

50 REASONS YOUR COOLING TOWER DOES NOT WORK RIGHT

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SUMMARY:

This report lists at least 50 reasons a cooling tower may not be working properly. The reasons vary from basic engineering theories to economic considerations to operating problems for both the cooling tower and the plant.

OBSERVATIONS:

Cooling towers are simple devices.

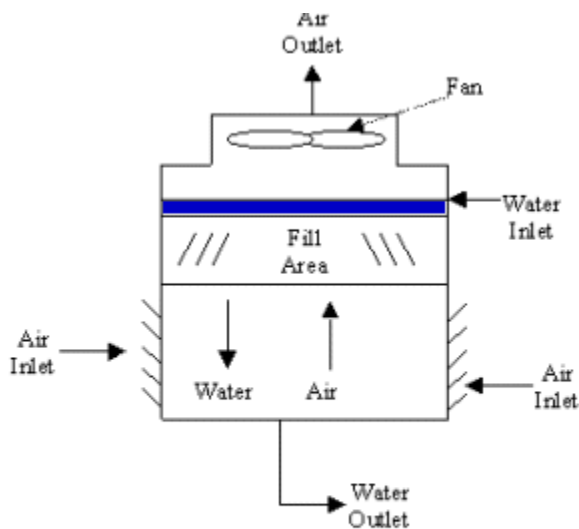


Figure 2: Mechanical Draft Counterflow Tower

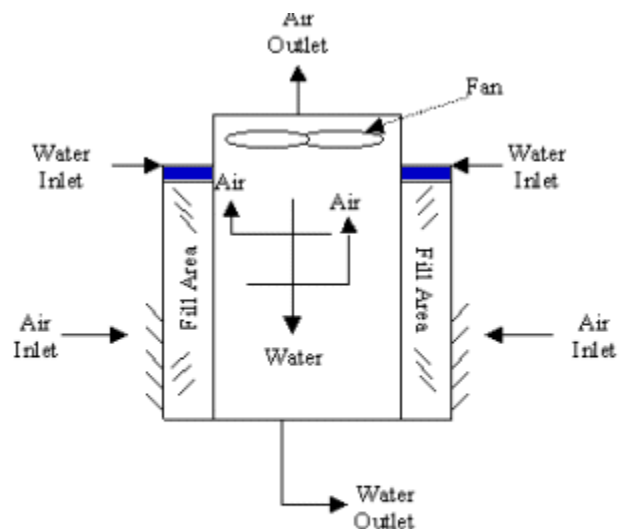
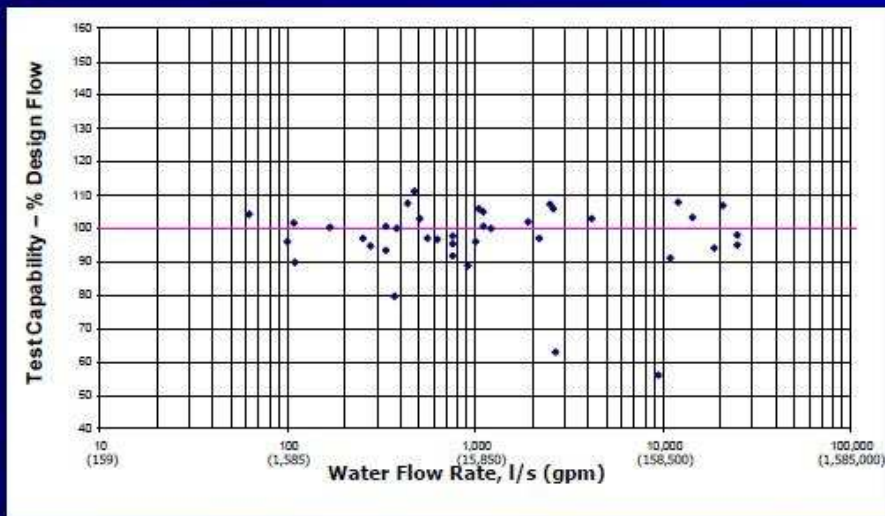


