DOCKETED

Docket Number:	15-WATER-01
Project Title:	Water Energy Technology (WET) Program
TN #:	205058
Document Title:	Baltimore Aircoil Company Comments on Three Proposals to Meet Objectives and Requirements of the WET Program
Description:	N/A
Filer:	Patty Paul
Organization:	Baltimore Aircoil Company/Larry Wei
Submitter Role:	Public
Submission Date:	6/17/2015 8:54:15 AM
Docketed Date:	6/16/2015

BALTIMORE AIRCOIL COMPANY

7600 Dorsey Run Road Jessup, MD 20794 · tel 410.799.6200 · fax 410.799.6416 · www.BaltimoreAircoil.com

June 15, 2015

Pamela Doughman
California Energy Commission

Water Energy Technology (WET) Program

Baltimore Aircoil Company (BAC) designs and manufactures a complete product portfolio that helps our customers save both energy and water. BAC has three proposals to meet the objectives and requirements of the WET Program relative to evaporative cooling equipment on both new and existing installations.

1. **Hybrid Closed Circuit Cooling Tower Optimizes Energy and Water Usage**
2. **EVERTOUGH™ Construction Reducing Corrosion and Increasing Cycles of Concentration Thus Reducing Water Usage**
3. **Energy and Water Savings Retrofit For Cooling Towers**

We appreciate consideration of these existing solutions that have proven to save energy and water and will also make an immediate and significant impact when implemented. Thank you for your consideration and we look forward to feedback and questions.

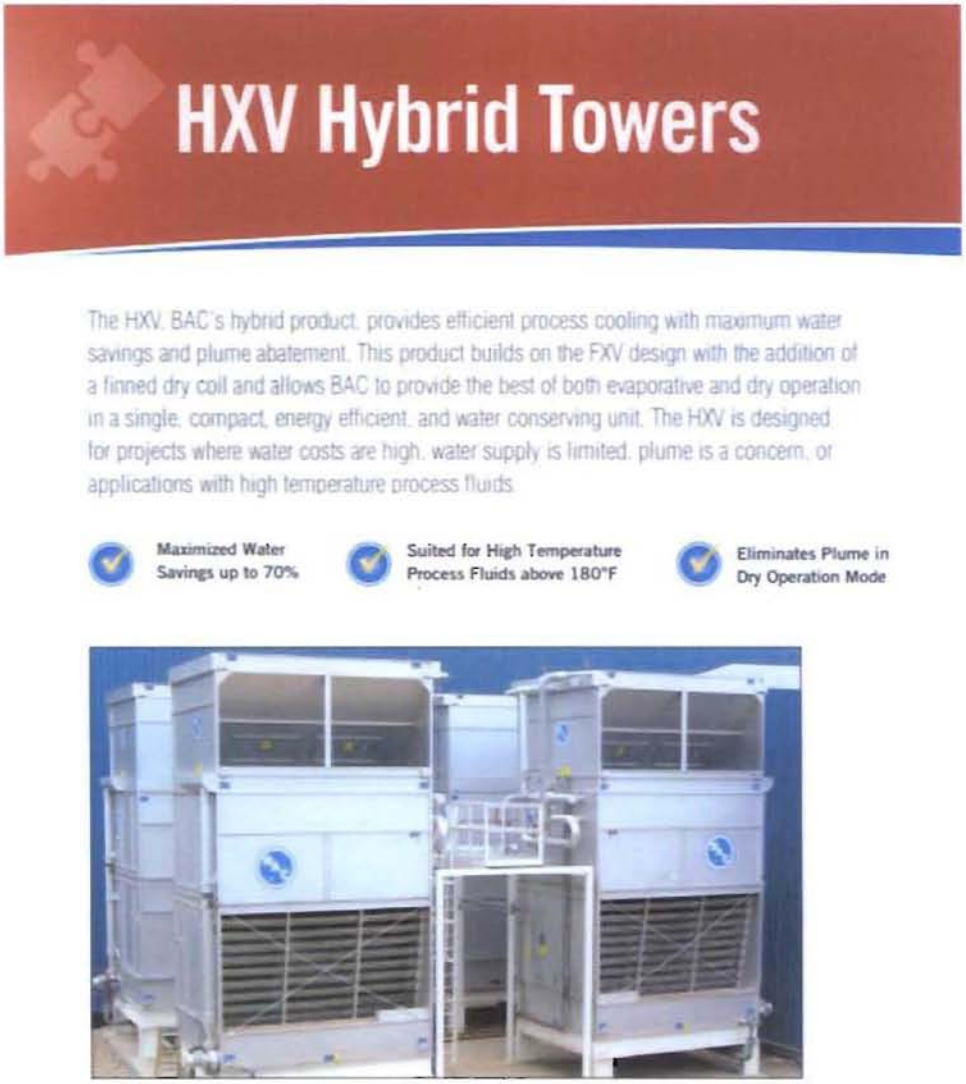
Sincerely,

Larry Wei
Director of Marketing

1: Hybrid Closed Circuit Cooling Tower Optimizes Energy and Water Usage

The HXV Hybrid Closed Circuit Cooling Tower has both evaporative (wet) and dry heat exchange sections that increase the efficiency of the system and allows the tower to operate in a number of modes to optimize energy and water usage.

