Upgrading Air-Cooled Heat Exchangers (ACHE) and Cooling Towers

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Many industrial facilities with air-cooled heat exchangers (ACHE) and cooling towers often have older units installed. Depending on the age, repairs, and maintenance done over the years it may have had an impact on performance. Upon conducting site inspections of the equipment, it is sometimes found that ACHE or cooling tower components have degraded. This can result in a system that is not very energy- efficient and delivers substandard cooling performance.

API 661 is an American Petroleum Institute (API) standard that details the requirements for air-cooled heat exchangers. API 661 ACHEs are also known as fin-fan heat exchangers, because the hot process fluid flows through finned tube bundles that are cooled by a fan that either pulls or blows ambient air over the tubes. The fan is driven by an electric motor.

Some of the recommendations to reduce energy usage include installing newer high efficiency motors that meet the latest U.S. Department of Energy's regulations, and adjustable speed drives (ASDs) that will adjust the speed of the motor to match the process flow and increase system efficiency.

Many ACHEs are used in the petrochemical industry and are specified to the API 661 specification, since it is considered a critical application. Often, the installation is in a harsh environment, such as close proximity to the ocean or presence of significant sand, dirt, and dust. Due to these considerations, the specification for motor robustness is very high and includes features to enhance the motor's ability for high reliability. Standard totally enclosed fan cooled (TEFC) motors used in API 661 ACHE locations often have incremental features to the industry-standard IEEE 841 motor that was developed for the petroleum and chemical industry.

API 661 calls out several standard drive arrangements, where the motor can be connected 1) directly to the fan, 2) to a right-angle gear attached to the fan, or 3) via a belt drive attached to the fan. When the fan is either belt driven or directly connected to the motor, the motor is installed in a vertical orientation. When the motor is installed shaft up, API 661 states that the belt sheave design should shield the motor from water; however, it also allows using an external shaft seal to prevent ingress of water into the motor housing. Labyrinth-type seals are typically utilized versus an external V-ring shaft slinger, since these types of seals provide a higher degree of ingress protection (IP 56 to IP 66).

A drive end cylindrical roller bearing is generally required when a motor is used in a belted ACHE application. In direct connected ACHE & cooling tower applications, the motor must utilize Conrad type ball bearings, since cylindrical roller bearings have a minimal radial loading requirement.

Like ACHE motors, cooling tower duty motors also operate in harsh conditions with high humidity, which necessitates utilizing a cast iron frame, bracket and conduit box with seals for IP55 protection. Cooling towers are used at industrial and petrochemical facilities to remove heat from recirculating water systems. Even though there are several different types, most have a fan driven by an electric motor that draws ambient air up and out of the top of the cooling unit. Enclosures for cooling tower duty motors are most commonly Totally Enclosed Fan Cooled (TEFC) or Totally Enclosed Air Over (TEAO). Mounting can be horizontal or vertical in a shaft-up or shaft-down orientation. Cooling tower duty motors are available in single speed, variable speed using an adjustable speed drive (ASD), or multi-speed (2 speed, 1 winding or 2 speed, 2 winding) for operation at two designated speeds.

Site inspections typically reveal that ACHE equipment or cooling tower components have degraded.

The following table compares the motor requirements of cooling tower duty motors, IEEE 841 motors (up to 444 frame) and 661 branded motors. The table should help in understanding the different motor product features to aid in selecting the appropriate motor for your cooling units.

Adjustable speed drives are commonly used for the fans on the ACHE and cooling tower units to control air flow and to provide energy savings by better matching motor power consumption to maintain the process temperature requirement. Most premium efficient motors are suitable for use with ASDs, but there are special installation considerations. Facility layout and site conditions might require situations where there could be long motor lead lengths from the ASD to the motor. ASDs use a switching technology called pulse width modulation (PWM) to generate the variable voltage and frequency to the motor. This high-frequency PWM waveform can result in unwanted effects like standing wave and excessive common mode voltage, which can cause damage to motors and electrical systems. Operation issues can be avoided by proper installation of the drives and support components.

It is strongly recommended to apply motors with an inverter duty winding designed to withstand voltage spikes, per NEMA MG1 Part 31 4.4.2. Bearing fluting protection, such as a drive end ground ring (if installed in an unclassified area) and an opposite drive end bearing if 400 frame and larger, should be considered.

