Best Practices for Minimizing Drift Loss In a Cooling Tower

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Abstract:

There are many factors associated with the drift loss potential of a cooling tower. With the greater restrictions on drift emissions that are now required in many locales, it is important to know all of these factors to make sure that the drift loss of a tower is minimized. This paper will explore the various factors involved for both counterflow and crossflow cooling towers.

Introduction

In order to study the best practices for minimizing drift loss in a cooling tower it is important to understand exactly what "drift" is and the major factor in its containment, the drift eliminator. From the Cooling Technology Institute's (CTI) glossary of cooling tower definitions, drift is, "[W]ater lost from a cooling tower as liquid droplets entrained in the exhaust air. It is independent of water lost by evaporation. Units may be in lbs./hr. or percentage of circulating water flow. Drift eliminators control this loss from the tower."

Another way to define drift is: Drift is the spectrum of water droplets created by the aerodynamic forces acting on droplets and films within the cooling tower and discharged into the environment. Drift also contains the same chemicals and solids present in the circulating water. It is also important to note that drift is not the condensing water vapor normally emitted from cooling towers, since this is pure water. This visible condensed water vapor is known as the plume. (See Figures 1 & 2.)

There are various types of drift eliminators on the market today. The underlying mechanism of the method of drift removal for drift eliminators used in cooling towers is inertial impaction. Drift eliminators force the air and the entrained water droplets to make several directional changes as the moisture laden air passes through the drift eliminator. The system is a two-phase flow – gas and liquid. The liquid has more mass than the gas and thus has greater inertia and resistance to change in motion. Because of the water droplet's greater mass they deviate from the air streamlines and impact and collect against the surfaces of the drift eliminator. The collected drift water then drains back into the wet section of the cooling tower as its mass accumulates.

There are two main types of drift eliminators offered today, blade type eliminators and cellular type eliminators. (See Figures 3 & 4.) Blade type eliminators consist of waveform shaped blades that are commonly assembled into modules via means of spacers and/or caps. As the initial kind of drift eliminator, blade type eliminators initially offered drift removal efficiencies of 0.01-0.08% Water Flow (WF) for the early designs, and newer designs improved their removal efficiencies to 0.002-0.008% WF or better. The first cellular type drift eliminators were designed after blade type eliminators, and offered further improvements in drift removal efficiencies. Current state of the art eliminators can offer drift removal efficiencies from 0.002-0.0005% WF. Cellular type eliminators also offer benefits in field installation since they are more readily able to be trimmed or notched around penetrations to the drift eliminator plane. Another important factor in the development of drift eliminators is the use of a nesting design (Figure 5) in which adjacent eliminators with matching concave and convex edges are able to fit together and prevent drift droplets from bypassing the joint between the two eliminators.

Drift eliminators designed for use in cooling towers are optimized to work effectively within the general air velocity ranges of cooling towers, 2.0-3.6m/s (400-700FPM), and every eliminator has its own efficiency profile based on its unique design. Based on the inertial impaction theory of operation, at low velocities both the air and the drift droplets are able to pass through the eliminator due to the low inertial values of each. As the air velocity increases, the changes in direction have more impact on the drift droplets and they begin to collect on the eliminator surfaces. At the upper ranges of air velocities the air is able to re-entrain the accumulated drift water and strip it out of the eliminator, a phenomenon known as "breakthrough." (See Figure 6.)

Reasons to Eliminate Drift

Historically drift emissions of cooling towers have decreased as drift eliminator designs were refined due to continually evolving forces pushing for reduced drift rates. Towers manufactured in the 1970's typically had stated drift rates of 0.01% WF, while towers a decade later in the 1980's cut that in half to 0.005% WF. The turn of the century in 2000 yielded towers typically rated for 0.001% WF, and an ever increasing push today is for drift rates of 0.0005% WF.

There are several forces pushing the refinement of drift eliminator design and reductions in drift emission rates. One force is the nature of the drift that is emitted and its effect on that with which it comes into contact. As stated in its definition drift contains all of the chemicals and solids contained within the circulating water of the cooling tower. This includes dissolved solids such as salts and other chemicals from the process water, and it also includes any water treatment chemicals used to keep the cooling tower system functioning properly. Drift droplets are also large enough at 20-2000 microns to contain bacteria which may lead to illnesses, such as Legionnaire's Disease. Since drift droplets contain salts and other chemicals they can have a detrimental effect on surrounding flora and fauna. Drift droplets can also be highly corrosive to surrounding equipment and environs. Drift emissions from cooling towers

have been known to spot and mar the paint finish of cars in nearby parking lots. They can also cause costly damage to surrounding equipment and buildings when the corrosive effects damage buildings and surrounding equipment.

