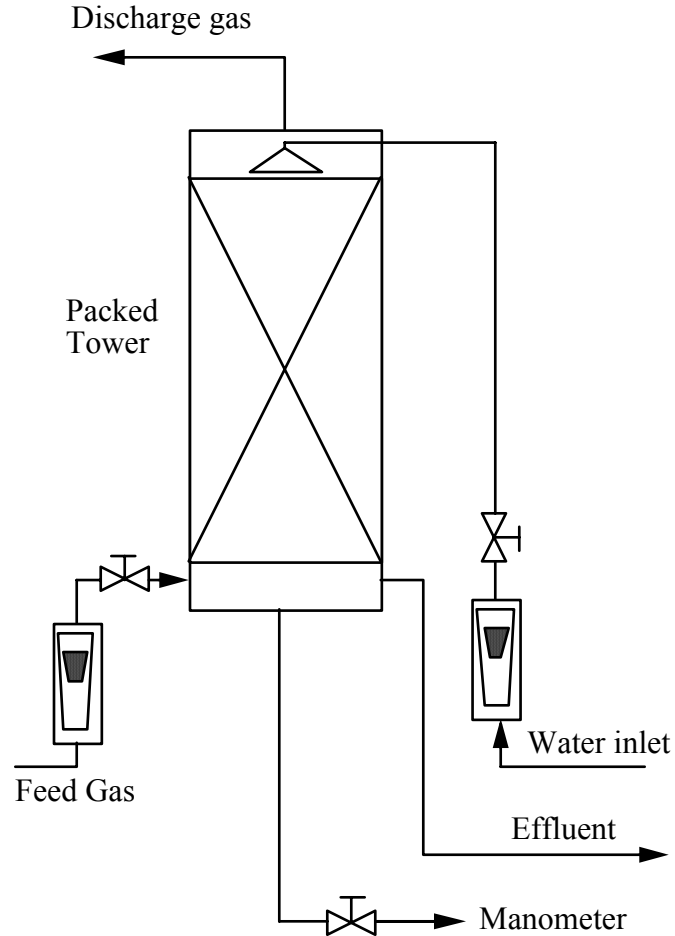
- Mc Cabe & Smith, "Unit Operations of Chemical Engineering"
- Foust, "Principles of Unit Operations"
- Leva, "Tower Packings and Packed Tower Design", United States Stoneware

Co.

You will find a good discussion on packed column characteristics in the text by Henley and Seader<sup>(1)</sup>.

1. Seader, J. D. and Henley E. J., Separation Process Principles, Wiley, 1998, pg. 325

### Column Operating Characteristics



**Fig. 1** Schematic representation of the packed column in the lab.

In a packed column used for gas-liquid contact, the liquid flows downward over the surface of the packing and the gas flows upward in the void space of the packing material. A low pressure drop and, hence, low energy consumption is very important in the performance of packed towers. The packing material provides a very large surface area for mass transfer, but it also results in a pressure drop because of friction.

The performance of packed towers depends upon the hydraulic operating characteristics of wet and dry packing. In dry packing, there is only the flow of a single fluid phase through a column of stationary solid particles. Such flow occurs in fixed-bed catalytic reactor and sorption operations (including adsorption, ion exchange, ion exclusion, etc.) In wet packing, two-phase flow is encountered. The phases will be a gas and a liquid in distillation, absorption, or stripping. When the liquid flows over the packing it occupies some of the void volume in the packing normally filled by the gas, therefore the performance of wet packing is different from that of dry packing.

For dry packing, the pressure drop may be correlated by Ergun equation

$$\left(\frac{\Delta P}{h}\right) \left[\frac{D_p g_c}{\rho_f v_s}\right] \left(\frac{\varepsilon^3}{1-\varepsilon}\right) = 150 \frac{1-\varepsilon}{N_{Re}} + 1.75 \quad (1)$$

where

- $\Delta P$  = pressure drop through the packed bed
- $h$  = bed height
- $D_p$  = particle diameter
- $\rho_f$  = fluid density
- $v_s$  = superficial velocity at a density averaged between inlet and outlet conditions
- $\varepsilon$  = bed porosity
- $N_{Re}$  = average Reynolds number based upon superficial velocity  $\frac{D_p v_s \rho_f}{\mu}$