Figure 3: Mechanical Draft Crossflow Tower

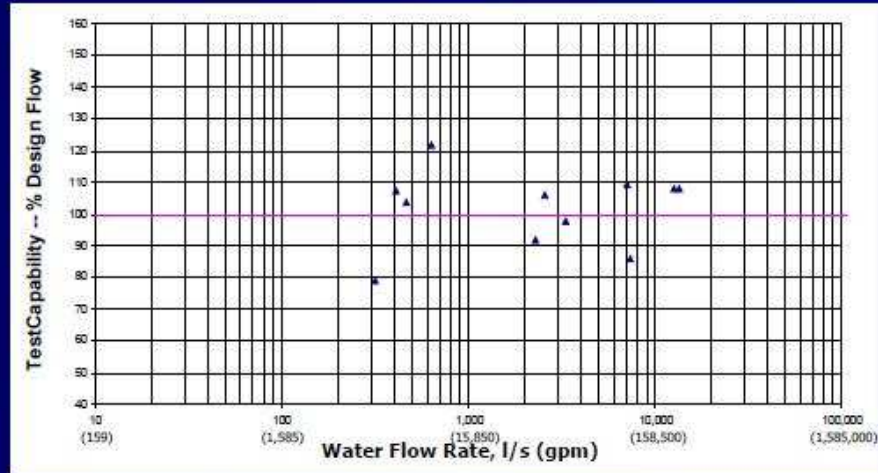
They work on the same principal you feel when you get out the swimming pool -- some water is evaporated and it makes you feel cold. It took energy away from your body when the water evaporated. A cooling tower works basically the same way. In a cooling tower we spray water over what we call the "fill" material and we speed up the process by blowing air through the fill. The basic theory is based on the "wet bulb" temperature (put a wet wick over the end of a thermometer and blow air over it). The wet bulb is usually quite a bit lower than the "dry bulb" temperature you are used to hearing about from the daily weather report. It is the ultimate low temperature heat sink for your system.

Every year a report is written by the Cooling Technology Institute summarizing the results of tests by their licensed testing agencies, and there really is not much difference in the results year after year. These tests are shown for new tower, rebuilt towers and towers tested just to find out how they are performing now. The results for 2008 show that a significant number of new towers were performing at less than 100% capacity and some of them were as low as 60% capacity. The results for rebuilt towers were not any better. As expected a lot of older towers tested were not performing as required and need repairs.