Drift droplets can also cause early wear and erosion of fan blades since the droplets hammer at the leading edges of fan blades. Taken to its extreme the result could be a severe reduction in the efficiency of a fan's capability to move air and a serious concern for structural failure as shown in Figure 7.

Another factor pushing the reduction of drift emissions in the United States is the fact that the United States' Environmental Protection Agency (EPA) considers drift to be a regulated emission from a cooling tower, and the EPA is tightening regulations for PM-10 and PM-2.5 emissions. The EPA's PM-10 Standard covers particles 10 microns and smaller that, "are likely responsible for adverse health effects because of their ability to reach the lower regions of the respiratory tract." Particulate matter that is 10 microns and smaller in size is small enough to penetrate the lower regions of the respiratory tract but may not be able to be exhaled out. Under the Clean Air Act the EPA has a mandate to continue to refine and set new air quality standards, and the new standards for PM-2.5 emissions are being given to the various states for enforcement via the appropriate individual state environmental regulatory agencies.

General Tower Design Considerations

Adequate Plenum

-Induced Draft Counterflow Towers

In induced draft towers the plenum is the area of the tower between the drift eliminators and the fan. The plenum serves as an air transition and equalization chamber in which the air that moved through the fill and drift eliminators is compressed and is forced through the fan out into the surrounding atmosphere. Due to this transition if there is too little room between the drift eliminators and the fan, then the air velocity profile through the drift eliminators may vary widely yielding regions of velocities that exceed the design limits of the drift eliminator. This could yield two negative consequences: 1) the velocity in certain areas may exceed the breakthrough velocity of the eliminator in which case the expected drift rate would be void and 2) higher velocities generally increase the pressure drop across the eliminator which will decrease the thermal performance of the tower.

In a counterflow tower an historically accurate rule of thumb, as presented at the 1999 CTI Annual Conference Educational Seminar, for determining an adequate plenum is to have a percentage of fan coverage of at least 80%, where the percentage of fan coverage is defined as the circle projected onto the drift eliminator plane from a cone defined from a 45° angle from the fan cylinder opening. (See Figure 8 and Reference 4.)

A general velocity profile across the drift eliminator plane in a tower with an adequate plenum is shown in Figure 9. An adequate plenum allows a greater percentage of the drift eliminator plane to reflect the calculated average air velocity (FanCFM/ACELL). An inadequate plenum forces the majority of the airflow to occur right under the fan cylinder and the resulting air velocities in that limited area can exceed the limits of the drift eliminator's optimum performance envelope.

-Induced Draft Crossflow Towers

Computational Fluid Dynamics (CFD) analysis of a variety of factory assembled induced draft crossflow towers shows that the plenum dimensions affect the velocity profile across the drift eliminator plane similar to the effect seen in counterflow towers. Figure 10 shows the basic set-up of a crossflow tower and the overall velocity vectors through the tower. Due to the different geometry involved in a crossflow tower with the drift eliminator sections extending in the vertical plane and the fan residing in a horizontal plane, in a double-flow crossflow tower the plenum dimensions can be represented by a ratio of the drift eliminator section height, referred to as "plenum height," divided by the horizontal distance between the opposing banks of drift eliminators at the mid-height of the drift eliminators, referred to as the "plenum width." This ratio will define a factor called the Plenum Ratio, (PR).

$$PR = HP / WP$$

HP = Vertical Height of Plenum (at drift eliminators)
WP = Width of Plenum (at mid-height of drift eliminators)

Based on the CFD analysis there is a relationship between the Plenum Ratio and the resulting ratio of the peak air velocity through the drift eliminators compared to the average air velocity through the drift eliminators, hence known as Velocity Ratio (VR).

$$VR = VPEAK / VAVG$$

VPEAK = Peak air velocity through drift eliminators
VAVG = Average velocity through drift eliminators

This relationship is shown in Figure 11. What makes this relationship important is that with a known average velocity and the plenum ratio defined by the tower geometry you can estimate what the peak velocity will be and then compare that to the breakthrough velocity of the drift eliminator in order to evaluate potential drift issues.

Another interesting facet of the CFD analysis is the visualizations that are possible of the air velocity profiles through the drift eliminator plane. Figures 12-16 show two different ways to view the information. Figures 12 and 13 show a three dimensional representation of two different towers. Figure 14 shows a general physical representation of the data contained in Figures 15 and 16 which show a grid format where the magnitudes of the velocities at discrete locations are highlighted by color coding. What is significant in the grid view is that the locations of velocities higher than 5m/s (1000FPM) are easily observed. The 5m/s (1000FPM) threshold is important because drift testing of an integral drift eliminator shows that the breakthrough velocity is slightly above that. Therefore 5m/s (1000FPM) is considered to be a conservative estimate of a velocity limitation for integral drift eliminators. As you can see between Figures 15 and 16, Figure 16 represents a tower with a much larger section of high velocities over the 5m/s (1000FPM) threshold. As such the tower represented by Figure 16 would have greater drift emissions than the tower represented by Figure 15 if only integral drift eliminators are used. The remedy is to change the drift eliminator to either a separate dedicated drift eliminator, which has better drift removal capabilities and better drainage, or a combination of both an integral drift eliminator and a separate dedicated drift eliminator for towers with the highest peak velocities and highest percentage of grid points over the 5m/s (1000FPM) threshold.

