MIST ENTRAINMENT SEPARATION

FOR BEET AND CANE SUGAR MILL EVAPORATORS AND CRYSTALLIZERS

(Mist elimination in the evaporation stage is affected by what occurs in up-front processing stages, consequently, we begin with processing for a clearer understanding of separation solutions.)

INTRODUCTION

Most sugar in the world comes from two primary sources, sugar cane and sugar beets. The cane is the top of the sugar cane plant that is cut off and processed, leaving the root which regrows. The beet is the root of the sugar beet plant, which needs re-planting each year. Both result in the production of 99.95% sucrose.

Other than the front end stock preparation where beets are sliced, cane is crushed, and the sugar juice is extracted by squeezing, diffusion, or both, the differences in process are not substantial. Both rely on hot water to extract the sugar. Both rely on lime slaked with weak sugar water, and sometimes carbonation, to clarify the juice of mud, fiber and other precipitate. Even at this point, there remain some impurities. Clarifiers and filters are used for final juice purification before the juice becomes concentrated in the evaporation stage. Sugar juice leaving the up-front purification stage and entering the evaporation stage is approximately 15% sugar concentration, and 90% sucrose.

The evaporation and crystallization processes for beet sugar and cane sugar are quite similar, using multiple effect evaporators to concentrate the juice, and then vacuum pan evaporators to further concentrate the juice to bring about crystallization. Impurities are both organic and inorganic, and all affect tubes. Examples of organic impurities are glucose and fructose carbonized sugar, gums, and organic lactic acids. Inorganic impurities are salts (such as, magnesium and silica), potash, and 250-300ppm calcium.

From an operational standpoint, the impurity that is usually of most environmental concern is BOD, or biological oxygen demand. BOD is defined as the oxygen needed by organisms to break down organic material present in a water sample. One of the sources of BOD in sugar refinery waste discharges is sugar entrained during the evaporation of liquors in the pans and evaporators. Barometric condensers condense the tail-end steam and often discharge this water to rivers with TDS (total dissolved solids) included. From a plant maintenance view point, inorganic impurities are a concern due to scaling. Sugar scale is a mixture of components that form on evaporator heat exchangers and internals during the concentration of sugar juice. Additionally, some processes rely on sulfur dioxide or sulfurous acid for neutralization of excess alkalinity, and to decolorize juices. If calcium sulfate is formed, a much harder scale results than if calcium sulfite is formed. Depending on the sugar juice source (cane or beet) and processing conditions, the amount of scale formed can vary significantly from mill to mill. In general, scale formation from sugar beet processing is less than that found in sugar cane mills due, in part, to the carbonation process that is more common with sugar beet processing.

Sugar solution entrainment has been a source of concern to sugar processors for many years. Initially this loss was solely a financial loss, but the additional burden of meeting environmental limits has put new emphasis on finding different ways to reduce sugar losses. Process control is important. If the juice becomes acidic in the final stages of evaporation, then sucrose breaks down to glucose and fructose, which affects crystallization (netting less of the more lucrative sugar, leaving more syrup to the molasses end of production) – all upsetting the sugar production economy.

EVAPORATION

The objective of evaporation is to concentrate a solution consisting of a non-volatile solute and a volatile solvent. In sugar evaporation the solvent is water. Evaporation differs from drying, as the residue is still a liquid (sometimes a highly viscous one) rather than a solid. In evaporation the thick liquor is the valuable product, though the steam vapor will continue to have value for its heat content.

Some of the most important concerns of evaporating liquids are as follows:

CONCENTRATION

Although thin liquor fed to an evaporator may be sufficiently diluted to have many of the physical properties of water, as the concentration increases, the solution's properties change. The boiling point of a solution may rise considerably as the solid content increases, thus the boiling temperature of a concentrated solution may be much higher than that of water at the same pressure.

Density and viscosity also increase with solid content until the solution becomes saturated to the point at which the liquor becomes too sluggish for adequate heat transfer. Continued boiling of a saturated solution causes crystals to form too soon, and must be removed or the evaporator tubes clog.

FOAMING

Some materials, especially organic substances (glucose, fructose, gums, amino acids, and color components), foam during vaporization. Stable foam accompanies the vapor out of the evaporator causing heavy entrainment.

SCALE

Scale ordinarily is caused by:

(1) Dissolved calcium and potassium salts, and silica and magnesium, whose solubility decreases as temperature and sugar concentration increase.

(2) Suspended solids in the clear juice, which are not properly separated.

Some solutions deposit scale on the heating surfaces, as well as on surfaces in the separator, and can be caught on encrustations that have been precipitated previously. The overall heat transfer efficiency then steadily decreases until the evaporator must be shut down and the tubes cleaned. When the scale is hard and insoluble, cleaning is difficult and expensive.

EVAPORATOR TYPES

Evaporators consist of a heat exchanger for boiling the product solution with special provisions for separation of liquid and vapor phases. Most industrial evaporators have tubular heating surfaces. The tubes may be horizontal or vertical, long or short; the liquid may be inside or outside the tubes. Evaporator types are illustrated in diagrams and tables below.

