

This is the 2021 Errata Pack for the FPS version of the 14th Edition of the GPSA EDB.

Errata **highlighted**

To update your book, replace the page in your Data Book with the page in the enclosed errata pack as follows:

- Section 19: 2-sided page 5 and 6

data should always be considered to more accurately predict the quantitative splits of the subject contaminants within the fractionation, rather than relying only on results from simulation software. This is particularly important when designing NGL treating units located downstream of the fractionation train.

Fig. 19-6 was created using commercial simulation software tuned to experimental phase equilibrium data taken by the GPA Midstream Association to develop a better estimate of sulfur contaminant distribution.³² A series of simulations were run using this tuned software to model a typical ethane and heavier fractionation train (i.e., deethanizer followed by depropanizer, debutanizer, and then deisobutanizer). A large range of liquid hydrocarbon feed compositions with nominal levels of each sulfur contaminant were evaluated.

Fig. 19-6 shows the approximate distribution of each sulfur contaminant relative to the various product streams. While some contaminants always distribute predictably, others such as COS (Carbonyl Sulfide), MeSH (Methyl Mercaptan), EtSH (Ethyl Mercaptan), and DMS (Dimethyl Sulfide) distribution are highly dependent upon feed concentration. The distribution of these particular troublesome contaminants is also largely dependent upon the operation of the fractionation towers (e.g., tightness or looseness of product specifications regarding the heavier and lighter hydrocarbons), and many vary even more than depicted in the table below (e.g., if making an ethane/propane mixture at the deethanizer overhead).

At minimum, Fig. 19-6 qualitatively summarizes the distribution of trace contaminants expected in practice, in particular where significant levels of sulfur bearing contaminants will likely show up in a fractionation unit. Some literature suggests the consumption or formation of some contaminants can occur within the fractionation unit making both qualitative and quantitative tracking of them even more difficult. Note that these potential unintended chemical reactions are not considered in Fig. 19-6.

The following important observations from real plant operational data should be noted in addition to Fig. 19-6.

- Even if H₂S is not present in significant quantities in the mixed NGL feed, some literature suggests that it often shows up in most of the liquid products. This is likely the result of decomposition of other sulphur compounds and/or hydrolysis of COS.
- COS follows propane to a greater extent than ethane. The more propane allowed in the ethane product (e.g. in the case of an ethane/propane mixed product at the deethanizer overhead), the less COS will end up in the purity propane product.
- The distribution of methyl mercaptan (MeSH) in a fractionation unit has proven very difficult to predict and is often not accurately modeled by process simulators. Distribution does not follow expectations and is further complicated by the fact that some amount of it can be generated during fractionation. Some literature has hypothesized generation of MeSH at operating conditions seen in the depropanizer and debutanizer and suggests this is likely due to the decomposition of DMDS when present.

FRACTIONATION COLUMN DESIGN CALCULATIONS

A material balance around the column is the first step in fractionation calculations. In order to perform this balance, assumption of the product stream compositions must be made. There are three ways of specifying a desired product from a fractionator:

- A percentage recovery of a component in the overhead or bottom stream.
- A composition of one component in either product.
- A specific physical property, such as vapor pressure, for either product.

The recovery and composition specifications can be used directly in the material balance. However, property specifications are used indirectly. For instance if vapor pressure is a desired specification of a product, a material balance is performed with an assumed component split. The calculated vapor pressure of the resulting stream is then compared with the desired value and the material balance redone until reasonable agreement is reached.

In a multicomponent mixture, there are typically two components which are the “keys” to the separation. The light key component is defined as the lightest component in the bottom product in a significant amount. The heavy key component is the heaviest component in the overhead product in a significant amount. Normally, these two components are adjacent to each other in the volatility listing of the components. For hand calculations, it is normally assumed for material balance purposes that all components lighter than the light key are produced overhead and all components heavier than the heavy key are produced with the bottom product. By definition, the key components will be distributed between the product streams.

Example 19-1 — For the given feed stream, estimate the product stream compositions for 98% propane recovered in the overhead product with a maximum iso-butane content of the overhead stream of 1%.

