

ChemSep Tutorial: System Factors

Ross Taylor and Harry Kooijman

The purpose of this tutorial is to review the options for setting the **System Factor** in *ChemSep*.

By way of background we note that the diameter of a tray distillation column is estimated as some percentage (75%, say) of the gas superficial velocity at flooding. The flooding velocity is calculated from:

$$u_{s, flood} = C_{flood} \sqrt{\frac{\rho_L - \rho_V}{\rho_V}}$$

where where ρ_V is the mass density and where C_{flood} is the C-factor at the flood point. This factor is estimated from an appropriate correlation of which more in a separate tutorial.

For some systems the flooding velocities predicted using this approach are known to be too high. Thus, in practice, an empirical correction is applied in the following form:

$$u_{s, flood} = C_{flood} SF \sqrt{\frac{\rho_L - \rho_V}{\rho_V}}$$

where SF is the **System Factor**, or **Derating Factor**, a parameter that has a maximum value of 1. The System Factor is sometimes called the **Foaming Factor** because there appears to be a relationship between the values of the system factor used in practice and a systems tendency to foam.

Quite often one simply finds a suitable value of the system factor in an appropriate reference (see, for example, Section 6.2.10 of Kister, H.Z. *Distillation Design*, McGraw-Hill, 1992).

In addition to such tabulations of system factors, there are two models that have been “published”.

The Koch model (*Design Manual: Flexitray Valve Trays*, Koch Engineering Bulletin 960-1) for the system factor may be expressed as:

$$SF_{Koch} = \begin{cases} 1.21 / \rho_V^{0.32} & \text{if } \rho_V > 1.81 \text{ lb/ft}^3 \\ 1 & \text{if } \rho_V \leq 1.81 \text{ lb/ft}^3 \end{cases}$$

where ρ_V is the mass density in lb/ft³. Alternatively, in SI units, we have:

$$SF_{Koch} = \begin{cases} 2.915 / \rho_V^{0.32} & \text{if } \rho_V > 29.1 \text{ kg/m}^3 \\ 1 & \text{if } \rho_V \leq 29.1 \text{ kg/m}^3 \end{cases}$$

The Norton model (*Valve Tray Design Manual*, Norton Chemical Process Products Corporation, 1996) is as follows:

$$SF_{\text{Norton}} = \begin{cases} \frac{1}{4}(4.5 - \ln(\rho_v)) & \text{if } \rho_v > 1.65 \text{ lb/ft}^3 \\ 1 & \text{if } \rho_v \leq 1.65 \text{ lb/ft}^3 \end{cases}$$

where ρ_v is the mass density in lb/ft³. Alternatively, with the density in kg/m³ the Norton model can be written as:

$$SF_{\text{Norton}} = \begin{cases} \frac{1}{4}(4.5 - \ln(0.06243 \rho_v)) & \text{if } \rho_v > 26.4 \text{ kg/m}^3 \\ 1 & \text{if } \rho_v \leq 26.4 \text{ kg/m}^3 \end{cases}$$

The gas/vapor phase density can vary quite considerably depending, primarily, on the operating pressure. At low pressures (say about 1 atm) the gas density is of the order of 1 kg/m³, whereas at high pressures (40 atm, say) the gas density can approach 100 kg/m³ (the actual relationship between the gas *mass* density and pressure also depends on the molecular weight so the pressures cited in this paragraph must be considered to be only for illustrative purposes).

The system factor given by both models is shown in Figure 1.

