SALT RIVER PROJECT
SANTAN GENERATING STATION

EMISSIONS ASSESSMENT FOR CERTIFICATE OF ENVIRONMENTAL COMPATIBILITY CONDITION 20 COOLING TOWER PLUME ABATEMENT

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FINAL

Prepared By:

Sargent & Lundy LLC

Project No. 12046-021

August 18, 2016

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CERTIFICATION

FOR

SALT RIVER PROJECT

SANTAN GENERATING STATION

EMISSIONS ASSESSMENT FOR

CERTIFICATE OF ENVIRONMENTAL COMPATIBILITY

CONDITION 20

COOLING TOWER PLUME ABATEMENT

I CERTIFY THAT THIS REPORT WAS PREPARED BY ME OR UNDER MY SUPERVISION AND THAT I AM A REGISTERED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF ARIZONA.

Electronic copy of final document;
Sealed original is with Nelson Rosado
Certificate No. 58529

REVISION	CERTIFIED BY	DATE
0	Nelson Rosado	August 18, 2016

APPROVAL PAGE

FOR

SALT RIVER PROJECT
SANTAN GENERATING STATION
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CONDITION 20
COOLING TOWER PLUME ABATEMENT
<u>NOT FOR CONSTRUCTION</u>

Rev.	Date/ Purpose	Prepared	Reviewed	Approved	Pages Affected
0	08/18/2016 Final	D. Anderson	W. A. Rosenquist W. Rosenquist	Nelson N. Rosado	All

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Exhibits

Abbreviation, Acronym, Term	Explanation
ACC	Arizona Corporation Commission
Cell	The smallest cooling tower subdivision which can function as an independent unit with regard to air and water flow; it is bounded by exterior walls or partitions
CEC	Certificate of Environmental Compatibility
Cold Water Basin	A device underlying the cooling tower to receive the cold water from the tower and direct its flow to the suction line or sump.
CWT (Cold Water Temperature)	Temperature of the water entering the cold water basin before addition of make-up.
Counter-flow	Water flows vertically down the cooling tower fill as air flows vertically up.
Cross-flow	Water flows vertically down the cooling tower fill as air flows horizontally across
Distribution Basin	A device utilized at the upper level of a cross-flow cooling towers to receive the hot water from the heat source and distribute the flow over the fill.
Drift	Water lost from the tower as liquid droplets entrained in the exhaust air. It is independent of water lost by evaporation. Units may be in lbs./hr., or as a percentage of circulating water flow.
Drift Eliminator	An assembly constructed of wood, plastic, cement board, or other material that serves to remove entrained moisture from the discharged air.
Evaporation Rate	The rate at which a liquid turns into gas and leaves the cooling tower.
Fan Deck	The surface enclosing the top of an induced draft tower
Fill	That part of a cooling tower consisting of splash bars, vertical sheets of various configurations, or honeycomb assemblies, tile or other materials, which are placed within the tower to effect heat and mass transfer between the circulating water and the air flowing through the tower.
Fogging	A fog condition created when the exhaust air or plume from a cooling tower becomes supersaturated so that part of the water vapor condenses into visible liquid droplets.
Mechanical Draft Cooling Tower	A cooling tower through which air movement is effected by one or more fans. There are two main types: Forced draft with fans located at the air inlet; Induced draft with fans located at the air exhaust
Plenum	The enclosed space between the eliminators and the fan stack in induced draft towers or the enclosed space between the fan and the filling in forced draft towers.
Plume	Visible exhaust from a cooling tower. (See Fogging)
SRP	Salt River Project
S&L	Sargent & Lundy LLC

1. Introduction

In May 2001, the Arizona Corporation Commission (ACC) issued a Certificate of Environmental Compatibility (CEC) for the Santan Expansion Project.