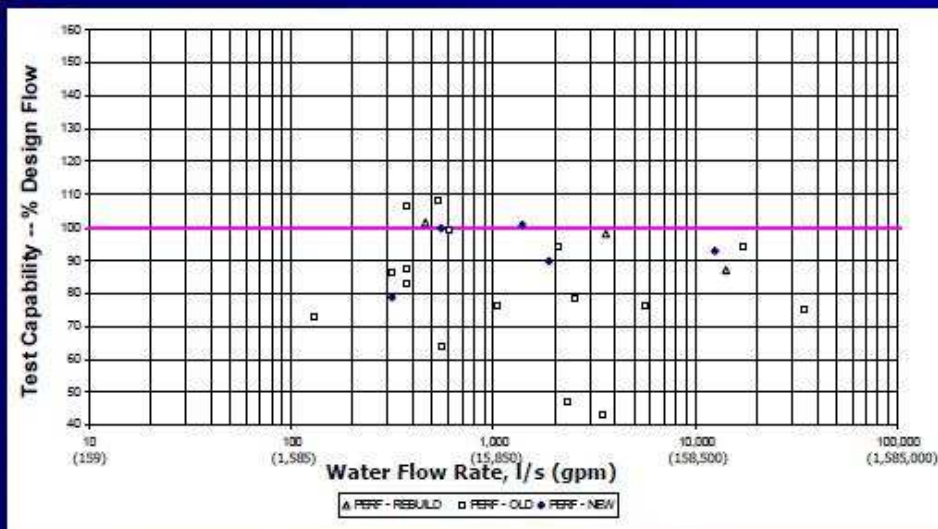
Thermal Acceptance Tests New Towers



Thermal Acceptance Tests Rebuilt Towers



Thermal Performance Status Tests

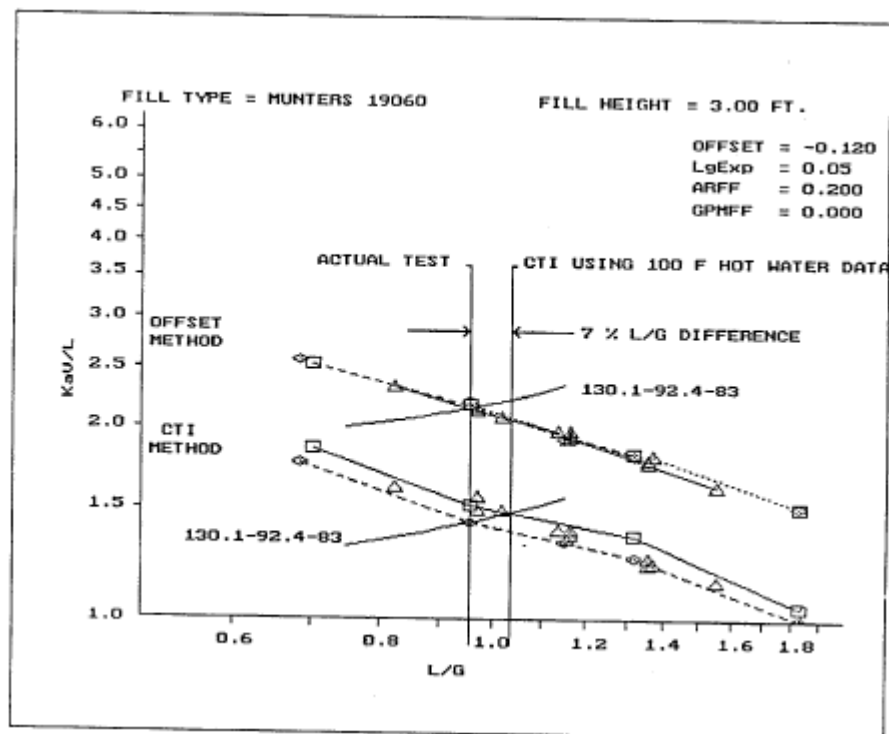


How do we explain these deficiencies?

BASIC THEORY:

We do have a basic theory of how to design a tower that will be the right size for your project. We perform laboratory tests and scale the results to large size towers. If it is done right we can come within 2% or less of the predicted capacity; Proper use of the psychrometric properties of moist air applied to both the fill and the fans can account for proper performance at any elevation if the proper theory is used.

In some cases, where the hot water temperature going to the tower is over 100° F, the standard *simplified* theory some manufacturers use may not be adequate, and they need to apply what we call a “hot water correction factor”. Not all of them know about this and some of them ignore the fact that the deficiency could cause capacity shortages of 5% to 10%.



The problem stems from a simplification of the original theory which left out several components such as the amount of water evaporated, some transport items like the Lewis number, and several others that we don't need to get involved with in this discussion.

$$\frac{KaV}{L} = \int_{T_1}^{T_2} \frac{dT}{h_w - h_a}$$

$$\frac{KaV}{L_{in}} = \int \frac{di}{L_{in}/G * [(i'_s - i_a)Le + (W'_2 - W_1)C_{pv}T]}$$

It is sufficient to know that some manufacturers do not use the more sophisticated system, and for this reason some of their designs may not perform as predicted.

Not all towers fail to meet their predicted capacity. With a proper data base, refined theory, and proper selection of components it is possible to build a tower that will perform as predicted. If you want something to perform at 100% capacity or higher, put some penalty provisions in the contract and you should get what you ask for. You usually get what you pay for, but not always what you ask for.

MARKET CONSIDERATION:

Basic design may not be the problem. Consider the possibility that the manufacturer needed a job, and he was willing to take a risk that he won't get caught. Performance in a cooling tower is proportional to the price on a 1 to 1 basis. If you cut the performance 1% the cost goes down 1%. A one percent change can be the difference in winning or losing a job. When you get several manufacturers doing the same thing you get a downward spiral in the tower size. It has been this way consistently for over 50 years. The manufacturers know a lot of towers do not get tested. It has been said many times that cooling tower performance is a function of the business cycle. The 2008 and 2009 test reports were no different than the others, and it can be predicted that next year will be worse because of the current economic problems.