Evaporator Types by Feed Condition

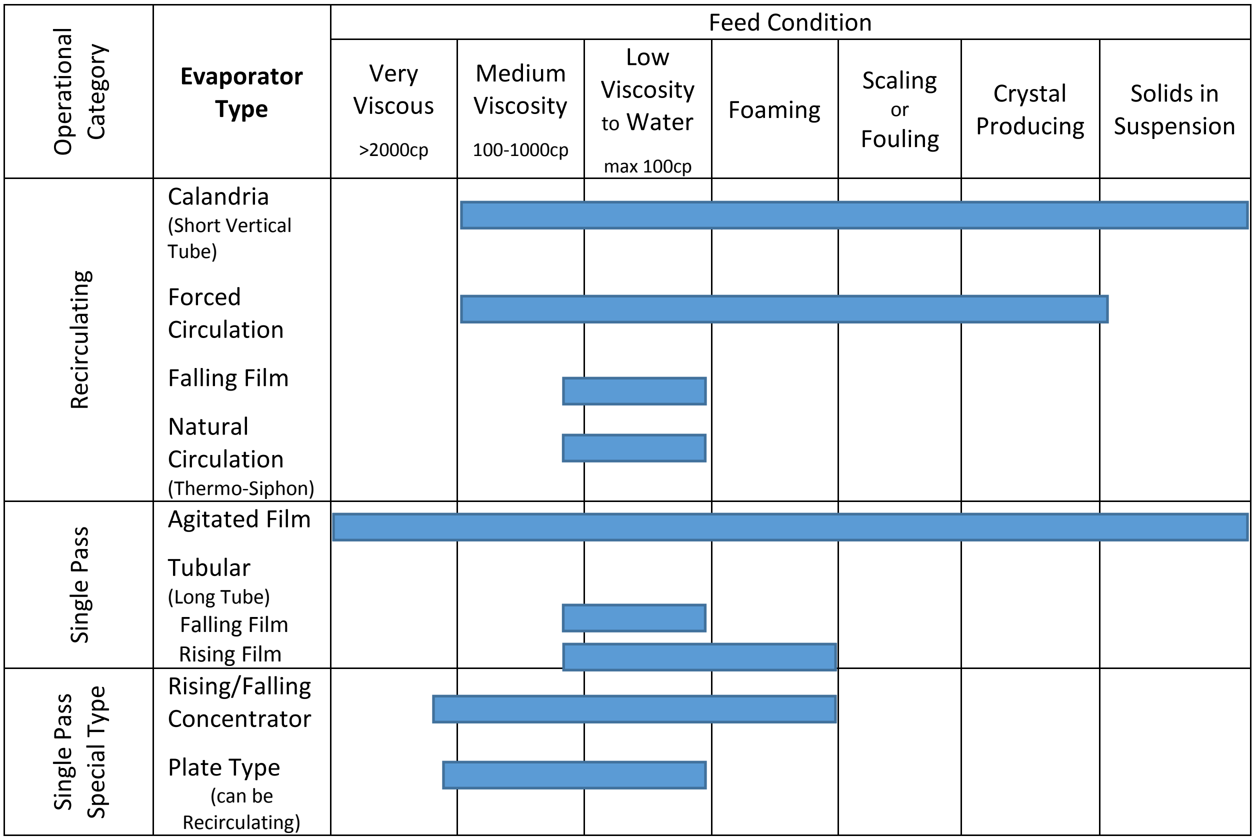
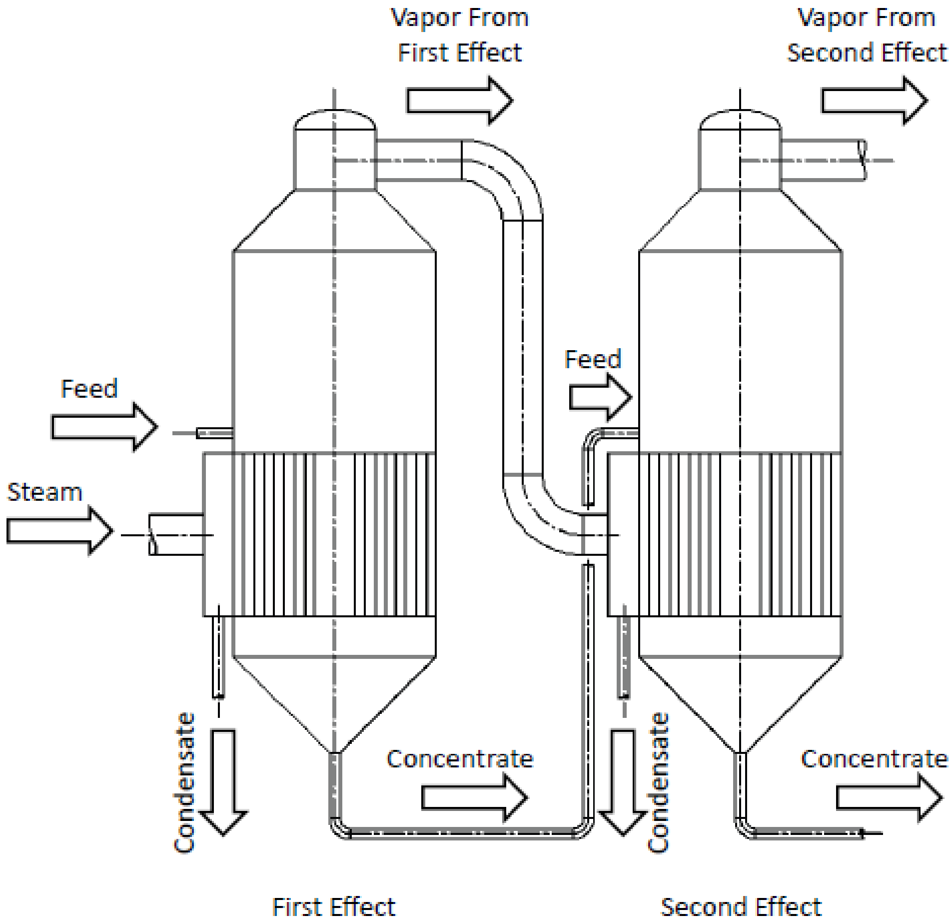


