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Optimize air-cooled heat exchanger performance

Use these guidelines to troubleshoot and correct cooling problems

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If air-cooled heat exchangers (ACHEs) are not meeting the required cooling demands, they need to be examined in the following areas and the necessary data collected. This will allow the end user to make an informed decision on options to improve the particular ACHE situation.

- Are the fans leaking air?
- What is the actual pitch? Is it the same as originally designed?
- What is the actual horsepower (hp) being used? Is there further potential in the motor?
- What kind of drives are installed—V-belt, timing belt or gearbox?
- What is the "tip clearance"?
- Are "inlet bells" installed?
- Are "seal discs" or "air seals" installed? If not, is the ACHE design lacking seal discs, or have they been removed and not reinstalled?
- Are the fin-tubes clean?
- Is the fan running at the design speed shown on the original specification sheet? Is the fan running in the correct direction, and are the blades pitched with the leading edge down?
- Are these fans delivering the airflow that the original specification sheet suggests?
- Is this original design sufficient to meet your requirements now and in the future?

This article addresses these issues.

Leaking fans. Normally, daylight can be seen directly through the tube-bundles, and this is also an excellent way to determine if the tubes need to be cleaned. If holes and gaps are seen when viewed from the bottom of the forced draft (FD) units, or when viewed from the top of the induced draft (ID) units, then air is leaking. These leaks are created from the obvious holes and gaps in the fan box. These holes result in air and costs going out the sides of the fan instead of through the fin tubes. The correct strategy is to push the air through the bundles, not out the sides of the fan housings.

FIG. 1 Knowing where to take the pitch reading is important.

Pitch. Always know and record the pitch for all fans. Every blade (for each particular fan) needs to be at the same pitch (±0.5°). It is also very important to know exactly where to take this pitch reading (Fig. 1). Most ACHE manufacturers have excellent Websites. This, and additional information including maintenance manuals and fan design software programs, can be found on these Websites.

Make sure the pitch-level tool covers the whole blade width. If it doesn't, place a long enough piece of wood under the pitch-level to get the correct blade angle reading.

The maximum allowable fan blade pitch is also important to know. However, many end users feel that if they know this, they can set the fan at this maximum pitch and use the variable frequency drives (VFDs) to control the fan during winter and summer conditions. This is a poor practice because the maximum pitch differs under various running conditions and could place the fan at or near a stalled condition.

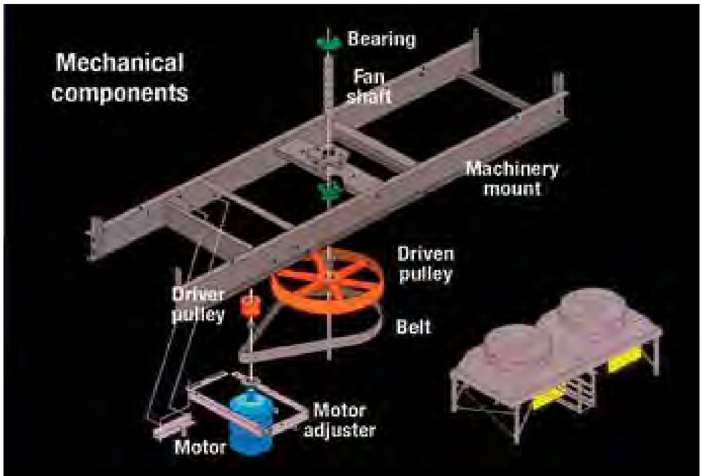

FIG. 2 Drives are a major area of opportunity for big improvements on ACHEs.

The best way to understand this issue is by using the information on the original specification sheet supplied by the cooler manufacturer at the time of the original purchase.

If there is any available unused hp at the current speed, slowly ramp up the airflow and static pressure using the fan program from the original manufacturer to make use of this available hp. It will be evident that the pitch angle will increase if the speed is kept the same. This exercise will reveal the correct pitch angle to run the blades. Pitching the blades higher to increase airflow will eventually stall the fan. Some fan programs' software indicate when the fan is in stall. If the program doesn't, then knowledge of how to read a fan curve is required.

