How to Specify Liquid-Liquid Separation

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Introduction

Liquid-liquid separation is one the most important processes in the hydrocarbon processing industry. One of the main applications where liquid-liquid separation plays a great role is production plants. Water and oil are separated in series of separators at different pressures. Liquid heating, desalting (electrostatic fields) and stripping processes are utilized to enhance oil and water separation and meet oil product specifications. Water entrained in oil can adversely affect the quality of product. On the other hand, entrained oil in produced water stream puts additional demands on effluent treatment systems.

The specifications of oil and water products are dictated by market, final consumer requirement and environmental regulations which are usually imposed by Client as a project performance guarantees.

Apart from product specification, feed condition also has to be specified by Client. Depending on the method in which feed is specified, different approaches can be used by separator designer to achieve required separation. This note is discussing different way of defining liquid-liquid separation and its effect on final design.

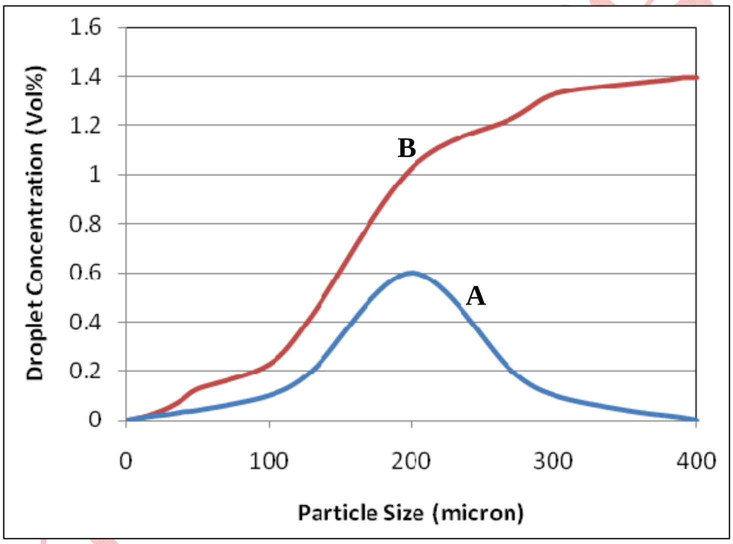

Figure 1 – Water droplet distribution at separator inlet

Liquid-Liquid Separation

Liquid-liquid separator and required separation can be specified with one of the following methods:

- **Droplet distribution**

May be the perfect way of defining the separator feed is to count number of droplets in different sizes in laboratory and prepare droplet distribution curve. Figure 1, curve-A is a typical curve which illustrates droplet volume percent as a function of droplet size. Droplet size distribution is not necessary normal distribution as shown in this figure. Droplet volume fraction can be ascending or descending or any shape, depending on the mechanism of droplet formation, physical properties of liquids and system configuration. The range of droplet size and their fraction can be different. For example chemical reactions create much smaller liquid droplet sizes than mechanical processes such as mixing, pumping and transporting two phase flow.

Curve A can be used to produce curve B where the cumulative droplet concentration is shown. This curve helps designer in selecting the optimized separation technology and guaranteeing equipment performance. Using this Curve, it is possible for process designer to judge if gravity separation is sufficient to achieve desired separation level or internal device (settling or coalescing media) should be utilized. Separating very fine droplets by using of gravity separation leads to very unreasonable huge sizes. Refer to note "Droplet Gravity Separation Fundamentals".

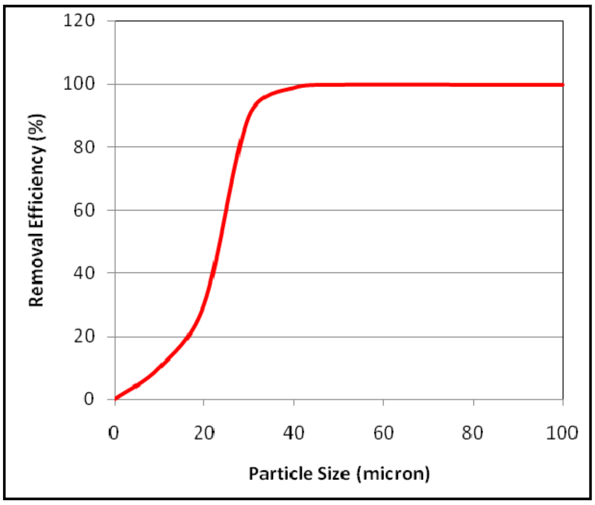

Figure 2 – Internal device removal efficiency

For example, for feed condition depicted in Figure 1 (containing 1.4 vol% water in oil), reducing water content to 0.2 vol% (2000 ppmv) calls for separating approximately 100 micron and larger droplets. This is usually practical size for gravity separation when the density difference between the phases is not very low and/or continuous phase viscosity is not high.

If further reduction in water carry over is needed, an internal device with separation efficiency shown in Figure 2 may be an appropriate selection. This particular internal device can enhance gravity settling and separate all particles of 40 micron and larger. 40 micron is called cut-off diameter. As shown in Figure 2, particles smaller than 40micron are separated with lower efficiencies. Using this particular internal will result in new droplet distribution at separator outlet shown in Figure 3 which illustrates 0.025 vol% (250 ppmv) of water in oil product from this separator. It should be noted that the oil droplets distribution in water and removal efficiency of internal device for oil droplets may not be necessarily same as water droplets.