Condition 20 of the CEC reads as follows:

> *Applicant will explore, and deploy where reasonably practicable, the use of available technologies to reduce the size of the steam plumes from the unit cooling towers. This will be a continuing obligation throughout the life of the plant.*

SRP has periodically reported to the ACC on its compliance with all of the conditions included within the CEC, including Condition 20. In 2010 and 2011 SRP Generation Engineering completed an updated assessment of technologies and costs for abating cooling tower plumes. The conclusions from that assessment were that there have not been any significant improvements in the retrofit technologies or reductions in cost associated with cooling tower plume abatement for decades. Discussions with major tower suppliers indicate that there have been no major R & D programs specifically for retrofitting existing cooling towers with plume abatement technologies, since it is such a small market. Only a very small number of utilities have cooling towers equipped with plume abatement technology, and these were furnished with the initial installations and were in locations with climate conditions that presented a public safety regarding plume visibility or icing. Retrofitting plume abatement systems on existing towers involves the application of these new unit plume abatement designs that require significant modifications to the tower and associated structures at substantial capital costs.

2. Existing Cooling Tower Design and Construction

Santan Generating Station currently has 3 cooling towers. One cooling tower serves Units 1-4, one serves Unit 5 and one serves Unit 6. Table 1 summarizes the design and construction of these cooling towers.

Table 1 – Existing Cooling Tower Design and Construction			
Characteristic	**Cooling Tower Units 1-4**	**Cooling Tower Unit 5**	**Cooling Tower Unit 6**
Tower Manufacturer	Marley	GEA	GEA
Model Number	664-3-06	545439-01-33-WCF	485430-51-33-WCF
Year Installed	1972	2003	2004
Number of Cells / Number of Fans per Cell	8 / 1	9 / 1	5 / 1
Type (cross-flow or counter-flow)	Induced Mechanical Cross-flow	Induced Mechanical Counter-flow	Induced Mechanical Counter-flow
Design Water Flow at Tower Inlet (gal/min)	101,500	172,923	80,755
Circulating Water Outlet Temperature (°F)	82.4	91.2	91.2

3. Plume Abatement Considerations

Drift eliminators are used to control water loss from a cooling tower by limiting the amount of circulating water droplets that are emitted with the exhaust air of the tower. The cooling tower industry uses drift rate to compare drift eliminator performance, a relationship that correlates droplet capture efficiency to the water circulation rate in a cooling tower. Modern, cellular, high efficiency drift eliminators installed on a cooling tower discharge can reduce the drift rate down to 0.0005% in a counter-flow tower and reduce the original drift rate in a cross-flow cooling tower. However, reducing the drift rate will not reduce the visible plume. Under certain atmospheric conditions, plumes of water vapor (fog) rise from the exhaust air discharge of a cooling tower. If the outdoor air is at or near saturation, and the tower adds more water to the air, saturated air with liquid water droplets can be discharged, which is seen as fog. This phenomenon typically occurs on cool, humid days, but is somewhat rare in most arid climates. Plume abatement is the process of removing the visible plume from a cooling tower's discharge.

4. Available Plume Abatement Retrofit Technologies

In order to meet the requirements of Condition 20, the use of available technologies to reduce the size of the steam plumes from the unit cooling towers was explored. S&L contacted two leading global manufacturers of large mechanical draft cooling towers, SPX Cooling Technologies (Marley) and Enexio (formally GEA Cooling Systems) to discuss the latest technologies available for eliminating visible plume from cooling towers. Both informed us that there has not been any significant improvement in the technologies or reductions in cost associated with retrofitting a cooling tower with plume abatement capabilities since the previous Condition 20 assessment in 2010 and 2011.

Table 2 summarizes the current available technologies for retrofitting cooling tower plume abatement on existing cooling towers. Exhibit 1 graphically illustrates the conventional counter-flow and cross-flow cooling towers designs. Exhibit 2 graphically illustrates the retrofit technologies currently available for cooling tower plume abatement. All of these technologies prevent visible cooling tower plumes by decreasing the relative humidity of the saturated discharge air and have been available since the 1970's. This design results in a hybrid cooling tower which functions in principle like a wet cooling tower. An additional dry section of the cooling tower reduces visible plume by heating wet air coming from the rain zone beneath the fill. For that purpose, in hybrid towers, saturated discharge air is mixed with heated, low relative humidity air. The discharged mixture has a comparatively low relative humidity and the fog is invisible.