The next step is to speed up the fan to eliminate this stalled condition. Understanding the relationship between static pressure and airflow is necessary to be able to input any air-flow increases in the fan program. (See formulas and rules under **Other ACHE best-performance practices.**) This is also available on a spreadsheet from the author.

Speeding up the fan is not as easy if it is driven by a gearbox, but purchasing a new set of gears to change the ratio of the box is easy.

When increasing the speed on a belt drive, it is easiest to increase the motor pulley size. This often has a hidden benefit because, in many cases, the driver pulley is already well worn and in need of replacement. It's generally easier to change compared to the larger driven pulley and costs less. The larger diameter on this driver pulley not only increases the fan speed, but also lowers the bearing load on the motor and increases the overall belt drive hp rating.

Noise. Increasing fan speed has very few disadvantages other than increased noise levels. Higher tip speed and any increase in airflow generally mean more noise. Be aware of local noise codes when making ACHE upgrades. Special low-noise blades are available. Contact the author for more information on this subject.

Don't set fan pitch based on motor amperage. One major problem often encountered is when the fan pitch is set by using the motor amp reading. This method rarely results in the fan running in its "sweet spot." The fan will draw more amperage when it is in stall or approaching stall. Therefore, using amperage as the only reference is not going to give the desired result. This could end up with less airflow and higher power costs. If, however, the fan speed is high enough and the pitch is flat enough, the fan is running very efficiently. If this is the case, amp readings can be used to fine-tune and get the fan running at its optimum pitch and efficiency.

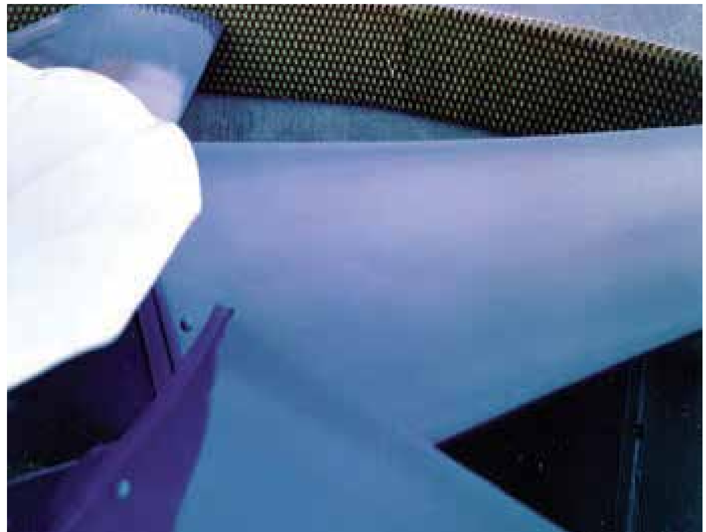

FIG. 3 The simplest way to remedy poor tip clearance is with a metal seal.

Is the hp being used efficiently? It is very important to know if the hp is being used efficiently to maximize ACHE systems. Take the amperage and voltage readings on all three phases, average them and insert the values into the following equation. Motor efficiency and power factor are also required. This will give a more accurate reading on the hp being used by the motor than simply reading amps.

One HP = ~1amp at 575volt or ~1.25 amp at 460 volt

Upgrading to new high-efficiency motors is recommended. These new motors are almost 10% higher in efficiency compared to motors from 20 years ago. This 10% adds up to increased cooling for the same power costs.

In addition to higher efficiency, consider the next size hp motor. Check to see if the motor leads and related equipment can handle the newer, larger motor. Higher hp means more airflow and more cooling. If the capital commitment is made to upgrade to a high-efficiency motor, upgrade to the next size motor if it means no other modifications.