Benefit: For San Francisco, CA, the HXV Closed Circuit Cooling Tower will operate dry approximately 50% of the time. A 900 gpm system will save approximately 500,000 gallons of water annually at 93°F/85°F/78°F design conditions compared to traditional closed circuit cooling towers.



Multi-cell HXV Installation

HXV Hybrid Towers

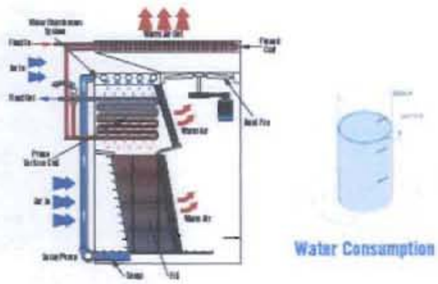
MODES OF OPERATION

COMBINED WET/DRY MODE:

- This mode employs the use of both coils, the dry finned coil and the prime surface coil. Water is sprayed over the prime surface coil, allowing evaporative cooling to occur, before falling over the fill, further cooling the spray water.

BENEFITS:

- Provides the most capacity by employing the use of both coils. Water is saved in this mode as the finned, dry coil, reduces the amount of heat that needs to be rejected in the prime surface coil. Flow through the wet coil can also be controlled and adjusted as ambient temperature and/or heat load drops.



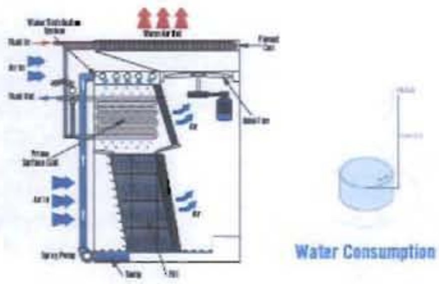
Combined Dry/Wet Operation Mode

ADIABATIC MODE:

- In this mode, the process fluid bypasses the prime surface coil, and instead only circulates through the dry finned coil. Recirculating water saturates and adiabatically cools the incoming outside air, reducing the air temperature within 2-3°F of the wet-bulb and greatly increasing the rate of sensible heat transfer.

BENEFITS:

- Provides a middle capacity range when outside temperatures will not allow for dry cooling.



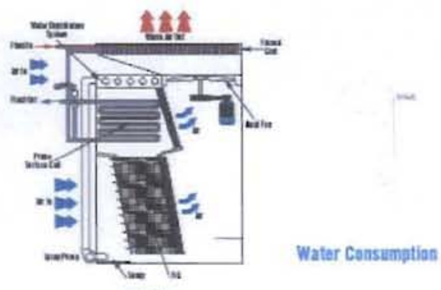
Adiabatic Mode

DRY COOLING MODE:

- In this mode, the spray water is turned off, saving pump energy, and the fluid to be cooled is circulated through both the finned and prime surface coils. Both coils receive full flow, utilizing the maximum heat transfer surface area.

BENEFITS:

- No water consumption occurs in this mode and plume is completely eliminated. This is the best mode of operation during extremely cold weather.



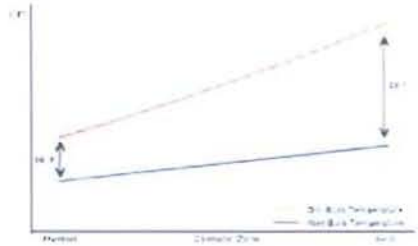
Dry Mode

HXV First Cost Benefits

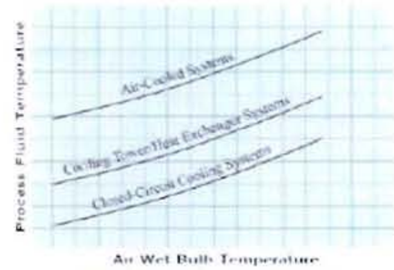
Heat rejection equipment must be selected for the maximum heat load at summer peak air temperatures. In most climates peak wet-bulb temperatures are significantly lower than peak dry-bulb temperatures. Evaporative cooling equipment based on the ambient air wet-bulb therefore has a greater temperature driving force, allowing the use of lower system temperatures. This greater driving force also allows the use of less heat transfer surface area. Since the HXV utilizes evaporative cooling during peak load operation it inherently benefits from this advantage. Evaporatively cooled units such as the HXV have a plan area and fan horsepower advantage over the typical air-cooled arrangement, saving on support structures and electrical hook-ups. The HXV design also avoids the corrosion and scaling that can be associated with spraying of standard air-cooled equipment on design days for additional capacity. The lower process fluid temperatures that can be achieved compared to air-cooled systems and the greatly reduced fouling factors of closed loop cooling result in lower first cost of process equipment such as chillers or refrigeration compressors. Lastly, the costs associated with plume abatement are eliminated, as the design is inherently plume-free.