Drift Eliminator Support Considerations

-Induced Draft Counterflow Towers

The placement and support of the drift eliminators also has an effect on the performance of the drift eliminators. In a counterflow tower there are two commonly used methods to support the drift eliminators. One method is to use the water distribution laterals as the drift eliminator supports. Another method is to provide an independent support system located above the water distribution headers and laterals designed specifically for the drift eliminators.

If the aim is to minimize drift loss from the tower, the preferred method is to follow the second method with the separate independent DE supports. The benefits for this method are realized by the increased distance the drift eliminators have from the spray nozzles. As separation from the nozzles increases, the likelihood of droplets from the nozzle being sprayed directly onto the drift eliminator decreases. If spray from the nozzles directly impacts the drift eliminators it is possible that the water may flood the eliminator and not allow it to function as designed yielding blocked airflow through the eliminator and/or water actually being sprayed through the eliminator. It is important to note that if an existing tower has the drift eliminators supported by the water distribution system, changing the drift supports to an independent system above the header and laterals will reduce the plenum at which point the Adequate Plenum factors above must be reviewed.

Case Study

Tower Type	Induced Draft Counterflow tower
Original DE Supports Config.:	Water distribution system
Desired new DE Support Config:	Independent support system located 2.1m (7ft) above the top elevation of fill to allow workspace for maintenance crews

Cell Length	7.3m (24ft)	Cell Width	9.1m (30ft)
Fan Diameter	4.9m (16ft)	"Adequate Plenum"	1.7m (5.5ft)
Orig. Plenum Ht.:	1.7m (5.5ft)	Rev. Plenum Ht.:	0.7m (2ft)
Orig. Tower Capability:	100.0% *	Rev. Tower Capability:	93.6% *
Orig. Avg. DE Velocity:	2.95m/s (581 FPM)	Rev. Avg. DE Velocity:	5.07m/s (998FPM)

*Tower Capabilities based on the following standard nominal HVAC operating conditions:

35°C Hot Water – 29.4°C Cold Water @ 25.6° Wet bulb

(95°F Hot Water - 85°F Cold Water @ 78°F Wet bulb)

In this Case Study, the end user had a tower with poor water quality issues that needed weekly maintenance on the water distribution system and fill sections. Maintenance crews had to remove or shift around all of the drift eliminators every time that nozzles and laterals needed cleaned out. The crews would also pull up large pieces of scale and debris from the top fill section during this maintenance. With only a 0.9m (3ft) space between the fill and the drift eliminators the crews had to remove drift eliminators in order to be able to complete the weekly maintenance. In order to reduce the handling and wear on the drift eliminators and to allow for ease of movement for the crews, the end user sought to increase the distance from the top fill layer to the drift eliminators from 0.9m (3ft) to 2.1m (7ft). As shown in this Case Study, the unintended consequence of this change was a drastic reduction in the plenum which resulted in a 6.4% reduction in tower capacity and a drift problem due to resulting high velocities through the drift eliminators. With a calculated average air velocity of 5.07m/s (998 FPM) and the drift eliminators now being only 0.7m (2ft) from the fan inlet, the drift eliminators are now in the wake zone of the fan inlet and as such velocities are highly variable and the airflow is very turbulent. Various sections of the eliminators located under the annulus defined by the fan blade path experience velocities that exceed the breakthrough velocity of the drift eliminator with the water being stripped right out of the drift eliminators and out through the fan.

As illustrated in Case Study 1 due to the need to perform maintenance on the mechanical components of a cooling tower, many of which are only accessible from the plenum section of the tower, many tower operators make it a common practice to walk on the drift eliminators. This is against the recommendation of most drift eliminator manufacturers due to safety and performance concerns. Regarding safety concerns, drift eliminators are not designed to be a structural walking surface in a cooling tower, and the common air travel depths of approximately 133-152mm (5.25-6in) limit the loading and span capability of the part. Walking directly on a drift eliminator will also tend to bend the edges of the eliminator where a shoe or boot comes into contact with the drift eliminator. This deformation of the eliminator edge will change its performance altering the pressure drop and drift removal capability. Since maintenance of the mechanical components is required for the proper upkeep and performance of a cooling tower, it is highly suggested that towers be designed and built with actual dedicated walking surface structures for the purpose of performing said maintenance. If it is unavoidable to walk on the drift eliminators, at the very least, a layer of scaffolding planks long enough to extend beyond the drift eliminator supports be placed on top of the drift eliminators to protect the upper surface of the drift eliminator from foot traffic and to distribute the person's weight. Extreme care also must be taken by the maintenance personnel to step at the locations of the drift eliminator supports and not mid-span of the drift eliminators where they are weakest.