The motor must be running in the correct direction for the fan blade. All ACHEs turn counter-clockwise when viewed from under the fan.

Drives. Drives are a major area of opportunity for big improvements on ACHEs (Fig. 2). If using V-belt drives, consider

FIG. 4 An inlet bell can be part of a fan ring or added later.

converting to one of the many timing belt options. The ACHE market has long recognized the advantages of belt drives that don't slip. Narrower belts help reduce motor bearing loads and overall drive costs.

The belt drives must be designed correctly. When a belt drive is designed with a motor pulley that is too small, it will create a problem for the motor bearings.

All timing belts are considered 98% efficient. Once they are installed, aligned and tensioned correctly, the belt drive may never have to be touched again. Experience dictates that these belts stretch slightly at first. After running for a few hours, and retensioned, they will not require any further attention for the life of the belt.

A V-belt is considered 97% efficient only if it is running on new pulleys and tensioned and aligned correctly, but this rarely happens on ACHEs. The driver is so small, and the driven is so large, that this belt slips most of the time. Slipping V-belts on an ACHE reduce efficiency and waste money. V-belts tend to slip more in the hot summer when cooling requirements are at their highest level. V-belts stretch by design, so they need to be retensioned several times during their life span. The problem with many ACHEs is that they often do not get the necessary attention required to maintain the V-belt drives correctly.

Tension information for all drive belts is on the drive sheets provided by your belt supplier. Make sure the maintenance staff have tension tester tools and the correct tension information for each drive. Writing the tension (in pounds) and the deflection force (in inches) on the side of the framework near the fan ensures that the information is readily available to the maintenance staff and decreases the opportunity for improper tension, which is the leading cause of all timing belt failures.

Tip clearance. Tip clearance is a major issue and is relatively easy to fix. The blade tip has the highest surface speed of the entire blade. Therefore, having a good tight tip clearance will pay back with increased airflow. Fans create an area of low pressure on the suction side of the fan. If there is any amount of tip clearance, the low-pressure area creates an opportunity for the air that is under high pressure on the opposite side of the fan to flow back to the low-pressure side, thereby causing air recirculation.

The more tip clearance, the higher the air flow will be from the high-pressure side back to the low-pressure side. The objective is to move that air once through the fin tubes, not to have it constantly recirculating at the blade tip. The industry suggests that good tip clearance can improve fan performance by 2% to 3% (depending

FIG. 5 Determining fan airflow can be difficult without outside help.

on existing clearances). Here is a guide as to what is considered acceptable for tip clearance for different fan sizes:

3-ft fan through and including 9-ft fan ¼ in. to ½ in.
10-ft fan through and including 11-ft fan ¼ in. to ⅝ in.
12-ft fan through and including 16-ft fan ¼ inf. to ¾ in.
18 ft and up (rcooling towers) ¼ in. to 1 in.

The simplest way to remedy poor tip clearance is with a metal (honeycomb aluminum) seal that attaches to the inside of the existing fan ring with metal screws (Fig. 3). An installer can easily adjust the tip seal to the requirements using a tool that attaches to the fan blade.

Inlet bells. An inlet bell can be part of the fan ring or added later. It is a simple curved section of fiberglass that is screwed to the inlet of the fan ring (Fig. 4). It is easy to cut by hand and to attach in most cases. This curved fiberglass housing allows air to smoothly enter the fan and has been measured to increase fan efficiency by 2% to 3%. In some cases, it can be somewhat difficult to retrofit the expanded metal guard after installing the inlet bell, but it is worth the effort to install these inlet bells to achieve the extra efficiency.

Seal discs or air seals. These are the large plastic or metal covers normally attached to the fan hub, providing a barrier for air that tries to recirculate back down, close to the center of the fan. The center of the fan is in an area of low blade surface speed and, therefore, is a low-pressure zone. The pressurized air that has just passed through the fan naturally tries to flow to this low-pressure area. If the seal disc is not installed, the fan can be losing efficiency by allowing this air to be recirculated. This seal disc should be about 25% of the fan's diameter. If there is no seal, or if the seal disc is broken, this can affect the fan efficiency by 2% to 3%.