HXV Operating Cost Benefits

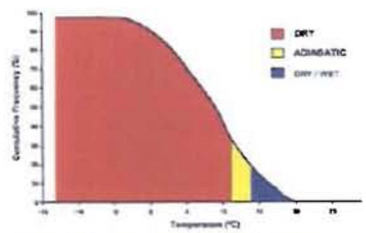
Due to its water saving concept and combined flow design, the HXV offers significant operating cost benefits. Water consumption is minimized throughout the year. During peak summer operation a large amount of heat load is already transferred by the finned coil. As the ambient temperature and/or heat load drops, the amount of evaporative heat transfer is further reduced by controlling the flow through the wet coil. This reduces the evaporation loss and blow-down as well as water treatment requirements compared to conventional evaporative cooling equipment. In the adiabatic mode only a small amount of water is needed to saturate the air and the amount of blow-down is reduced even further. Finally in the dry mode no water is used at all (while saving the energy associated with running the spray pump). With HXV hybrid units, water savings up to 70% as compared to traditional closed circuit systems is possible. Depending on local water costs and availability, this advantage alone can pay for the equipment in as little as two years through cost savings in water use, water treatment chemicals, and higher system efficiencies. In addition, fouling potential associated with open circuit cooling towers is eliminated through both the closed loop cooling system and the Combined Flow Technology design of the HXV, assuring peak efficiency and energy savings over time. Finally, the induced draft propeller fan design results in low fan energy requirements compared to centrifugal fan units.



Dry-bulb/Wet-bulb Difference Versus Climate Zone



Closed Circuit Cooling Systems offer the Lowest Fluid Temperatures



Typical Annual Distribution of Ambient Temperature with the Three Operating Modes

2: EVERTOUGH™ Construction Reducing Corrosion and Increasing Cycles of Concentration

EVERTOUGH™ Construction combines BAC's innovative corrosion-protection features to allow for higher cycles of concentration that reduce water usage due to blowdown compared to standard materials of construction for new evaporative heat rejection units, including open circuit cooling towers, closed circuit cooling towers, and evaporative condensers. Additionally, reduced corrosion leads to reduced leakage and wasted water. Benefit: Doubling the cycles of concentration from an industry average of 3 to 6 will result in 20% in water savings. A 300 ton system will save approximately 200,000 gallons annually.

What is BAC's EVERTOUGH™ Construction?

EVERTOUGH™ Construction combines a number of BAC's innovative corrosion protection features in a single cost-effective package.

TriArmor® Corrosion Protection System

Is a proprietary polyurethane barrier that offers a level of corrosion protection for cold water basins that is superior to conventional stainless steels. TriArmor® Corrosion Protection System was specifically designed for evaporative cooling applications and has undergone accelerated testing to simulate years of operation in the harshest environments.

PFRP Composite Panels

Pultruded fiberglass reinforced polyester (PFRP) panels provide a lightweight and high strength alternative to conventional stainless steel with an added level of corrosion resistance. BAC's fiberglass reinforced panels are impervious to a wide variety of chemical and atmospheric contaminants.

Thermosetting Hybrid Polymer

A manufacturing process fuse bonds a hybrid polymer to heavy-gauge G-235 galvanized steel providing superior corrosion protection. Over the past 25 years, this corrosion protection system has been installed on thousands of units worldwide.

Warranty

Backed by a comprehensive Louver-to-Louver℠ 5-year warranty.

Component-Specific Protection

Cold Water Basin Protected with the TriArmor® Corrosion Protection System

- Backed by BAC's 5-Year Leak and Corrosion Warranty
- Meets or exceeds the level of protection provided by stainless steel
- Impervious to chloride attack

PFRP Hot Water Distribution Basins (Series 3000)

- Strength in tension and compression comparable to that of steel at a reduced weight
- Resistant to chemical and UV degradation

PVC Spray Distribution (PT2, VCA)

- Resistant to chemical and UV degradation

Thermosetting Hybrid Polymer Protected Structural Members

- Withstand 6000+ hours of a 5% salt spray test per ASTM B117
- Withstand 6000+ hours of acid and alkaline exposure
- Resistant to chemical and UV degradation

PVC Fill

- Impervious to rot, decay and biological attack

FRP Casing Panels and Louvers (Series 3000)

- Resistant to chemical and UV degradation
- Shatter resistant

PVC Sectional Air Inlet Louvers (PT2)

- Impervious to rot, decay and biological attack

3: Energy and Water Savings Retrofit For Cooling Towers

Cooling tower energy and water efficiency for the existing stock of evaporative heat rejection equipment will increase through various feature upgrades. This is analogous to retrofitting mechanical equipment with variable frequency drives (VFDs), or inspecting and maintaining economizers on packaged rooftop units to reduce energy usage. Incentives to encourage feature upgrades and retrofits will yield the most immediate and largest benefits.