Table 2 – Current Available Retrofit Technologies for Cooling Tower Plume Abatement

Option	Method	Modifications Needed for an Existing Tower	Challenges, Existing Tower Constraints	Pump Head	Fan HP
1	Pre-cooling coils installed on "short walls" above distribution basin.	Short wall/plenum must be extended in height to add coils. Booster pumps may be required to pump hot water to top of pre-cooling coils.	Existing structure and basin may not be adequate to hold weight of coils and additional wind loads from taller plenum.	Increase in winter	Stays the same

Table 2 – Current Available Retrofit Technologies for Cooling Tower Plume Abatement					
Option	**Method**	**Modifications Needed for an Existing Tower**	**Challenges, Existing Tower Constraints**	**Pump Head**	**Fan HP**
2	Air to Air Heat Exchanger (i.e. Marley ClearSky)	Plenum must be increased in height.	Existing tower may need significant modifications to install bracing for additional wind loads. Existing design is only applicable to tower design with 6' x 8' bays.	Stays the same	Increases, more cells needed, increased basin size
3	Pre-cooling coils installed on side walls above distribution header.	External supports as structure will not support coils. Booster pumps needed.	Air control dampers needed, freeze hazard. Tower walls will not support coil weight.	Increase in winter	Stays the same
4	Pre-cooling coils installed on fan deck	Booster pumps needed.	No forced air available so many coils are needed for any effect, freeze hazard. Structure and basin would likely need to be modified to hold weight.	Increase in winter	Stays the same
5	Pre-cooling coils installed in plenum	Slight increase in pump head	Existing tower may need significant modification to install bracing for additional wind loads. Increased pressure-drop.	Increase in winter	Increases, more cells needed
6	Pre-cooling coils installed in fill area	Some existing fill must be removed	Summer time capacity reduced per cell due to fill being removed.	Stays the same	Increases, more cells needed

In five of these available options, a portion of the hot water arriving at the cooling tower is routed through pre-cooling coils to heat and dry ambient air that it is drawn into the cooling tower to mix with the moisture laden air exiting the cooling tower. Each of these options differs by where the pre-cooling coils are placed. The other option uses air to air heat exchangers. As ambient air is drawn in to the tower, it passes through the warm, wet section of the cooling tower and the heat exchanger absorbing heat. The warmer, dryer ambient air then mixes with the cooler saturated air from the wet section of the tower resulting in a discharge that has lower relative humidity and, dependent on the ambient conditions, reduces the potential for fogging.

In assessing the factors relating to the best available plume reduction technology, considerations included the age of Santan Generating Station's existing equipment and facilities, the process employed, the engineering aspects of the application of various types of control techniques, process changes, visibility impacts of taller cell structures, the cost of achieving such plume reduction and non-water quality environmental impact (including energy requirements).

Modifying an existing cooling tower with plume abatement technology usually involves a considerable expenditure of time and a very high cost. This is because the existing towers usually cannot support the weight of the added heating coils or heat exchanger and the taller structure required to install them often results in additional wind loads that will require bracing be added to the structure. The addition of heating coils or stack extensions could add as much as 25-feet to the height of the towers. Since these additional weight and wind loads are transferred to the concrete basin, it may also require modifications to accept these higher loads. Also the additional ambient air for mixing may require more fan horsepower or additional cells might have to be added. Additionally, maintenance will be a continuing issue, due to the harsh environment that the coils or heat exchanger are installed in. Adding height to the towers would increase the visibility of the Units from the surrounding neighborhood. The issue of plant visibility was of concern during initial planning; and the site was lowered and a perimeter berm built to reduce the visibility.