-Induced Draft Crossflow Towers

For towers with separate dedicated drift eliminators, most induced draft crossflow towers use some type of shelf or tray as the support for the drift eliminators. What is important to consider here is that the supports must be able to drain any collected water back into the "wet" section of the cooling tower. Since the drift eliminator shelves/trays act as a collection point for draining water, the DE supports should have drainage slots or holes to allow the water to move back into the wet/fill section of the tower.

For large industrial field erected towers it is also important that the drift eliminators be supported in multiple shorter height sections so that the water is able to drain from each section and not overload the drift eliminator. In general this is to mean that the drift eliminator panel heights match the tower structure heights. Thus for an 11m (36ft) tall tower with vertical bay spacing of 1.8m (6ft) it is better to have 6-1.8m (6ft) drift sections than 3-3.7m (12ft) sections. In this manner there is a reduced chance of the drift eliminator supports filling with water and allowing carryover through the drift eliminators.

In induced draft crossflow towers that utilize a splash fill it is important that the drift eliminators be installed far enough from the

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splash fill in order to prevent water from directly impinging on the drift eliminators. One guideline or rule of thumb to help prevent this is to make sure that the drift eliminators in the top bay (nearest the fan deck) be at least 305mm (12in) from the splash fill. An important consideration regarding this point is that a tower that changes from a splash fill orientation that was perpendicular to the airflow to an orientation parallel to the airflow will "breathe" better. This is generally a positive aspect from a thermal performance viewpoint since greater airflow yields more cooling, but from a drift elimination aspect it could have a detrimental effect. If the airflow is increased greatly, then the water flow through the fill section will be shifted more toward the drift eliminators. This shift could violate the distance from splash fill to drift eliminators guideline above, and the increased air velocities may exceed the design velocities of the drift eliminators.

Induced draft crossflow towers that use Integral Drift eliminators ("ID") should be supported per the fill manufacturer's recommendations. Towers that have multiple lifts of fill with ID should have seals and water diverters installed at each lift interface to ensure that the water draining from the integral drift eliminators of the upper lift is directed toward the center of the fill pack section of the lower lift. The goal is always to have proper water management with respect to the airflow and drift eliminator location.

Installation Details to "Finish the job"

Sealing the Drift Eliminator Plane

One of the most basic factors to consider when looking at a drift eliminator installation and getting the expected drift removal performance from the cooling tower is that all of the air and its entrained drift must be forced to transit through the drift eliminators. Since the air will always seek the path of least resistance, gaps between adjacent drift eliminator modules, drift eliminator modules and penetrating tower structures (support columns, cross-braces, transverse girts, etc.), drift eliminator modules and partition or end walls or tower casing must be avoided to maximize drift removal. One of the largest factors in minimizing drift is the quality of workmanship of the installer. Drift eliminator panels must be installed tightly side-to-side and end-to-end (if applicable). Drift eliminators need to be trimmed to within 1.6mm (1/16th in.) of any obstruction or penetration. At a minimum seals around any obstruction or penetration should also be placed on the "wet side" of the drift eliminators to prevent drift laden air from entering any gaps, and they can also be placed on the "dry side" of the drift eliminators to ensure complete blockage of any gaps. (See Figure 17.) The interface between the drift eliminators and any walls must also be sealed on the "wet side" of the drift eliminators to prevent bypass. Closed cell expanding foam may also be used to close any gaps not covered by other sealers.

Another important installation consideration for crossflow towers are seals and diverters at the water distribution level and the cold water basin. If not properly sealed, air can bypass the fill section and go above or below the fill taking with it some of the circulating water. Thus air seals should be placed at the air entering and air exiting side of the hot water basin to prevent this bypass. Seals that extend below the cold water basin operating waterline should also be installed. Water diverters should be placed on the underside of the hot water basin to prevent spray from the nozzles from directly impacting on either integral drift eliminators or separate dedicated drift eliminators. Water diverters should also be used at vertical fill section transitions to make sure the water is kept within the fill section which helps improve tower performance.

Drift Eliminator Directional Orientation

Many of the latest generation drift eliminators have specific directional installation orientations, and it is important to make sure the eliminators are installed correctly. In counterflow towers the highest efficiency eliminators on the market have drainage tips that allow the eliminator to drain the collected water better and help to reduce pressure drop through the drift eliminator. These drainage tips should be installed "down" in order for them to work appropriately. (See Figure 18.) In crossflow towers, many eliminators have a directional discharge helping to direct the exhaust air upward. (See Figure 19.) When combined with the usual angled installation of the drift eliminator plane into the airflow, commonly approximately 10deg from the vertical, this also yields a gravity-assisted drainage path for the collected water. If these eliminators are installed upside down, then any water collected in the drift eliminator will be forced out into the plenum via gravity, which is the exact opposite of the intended purpose of the drift eliminator.

