

## ENTRAINMENT IN EVAPORATORS

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### Summary

The process of evaporation generates mists by the entrainment of liquid droplets into the gas stream. In desalination operations, this may result in carry-over of brine with the vapor into the condenser creating an unacceptably high TDS in the product. Mist eliminators or entrainment separators are used to eliminate the mist so that the amount of brine carry-over is within acceptable limits. Separators can be selected and sized for removal efficiencies greater than 99 per cent, but even this degree of efficiency may not ensure product purity. It is therefore necessary to establish parameters and formulas to predict the entrainment and/or establish the parameters to ensure that the required product purity can be met.

While there are various types of separators used within the process industry (fiber mist, electrostatic precipitators, centrifugal, and others), the impingement separator is most applicable for evaporators in desalination units. The wire mesh type impingement separator or demister is the most widely used.

The arrangements for MSF evaporators, HTME evaporators and VTE evaporators result in very different methods for determining the entrainment reaching the mist eliminators. In flash evaporators, the release rate is the critical parameter in determining the entrainment. This release rate also is important in calculating the height to the demisters and size of the demisters as well as the product purity. In HTME and VTE evaporators, the brine curtain velocity is the critical factor in determining entrainment. A curve fit based on the curtain velocity is utilized in calculating the entrainment.

### 1. Introduction

In the process of evaporation or the release of vapor from a mass of liquid, mists are generated by the entrainment of liquid droplets into the gas stream. In desalination operations, the formation of such mists may result in carry-over of brine with the vapor into the condenser. This would result in high total dissolved solids (TDS) in the

resulting product, which would be unacceptable. To eliminate the mist so that the amount of brine carry-over is within acceptable limits, mist eliminators or entrainment separators are utilized. These separators can be selected and sized for removal efficiencies greater than 99 per cent. However, the entrainment reaching the separator must be known and considered as even a separator efficiency of 99.9 per cent may not be sufficient to ensure product purity.

To determine the entrainment into the condenser or out of the demister, the following is used:

$$EO_{TDM} = C_p \times GDM / (CAVE \times 10^6 - C_p)$$

where:

$C_p$  is the TDS in product in parts per million (p.p.m.) by weight, GDM is the vapor release rate in kilograms per hour per square meter, and CAVE is the TDS in brine as weight percent.

Therefore, if  $C_p = 25$  p.p.m.,  $GDM = 100 \text{ lb h}^{-1} \text{ ft}^{-2}$  ( $488.3 \text{ kg h}^{-1} \text{ m}^{-2}$ ) and  $CAVE = 0.06$ , then the maximum allowed entrainment leaving the demister is  $0.041 \text{ lb h}^{-1} \text{ ft}^{-2}$  ( $0.2 \text{ kg h}^{-1} \text{ m}^{-2}$ ) and that entering a demister with 99.9 per cent efficiency would be  $41.72 \text{ lb h}^{-1} \text{ ft}^{-2}$  ( $203.7 \text{ kg h}^{-1} \text{ m}^{-2}$ ). This equates to 0.4168 pounds of brine per pound of vapor or 0.4168 kilograms of brine per kilogram of vapor.

Thus, it is necessary to establish formulae that apply to predict the entrainment and/or establish the parameters that apply to insure that the required product purity can be met.

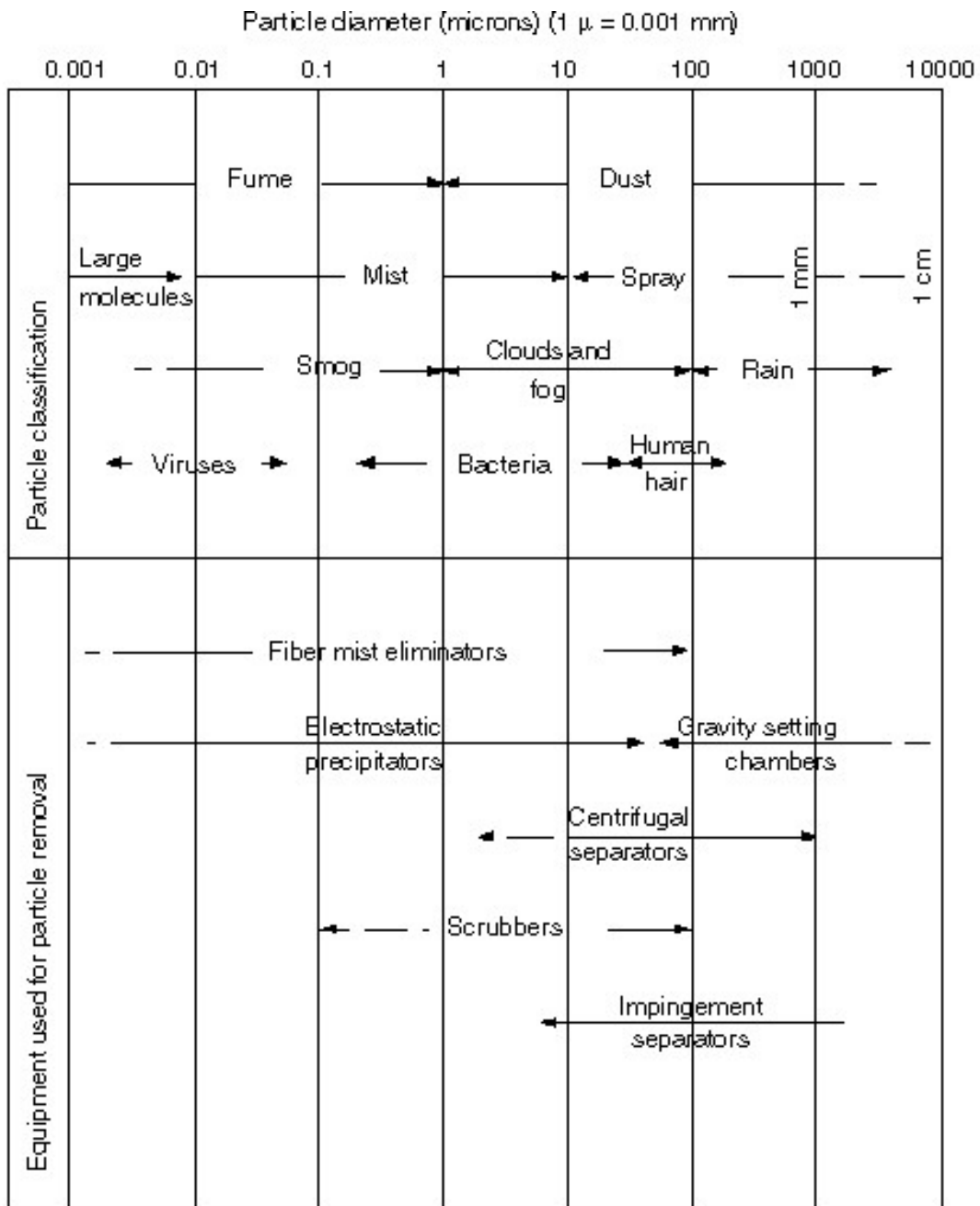
This section is concerned with the determination of these parameters and relationships while the next section is concerned with the sizing of the mist eliminators to achieve maximum efficiency.