Plume abatement technologies are best designed into the original tower for a specific plume point and the tower's design conditions. Table 3 summarizes the estimated cooling tower costs for new and retrofitted cooling towers. These estimates are based on our recent cooling tower procurement experience, and input from SPX and Enexio who have indicated that, depending on the climate conditions, a new tower with plume abatement technology would cost two to three times the cost of a conventional non-plume abated tower. SPX and Enexio further advised that, in their experience, to modify an existing conventional cooling tower to mitigate visible plume would cost more than a new cooling tower with plume abatement. This is due to the extensive modifications that would be required to adapt plume abatement technology to the existing cooling tower. If there was space on site for new plume abated tower designs, these towers would be much taller than the existing towers, which would create a visibility issue in addition to the significant capital costs.

Table 3 – Estimated Cooling Tower Costs		
	Estimated Cost per Cooling Tower Cell	**Estimated Cost for 9 Cell Cooling Tower**
New Non-Plume Abated Cooling Tower	$500,000	$4,500,000
New Plume Abated Cooling Tower	$1,000,000 to $1,500,000	$9,000,000 to $13,500,000
Retrofit Existing Cooling Tower for Plume Abatement	$1,200,000 to $1,800,000	$10,800,000 to $16,200,000

5. Performance, Maintenance and Reliability

The current identified plume abatement technologies should not affect the cooling tower performance (cold water outlet temperature) as long as the quantity of fill, circulating water flow and air flow across the fill does not change. However, the auxiliary load for the cooling tower will increase slightly for several options based on the increase in fan horsepower due to additional air being handled as well as an increase in pumping horsepower due to raising the circulating water pumping head to reach the elevated location of the pre-cooling coils and the additional pressure drop through the coils.

Maintenance costs will increase with a plume abated tower due to the addition of the pre-cooling coils, dry side air dampers and the potential addition of circulating water booster pumps.

Reliability should not change because if any of the plume abatement equipment should fail, it can be bypassed without affecting the performance of the cooling tower.

6. Conclusions

Based on current technology, we do not find cooling tower plume abatement at Santan Generating Station to be reasonably practicable by either retrofitting the existing cooling towers or building new plume abated towers.

Replacing the existing cooling towers with new plume abated towers is not feasible for the Santan Generating Station for a number of reasons. If the presence of a plume was an issue the ideal situation would be to build the new towers adjacent to the old towers while the units continue to run. There would be a significant capital expenditure for this option as well. When each new towers completed, it would then be placed in service during a short unit outage. There does not appear to be sufficient space to accomplish this at the Santan Generating Station site.

Although a lengthy unit outage can be avoided by retrofitting the existing cooling towers for plume abatement with one cell out of service at a time, tower performance will be affected during certain times of the year resulting in higher back pressures on the operating units causing a decrease of net output. The cost of modifying an existing tower one cell at a time may offset the cost of purchased replacement power during a long unit outage when constructing a new plume abated tower with the existing tower out of service. However, discussions with major tower OEMs indicates that the cost of modifying an existing tower most likely would be more than the cost of building a new plume abated tower.

We further conclude the following with respect to cooling tower plume abatement:

- In general, due to the high cost of plume abated cooling towers, they have only been installed in places where the location and climate conditions have resulted in a public safety issue regarding visibility or icing.
- Since the cooling towers at Santan Generating Station do not present a visibility or safety issue, the high cost of cooling tower plume abatement is not justified for the relatively short period of time per year when visible cooling tower plume may be experienced. The previous assessment pointed out that these units operate in climate conditions that are usually warm with low humidity.
- Discussions with major OEMs indicated that there has not been any significant improvements or developments in retrofit technologies or reductions in cost associated with cooling tower plume abatement retrofit options since SRP’s prior Condition 20 assessment.
- Plume abatement technologies are best designed into the original tower for a specific plume design point and the tower’s design conditions. A new cooling tower with plume abatement technology would cost two to three times the cost of a new conventional non-plume abated tower.
- Based on the experience of SPX and Enexio, to modify an existing conventional cooling tower to mitigate visible plume would cost more than a new cooling tower with plume abatement. This is due to the extensive modification often required to the existing tower structure.