The solution is to thoroughly review your bids, and maybe consult with someone who has a data base and the computer tools to review the designs. As a minimum you should compare the selections to each other. Some good practical limits will be provided later in this report.

You should also review the performance curves the manufacturer provides to see if they are "pulled" in a manner that shows the tower would pass a test when in fact it did not. Your cooling tower consultant can check for this.

DESIGN CONDITIONS:

There are a lot of other reasons your cooling tower is not meeting your needs.

Did you select the right design condition, and is your cooling system performing as expected?

Many operators say their cooling tower is not working when it really is. When they say it is only cooling 8 degrees when it should be cooling 10 degrees they may be lacking a basic understanding of what a cooling tower does – or does not do.

The cooling tower does not set the heat load. It will reach equilibrium at temperatures that get rid of all the heat you put on it. The tower size or capability sets the level or approach of the cold water temperature to the wet bulb temperature. If your tower is too small or not in like new condition the heat may go off as steam, but it will get rid of all the heat you put on it. If your tower is too big you spent too much money or you can cut down on the air flow and save parasitic energy.

If you increase the gpm, the range (hot water temperature minus cold water temperature) will decrease, and visa versa. Maybe your operator did not realize someone turned on another pump – so the range went down. The tower may not be working as you expected, but it is working properly.

On the other hand, maybe your process changed and you have more heat than expected. What happens? The hot and cold water temperatures both rise, with the hot water going up more than the cold water.

Maybe your plant was designed for a low wet bulb temperature, and an unusual or ignored summer day has a high wet bulb temperature. Both the hot and cold water temperatures will rise. This is not unusual – maybe it is more economical to choose a low design wet bulb, with a resulting smaller tower, but do not ignore the possibility of an unusually high summer condition that would shut down your plant because some piece of equipment went off on high head pressure or you cannot condense your product.

TOWER ORIENTATION:

Another design condition that often gets ignored is tower orientation. In general it is best to orient your tower with the longitudinal axis parallel to the direction of the prevailing daylight summer winds. The “plant beautiful committed” may want it aligned with the rest of the plant when the practical idea is to avoid *recirculation* of the fan discharge air back into the air inlets or *interference* of the discharge from one tower into the air inlet of an adjacent tower. Unusual recirculation can increase the inlet wet bulb temperature as much as 8 degrees F (4 degrees C).



Try to avoid orientation perpendicular to the prevailing wind. Recirculation also gets very high for counterflow towers with back to back configuration – 4 F to 8 F is not unusual – and they should be avoided if the plot area permits.

Try to avoid situations where the inlet air is being blocked by other structures or it is located where the exhaust from an adjacent hot stack or other heat source is sucked into the tower. If you must have an architectural enclosure around the tower then be sure it has plenty of free air inlet to avoid affecting the air flow to the louvers or excess pressure drop on the fan. Cooling towers need to breathe fresh air.



It is also best to avoid structural interference like a structural beam above the fans which can affect air flow and induce stress on the fan blades.

TOWER CONFIGURATION:

You can have a big tower with not much air flow or a little tower with high air flow. Both will do the same duty. The art is to pick the economic box size. If you give your manufacturer the economic evaluations for fan and pump power he can optimize the design for your project.

There are design limits that sometimes get ignored in trying to come up with a competitive tower, and these do cause performance problems.

For example:

Air inlet velocities in a counterflow tower should not exceed 1050 fpm because it causes air to by-pass the outer few feet of fill and this is usually a large percentage of the total fill area. If air velocities in a cross flow tower are too high it can pull the water off the fill and cause excessive drift.

The upper plenum height of a counter flow tower needs to be high enough to allow smooth transition to the fans from the corner of the tower. Even air flow distribution is necessary to maximize performance and what happens in the upper plenum affects the air flow below the fill.

The fan plenum for a cross flow tower needs to be wide enough to let the air flow smoothly for the full fill height. A narrow plenum forces all the air to the top, and a major portion of the fill will not get the proper air flow. Also the length of the cell of a cross flow tower may require a raised fan deck to allow the air from the end bays to get to the fan entrance without high velocities that will impede the air through the fill.