Table 1

Most evaporators are heated by steam condensing on the outer tube surface. The material to be evaporated nearly always flows through the tubes. Usually, the steam is at a low pressure, while the boiling liquid often is under a moderate vacuum, which reduces its boiling point. Reducing the boiling temperature of the liquid increases the temperature difference between the steam and the boiling liquid, thereby increasing the heat transfer rate in the evaporator.

When a single evaporator is used, the vapor from the boiling liquid is condensed and discarded. This method is called single effect evaporation. Although this is a simple method, it utilizes steam ineffectively. If the vapor from one evaporator is fed into the steam chest of a second evaporator, and the vapor from the second is then sent to a condenser, energy utilization improves. *(See Diagram 1, Multiple Effect Evaporation)*. The heat in the original steam is reused. Hence, with the same amount of steam, the amount of water evaporated is almost doubled. Additional “effects” can be added in the same manner, each subjected to a progressively higher vacuum, which boils the liquid at progressively lower temperatures, greatly enhancing efficiency. The general method of increasing the evaporation per unit of steam by using series of evaporators between the steam supply and the condenser is called multiple effect evaporation. Steam utilization efficiency increases linearly with an increasing number of effects.

Multiple Effect Evaporation



Steam Consumption and Operating Costs of Evaporators		
Number of Effects	Steam Consumption Kg Steam / Kg Water Evaporated	Operating Cost (Relative to Single Effect)
One	1.1	1.0
Two	0.57	0.52
Three	0.40	0.37

Diagram 1

The major types of steam-heated tubular evaporators in use are:

1) Short tube evaporators
2) Long tube evaporators

SHORT TUBE VERTICAL EVAPORATORS

Short tube vertical evaporators and vacuum pans generally are older types of natural circulation evaporators (often referred to as calandria evaporators), in which tubes of 4 to 8 feet in length and 2 to 4 inches in diameter are used. The tube bundle contains a large central or perimeter downcomer. The active liquid level is maintained 1 meter above the upper tube-sheet. Recirculation is by natural convection, or thermosiphon. Thermosiphon is a method of passive heat exchange created by the difference in specific gravity between the body liquor and the heated liquor. The driving force for the flow of liquid through the tubes is the difference in density between the liquid in the downcomer and the mixture of liquid and vapor in the tubes. The vapor generated inside the tubes, and the resultant vapor lift effect, creates a circulation pattern that carries the heated liquid up through the tubes causing the cooler liquid to flow through the downcomer. The vapor formed escapes through the vapor outlet at the top of the space above the tubes, carrying entrained sugar solution.

Taller short tube evaporators with greater disengagement height above the heat exchanger, known as Roberts evaporators, carry less entrainment to the separator or mist eliminator sector. The Roberts evaporator has a wide circulation tube in the center of the heating tube bundle through which concentrate flows back to the bottom of the tube bundle.