- New plume abated cooling towers are not a practical solution for Santan due to the lack of available real estate adjacent to the existing towers, and that they would be taller than the existing towers. This additional height would result in the plant being more visible to the nearby community.
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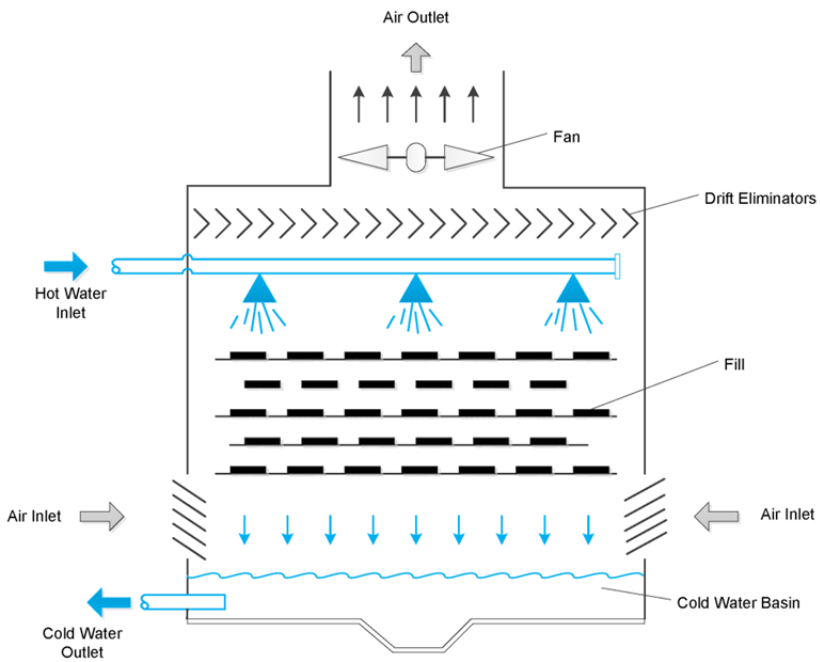
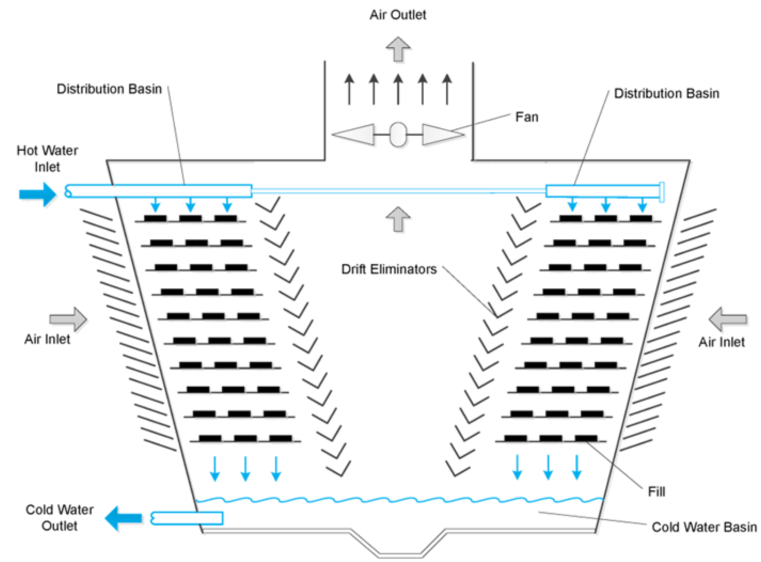
As part of SRP's continuing obligation to explore cooling tower plume abatement technology throughout the life of the plant, SRP will monitor and evaluate technological advances in the cooling tower industry and re-evaluate Condition 20 every 5 years to coincide with the 5 year frequency as stated in Condition 38 – Emissions Improvement.