ENDURADRIVE™ Fan System Retrofit– a belt or gear-drive motor/fan assembly will have inherent power transmission losses by design. The ENDURADRIVE Fan System retrofit kit is a direct-drive solution that includes a new mechanical support, a new direct-drive fan/motor assembly, and a custom-programmed VFD, eliminating power transmission losses associated with gears and belt systems.

Benefit: 10% energy savings by eliminating mechanical losses from power transmission components.

PAPER NO: TP09-18
CATEGORY: FANS

COOLING TECHNOLOGY INSTITUTE

RECENT DEVELOPMENTS IN MOTOR TECHNOLOGY ALLOW DIRECT DRIVE OF LOW SPEED COOLING TOWER FANS

ROBBIE MCELVEEN
BILL MARTIN
RYAN SMITH
BALDOR ELECTRIC

©

Presented at the 2009 Cooling Technology Institute Annual Conference
San Antonio, TX - February 8-12, 2009

Abstract - **Improved reliability of cooling tower fan drives is now possible due to new advancements in motor technology. This paper discusses the development of low speed, permanent magnet motors and how they can be used in direct-drive applications to eliminate the gearbox, NEMA motor, driveshaft, and disc couplings from cooling tower designs. A case study is presented where a tower was refurbished using a direct-drive motor designed to fit the exact footprint and height of the existing gearbox. Design considerations, performance data, maintenance, and efficiency comparisons will be discussed.**

I. INTRODUCTION

The most common solution for driving the fan in current cooling tower designs utilizes an induction motor, driveshaft, disc coupling, and gearbox arrangement, as shown in Figure 1. Few changes to this design have been made in the last twenty years.

Figure 1: Typical Fan Drive Arrangement

The motor used is normally a standard NEMA induction motor. For reduced energy consumption, two speed motors have been applied for use when full fan speed is not required due to decreased heat load. As the horsepower required to drive the fan varies as the cube of the fan speed, it is advantageous to reduce the fan speed when possible. When the heat load decreases enough, the drive motor can be run at half speed. This lowers the horsepower required to only 12.5% of the rated value [1]. However, when any air flow even slightly above that provided by half speed operation is required, a two speed motor must be run at rated horsepower as there is no other speed available. Two speed motors do provide some energy savings, but still must be cycled on and off to maintain the desired water temperature. This cycling involves many "across the line" starts drawing high amps and placing unnecessary strain on the mechanical components of the system [2]. While providing some flexibility in the tower control logic, two speed motors are not optimal when it comes to maximizing energy savings during times of reduced heat load.

The use of variable frequency drives (VFDs) has become much more commonplace in recent years. Data from a noted cooling tower manufacturer indicates that VFDs are being installed in the majority of all new towers being constructed. Additionally, most towers being upgraded or refurbished are also being equipped with VFDs. These drives have the advantage of a soft mechanical start, no large starting current draw, and the ability to run the fan at any desired speed from zero to the maximum design speed for the application [3]. The energy savings realized by using a VFD are well recognized and documented, so no further discussion will be introduced here [4]. Several factors that must be considered when applying a VFD are any critical speeds of the mechanical system, the cooling ability of the induction motor at low speed, and the proper lubrication of the gearbox at slow speeds. For practical purposes, the fan is generally not run at speeds below 30% of the nominal design speed.

Historically, the mechanical components of the fan drive system, specifically the right angle gearbox, have been the largest maintenance issue for cooling tower installations [5]. Gearbox failures, oil leaks, oil contamination, failed drive shafts, misaligned drive shafts and excessive vibration are all significant problems related to this type of fan drive system [6], [7].

In this paper, recent developments in motor technology are presented. It is demonstrated how these innovative designs can be used to improve the reliability and reduce maintenance associated with today's cooling tower installations. The design and installation of a 208 rpm, 50 horsepower PM motor for a retrofit application is discussed in detail. The possibility of improved efficiency and lower energy consumption with the proposed solution is discussed.

II. IMPROVEMENTS IN MOTOR TECHNOLOGY

Increased efficiency and improved power density are being demanded in the motor industry. To achieve these goals, along with lower noise and variable speed operating capability, other technologies beyond simple induction motors should be considered. Permanent magnet (PM) motors have long been recognized as providing higher efficiencies than comparable induction motors. However, limitations in terms of motor control, as well as magnet material performance and cost, have severely restricted their use. Due to dramatic improvements in magnetic and thermal properties of PM materials over the past 20 years, synchronous PM motors now represent viable alternatives. Figures 2 & 3 show typical efficiencies and power factors for various motor types [8].