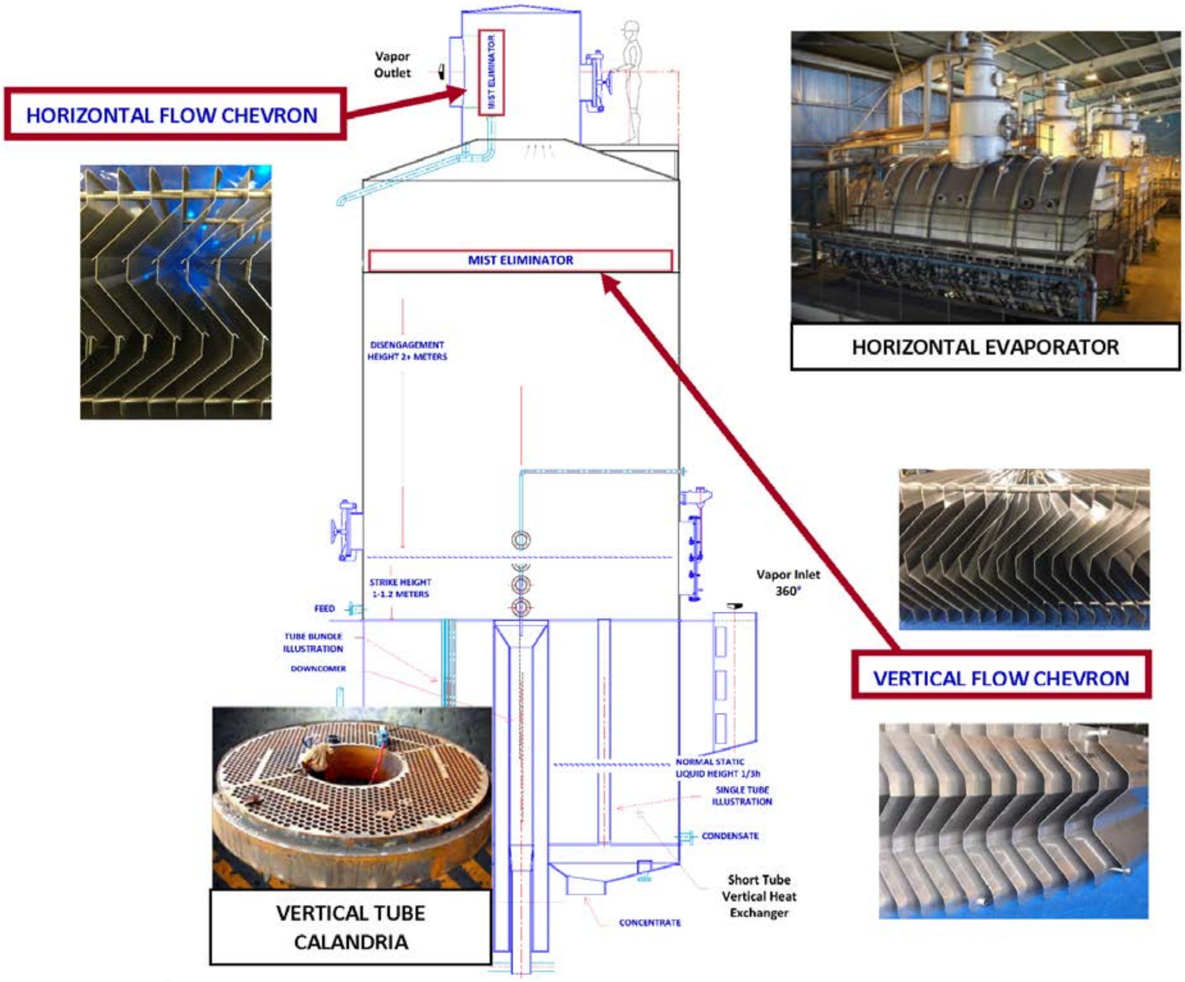
Short tube evaporators provide moderately good heat transfer at reasonable cost. Thermosiphon occurs at a much slower rate than in long tube natural circulation evaporators. Therefore, the heat transfer coefficients are fairly high with thin liquids, but lower when liquid is viscous. These evaporators are fairly effective with scaling liquids, since the inside of the tubes are accessible for easy cleaning. They are now used, most often, for crystallization after the early evaporation stage. Separation of formed crystals, and sugar solution droplets from the steam vapor takes place in the dome at the top of the vessel or the external catchall prior to the vapor being carried to the condenser.

HORIZONTAL TUBE EVAPORATORS

A popular evaporator in the US has been the horizontal tube type, in which the tube bundle is located in a rectangular heat exchanger. As with the vertical evaporator tubes, the sugar solution flows through the inside of the tubes. In horizontal tube design heat exchangers, liquor circulation is not as robust so, generally, they are not used with viscous liquids.

VACUUM PANS

Vacuum pans, historically, used to be run on a batch basis. Today, however, design leans toward continuous vacuum pans using either horizontal or vertical tubes. In continuous vacuum pans, the sugar concentration increases continuously under constant flow and conditions as compared to batch pans technology.



Short Tube Vacuum Pan Evaporators

Material flows through tubes heated by low pressure steam condensing on the outer tube surface. The boiling liquid is under a moderate vacuum, which reduces its boiling point, thereby increasing the heat transfer rate in the evaporator.

In single effect evaporation, vapor from the boiling liquid is condensed and discarded. Although this is a simple method, it utilizes steam ineffectively. If vapor from one evaporator is fed into the steam chest of a second, and vapor from the second is sent to a condenser, the operation doubles efficiency. The heat in the original steam is reused and the amount of water evaporated is almost doubled. Multiple "effects" can be added, each subjected to a progressively higher vacuum, boiling the liquid at progressively lower temperatures, greatly enhancing efficiency. Steam utilization efficiency increases linearly with an increasing number of effects.