Cleaning. In many cases, it is easy to determine if the tube bundles are dirty simply by looking up through the fin bundle with louvers open toward a light source. If daylight cannot be seen when looking up at 11 o'clock or 1 o'clock positions, the bundles need to be cleaned. Many different types of cleaning methods are available. It is best to find a contractor in your area that can offer different

FIG. 6 Water spray loosens the L-wrap type of fin.

cleaning options. Some fan manufacturers have cleaning information on their Websites. A general practice is to get the bundles cleaned once a year.

Fan speed. A physical survey of the fan drives helps determine the exact speed. Compare this to the original specification sheet to see if it has sped up or slowed down over the years. Increasing speed is generally advantageous, provided that the maximum recommended tip speed of the fan blade is not exceeded and that increased noise is not a concern. On the other hand, slowing the fan speed can result in a stalled condition. When using V-belts, an actual shaft-speed should be recorded. As stated earlier, the V-belts slip so the accurate shaft speed cannot be determined by pulley size alone.

Are the fans delivering the designed airflow, and is this enough? This is difficult to determine without outside help. Some end users have the tools and training to be able to perform airflow tests on ACHEs, but, in most cases, it might be better to hire an experienced local contractor that knows how to measure airflow and can offer overall ACHEs solutions (Fig. 5).

If it is determined that the ACHE is delivering its best possible airflow based on all the discussions so far in this article, but the process still requires more cooling, have the process engineers review the application. The cooling demands might be more than the existing ACHEs can handle with the current blade design.

Before making a decision to purchase any new exchangers, remember that the blade type can also greatly increase cooling. Experience has shown that most aluminum fan blades are unable to achieve the airflow that was on the original specification sheet due to their inefficient blade design. Technical papers, airflow tests and other information that deal specifically with the issue of fan blades are available from the author.

Blade design can greatly affect the airflow of any fan, and high-efficiency blades are available to fit any ACHE unit. Lowefficiency, straight-cord aluminum fan blades can have efficiencies as low as 35% to 55%. Modern fans are more aerodynamic, with efficiencies as high as 75% to 85%.

The more air that is pushed through the fin tubes, the better. This increased airflow will have a positive effect on cooling.

Note: This is not the case on a wet "cooling tower," where more air can pull the water curtain too far into the tower and create other problems.

Other ACHE best-performance practices. Some plant operators will spray water on the fin tubes for additional cooling. This practice gives little cooling benefit and adds costly long-term effects.

The effect of this water spray loosens the L-wrap-type of fin that is most common on fin tubes. This L-wrap is only in contact with the tube due to the tight wrap during manufacturing.
When rapidly cooled, due to water spray, the L-wrap contracts. When normal temperature returns, the wrap expands and is now loose on the tube (Fig. 6).

This L-wrap expansion allows the water to get in between the tube and the wrap, minimizing the effect by insulating the wrap from the heat of the tube. It also allows for buildup of calcium carbonate and other deposits, which also act as insulators. This makeshift water spray, often referred to in slang terminology as "California coolers," is not a good idea. The short-term gain is more than offset by the long-term consequences. Note that a 10% increase in airflow relates to an improved thermal duty increase for ACHEs as follows:

ACHE service	Condensing	Liquid cooling	Vapor cooling	Viscous cooling
Min. duty	5%	3%	2%	½%
Max. duty	7%	6%	5%	1%

Formulas and rules. *cfm* (airflow) = *fan rpm,* (Airflow varies in direct proportion to rpm.)

SP (static pressure) = *fan rpm* 2, (Pressure capacity varies with the square of a change in rpms.), or a 10% increase in fan speed equals a 21% increase in *SP:* 1.1 X 1.1 = 1.21 or the square root of 1.21= 1.1.