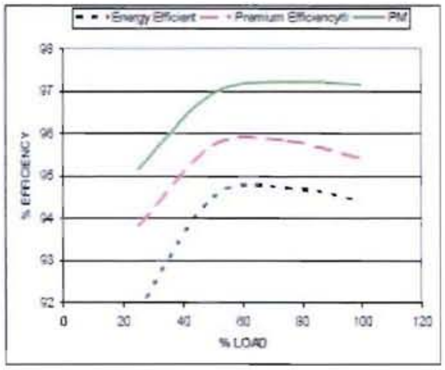


Figure 2 - Typical Partial Load Efficiencies of 75 HP, TEFC, 1800 RPM Motors

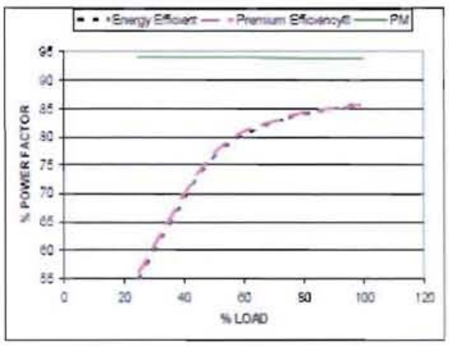


Figure 3 - Typical Partial Load Power Factors of 75HP, TEFC, 1800 RPM Motors

Another innovation which merits discussion is the laminated frame motor technology used in this design. Laminated frame motors consist of a stack of laminations permanently riveted under controlled pressure. The cast iron outer frame is eliminated, allowing more room for active (torque producing) magnetic material. Figure 4 below is a representation showing how the stator frame is constructed.

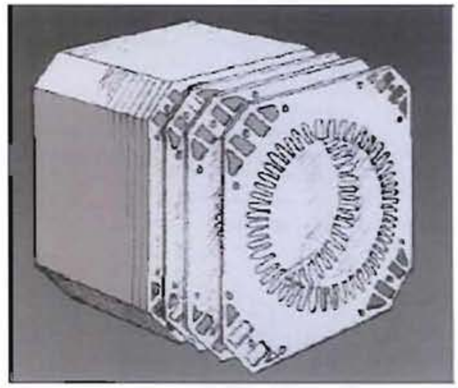


Figure 4 – Laminated Frame Construction

Another advantage of this construction is that the air used to cool the motor is in direct contact with the electrical steel. There is no thermal resistance path as that which exists in a traditional cast iron frame with contact to the stator lams. The heat transfer mechanism in a cast iron frame motor is highly dependent upon the stator to frame fit. Laminated frame construction eliminates this issue.

In recent years, industry drivers have forced the development of an optimized, finned, laminated motor design. To improve the cooling and increase power density, fins have been added to the exterior of the stator laminations. The addition of the optimized cooling fins increases the surface area available for heat dissipation. The result is improved heat transfer and a power increase of 20-25% is typical for a given lamination diameter and core length. Figure 5 shows the increased surface area achieved by including these cooling fins.

Figure 5 – Finned vs. Non-finned lamination

It is this improved cooling method, along with the higher efficiency and power factor achieved with the PM technology that allows for increased power density in these motor designs. Power density is the key for being able to match the height restriction of the existing gearbox. For comparison, a paper study was performed to determine the approximate sizes and weights of various motor types for use in this application. The results are shown in Table 1 below. The rating is 50 horsepower at 208 rpm. Each motor was designed for the same temperature rise.

Motor Type	Height (in.)	Width (in.)	Width (in.)	Wt. (lbs.)
Cast Iron Frame Induction	41	28	28	3950
Finned, Laminated Frame Induction	28	22	22	2320
Finned, Laminated Frame PM	22	22	22	1670

Table 1 – Motor Size Comparisons

III. CASE STUDY

The case study involves the retrofit of an existing cooling tower constructed in 1986 at Clemson University in South Carolina. The tower information is as follows:

Fan Diameter:	18'-0"
Flow Rates:	4,250 gallons per minute (GPM) per cell - 8,500 GPM total
Motor Information:	Frame – 326T HP – 50/12.5 Speed – 1765/885 rpm
Gearbox:	Size – 155, Ratio – 8.5:1

As shown in the above data, this tower is comprised of two identical cells. For this study, one cell was retrofitted with the new slow speed PM motor and VFD while the other was left intact as originally constructed. This allows for a direct comparison of the two fan drive solutions. Figure 6 below shows Cell #1 in the original configuration, while Figure 7 shows the PM motor installed in place of the gearbox in Cell #2.

Figure 6 – Original Installation

Figure 7 – PM Motor Installed in Place of Gearbox & Driveshaft

Prior to the installation, the current being drawn by the two original induction motors was measured with the fans running at full speed. An ammeter was used and the current was measured to be forty seven (47) amps, rms on both induction motors. As the induction motors are identical, this is a good indication that both cells were operating under the same load conditions. After the PM motor and VFD installation was complete, the current was again re-checked and found to be only forty one (41) amps for the PM motor. The induction motor on the original, identical, tower was still drawing forty seven (47) amps.

A power meter was used to measure the input power to both solutions. The fans were running at the same speed. Data was taken at both the input and output of the drive to allow for a direct comparison of the induction motor / gearbox combination to the PM motor. The results of the measurements are shown in Table 2 below.