Diagram 2

LONG TUBE VERTICAL EVAPORATORS (RISING FILM EVAPORATORS)

The essential parts of the system are:

1) A tubular heat exchanger with steam in the shell; liquid is concentrated in the tubes;
2) A separation, or vapor space, for removing entrained liquid from the vapor;
3) A return leg, which directs the liquid from the separator to the bottom of the heat exchanger when operated as a recirculation unit.

Inlets are provided for feed liquid and steam, and outlets are provided for the evaporated liquid vapor, thickened sugar solution, steam condensate, and non-condensable gases from the steam.

In **Rising Film Evaporators,** liquid and vapor flow upward inside the tubes as a result of the boiling action; separated liquor flows to the bottom of the tubes by gravity. Dilute feed enters the system and mixes with the liquor returning from the separator. The mixture enters the bottom of the tubes, flows upward as a liquid, and is heated by the steam outside the tubes. Bubbles then form in the liquid as boiling begins, increasing the vertical velocity and rate of heat transfer. Near the top of the tubes the bubbles grow rapidly. In this zone, bubbles, alternating with surges or slugs of liquid, rise very rapidly, and the product is pressed as a thin film on the walls of the tubes. High steam velocity is an advantage during the evaporation of highly viscous products and products that have a tendency to foul the heating surfaces, as the velocity forces more of the product out of the tubes before it has a chance to stick to the heating surfaces. The steam and product emerge at high velocity from the top of the heat exchanger, where the mixture of liquid and vapors enters the separation region. The diameter of the separation region often is larger than that of the exchanger, so the velocity of the vapor is greatly reduced, which aids the separation of entrained liquid from steam. As a further aid in eliminating liquid droplets, the vapor then passes through some form of mist eliminator. Long tube rising film evaporators are referred to as Kestner evaporators. Deflectors are needed above the heat exchanger to reduce carryover to the mist eliminator.

LONG TUBE FALLING FILM EVAPORATORS

In **Falling Film Evaporators**, liquid is pumped into the top of the evaporator where it is evenly distributed to the heating tubes. Thin film starts to boil from the external heat as it flows downward inside the tubes, and is partially evaporated. The product and the vapor flow co-currently, augmented by gravity. Vapor liquid separation may occur in an expanded vapor body section at the bottom of the heat exchanger before exiting the evaporator, or separation may occur external to the evaporator. When equipped with well-designed automatic control systems, multiple effect falling film evaporator trains can produce very consistent concentrated products with excellent energy efficiencies.

ENTRAINMENT

Entrainment occurs in nearly all processes involving gas-liquid contact. The quantity of liquid and size of droplets entrained is roughly proportional to the amount of energy expended in the contact process. High-energy processes, such as evaporation, and in certain cases gas scrubbing, would therefore be expected to have smaller droplet size with high entrainment rates. Poor vacuum control and other factors, such as equipment design and physical properties of the liquid, especially viscosity and surface tension, also can contribute to entrainment problems. Droplet distribution for sugar evaporation is in the range of 5-1000 microns. The quantity of entrainment, in part, is related to the velocity of the vapor and the proximity of the mist eliminator to the heat exchanger.

A falling film evaporator vs. a rising film evaporator is one example of a design choice to diminish entrainment. There are other design opportunities for *pre*-separation before the entrainment separation. The choice of a proper design involves matching process conditions to the operating characteristics of the separator. A properly designed and operated separator on a vacuum pan or evaporator should reduce sugar losses to very low levels with reasonable maintenance requirements. Also, a properly designed system will take into account the need for a balance between high efficiency and pressure drop.

While entrainment can be reduced by proper evaporator design, it cannot be completely eliminated. Therefore, recovery devices referred to as entrainment separators or mist eliminators generally are installed in the system to recover the entrained liquid. A wide variety of design options are available.

ENTRAINMENT COLLECTION MECHANISMS

The collection mechanisms important in entrainment separator operations are:

1) Sedimentation or Settling (Gravitational Separation)
2) Inertial Impaction
3) Centrifugal Force

Sedimentation

The sedimentation process is related to the gravitational forces acting on droplets causing them to settle over time in a moving gas stream. Liquid droplets will settle out of the vapor phase if the gravitational force acting on the droplet is greater than the drag force of the gas flowing around it. Gravitational forces control separation; the lower the gas velocity and the larger the vessel size, the more efficient the gas-liquid separation. Gravitational separation is the initial separation process to occur after evaporation, but it cannot be the sole separation process since the vessel would need to be too large. Applying Stoke's Law, some idea of the droplet size that will be entrained can be determined. Adjusting the apparent liquid specific gravity for the true liquid specific gravity will affect the carryover drop size and total mass. All drop sizes that fall below the curve will settle out and those above the curve, mostly, will be entrained. *(See Diagram3, Terminal Velocity)*. In rising film short tube evaporators, the greater the disengaging distance above the strike height (turbulent liquid height), the lower the entrainment into the mist eliminator.