Exhibit 1 – Diagram of Conventional Counter-Flow and Cross-Flow Cooling Tower Designs

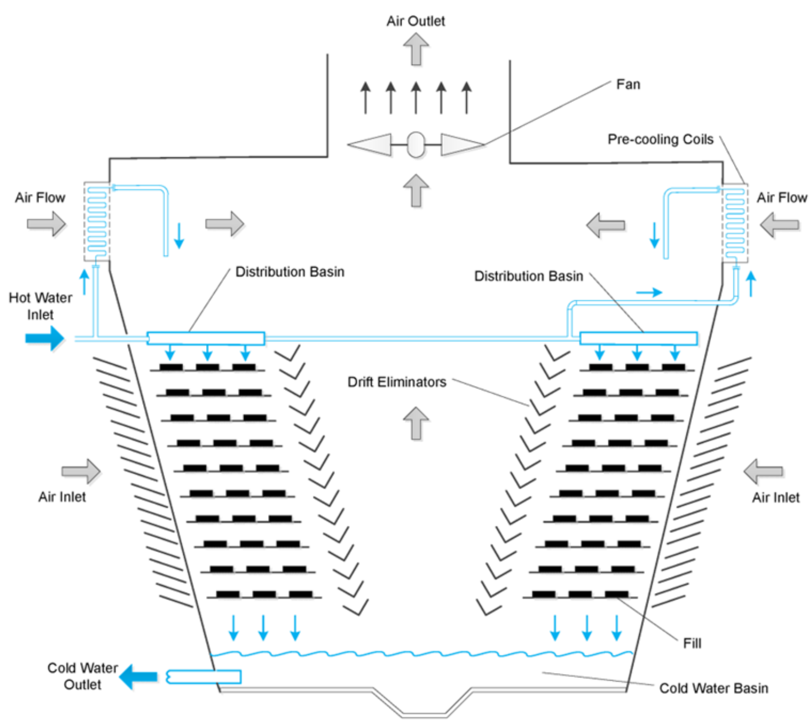


Conventional Mechanical Draft Counter-Flow Cooling Tower

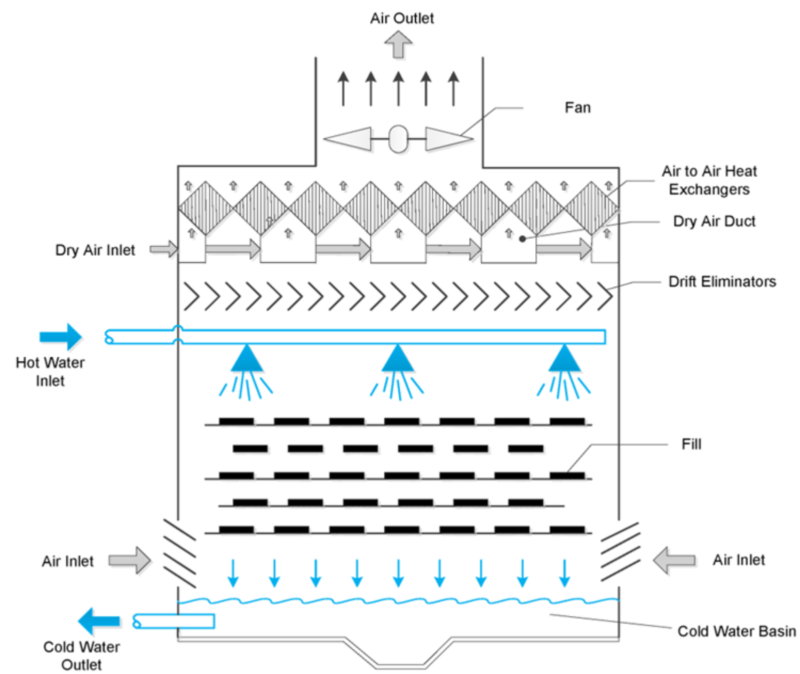


Conventional Mechanical Draft Cross-Flow Cooling Tower

Exhibit 2 – Diagram of Current Available Retrofit Technologies for Cooling Tower Plume Abatement