Location	Volts, mean	Amps, rms	Input kW	Power Factor (%)
Input to Induction	477	46.7	31.5	81.7
Input to VFD, PM	477	44.5	28.5	77.6
Input to PM	459	40.9	28.0	86.1

Table 2 – Power Consumption Comparison, Original blade pitch, manufacturer data

From this data, it was determined that both cells were running at less than full load and that the load should be increased on each cell. To this end, the pitch of the blades on each fan was increased to 12°. This change of pitch caused the fans to draw more air, thus increasing the load on each motor. Further, the increased air flow improved the effectiveness of the overall tower performance. Again, power measurements were made and a third party testing service was engaged to verify the manufacturer's results. The data is shown in Tables 3 & 4 below.

Location	Volts, mean	Amps, rms	Input kW
Input to Induction	477	54.8	38.1
Input to VFD, PM	477	49.8	33.6

Table 3 – Power Consumption Comparison, 12° blade pitch, manufacturer data

Location	Volts, mean	Amps, rms	Input kW
Input to Induction	478	54.3	37.9
Input to VFD, PM	477	49.8	33.0

Table 4 – Power Consumption Comparison, 12° blade pitch, testing service data [9]

For the final blade pitch, 4.5 kW less power consumption was observed on the cell with the PM motor installed. In order to document the savings realized at various speeds on this application, input power was recorded at intermediate speeds for the PM motor cell. Figure 8 below shows the actual measured input power for the induction motor / gearbox solution and the PM motor solution at various speeds.

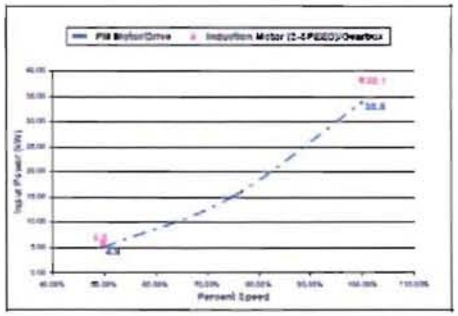


Figure 8 – Input Power vs. Speed, 12° blade pitch

As shown in Tables 2-4, the PM motor solution requires less input power for each load point (blade pitch). Figure 8 shows the total input power in kilowatts for each solution over a range of operating speeds from 50-100%. Again, the PM motor has an advantage over the induction motor / gearbox solution. Using an average price of $.08/kWh, the annual cost savings for various applications and duty cycles are shown in Table 5. This table does not account for the additional savings achieved by using a VFD and having the ability to run at speeds between 50% and 100% of rated.

		Annual Savings (%High Speed/%Low Speed)		
Application	Daily Use	100 / 0	75 / 25	50 / 50
Power Plant	24 hrs.	$3154	$2488	$1822
Hospital	18 hrs.	$2365	$1866	$1367
University	12 hrs.	$1577	$1244	$911

Table 5 – Annual Energy Savings Based on Various Duty Cycles

IV. ELECTRICAL CONSIDERATIONS

PM Control Algorithm

In addition to the PM motor design features already detailed, another challenge of this application was that the PM motor had to be run sensorless. There was no room to install a speed feedback device, such as an encoder or resolver, and still meet the height restriction of the existing gearbox. In this harsh environment, a feedback device would be a liability as far as reliability is concerned. Therefore, a sensorless PM control scheme was developed to satisfy the requirements of this application. Several things had to be considered when forming this algorithm. One challenge was the inertia of the fan. This was taken into account to prevent the motor from falling out of synchronism when starting and changing speeds. Figure 9 is a portion of a typical start from rest. Note the smooth acceleration and low starting current required. A typical 480 volt induction motor started across the line would draw 347 amps [10], compared to 12 amps for this PM design started on the VFD.

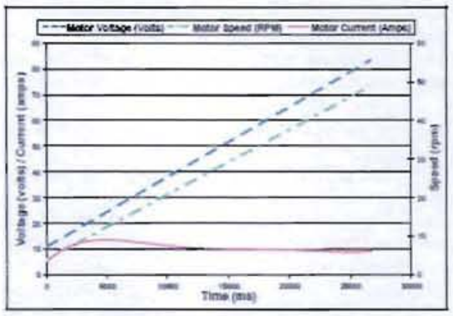


Figure 9 – Motor Starting Performance

Improved Process Control

As mentioned earlier, the addition of the VFD allows the user to more accurately and efficiently control the process. Figure 10 shows how the motor speed is changed automatically with control logic as the heat demand on the system changes with time.

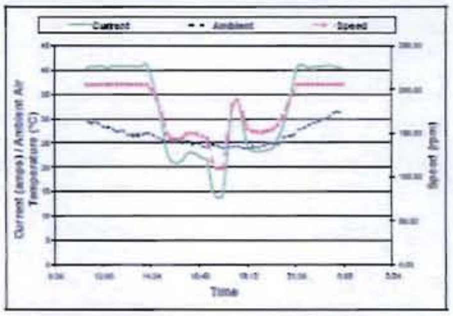


Figure 10 – Motor Speed Variation with Changing Heat Load

Braking and Condensation Control

The use of a VFD also provides the opportunity to offer some additional features that across the line systems do not. The drive may be configured to apply a trickle current to the motor windings to act as a brake during down time. This prevents the fan from free wheeling due to nominal winds or adjacent cooling tower turbulence. However, a mechanical locking mechanism should be using during any maintenance procedures. This trickle current also acts as an internal space heater by raising the winding temperature, preventing condensation when the motor is not running.