The air takes the path of least resistance. It does not always go where you draw the arrows.

Picking the right fill height is important for both crossflow and counterflow towers. In addition, the air travel is important for the cross flow. Actually, it is the height to air travel ratio that needs to vary for a crossflow tower based on the difficulty of the design temperature conditions.

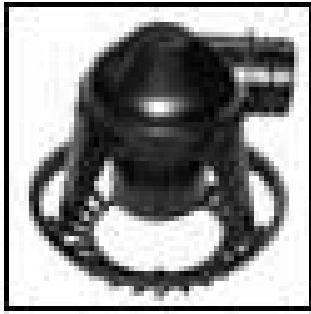
If your manufacturer doesn't provide enough fill you need to have a box that is big enough to add some more and this is seldom the case when you discover your tower is not working properly. If you think the design is marginal, be sure there is someplace you can make an adjustment by either adding more fill or adding more air flow (more fan power) or leave room for one or more cells.

Some of the things that are hard to fix after the tower is built are

- The box is too small
- The fans are too small
- The motors are too small
- The gear box does not have sufficient service factor or the manufacturer used optimistic gear efficiencies.
- The manufacturer used fans that were not as efficient as the fan manufacture said they would be or they are not running in the "sweet spot" of the fan curve.
- The manufacturer did not know the actual air side pressure drop of all of the components.

DISTRIBUTION SYSTEM

Good (even) water distribution is usually a major key to good performance. In crossflow towers the problem is to space and size the nozzles so all areas of the fill get even distribution and if you are using film-type fill it is necessary to get the water evenly between ALL the sheets. In counterflow towers a significant portion of the cooling can come from the nozzles. There are good nozzles and there are cheap nozzles. Some nozzles allow reasonable flow variations, but most do not. The requirement to evenly wet all of the fill sheets all the time is the same for both cross flow and counterflow towers – it is very important.



The piping system in a counterflow tower should have velocities that allow even pressure all across the top of the tower. This is very important for even water distribution. For large projects lower nozzle pressures are important to minimize pumping power.

Nozzle plugging is often a major problem. It can be caused by oil or chemicals in the water, sludge, algae, small nozzle orifices, plastic sacks, work gloves and even hard hats. Nozzles should be checked at least once a year for plugging.

Water balance between the cells is important. If your main pipe header feeds the tower from grade at one end and there are individual cell risers, there is a great chance that the last cell will get a lot more water than the first one. The Willa method suggests installing a fitting so a clear plastic tube can be attached to the inlet pipe to each cell. Extend the tube up through the fan deck access door and attach it to the hand rail. You can then see the water column in the tube, and you can adjust the valves for even head on all cells.

AIR FLOW:

In a cooling tower air flow is directly proportional to performance. If you are down 1% on air flow you are down 1% on performance.

There are many reasons to have air flow problems:

Fan problems are the first place to look. Maybe the original tower designer used the fan manufacturer's standard fan performance curves. There is a very good chance these curves were based on tests in what we often call "ideal eased inlet" fan cylinders with very close tip clearances. Fan efficiencies may be stated to exceed 90%. Such high efficiencies are unachievable in cooling tower applications.

Typical tip clearances for industrial sized towers are $\frac{3}{4}$ " to 1-1/2" depending on the diameter. These tip clearances are necessary to allow for fan cylinder deflections during high wind conditions. The larger tip clearances can reduce fan performance and efficiencies 5% to 8%. It is the responsibility of the cooling tower designer to make the necessary adjustments to his design to account for these significant differences. If you are buying replacement fans do not be misled by unadjusted curves that claim efficiencies exceeding 85%. Efficiencies closer to 75% would be normal.

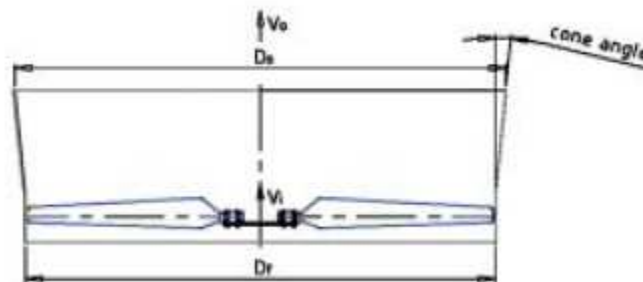
Be sure your fans are installed properly with the correct pitch on all blades, all blades tracking on the same plane, and center hub seals in place.