HP = *fan rpm* 3, (Power required varies with the cube of the change in rpm). So a 10% increase in fan speed means 1.1 X 1.1 X 1.1 = 1.33 or a 33% increase in hp.

10% more flow = 21% more *SP* = 33% more hp. This is conservative; the actual numbers are normally: 10%/18%/29% increase in hp.

Will a fan, in stall, produce higher *SP?* High system resistance at too low of a fan speed will produce fan stall. However, when the fan is in stall, or more correctly, as it moves more into stall, the *SP* will increase but the airflow will decrease. This will typically produce increased vibration (flutter) and increased noise. From above, it sounds like the fan is in stall.

Winter and summer pitch. Winter and summer pitch is more of an issue in the colder northern regions, and with VFDs, this issue can be controlled very easily. The air is heavier in the winter, so if the pitch is set for summer conditions, the motor will overload. With VFDs, the speed can be turned down to control this condition. It is very common for plants to have a winter and summer pitch.

With the necessary information and knowledge to be able to read the fan curves or use a fan program, the end user can design

FIG. 7 An anti-rotation device can prevent windmilling.

summer and winter speeds. This way the pitch can remain the same all year.

Following are the benefits of leaving the pitch the same throughout the year:

It is faster and easier to change a motor pulley than change the pitch of all the blades. Changing just the motor pulley is not considered a confined-space issue, so less manpower is needed with quicker results.

The small pulleys wear fast and should be replaced occasionally regardless. These are very inexpensive parts. The money saved on the quicker turnaround, with fewer people (no man-watch required), will more than pay for new pulleys every year.

If the driver pulley is kept in good condition, replacing it every six months results in better belt life and less downtime on the fans.

Vibration. If experiencing vibration, a few things can be examined before the experts are called in. Three main types of frequencies to be concerned about related to an ACHE are:

• Motor frequency. If the vibration frequency is at motor speed, investigation needs to focus on the motor, belt or gear drive. Is the belt tensioned correctly? Are the bearings okay? Is the drive aligned?

• Fan frequency. If the vibration frequency is at shaft speed, this kind of vibration is associated with the fan only. Look for blade tracking issues, blade sweep issues (which is the distance between each blade) or an unbalanced fan blade. Are all the blade pitches for a particular fan within ½° total?

• Blade-pass frequency. If the frequency is fan speed times the number of blades, look for loose parts in the structure. Are any welds broken? Is this structure flimsy? Are the bearing and motor bolts all tight? Keep in mind that if everything is fine, your blade-pass frequency should always be dominant.

Windmilling ACHE. If the system is built so that more than one fan shares the same housing, the fans can windmill backward when one or more fans are turned off. This can be very destructive to the drive system once this fan gets a signal to go forward. Again, VFDs can control this.

Another way of solving this problem is with an "anti-rotation device" (Fig. 7). It was developed and patented in the mid-90s to solve this problem. It's a simple, mechanical device that bolts onto the large fan pulley with no additional modifications required. Further information is available from the author. HP

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Nick Agius has three decades' experience with bearings, seals, cooler fans, material handling and power transmission products, and is well known within the petrochemical industry worldwide as a solution provider.

He presently holds two patents for an anti-rotation device that he invented and developed to solve windmilling fans on air-cooled heat exchangers. Mr. Agius wrote a technical paper on fans and blowers that has been published by two international magazines. He is also the only person to have developed a very unique and detailed cross-over catalog for angular contact ball bearings that has been utilized and appreciated by pump end users globally. Mr. Agius can be reached at e-mail: **nickagius2014@gmail.com.**

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The new DG-II anti-rotation device (Fig. 10) accommodates all standard bushing configurations as well as being able to mount on the end of an extended shaft. This DG-II stops fans from wind-milling backwards, causing safety issues or damage to belts and equipment.

FIG. 8 High-efficiency fans

FIG. 9 Hudson fin fan bearings

FIG. 10 DG-II anti-rotation device