Insulation System

Inside the fan stack is an extremely humid environment. Therefore, the insulation system on the stator windings must be robust and highly moisture resistant. To this end, an insulation system derived from a system originally developed for use by the US Navy was employed. This system utilizes an epoxy compound applied via a vacuum pressure impregnation (VPI) system. The VPI system is widely recognized as a superior insulation system for harsh applications such as this. This particular system has been successfully employed on "open" motors in tough applications such as oil platforms operating in the North Sea.

V. MECHANICAL CONSIDERATIONS

Shaft Seal

Due to the harsh environment inherent with a cooling tower application, the motor's drive end is protected by a metallic, non-contacting, non-wearing, permanent compound labyrinth shaft seal that incorporates a vapor blocking ring prevent an ingress of moisture. This seal has been proven to exclude all types of bearing contamination and meets the requirements of the IEEE-841 motor specification for severe duty applications. This type of seal has been successfully used in cooling tower gearboxes for many years [11].

Maintenance

Another consideration is overall system maintenance. For motor / gearbox combination drives, the lubrication interval is determined by the high speed gear set. The recommended lubrication interval for this type of gear is typically 2500 hours or six months, whichever comes first. In addition, gear manufacturers recommend a *daily* visual inspection for oil leaks, unusual noises, or vibrations. As these units are installed in areas which are not readily accessible or frequented, this is an unreasonable expectation and burden on maintenance personnel. When a gear is to be idle for more than a week, it should be run periodically to keep the internal components lubricated because they are highly susceptible to attacks by rust and corrosion. When being stored for an extended period, it is recommended that the gearboxes be completely filled with oil and then drained to the proper level prior to resumed operation. Because the high speed input has been eliminated with the slow speed PM motor design, the lubrication cycle can now be extended up to two years. The PM motor need not be inspected daily for oil leaks, as the motor contains no oil. As mentioned previously, the VFD can provide a trickle current to heat the stator windings to a temperature slightly above ambient to prevent moisture from forming inside the motor.

Vibration

With the elimination of the high speed input to the gearbox, the system dynamics from a vibration standpoint have been simplified. There are no longer any resonance issues with the driveshaft. The maximum rotational excitation is now limited to the rotational speed of the fan. The number of bearings in the drive system has been reduced from six to two for a single reduction gearbox and from eight to two for a double reduction gearbox. This reduces the number of forcing frequencies present in the system.

Noise Level

Many cooling towers are in locations where airborne noise can be an issue, such as hospitals and universities. To this end, a third party testing company was engaged to conduct comparative sound tests between the two cells. Data was taken at both high speed and low speed for both cells. The induction motor cell was designated as Cell #1 while the PM motor cell was designated as Cell #2. Sound level measurements were taken on Cell #1 while Cell #2 was turned off. There were twelve 30-second readings taken at high speed and twelve 30-second readings taken at low speed around the perimeter of the tower and the fan motor. As there was no motor outside of the fan stack on Cell #2, only nine readings were taken on Cell #2 with Cell #1 turned off. A single point measurement was taken where the old induction motor was mounted on Cell #2 in order to have some reference to Cell #1. It was not possible to turn off the water flow for either cell at any time so there was a significant amount of background noise, but as this condition was the same for both cells, it should not affect the comparative data [9]. Average A-weighted sound pressure results are shown in Table 6 for both high speed and low speed operation.

	A-weighted Average	
Cell	High Speed	Low Speed
Induction	82.3 dBA	74.4 dBA
PM	77.7 dBA	69.0 dBA

Table 6 – Sound Pressure Data

At high speed, the PM motor cell was 4.6 dBA lower than the induction motor cell. For low speed operation, the PM motor cell was 5.4 dBA lower. Although there may be some slight differences in the background noise for each cell, these likely do not account for all of the noise level reduction realized with the PM motor solution. The removal of the high speed induction motor from the outside of the fan stack appears to have the biggest influence on the noise level of the tower itself.

VI. CONCLUSIONS

Cooling tower fan drives have changed very little over the past two decades. Failures of the gearbox, driveshaft, or disc couplings have been the biggest reliability issue facing tower manufacturers and end users. Increasing energy costs have placed a premium on power consumption for all motors and applications.

Many of the problems associated with cooling tower maintenance and reliability are solved with the PM motor design. The relatively high speed (typically 1750 rpm) induction motor has been eliminated. The motor itself has not historically been a problem, but the associated resonances and potential vibration concerns have been an issue. The driveshaft and associated disc couplings have been removed, thus eliminating problems associated with misalignment, improper lubrication, natural frequencies, or delaminating of the driveshaft itself [12]. The right angle spiral-beveled gearbox has been removed. Difficult maintenance associated with changing the oil, proper oil fill levels, contamination of the oil, oil leaks, and gearbox failures is no longer a concern.