- **Residence time**

Sometime laboratory techniques are utilized to define the feed separation characteristics by directly measuring the time required for water and oil to separate out. In this method, the residence time of each phase or total separator residence time is advised based on the observation from laboratory tube. Although the result of this method is coming from laboratory test, but there is no way to make sure that it will lead to required separation unless it is demonstrated in real plant. This is because of inherent differences between real condition in plant and laboratory condition. This time is only valid if it is the outcome of frequent sampling from oil and water phases to check the contamination level. This method of specifying feed and separation requirement is good if gravity separation is going to be used. But in case internal device is justified, it is very hard to predict the effect of adding an internal device on final separation.

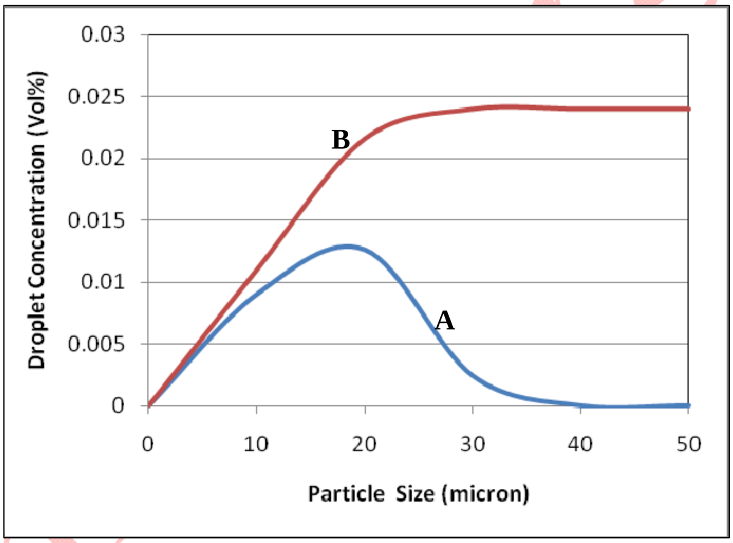

Figure 3 – Water droplet distribution at separator outlet

If residence time is according to the experience with same fluid at existing fields, it must be carefully incorporated into design considering the fact that design parameters change during plant life especially in production plants. This method may not be useful if the technology used for separation in new design is different from existing one. Separators can be sized for residence time advised by vendor or licenser in special processes where the droplet distribution is completely known and is not going to change much during plant operation.

There are Clients who make reference to API-12J, specification for oil and gas separators, where typical residence time has been given for different type of oil (Table 1). The disadvantage of this method is that it is not customized based on actual feed characteristics.

Table 1 – API Recommendation on residence time

Oil API Gravities	Separation Temperature (°F)	Residence Time (min)
> 35°	Any	3-5
	> 100	5-10
	> 80	10-20
< 35°	> 60	20-30

None of these methods can ensure the product specification is met unless extra precautions are taken by equipment designer who is going to guarantee the equipment performance.

- **Cut-off diameter**

There are projects in which none of above methods is used to specify the desired liquid-liquid separation. In other words, what is expected at separator outlet is specified in project without proper definition of separator feed. For those cases, designer should generate/assume proper droplet distribution curve and pick a cut-off diameter at which the project desired separation is met. For producing such graph minimum three points are required; maximum droplet size (d_{max}), Sauter mean droplet size (d_{32}) and mass mean droplet size (d_{50}). Since providing these data need droplet screening in laboratory which is not always possible in design stage, using cut-off diameter as basis for separator sizing is proposed. Figure 4 shows the relation between selected cut-off diameter and separator outlet specification. According to this figure, droplets larger than 200 micron should be targeted for separator design if product specification calls for 2 vol% carryover of dispersed phase in continuous phase.

This graph can be used for designing production (oil and water) separators and all similar applications where droplet particles are in the same range. This figure may not be applicable to the processes in which very small droplets are generated or the shape of droplet distribution curve is much different from Figure 1.

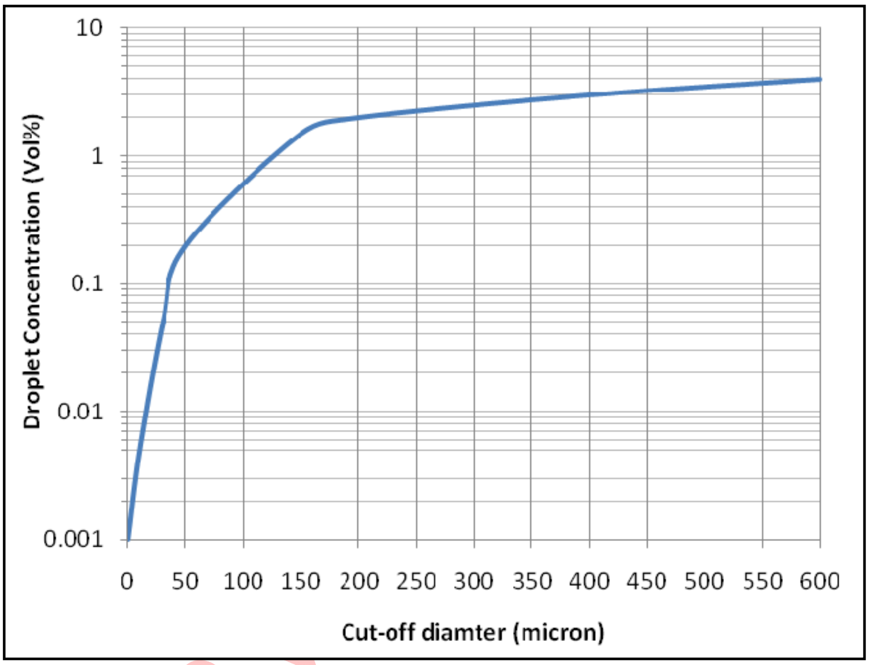

Figure 4 –Droplet carry over vs. cut-off diamter

Contact

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