## 2. Fundamentals

There is some confusion among practicing engineers regarding the terminology of mist and sprays. Mist particles are defined to be gas-separated liquid particles which have diameters less than  $10 \mu$ . This classification is somewhat arbitrary but is generally accepted and follows Lapple's classification (Perry et al. 1963). Figure 1, an adaption of a chart by Lapple, shows the approximate size range for some particulate matter and some typical types of entrainment separators.

The types of separators used in the process industry are fiber mist, electrostatic precipitators, gravity settling chambers, centrifugal, scrubbers, and impingement separators. In evaporators for desalination units, the majority of the liquid-in-gas dispersions are in the mist and spray ranges consisting of particles with diameters about  $1.0\text{-}1000 \mu$ . Therefore, the impingement separator is most applicable for the particle diameter encountered in evaporators for desalination units (see Figure 1). The impingement separator is characterized by using obstructions placed in the gas stream to

divert the flow of gas. The entrained liquid particles are carried forward by their momentum relative to the gas flow and tend to impinge on the obstruction and be collected. A comparison of three types of impingement separators is given in Table 1.



Brink, Burggrabe, and Greenwell, Chem. Eng. Progr.,  
62(4), 60 (1966)

Figure 1. Particle classification and useful collection equipment versus particle size.  
From Brink et al. (1966).

	<b>Wire mesh</b>	<b>Vane</b>	<b>Fiber bed</b>
Cost	Lowest	2-3 times wire-mesh unit	Highest
Efficiency	100% (for droplets larger than 3-10 $\mu\text{m}$ )	100% (for mists >10-40 $\mu\text{m}$ )	Up to 99.9% (for mists <3 $\mu\text{m}$ )
Pressure drop	<25 mm H <sub>2</sub> O	<15 mm H <sub>2</sub> O	100-300 mm H <sub>2</sub> O
Gas capacity	Good	Up to twice that of a wire-mesh unit	Lowest
Liquid capacity	Good	Best	Lowest
Solids	Good	Best	Soluble particles only

<sup>a</sup> Extracted from Fabian et al. (1993a).

Table 1. Features of traditional impingement-type mist eliminators.<sup>a</sup>

Because of this, wire mesh-type demisters are most widely used. However, it has some limitations in that it is most effective when installed horizontally and the face area required is over twice that required for vane-type separators. Thus, vertical vane-type separators can be more effective when space is limited and vertical installation more appropriate (see discussion below).

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#### **Bibliography and Suggestions for further study**

Brink, Burggrabe and Greenwell (1966) *Chemical Engineering Progress* **62**(4), 60.

Burns and Roe Construction Corporation (1973) *Final Report Horizontal Spray Film (HTEX) and Vertical Tube (VTEX) Evaporator*. OSW San Diego Test Facility, May for Office of Saline Water.

Fabian P et al. (1993a) Demistifying the selection of mist eliminators, part 1. *Chemical Engineering*.

Fabian P et al. (1993b) Demistifying the selection of mist eliminators, part 2. *Chemical Engineering*.

Perry and Chilton (ed.) (1973) *Chemical Engineers Handbook*, 5th edn, pp. 18-58-18-93, New York: McGraw-Hill.

Perry, Chilton and Kirkpatrick (ed.) (1963) *Chemical Engineers Handbook*, 4th edn, pp. 20-66. New York: McGraw-Hill.

Union Carbide Corporation, Nuclear Division (1966) *Demisters for 50 MGD and Larger Desalination Plants*, ORNL 65-11-541.