In ACHE applications where the fan is belt driven, changing the belting system from a multiple strand V-belt to synchronous poly chain belting can provide higher efficiency, increase bearing life due to lower belt pull, eliminate

Feature	Summary List of Typical Features on a Cooling Tower Duty Motor	Summary List of Electric Motors Requirements Detailed in API 661 Std.	Summary List of Main Electric Motors Requirement Detailed in IEEE 841 Std. (Up to 444 Frame)	Summary List of Main Electric Motors Standard Features for 661 Branded Motors
Enclosure	Totally enclosed fan cooled (TEFC) or Totally enclosed air over (TEAO) suitable for harsh, high humidity and environment	Totally enclosed fan cooled (TEFC) suitable for petrochemical service	Severe-duty totally enclosed fan cooled (TEFC) suitable for petroleum and chemical service	Severe-duty totally enclosed fan cooled (TEFC) suitable for petroleum and chemical service
Service Conditions	Ambient temperature between –25°C to +40°C and maximum altitude of 1000 m	Rated for operation at 40°C (104°F) ambient temperature at altitudes less than 1000 m (3280 ft)	Ambient temperature between –25°C to +40°C and maximum altitude of 1000 m	Ambient temperature between –25°C to +40°C and maximum altitude of 1000 m
Temperature Rise	Winding temperature rise of 80°C	Maximum winding temperature rise of 80°C	Maximum winding temperature rise of 80°C	Maximum winding temperature rise of 80°C
Construction	Corrosion resistant cast iron motor frames and end brackets	Cast steel or corrosion resistant cast iron motor frames	Cast iron construction, including the frame, end brackets, fan cover. Corrosion-resistance, includes stainless steel nameplate, paint on external surfaces and on exposed internal surfaces.	Cast iron construction, including the frame, end brackets, fan cover. Corrosion- resistance, includes stainless steel nameplate, paint on external surfaces and on exposed internal surfaces.
Seals/Ingress	Ingress protection of IP 55 minimum.	Suitable shaft seals and bearing lubrication system when motor is installed vertically	Ingress protection of IP 55 minimum. Non-contacting labyrinth type shaft seals are commonly used to achieve IP 55 or higher.	Ingress protection of IP 55 minimum. Non- contacting labyrinth type shaft seals are commonly used to achieve IP 55 or higher.
Drains	Replaceable, corrosion-resistant drains at the lowest point of enclosure	Drains installed at the lowest point of the frame and/or endshield	Replaceable, corrosion-resistant drains at the lowest point of enclosure	Replaceable, corrosion-resistant drains at the lowest point of enclosure
Starting	Full voltage starting	Full voltage starting	Full voltage starting*	Full voltage starting*
Bearing Life		Grease lubricated bearings with at least 40,000 hours L 10 bearing life	Regreaseable bearings with at least 50,000 hours L 10 bearing life when direct connected	Regreaseable bearings with at least 50,000 hours L 10 bearing life when direct connected
Foot Flatness			Special mounting foot flatness for ease of installation and proper alignment	Special mounting foot flatness for ease of installation and proper alignment
Shaft Runout			Special shaft runouts – 0.001" for shafts up to 1.625" and 0.0015" for larger shafts	Special shaft runouts -0.001" for shafts up to 1.625" and 0.0015" for larger shafts
Vibration			Unfiltered vibration not exceeding 0.08 in/s for 4-pole motors	Unfiltered vibration not exceeding 0.08 in/s for 4-pole motors
Noise			Low noise level not exceeding 90 dBA sound power	Low noise level not exceeding 90 dBA sound power
Division 2			Suitability for installation in a Class I Division 2 or Class I Zone 2 area	Suitability for installation in a Class I Division 2 or Class I Zone 2 area
Belting bearings				Drive end roller bearing for belted applications
Incremental Sealing	RTV sealant on the bracket register fits and bolt holes for incremental sealing			RTV sealant on the bracket register fits and bolt holes for incremental sealing
Shaft up/down draining	Shaft up and shaft down mounting arrangements for proper draining			Shaft up and shaft down mounting arrangements for proper draining
Drip Cover	Optional Drip cover kits available when motor is installed shaft down			Optional Drip cover kits available when motor is installed shaft down
* Most, if not all, off the shelf 841/661 branded motors come standard with an inverter duty winding suitable for 20:1 variable				