When the packing has a shape different from spherical, an effective particle diameter is defined

$$D_p = \frac{6V_p}{A_p} = \frac{6(1-\varepsilon)}{A_s} \quad (2)$$

where

- $A_s$  = interfacial area of packing per unit of packing volume, ft<sup>2</sup>/ft<sup>3</sup> or m<sup>2</sup>/m<sup>3</sup>

The effective particle diameter  $D_p$  in Eq. (1) can be replaced by  $\phi_s D_p$  where  $D_p$  now represents the particle size of a sphere having the same volume as the particle and  $\phi_s$  the shape factor. The bed porosity,  $\varepsilon$ , which is the fraction of total volume that is void is defined as

$$\begin{aligned} \varepsilon &\equiv \frac{\text{volume voids}}{\text{volume of entire bed}} \\ \varepsilon &\equiv \frac{\text{volume of entire bed} - \text{volume of particles}}{\text{volume of entire bed}} \\ &= \frac{\pi R^2 h - \frac{\text{weight of all particles}}{\text{particle density}}}{\pi R^2 h} \end{aligned} \quad (3)$$

where  $R$  = inside radius of column,  $A_s$  and  $\varepsilon$  are characteristics of the packing. Experimental values of  $\varepsilon$  can easily be determined from Eq. (3) but  $A_s$  for non-spherical particles is usually more difficult to obtain. Values of  $A_s$  and  $\varepsilon$  are available for the

common commercial packing in the various references (Ref. 2, 4).  $A_s$  for spheres can be computed from the volume and surface area of a sphere.

For wet packing, the pressure drop correlation is given by Leva (Ref. 7)

$$\left(\frac{\Delta P}{h}\right) = \alpha \left(10^{\beta L / \rho_L}\right) \left(\frac{G_v^2}{\rho_v}\right) \quad (4)$$

where  $\Delta P$  is the pressure drop (psf),  $h$  is the packing height (ft),  $L$  is the liquid mass flow rate per unit area (lb/hr-ft<sup>2</sup>),  $G_v$  is the gas mass flow rate per unit area (lb/hr-ft<sup>2</sup>),  $\rho_L$  is the liquid density (lb/ft<sup>3</sup>),  $\rho_v$  is the gas density (lb/ft<sup>3</sup>), and  $\alpha$  and  $\beta$  are packing parameters (Ref. 5, 7).

For each column studied, determine the pressure drop at various air flow rates (correct rotameters for pressure and temperature). Keep the liquid flow rate constant at different gas rates.

**Table 1. Packing Information**  
**R: Raschig Rings, B: Berl Saddle**

Normal Size, Inch	Approximate Number per Cu. Ft.	Approximate Weight per Cu. Ft., lb	Approximate Surface area Sq. Ft./Cu. Ft.	Percent Free Gas Space	Effective Diameter $D_p$ , Inch
<b>R: 1/4</b>	88000	46	240	73	0.22
<b>R: 5/16</b>	40000	56	145	64	0.31
<b>R: 3/8</b>	24000	51	134	68	0.35
<b>B: 1/4</b>	113000	56	274	60	0.23
<b>B: 1/2</b>	16200	54	142	63	0.42
<b>B: 3/4</b>	5000	48	82	66	0.58

Minimum Data Analysis

1. Plot a graph of  $\Delta P/h$  versus  $G_v$  for each column and compare with published data (Ref. 5, 7).
2. For the runs with dry packing correlate your data by Eq. (1)
3. For the runs with wet packing correlate your data by Eq. (4). Determine your measured values of  $\alpha$  and  $\beta$ .

**References**

1. Middleman, Stanley, An Introduction to Fluid Dynamics, Wiley, 1998, pg. 411

2. McCabe W. L. et al , Unit Operations of Chemical Engineering, McGraw-Hill, 1993, pg. 689
3. Hanesian, D. and Perna A. J., “A Laboratory Manual for Fundamentals of Engineering Design”, NJIT.
4. Perry, J. H., Chemical Engineers’ Handbook, McGraw-Hill, 1984, pg. **18-23**
5. Wankat, P. C., Equilibrium Staged Separations, Elsevier, 1988, pg.420
6. Leva M., Chem. Eng. Prog. Symp. Ser. **50**(10): 51 (1954).
7. Max S. Peters and Klaus D. Timmerhaus, Plant Design and Economics For Chemical Engineers, McGraw-Hill, 1991, pg. 694.