Feed:	C ₂	2.4
	C ₃	162.8
	iC ₄	31.0
	nC ₄	76.7
	C ₅	<u>76.5</u>
		349.4 moles

Solution Steps

For Propane (light key):

$$\text{Moles in overhead} = (0.98) 162.8 = 159.5$$

$$\text{Moles in bottoms} = 162.8 - 159.5 = 3.3$$

For Ethane:

$$\text{Moles in overhead} = 2.4 (100\% \text{ to overhead})$$

Since the isobutane (the heavy key) is 1% of the overhead stream, the sum of propane and ethane must be 99% (all n-C₄ and C₅+ are in the bottoms). Thus:

FIG. 19-6
Qualitative Contaminant Disposition in C₂+ NGL Fractionation Unit

	H ₂ S	COS	MeSH	EtSH	iPrSH	tBuSH	DMS	DMDS	CS ₂
Ethane	> 97%	10 – 50%	Trace						
Propane	< 3%	50 – 90%	75 – 85%	<1%	Trace		Trace		Trace
Mixed Butane		Trace	15 – 25%	20 – 85%	< 2%	Trace	10 – 80%		Trace
Iso-butane		Trace	15 – 25%	Trace	Trace		Trace		Trace
N-Butane				20 – 85%	< 2%	Trace	10 – 80%		Trace
Natural Gasoline				15 – 80%	> 98%	100%	20 – 90%	100%	100%

$$\text{Total Overhead Moles} = \frac{159.5 + 2.4}{0.99} = \frac{161.9}{0.99} = 163.5$$

$$\text{Moles of } iC_4 = 163.5 - 161.9 = 1.6$$

The overall balance is:

Comp.	Feed			Overhead		Bottoms	
	Moles	Moles	Mole %	Moles	Mole %	Moles	Mole %
C ₂	2.4	2.4	1.5	—	—		
C ₃	162.8	159.5	97.5	3.3	1.8		
iC ₄	31.0	1.6	1.0	29.4	15.8		
nC ₄	76.7	—	—	76.7	41.2		
C ₅	76.5	—	—	76.5	41.2		
Total	349.4	163.5	100.0	185.9	100.0		

In actual operation, the lighter than light key components and heavier than heavy key components will not be perfectly separated. For estimation purposes and hand calculations, perfect non-key separation is a useful simplifying assumption.

KEY PARAMETERS

Two important considerations which affect the size and cost of a fractionation column are degree of separation and component volatility.

The degree of separation or product purity has a direct impact on the size of the column and the required utilities. Higher purity will require more trays, more reflux, larger diameter, and/or a reduced product quantity. One quantitative measure of the difficulty of a separation is the separation factor, S_F , defined as:

$$S_F = \left(\frac{X_D}{X_B} \right)_{LK} \left(\frac{X_B}{X_D} \right)_{HK} \quad \text{Eq 19-1}$$

Note that Equation 19-1 defines the specification for the tower design.

Typically, for most fractionation problems this factor ranges from around 500 to 2000. However, for sharp separations, it can be in the 10,000 range. The number of trays will be roughly proportional to the log of the separation factor for a given system.

The volatility of the components is usually expressed as relative volatility, α . This quantity is computed as the ratio of the equilibrium K-values of two components at a given temperature and pressure. For fractionation calculations the α of the key components is important. Therefore:

$$\alpha = K_{LK}/K_{HK} \quad \text{Eq 19-2}$$

This is a measure of the ease of separation. The larger α is, the easier is the separation.

DESIGN CONSIDERATIONS

Operating Pressure

Before any design calculations can be made on a fractionation problem, a tower operating pressure must be determined. One of the primary considerations for operating pressure is the cooling medium available for the reflux condenser. The overhead product will be at bubble point conditions for a liquid product or at dew point conditions for a vapor product. The bubble point (or dew point) pressure is fixed by a desired component separation and the temperature of the cooling medium.

The cooling media typically used are air, water, and refrigerant. Air cooling is normally the least expensive cooling method. Practical exchanger design limits the process to a 20 °F approach to the ambient summer temperature. This translates to a process temperature of 115 to 125 °F in most locations. With cooling water, process temperatures of 95 to 105 °F are possible. Below about 95 °F, mechanical refrigeration must be used to achieve the desired condensing temperature. This is the most expensive cooling method from both a capital and operating cost standpoint. Generally, it is desirable to operate at as low a pressure as possible to maximize the relative volatility between the key components of the separation. However, if reducing the pressure requires a change to a more expensive cooling method, this is usually not a desirable choice.

In some cases, the overhead from the column must be compressed to sales or another process unit. In this case a higher operating pressure may be desired to reduce compression horsepower.

Other items must be considered which will limit pressure selection. If an operating pressure is too high, the critical temperature of the bottom product may be exceeded and the desired separation cannot be achieved. Additionally, the pressure cannot exceed the critical pressure of the desired overhead product.

The selection of a partial or total condenser is fixed by the disposition of the overhead product. A total condenser is used for a liquid product and a partial condenser for a vapor product. However, a liquid product can be produced as a vapor and subsequently cooled and/or compressed to produce a liquid product. There may be cases where this downstream liquefaction is economically attractive. In most cases, the fractionation system for a partial condenser will be cheaper and will have to be balanced against the cost of additional downstream equipment. Before a