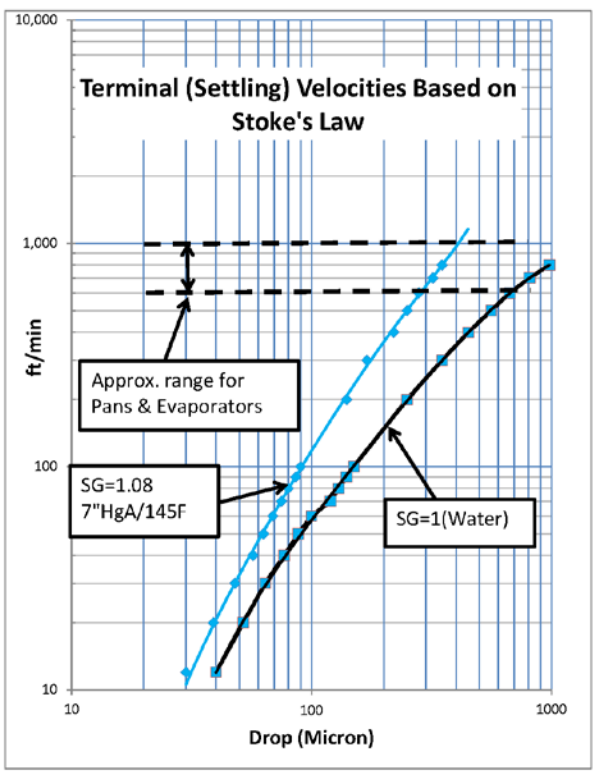


Diagram 3

Inertial Impaction

Inertial Impaction is the most important single mechanism in entrainment separators. As a gas approaches an obstacle, for example wire or vane, it spreads out around it. At the same time, the inertial mass of an entrained drop causes the drop to resist the drag effect of the gas, and the drop strikes the obstacle. The factors that affect impaction collection efficiency, therefore, are gas velocity, gas density, droplet mass, and the size and shape of the collector. Collection efficiencies (capacity factor K) for different types of collectors can be calculated. *(See Table 2, Typical Souders-Brown 'K' Values…)*.

Typical Souders-Brown 'K' Values and Performance for Mist Eliminator Devices

Mist Eliminator Style	Flow Direction	Density (lb/ft^3)	Vane Spacing	Capacity Factor *at low liquid rate <0.3gpm/ft²*	Typical Performance		
				K	Pressure Drop ("wc)	Removal Efficiency *(@ 20 microns)*	Resistance to Fouling
Mesh	Vertical	5-7	N/A	0.40	0.8"	100%	Poor
Mesh	Vertical	9-11	N/A	0.35			
Mesh	Horizontal	5-11	N/A	0.42			
Vane 2-pass	Vertical	N/A	1.5"	0.40	0.25"	90% - 95%	Good
Vane 3-pass	Vertical	N/A	1.25"	0.41			
Vane 2-pass	Vertical	N/A	0.87"	0.51			
Vane 3-pass	Horizontal	N/A	1.25"	0.88	0.75"	95% - 99%	Better
Axial Cyclone	Vertical	N/A	N/A	0.5-0.8	0.5" – 1"	75% - 80%	Best
Coalescer (2" Mesh)	Horizontal	7-11	N/A	0.88	0.5	100%	Fair
15° - 45° Tilt	Vertical/Horizontal	Most styles have the option to tilt to improve capacity and drainage.					
Velocity *(max)*	$V = k \times \sqrt{\frac{\rho L - \rho V}{\rho V}}$ (Souders-Brown)	V = Maximum Allowable Vapor Velocity K = Vapor Velocity Factor ρL = Liquid Density ρV = Vapor Density NOTE: The resulting velocity (fps) is the maximum velocity. Allowances need to be made for lost support or framing area.					

Table 2

Centrifugal Force

The second most important collection mechanism is the effect of centrifugal force on a droplet entrained in a gas stream that is moving in an arc. The centrifugal force can be calculated from the mass of the droplet, the gas velocity and its density, and the radius of the arc. The time required for a drop of given size to move to the wall of the separator also can be calculated. Centrifugal separators generally are divided into two types: stationary vane separators and cyclone separators. Chevron vane separators operate both by inertial impaction and by centrifugal force as a result of directional changes.

ENTRAINMENT SEPARATORS

Operating Characteristics

The following is an outline of the design and operating characteristics of the three most common types of entrainment separators for pans and evaporators, taking into consideration the brief description of the various collection mechanisms as background. The three principal types are:

1) Vane Mist Eliminators
2) Wire Mesh Pads
3) Centrifugal Separators

The maximum allowable vapor velocity for vane mist eliminators and pads varies inversely with the vapor density to approximately the 0.5 power. The velocities shown in Table 2 (Souders-Brown) for these two types of separators have been adjusted to the typical vacuum conditions in pans and evaporators.