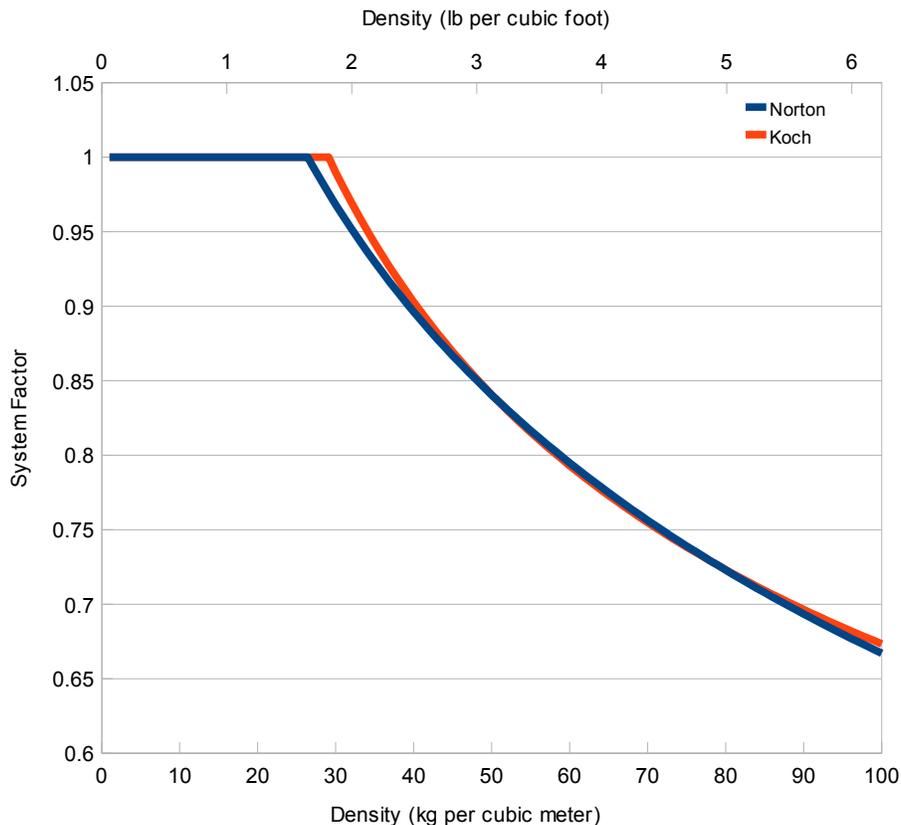
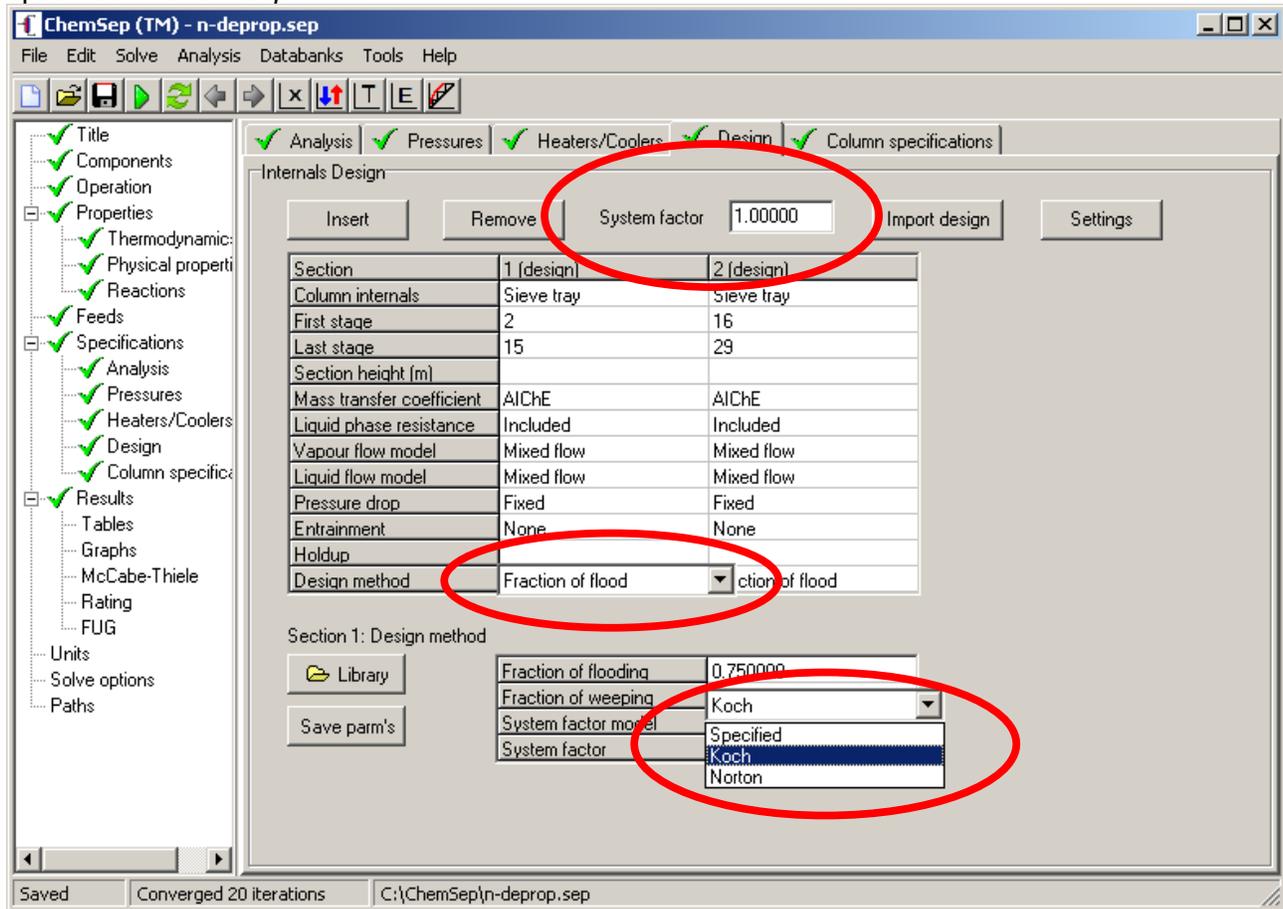


Figure 1: System Factor from Koch and Norton models.

We make no specific recommendations here as to the suitability of either of these models for any particular application, although it is clear from the above figures that there is very little difference between the two models. *ChemSep* users can select either of these models for estimating the system factor. It is also possible to specify a single value that can be used on all trays, as discussed below.

The image below is a screen shot of the design panel that shows where the system factor can be specified in *ChemSep*.



The large red oval near the top of the image highlights the cell where you must specify the default value of the system factor. If no value is provided *ChemSep* will assume the system factor is 1.0.

ChemSep now allows you to specify the system factor for each section of the column independently of one another. To make use of this feature select either *Fraction of Flood* or *Pressure drop* as the design method. This you can do on the last line of the spreadsheet in the upper section of the design panel (see the red oval in the middle of the screen shot).

When the cursor stands on the selected design method, you will see a small spreadsheet with just 3 (with *Pressure drop*) or 4 items (with *Fraction of Flood*) appear below the main design spreadsheet. Click on the line that reads *System factor model* to see a list of 3 items as shown above under the 3rd red oval from the top in the image above. Select from *Specified*, *Koch*, and *Norton*. If you select *Specified*, then you **must** enter a value of the system factor ($0 < SF < 1$) in the space below (on the 4th line of the spreadsheet at the bottom of the screen. This value will be used for all the stages in this section of the column. If you choose either *Koch* or *Norton* the model will be used to estimate the system factor **on each tray**, and any value entered on line 4 will be ignored.

You must select a system factor model for each section of the column. Note further that you may select different models in different sections: for example, you can specify the system factor in one section of the column, use the Koch model in a second section of the column, and the Norton model in yet another section of the column.