Center hub seals are necessary to keep air from recirculating back down the center of the fan, and if they are not in place the performance can be reduced 5% or more.

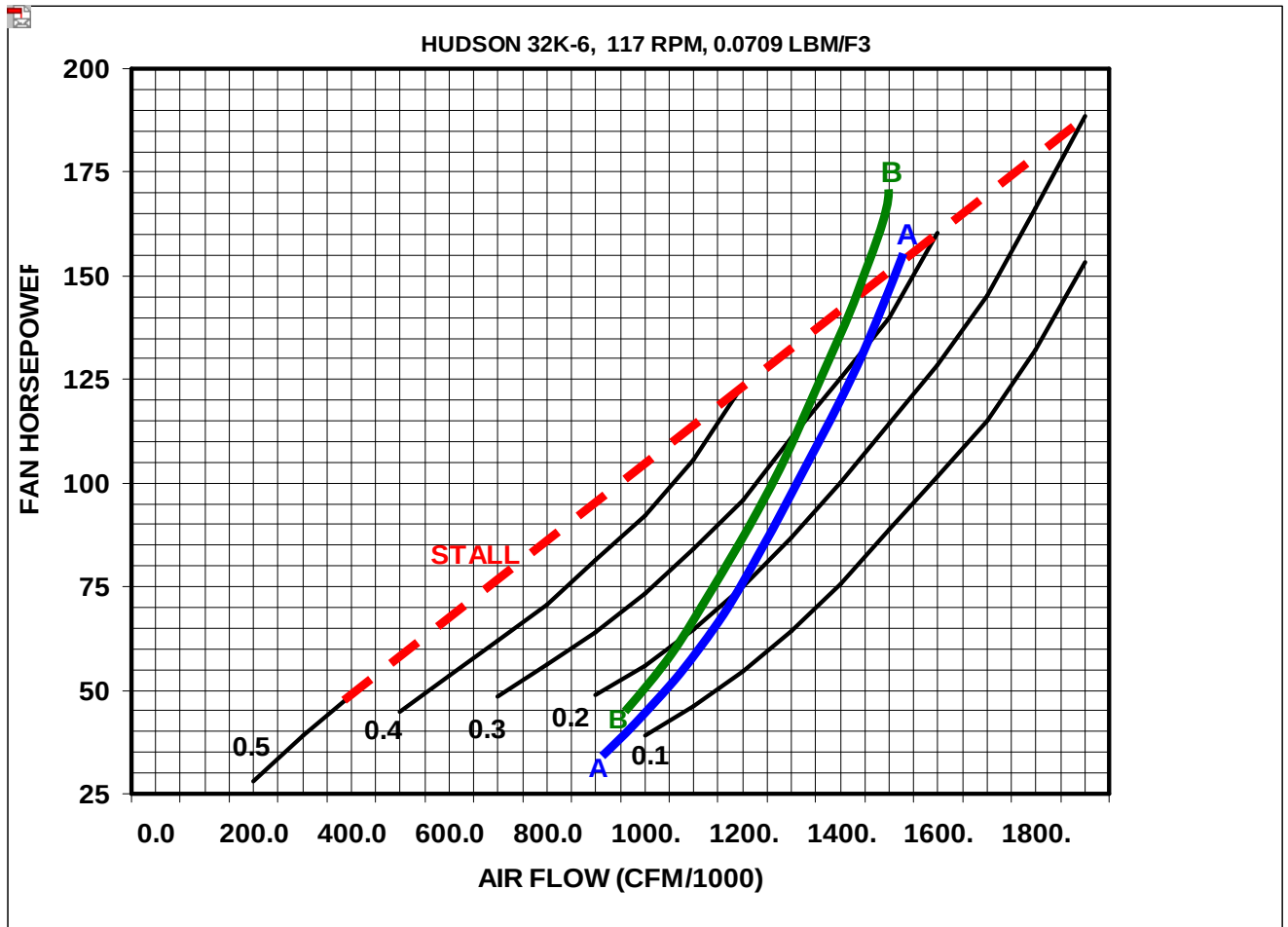


If fans are more than 24 feet in diameter it is advisable to install fan stacks that are at least 10 feet tall to avoid high winds from “spoiling” the air flow at the blades. Also, taller stacks can recover as much as 70% of the velocity head and thus increase the tower performance. 14 ft to 20 ft tall stacks are common.



