

Troubleshooting Columns

Impact of Pressure Drop

In any column, the vapour pressure at bottom has to be higher than that at the top, because the vapour has to pass through various resistances on its way up. ΔP_v , or vapour pressure drop, is the difference between the vapour pressure at column bottom and column top. It depends upon factors such as the type and design of contacting elements (trays / packings) and column diameter.

There are well established procedures for calculating ΔP_v . However, due to reasons such as design errors, not operating at design conditions, accumulation of solids in the column (choking or fouling) and wrong selection of packings, internals, or trays, actual ΔP_v can differ from that recommended.

Low pressure drop can result in weeping of sieve or valve trays. Here, the upward force of vapour on the tray bottom is not enough to prevent the liquid leaking directly down the tray perforations. This results in drastic reduction of efficiency. Low ΔP_v can also cause maldistribution of vapour, i.e. vapour tends to flow preferentially through some parts of column cross-section, instead of flowing uniformly throughout.

High pressure drop can result in entrainment and flooding, but also has effects such as changing the design parameters themselves.

Flooding: Liquid flowing down the column has to overcome the pressure of vapour flowing upwards. If the vapour pressure is too high, liquid head increases in order to overcome it – but this results in even higher vapour pressure drop due to liquid gravity head! This cycle leads to the column getting filled with liquid - and a sharp increase in pressure drop. This is called flooding. It not only reduces efficiency, but can be a severe safety issue.

Entrainment: Excess entrainment occurs when the vapour flow is so high that it carries ('entrains') droplets of liquid upwards with it. The additional weight of these droplets gives rise to higher vapour pressure drop – which can also cause flooding.

Miscellaneous: High ΔP_v can also cause maldistribution of vapour or damage to internals. When vapour/gas is introduced at column bottoms through a compressor (viz in absorbers), higher column bottom pressure means higher compressor power.



Impact on design parameters: An often-ignored effect of high ΔP_v is on the column temperature profile. Basically, it results in higher pressure at column bottoms, which in turn raises bottom temperature as well. This can have a number of effects –

a) Reduced vaporisation: Reboiler vaporisation rate is approximately $(U_d * HTA * \Delta T) / \lambda$,

where,

U_d = Overall heat transfer coefficient

HTA = Heat Transfer Area of reboiler.

ΔT = (Temperature of heating medium – Temperature of liquid at column bottom)

λ = Latent heat of vaporisation.

When the temperature at column bottom increases, ΔT decreases. Other parameters being substantially unchanged, the vaporisation rate also decreases. One consequence is reduced plant capacity. But this also changes the (L/V) ratio, which can affect composition of top and bottom products. The impact is more pronounced for vacuum distillations. In these cases, the operating pressure itself is low, so even a small increase in pressure drop causes large percentage increase in column bottom pressure. Following example illustrates what happens when pressure drop increases from 10 mm Hg to 20 mm Hg in a dichlorobenzenes column.

Bottom product		Ortho-dichlorobenzene		
Top product		para- and meta-dichlorobenzenes		
Pressure at column top		50 mm Hg absolute		
Heating medium temperature		120 C		
Case No	Pressure drop, mm Hg	Bottom pressure, mm Hg	Bottom temperature, °C	Delta-T, °C
1	10	60	98	120 – 98 = 22
2	20	70	102	120 – 102 = 18

Reduction in vaporisation rate = $100 * (1 - \frac{18}{22}) \% = 18.2 \%$

In order to bring down column pressure, top pressure could be decreased by increasing vacuum. But this will result in lower pressure and temperature, which now reduces column and condenser capacities.

b) Damage to bottoms product: Higher temperature can also damage heat-sensitive bottom products, which is not acceptable.



- c) Changes in properties: A change in pressure can significantly change the properties of the fluid mixture. An important characteristic is its vapour-liquid equilibrium, which can shift significantly depending on pressure. This will influence the number of trays, reflux ratio etc, and could even form or break azeotropes. Other properties like viscosity, surface tension, latent heat of vaporisation etc can also be affected significantly by changes in column bottom temperatures.

Thus, attention has to be paid to column pressure drop in design and operation of a column.