Vane Mist Eliminators

Plate or vane type mist eliminators are impingement separators, which consist of a series of parallel plates. Mist eliminators containing plates that each have two or more changes of direction are frequently called chevrons. The vane bends can be sharp 90° angles, or curved. Vane type mist eliminators can remove droplets as small as 15-25 µm depending on flow direction and temperature. The operating range of gas velocities, corrected for vapor and liquid densities, is approximately 1200-2200 FPM depending on vane orientation and liquid loading. Historically, plate mist eliminators operated with moderate efficiency at lower velocity ranges. Chevrons operate with higher efficiencies at higher velocities.

Vane mist eliminators can be used in either a horizontal or vertical position.

With the mist eliminator assembly in the horizontal position (for vertical gas flow), re-entrainment will begin at about 1200-1500 FPM, depending on the vacuum, vane design, and vane spacing. Pressure drop is very favorable at 0.20-0.30 inch water column. These units generally operate quite free of plugging although, in certain applications, liquid hold-up may be a problem with high viscosity solutions, and scale could build up over time. Operating pressure drop should be monitored regularly and compared with the baseline. An increasing pressure drop across the mist eliminator or deterioration of condensate quality may indicate plugging from scale or debris. For most cases involving sugar liquors, regularly scheduled washing from beneath should be adequate.

Horizontal flow chevrons, with the mist eliminator element standing vertically, operate at higher velocities (1500-2200 FPM). Because liquid drainage occurs across the gas flow, drainage is improved, liquid hold-up generally is not a problem with higher viscosity liquids, and solids hold-up and resulting fouling also is reduced. Drained wash water can be piped away and separated from the sugar solution being evaporated. Higher gas velocities are possible before re-entrainment decreases collection efficiency and, because the mist eliminators operate at higher velocities, the effective area is less than that of vertical flow chevrons, so less total wash water is needed and, consequently, there is less water to evaporate.

Mesh Pads

Mesh pads for use in the sugar industry are fabricated with multiple layers of crimped knitted wire mesh. They are impingement separators and are very effective in reducing entrainment when new. Mesh pads will recover droplets larger than 8-10 µm and, by arranging pads of assorted densities in series, even smaller droplet size can be removed. The pads typically are 6-8 inches in thickness, including the supporting grids.

Mesh pads can accommodate an operating range of gas velocities from 600-1800 FPM, depending on pad configuration and liquid loading. Pressure drop range is generally from 0.3-1.5 inch WC. Both capacity and pressure drop can be varied by changing the mesh density and thickness.

As a general rule, mesh will have a lower vapor and liquid capacity than vane type mist eliminators, higher pressure drop, greater efficiency, and greater tendency for fouling, which may require that pads be replaced every two to three years. Mesh mist eliminators, generally, are washed from above. The point at which re-entrainment starts is greatly affected by liquid loading and there will be re-entrainment of wash water during any online washing. When installed in the domes of white sugar pans, it may not be possible to wash the pads completely free of all solids and, therefore, can be a source of contamination. In sugar applications, a strict program of washing is required to prevent build-up of degraded product inside the mesh. Once this build-up takes hold, it is very difficult to stop. The life of the pad will be shortened significantly once a mesh pad has experienced fouling.

It is uncommon to use mesh mist eliminators for horizontal gas flow applications, unless the mesh is used as a coalescer in front of the chevron.

Centrifugal Separators

Centrifugal separators usually are installed in the evaporator dome. A separator consists of an inner shell with a series of two or more vanes that force the vapor to flow in a circular path in an annular space between the inner shell and the vapor body. This motion provides the centrifugal action required to throw the entry droplet against the outer wall of the dome where the entrained sugar can be collected. The liquid readily drains from the walls and can be returned to the pan.

The collection efficiency of a centrifugal separator is quite high and will recover drops as small as 20 µm. However, these efficiencies require high vapor velocities (2000 – 6000 fpm) and, as a result, these units have one of the highest pressure drops (up to 5 inches WC).

Centrifugal separators normally are free from fouling and plugging problems, however, there are conditions during the strike which may require special design considerations. *(See Separator Selection Considerations below.)*

ENTRAINMENT SEPARATION DESIGN

Separators often are referred to as catchalls when they are located as a dome on top of an evaporator, or as an external vessel before the condenser. When the separator is external to the evaporator, the term separator or catchall includes the vessel as well as the internal separating element – the ***mist eliminator***. The design and operation of most entrainment separators is determined in part by whether the application is for a new or existing evaporator, and then is governed by a number of factors:

1) Steam Vapor Rate and Steam Density

   Steam vapor rate and vapor density are key to sizing any type of separator. An under-sized separator will result in re-entrainment and high pressure drop.

2) Liquid Density and Viscosity

   The greater the difference between the vapor and liquid densities, the higher the vapor velocities can be, and the easier it is to separate droplets from the vapor. As the density of liquid becomes greater, the inertia of droplets increases, allowing smaller droplets to be collected with the same efficiency as larger, less dense droplets.

   Fluids with higher viscosity than water will tend to have higher mean droplet sizes, with other variables unchanged.