Tower Operation Considerations

Drift elimination performance is also affected by different tower operation factors, especially those that influence the formation or size of droplets. One example of this is the water treatment program. Water treatment programs that include biodispersants, scale inhibitors, and some non-oxidizing biocides are surface-active (surfactant) and cause a reduction in the surface tension of the water. As surface tension decreases droplet sizes also decrease. Since drift eliminators are designed to be effective on typical drift droplets that measure 20-2000μ, a tower being treated with surfactants will have a greater quantity of smaller droplets that are able to pass unimpeded through a drift eliminator. It is for this reason that the latest revision of CTI Drift Test Code ATC-140 limits the surface tension of the circulating water to a minimum of 63 dynes/cm. For comparison pure water at a temperature of 48.9°C (120°F) has a surface tension of 68 dynes/cm. If the goal of a drift test is to measure the absolute lowest drift emissions from a tower, all surface-active treatments should be discontinued at least 72 hours prior to and during the testing period to ensure that the surfactant effects are minimized or removed. Please note that there could be other factors such as regulatory requirements or evaluative reasons for running a drift test that inhibit or preclude discontinuing surfactant use.

Another tower operation factor for pressurized water distribution systems is the water pressure. Higher pressure systems will yield smaller droplets, and as in the surface tension impact mentioned above, if the spray system is able to provide a fine enough mist due to high pressure levels, then the smaller droplets may be able to transit the drift eliminators. It is important to remember that specific nozzles are designed for specific operating pressures and changing the system pressure from its design point might yield unforeseen consequences.

Drift eliminators, the same as polymer fill products, must be conditioned during a "break in period" in order to achieve expected performance. Polymer materials have relatively low "surface energy" which causes water droplets to "bead up" instead of wetting out. The break in period provides an opportunity for a very thin layer of mineral scale to form, and this acts as a physical aid


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that allows the water film to become fully established. Therefore, just like new fill in a cooling tower that is going to be tested for thermal performance, it is important to let a tower operate under normal conditions for approximately 4-6 weeks before performing any drift tests in order to achieve expected performance from the drift eliminators.

Specifying Drift Eliminators

Since drift eliminators are the items used to control drift emissions from a cooling tower it is important to specify the proper eliminator. A proper drift eliminator specification will detail:

- Expected drift rate
- Material thickness and span requirements
- Material choice: If the material is a thermoplastic, specify that the material meets CTI STD-136, "Thermoplastic Materials Used for Film Fill, Splash Fill, Louvers and Drift Eliminators."
- Operating temperature
- Chemical composition of the bulk water
- Any other factors that might affect the drift eliminators.

Conclusions

As drift emissions become a greater concern to cooling tower owners and operators and to regulatory organizations, the practices associated with drift elimination will continue to rise in importance. These practices involve everything from tower design and drift eliminator design to installation and actual tower operations. Each aspect must be carefully planned and implemented in order to achieve the best drift removal possible. New tower designs need to incorporate adequate plenums to ensure that the drift eliminators experience airflow profiles across the entire drift eliminator plane that do not exceed the breakthrough velocities of the drift eliminators. Modifications to existing towers need to take into account the ramifications of changes to the original design of a tower and how they might affect drift performance. Water and airflow management concerns need to be addressed so that the circulating water is maintained within the fill section of the tower including water diverters and air/water seals at structural elements of the tower. The cooling tower operator must be vigilant about how he operates the tower and what water treatment protocols are followed. And after all of that is addressed, actual installation must be done by work crews that pay attention to detail, since all of the preceding work can be negated by a sloppy or poor installation. As one seasoned cooling tower industry individual explained once, "A piece of plywood makes a pretty darned good drift eliminator." However even the best piece of plywood, like the most efficient drift eliminator, will not prevent drift emissions if there are gaps surrounding it allowing the air to bypass it and escape the tower.

It is important to note that all guidelines and rules of thumb presented in this paper are suggested measures that, if followed, will help to minimize the drift loss from a tower. Specific situations with special conditions may exist that yield actual data from a drift test with a tower design or with installation practices that are in conflict with these guidelines. If this is the case, then the test data relevant to that specific design would supersede any guidelines or rules of thumb presented herein.