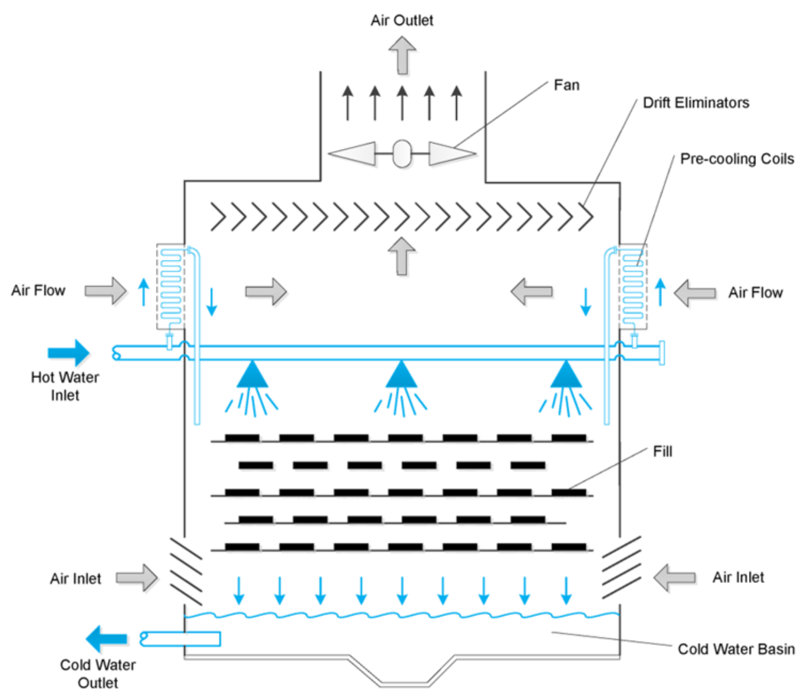


Option 1 - Pre-Cooling Coils Installed on "Short Walls" Above Distribution Basin

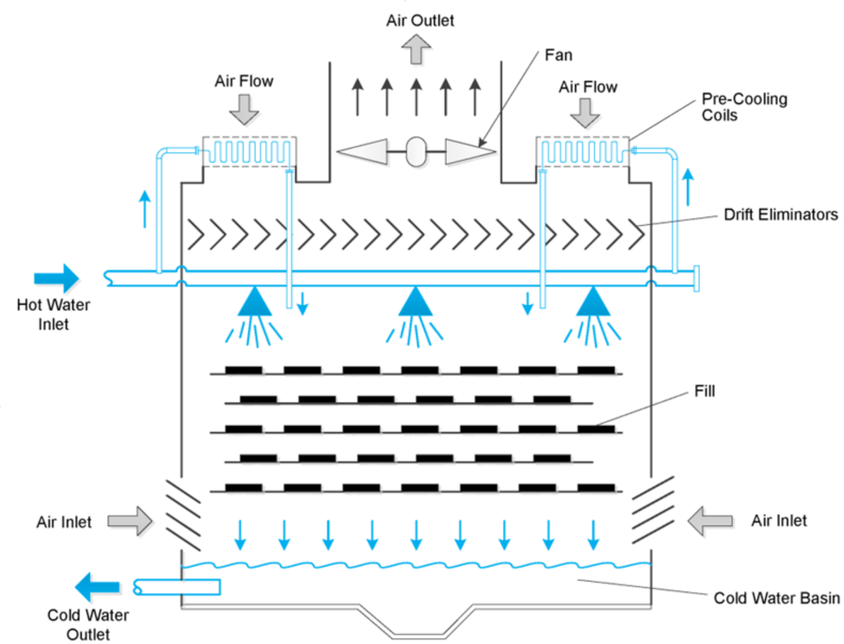


Option 2 - Air to Air Heat Exchanger (i.e. Marley ClearSky®)

Exhibit 2 – Diagram of Current Available Retrofit Technologies for Cooling Tower Plume Abatement