Other places to look for fan problems is leading fan blade edge wear from water erosion, tight meshed fan guards that add unaccounted additional static pressure loss, drive shaft holes that are too big and allow excessive air flow from outside the stack.

If the fill has been changed it might not be same as what was originally provided, and the pressure loss differences compared to the original fill may greatly affect the fan performance.



Air velocities can go up and cause excessive drift, and they can be forced down by high static pressure and require a different fan pitch and more fan power. Such a change may put the fans into stall which would require higher fan speeds that may result in excessive blade loadings, or they may require revised gear boxes and drive shafts, and motors. You are cautioned to remember that a cooling tower works as a system, and what changes in one place causes changes someplace else. What you changed may be worse than you expected. It is recommended you consult an expert before making fill, fan spray system modifications.



One of the first places to look for performance problems is plugging of the fill by scale, algae, sand, or dirt. With the now common use of high efficiency film fills plugging has become prevalent. It can be visible from the top or bottom, or it can be hidden at the joints between the fill packs, especially if they are installed in alternating directions for each layer. Check your tower often to find these problems before they reach an un-repairable state. Failure to use adequate blow-down or ignore water treating can be very expensive. Side stream filters can help remove excessive particulate in the circulating water system to help prevent plugging. Keeping the water flow rates above 3.5 gpm/sq ft can help keep the fill “washed”. It would be best if the water flow rate is higher, but remember this is a function of the required performance which is not related to what you need to keep your fill clean. You may not have control over the flow rate over the fill area.

If you cannot keep your fill clean it is suggested you try another fill design or change to splash type fills. These are radical changes and the existing “box size” may not be adequate to make this change without adding additional cells. However, it must be remembered that a fill that plugs is not acceptable and will cost you more in the long run. Be practical and buy what you need for your operating conditions, even if it cost a lot more. Nothing is more expensive than a non operating plant.



Vertical flute designs with microstructure



Offset flute designs

Air flow can also be affected by the air inlet louvers, if you have them. They can be plugged by scale build-up, ice in freezing weather, improper installation of the louvers to stop splash-out, obstructions from sprinkler system houses, conduit supports, riser pipes, water treating tanks or other plant equipment. All of these obstructions affect the air flow to the fill. Once again the tower must freely breathe fresh air.

Even the water level in the cold water basin can affect the air flow. Your tower was probably designed with the intent of having the water level one foot below the top of the cold water basin curb. If your pumping and piping system was not designed properly you may have to increase the water depth to get proper flow to your other equipment or prevent surging of the water flow rate from the basin, and this takes away from the available air inlet area. The increase in air inlet velocity can create air by-pass of the outer fill sheets as mentioned before. Of course the basin free-board needs to be adequate to handle water rise on tower shut down, and the basin needs to be deep enough to handle draw-down of the water level on start-up so the piping

and fill and water can collect on the fill sheets. The head over the suction pipe needs to be adequate to prevent vortexing and cavitation at the pump.