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Appendix I

Tables & Figures

Figure 1: Cooling Tower Plume

Figure 2: Cooling Tower Drift

Figure 3: Blade Type Drift Eliminator

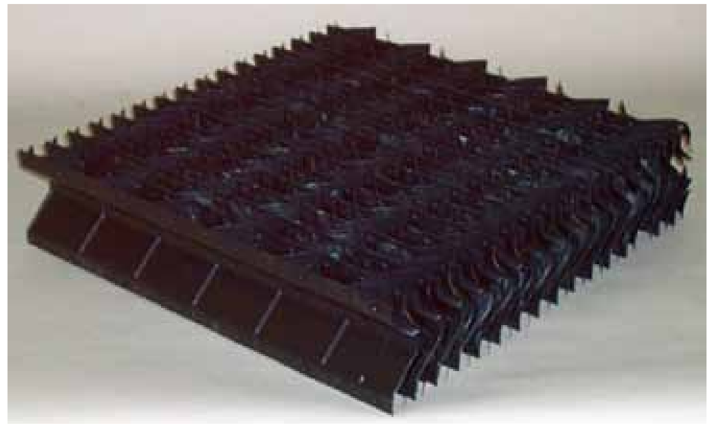


Figure 4: Cellular Type Drift Eliminator

Figure 5: Non-nesting vs Nesting Eliminator Designs

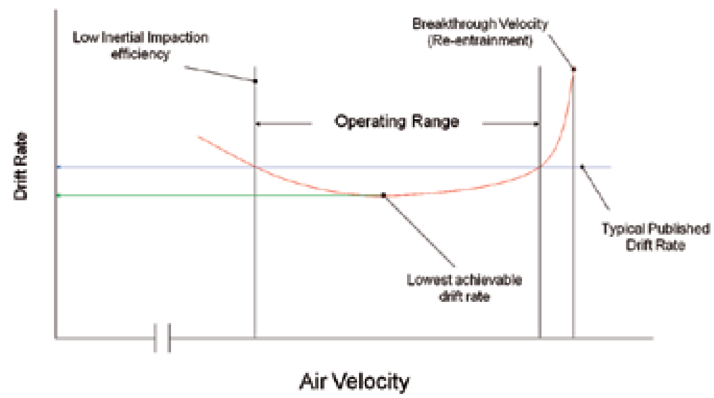
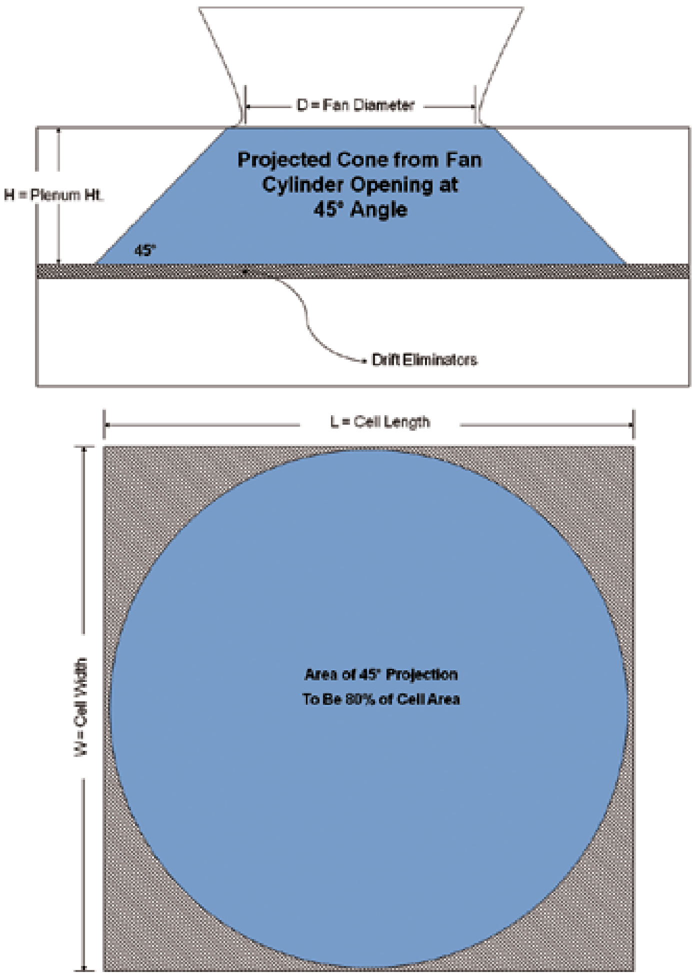