   Once droplets are collected by the mist eliminator, they must drain out. In vertical flow mist eliminators, drainage occurs against the vapor up-flow. Viscous liquids may be sluggish in draining –particularly if the mist eliminator is sized close to its capacity. With horizontal flow mist eliminators, drainage occurs across the flow of vapor and drainage hold-up is usually not a problem.

3) Required Collection Efficiency

   Efficiency depends on the size and geometry of the separator, flow direction through the mist eliminator, liquid rate, liquid drop size distribution and, most importantly, velocity through the mist eliminator element. Drop size is very important since all separators have a lower limit in drop diameter, below which collection efficiency decreases rapidly. (*Unfortunately, there is little data available on drop size produced during evaporation in sugar pans, and only general information on drop size produced in evaporators.*)

While sufficiently high velocity enhances removal efficiency, re-entrainment occurs when the gas velocity becomes too high causing the collected liquid to be picked up again and swept out of the separator. At this point, collection efficiency drops rapidly. Re-entrainment velocity, in conjunction with vapor and liquid density, therefore determine the maximum allowable vapor throughput rate for the entrainment separator.

4) Evaporator Design

Some evaporator designs, such as most short vertical tube calandria evaporators, are designed for low vapor velocity exiting the heat exchanger section. Low velocity results in mostly larger droplets breaking free of the liquid surface above the calandria. If the strike level is sufficiently above the upper tube sheet, most of the largest entrained droplets will fall back into the liquid. Often, the mist eliminator for a calandria evaporator can be designed with a smaller cross section than the evaporator, but how much smaller depends on how high above the liquid level the mist eliminator can be installed.

5) Available Pressure Drop

Pressure drop costs energy. Different separator designs result in different pressure losses during both clean and fouled conditions. Pressure drop across the mist eliminator must be known so that an allowance can be made for the anticipated energy loss.

RE-ENTRAINMENT

A separator is not functioning properly if there is re-entrainment. In a properly designed entrainment separator, the collected liquid should drain away freely. As noted above, one of the major causes of re-entrainment is high gas velocity or viscosity, which hinders drainage and causes liquid hold-up in the separator to increase. This results in an increase in the thickness of the liquid film on the collector plates, vanes or wires. At this point re-entrainment can occur in several ways:

- The increase in liquid hold-up can reduce the area available for vapor flow.
- The resulting increase in gas velocity can blow liquid out of the separator.
- 'Waves' may develop on the liquid as it drains from the separator. High gas velocities can tear off the wave crests re-entraining the separated liquid.

High gas velocities and low surface tension also can cause shattering of the liquid droplets as they strike the collector surface. Since shattering causes small drops, the resulting re-entrained droplets are more difficult to recover than the original ones.

SEPARATOR SELECTION CONSIDERATIONS

Separator / mist eliminator selection is based on an analysis of the operating conditions of the individual vacuum pan and evaporators, consideration of the separator characteristics, and the condensate purity requirements. The most essential criteria are collection efficiency, pressure drop, and fouling tendency. *Although droplet size distribution also is a factor in design, there is no convenient way of measuring for test data, so droplet size is inferred from condensate data collected on known past separators within a known type evaporator.*

Conditions in pans and evaporators are summarized in Table 1 *(Evaporator Types by Feed Condition)*. While evaporators operate under steady conditions, those in the pans change during the strike (the removal of massecuite from the boiling operation at the required concentration). There are three separate periods during the pan boiling cycle:

1) Concentration: The period during which the graining charge is brought up to the seeding density. Steam flow generally is intense during this period.

2) Grain Development: The short period of about 20 minutes between the seeding point and the time when liquor feed is started. Steam flow during this period is very low.

3) Feed Period: High steam flows generally are required at this time to keep production on schedule.

Of these three, only the concentration and feed periods have vapor velocities great enough to cause significant entrainment.

During these periods, a centrifugal type separator, usually located inside the dome of a vacuum pan usually is ruled out, mostly due to large pressure drops and the difficulty in revising the design, if necessary, once the separator is installed. There are other design challenges, as well, with this type of separator. One is allowing sufficient time for the smaller drops to strike the wall. Since the vapor dome of a pan generally is quite small, the resident time of the drop in the centrifugal field may be too short and the drop will escape. Excessive liquid levels, or turbulent liquid strike heights, may cause a heavy carryover of massecuite (suspension of sugar crystals in a mother liquor resulting from the crystallization process) into the separator, leading to large pressure drops and plugging of the drain lines. When properly designed, however, excessive sugar liquor heights may not pose a problem as long as the drain lines are adequately sized and provided with sufficient liquid seal.

CONCLUSION

Entrainment separators or mist eliminators significantly increase the efficacy of sugar processes and product. Types of collection mechanisms depend on operating conditions, separator characteristics, and condensate purity requirements. In general, one can expect that if the sugar content within the steam condensate needs to be in the 10-20 ppm range, a horizontal flow chevron will be required; if 20-30 ppm is acceptable, a vertical flow chevron will be sufficient. For condensate quality of less than 10 ppm, selection must follow a close review of the liquor concentrate, evaporator configuration (falling film accomplishes better pre-separation than rising film), and chevron spacing.

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