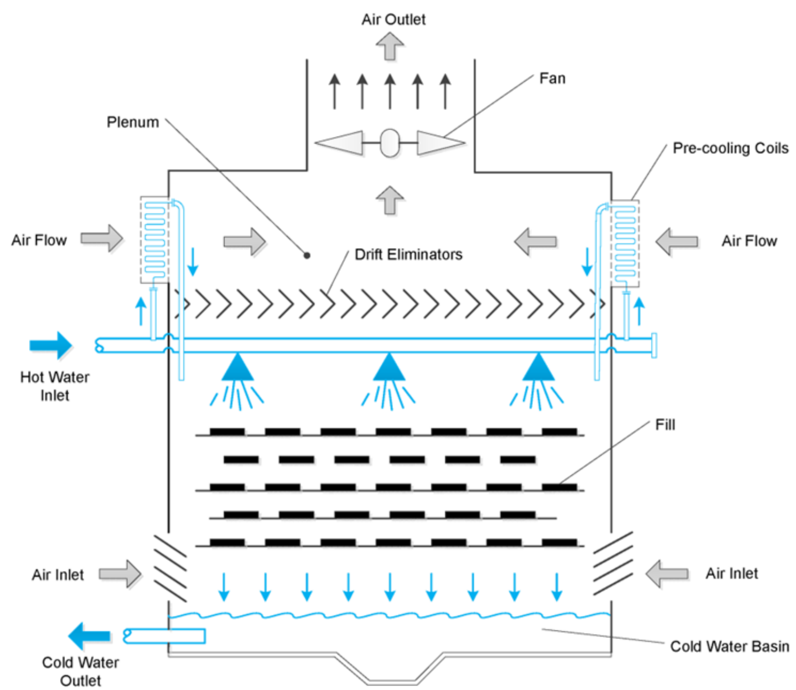


Option 3 – Pre-Cooling Coils Installed on Side Walls Above Distribution Header

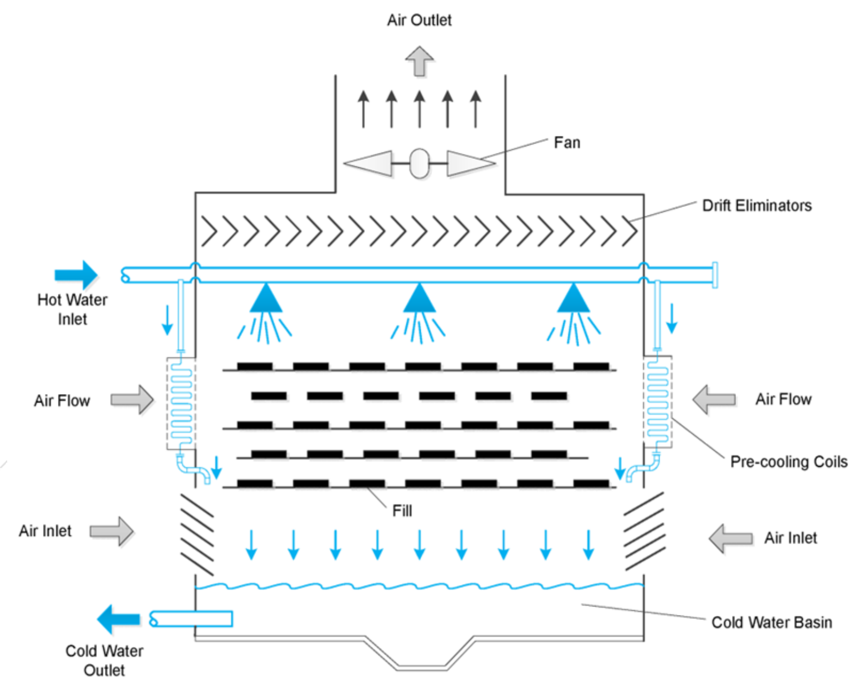


Option 4 – Pre-Cooling Coils Installed on Fan Deck

Exhibit 2 – Diagram of Current Available Retrofit Technologies for Cooling Tower Plume Abatement



Option 5 - Pre-Cooling Coils Installed in Plenum



Option 6 - Pre-Cooling Coils Installed in Fill Area