New motor technology now provides an alternative solution, the direct drive of cooling tower fans. PM motor technology combined with the finned, laminated frame design now allows the construction of low speed, compact motors for use in place of the existing gearbox. Data obtained to date indicates this solution will eliminate the problems associated with the right angle gearbox and drive shaft design. By eliminating the gearbox, which is a significant source of loss in the system, improved system efficiencies can be realized.

VII. ACKNOWLEDGEMENTS

The authors of this paper extend their thanks to Clemson University and Tower Engineering, Inc. for their contributions and participation in the project.

VIII. REFERENCES

[1] Benjamin Cohen, "Variable Frequency Drives: Operation and Application with Evaporative Cooling Equipment", Cooling Technology Institute Paper No. TP07-22, 2007

[2] William F. Immell, "Variable Speed Fan Drives for Cooling Towers", Cooling Technology Institute Paper No. TP96-03, 1996

New High Efficiency Fill – replacing scaled or clogged fill with BAC's high efficiency fill kits are designed to increase the energy and water efficiency of the cooling tower

Benefit: 7% to 10% energy savings. Up to 5% reduction in water usage by reducing the amount of scale and build-up that requires additional cleaning, drainage, and blowdown along with less splashout and drift.

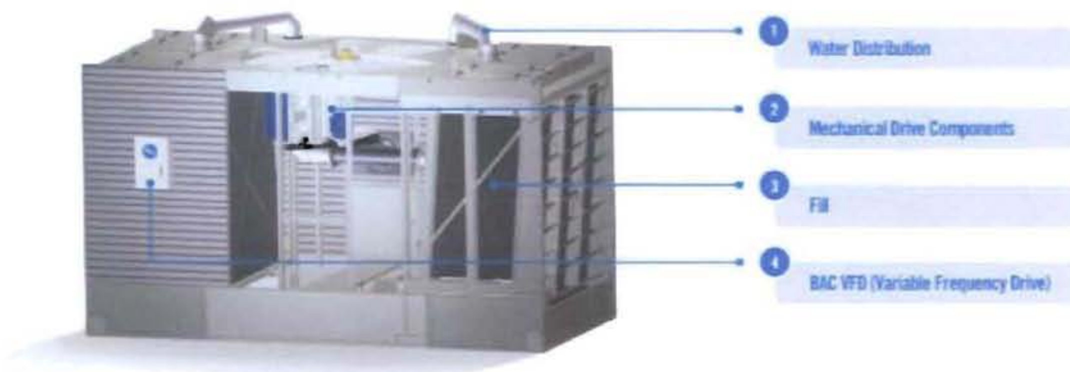
Nozzle Replacement – broken or clogged nozzles causes uneven water distribution over the fill, scale build up, and decreased efficiency.

Benefit: 2% to 3% energy savings. Up to 5% reduction in water usage by reducing the amount of scale and build-up that requires additional cleaning, drainage, and blowdown along with less splashout and drift.

PRODUCT SPOTLIGHT:

Energy Saving Retrofits

Retrofit Opportunities



A 2°F Decrease in Leaving Water Temperature Saves 6% in Electricity Costs

On average the HVAC system uses 25% of a building's electricity. The slightest increase in cooling tower leaving water temperature will result in significantly higher energy costs.[1]

Annual Cooling Tower Efficiency Savings[2]

Note 1: U.S. Energy Information Administration (EIA)

Note 2: Savings are based on the energy costs for a 500 ton centrifugal chiller; 0.58 kW/ton chiller efficiency at full load.

PRODUCT SPOTLIGHT:

Energy Saving Retrofits

2% to 3% Energy Savings

1°F Decrease in Leaving Water Temperature

Pay Back Period: Less than 1 Year

3% to 7% Energy Savings

1-2°F Decrease in Leaving Water Temperature

Pay Back Period: Less than 1 Year

7% to 10% Energy Savings

2°F Decrease in Leaving Water Temperature

Pay Back Period: 2-3 Years

30% to 40% Energy Savings

Pay Back Period: Less than 1 Year

1 Replace Nozzles

- ✓ Broken or clogged nozzles cause uneven water distribution over the fill, scale build up, and decreased capacity.

2 Upgrade or Replace Drive Components

- ✓ For increased building heat loads, BAC's drive upgrade kits will increase the capacity of your cooling tower.
- ✓ To maintain the peak performance of your cooling tower, replace your motors, drive sheaves, drive bushings and belts with BAC Factory Authorized Parts.

3 Install New Fill

- ✓ Replace scaled or clogged fill with BAC's replacement fill kits that are designed with state of the art fill technology to restore or increase the capacity of your cooling tower.

4 Install a VFD

- ✓ Adding a Variable Frequency Drive will provide a more efficient method of operating your cooling tower while extending the life of the motor and mechanical drive system.