Figure 6: Generic Drift Eliminator – Drift Rate vs Air Velocity Profile

Figure 7: Severely Eroded Fan Blades



$$H = \sqrt{\left(\frac{0.8LW}{\pi}\right)} - \frac{D}{2}$$

Figure 8: Counterflow tower – Adequate Plenum Rule of Thumb

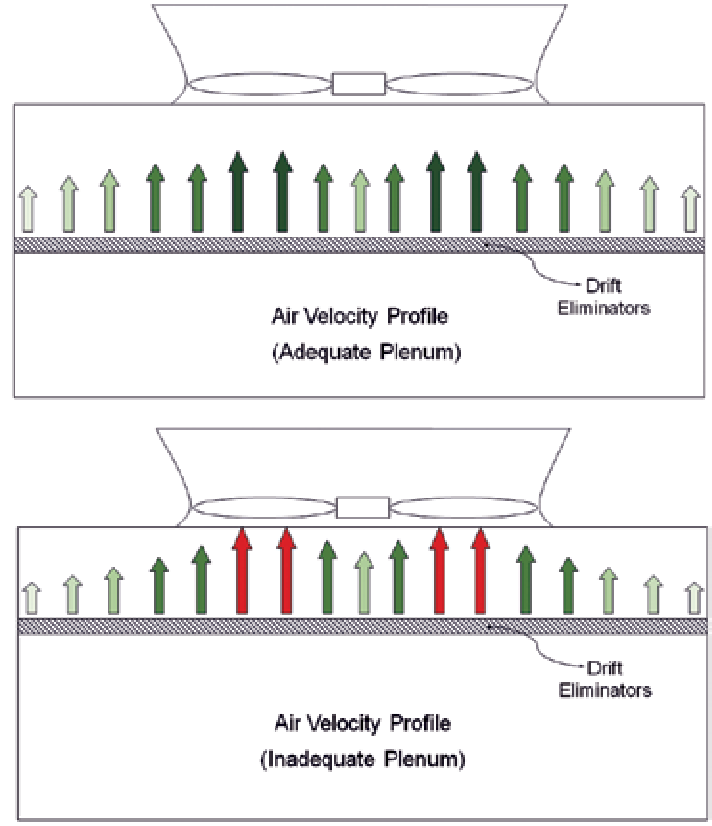


Figure 9: Adequate vs Inadequate Plenums Air Velocity Profiles (Counterflow towers)