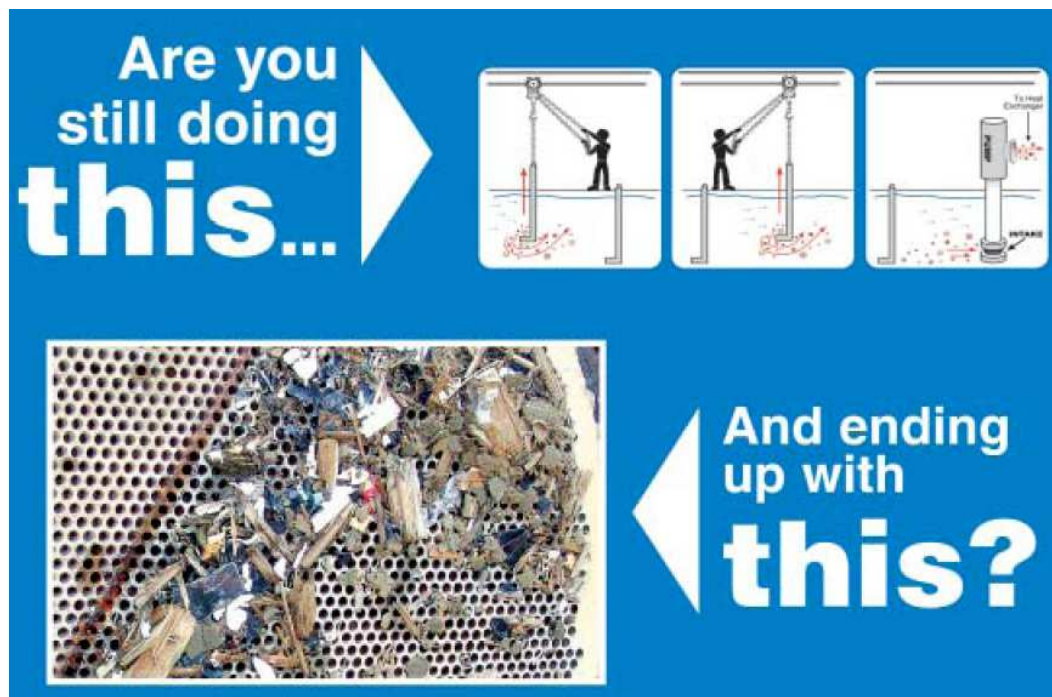
Fan power draw is affected by the motor efficiency. It is recommended that you use new, high efficiency motors. Re-wound motors are often much less efficient than new motors.

THE SYSTEM

Your cooling tower operates in a system. It is affected by other equipment, and it can affect the other equipment. If you have PVC fill and drift eliminators that are deteriorating and small pieces are plugging your heat exchangers your output will be affected.

Proper water treatment is critical. You may need side stream filtration because of blowing sand and dust or impurities in the make-up water it. Plan for it in the initial plant design. The tower is usually the first place you see bad water, but it has probably caused problems in your heat exchangers first. If your total dissolved solids get too high they may affect performance because the vapor pressure of water is affected and this reduces the enthalpy driving force between the air and water. A 25% salt concentration can reduce performance as much as 20 percent.

If you foul your heat exchanges because of bad water treatment it will affect the water flow to the tower as well as the heat transfer in the exchangers.



If your water is not cold enough it can cause your system to shut down or your production to be decreased. There is probably in infinite list of interactions between the tower and other equipment that could cause tower operating problems.

RECOMMENDATIONS:

Analyze your tower proposals for adequate thermal performance and design before you buy a new tower or rebuild an old one. Use someone who understands performance issue and can check the manufacturer's performance curves. Use a competent cooling tower expert to review your specifications and plant layout. They can save you time and money.

It is recommended that you plan on paying for a thermal performance test by a qualified testing agency or engineer.

Put teeth in your contract that covers all the expenses you would incur if the tower did not pass a performance test including wiring, starters, controls, piping, concrete basin, etc.. What would you do if it did not pass a test? Could it be fixed?

Encourage plant operators to frequently inspect the tower. Teach them what to look for. Be sure they read the O&M manuals.

This report lists at least 50 ways your cooling tower may not be working. You probably can find others if you look closely at your tower and your system.

ABOUT THE AUTHOR:

Richard J. DesJardins has over 50 years experience with cooling towers and evaporative cooling equipment. He received a BSME at the University of Colorado and MBA at the University of Missouri - Kansas City. He formed his own company in 1984 after working for twenty-five years with the Marley Co and its subsidiaries. He has represented several different cooling tower, heat exchanger and industrial equipment manufacturers, been Principal Engineer for an air pollution control company, and designed and fabricated several different types of evaporative cooling equipment. He is the author of cooling tower and psychrometric computer programs and technical papers published by the Cooling Technology Institute.