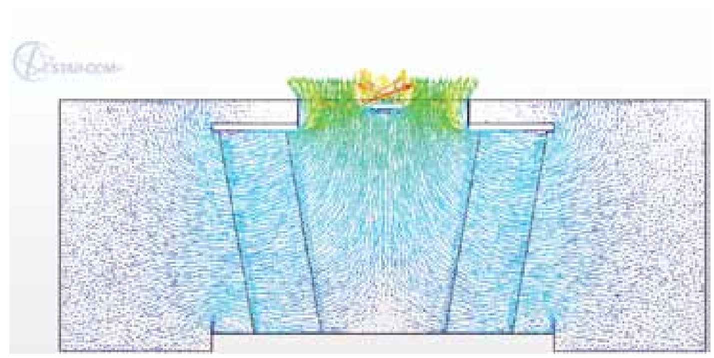


Figure 10: Basic Set-up of CFD Model – Crossflow Tower

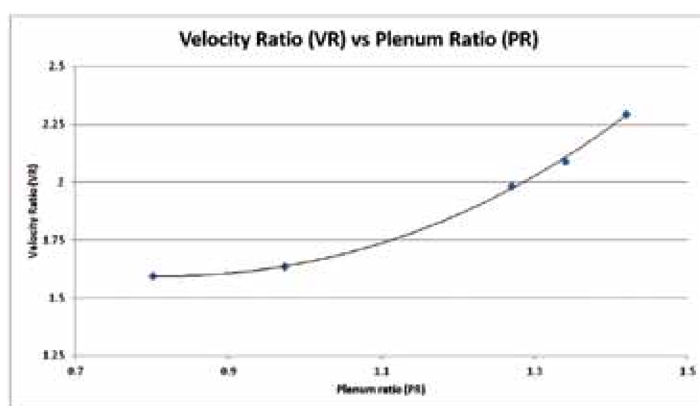


Figure 11: Crossflow Tower – Velocity Ratio vs Plenum Ratio

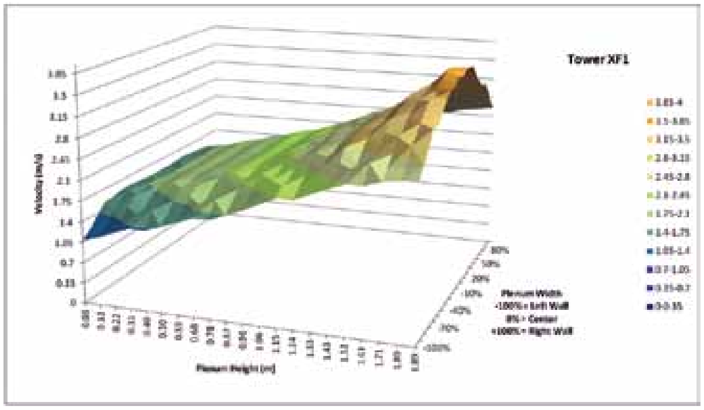


Figure 12: Crossflow Tower XF1 – 3D Velocity Profile

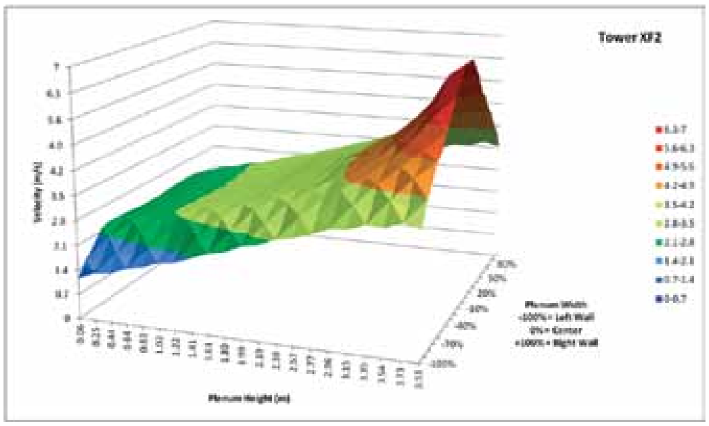


Figure 13: Crossflow Tower XF2 – 3D Velocity Profile

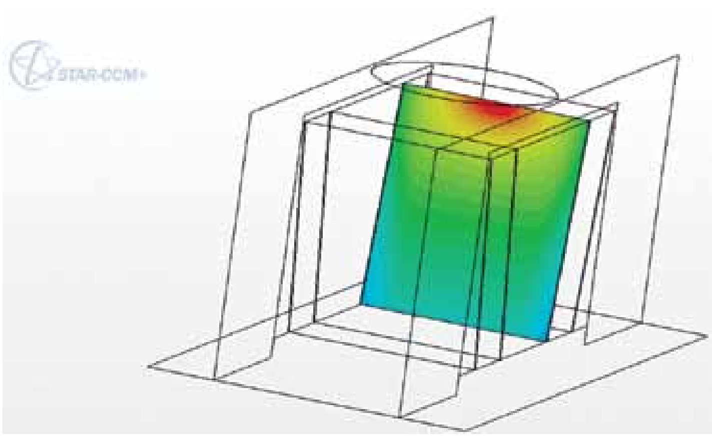


Figure 14: CFD DE Velocity Profile – Crossflow Tower

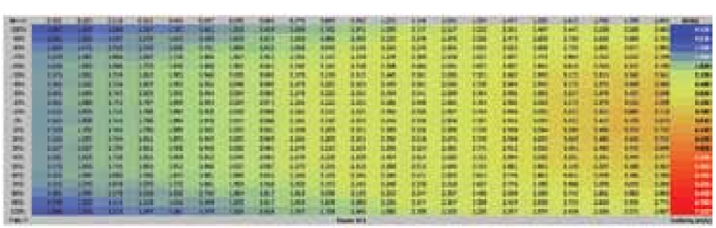


Figure 15: Crossflow Tower XF1 –Velocity Profile Grid

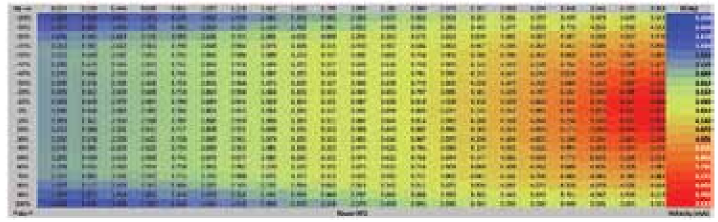


Figure 16: Crossflow Tower XF2 –Velocity Profile Grid

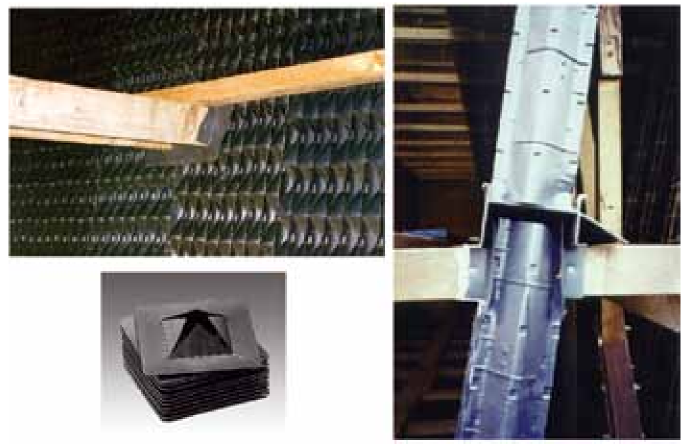


Figure 17: Sealing Methods for Structural Penetrations of Drift Eliminators Figure

18: High Efficiency Eliminator Drainage Tips (Counterflow towers) Tips go “down” when installed


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Figure 19: Crossflow Drift Eliminator Proper Installation Orientation