Sources for table:
API Std 661 (R2018) Petroleum, Petrochemical, and Natural Gas Industries - Air-cooled Heat Exchangers, Seventh Edition
IEEE 841-2009 IEEE Standard for Petroleum and Chemical Industry--Premium-Efficiency, Severe-Duty, Totally Enclosed Fan-Cooled (TEFC) Squirrel Cage Induction Motors--Up to and Including 370 kW (500 hp)

tensioning which reduces maintenance cost, and reduce the number of sheaves, thereby reducing component count and providing increased safety. Synchronous belting is now available with higher temperature range (up to 248°F) and options to overcome static conductivity.

Additionally, there are new developments in fan and drivetrain components used in the design of these cooling units that can improve the units' cooling performance and energy efficiency. Items such as FRP (Fiberglass Reinforced Plastic) fan blades can provide greatly improved performance over the aluminum fan blades that typically come with the ACHE units. FRP fan blades are available for ACHE units and cooling towers. Various materials and designs are available. All have improved performance over aluminum fan blades. One design offered can improve fan efficiency up to 20% and air flow up to 10% over the manufacturer's standard FRP fan blade. There are other optional features such as an inlet bell on the ACHE fan blades to reduce noise and gain up to 5% efficiency.

In one case, it was found that the ACHE equipment — although not very old — and designed per API 661 as a guideline, could not achieve the required performance. The company was looking at doing an expansion at another site, in order to meet the product demand because they could not achieve the needed output due to process cooling limitations. It was discovered that the aluminum fan blades on the cooling units they had purchased could not handle the air flow demand. This was overcome by replacing the fan blades with FRP fan blades, which could handle the required demand.

Here are some additional items that should be evaluated and considered for upgrade:

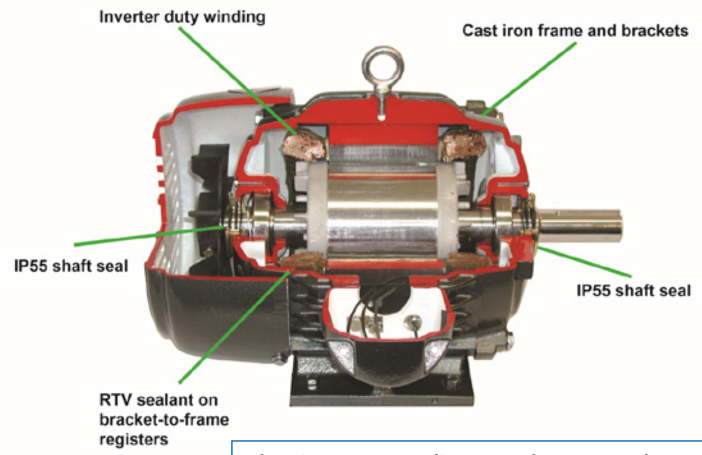
Composite tube couplings that are available for cooling towers which are almost ⅕ the weight of a steel coupling. This can greatly improve bearing life on the motors and gearboxes, as well as provide resistance to corrosion. They also have a lower coefficient of thermal expansion, which reduces concern for axial thrust.

Newer cooling tower gearboxes that have improved shaft seals using V rings and isolator seals. They are better at keeping water out of the oil by providing an expansion chamber in place of a breather. There are manufacturers offering factory trade-out programs with a warranty and shorter lead times.

There are newer bearing designs, used in the drivetrain for the cooling unit that provide greater moisture and corrosion resistance, as well as greater bearing life and higher tolerance to misalignment.

Adding a cooling tower brake can provide features such as slow-stopping a fan, which is a great timesaver for maintenance personnel. The brake can also hold the fan in place to avoid wind milling, which can cause damage in high wind as well as provide lockout for maintenance safety. There are even less intrusive devices that can be added — such as a torque arm — which helps eliminate wind milling.

All of these improvements can extend unit life and reduce downtime for cooling units. Having the units inspected and evaluated may produce some surprising information. **PTE**



Like ACHE motors, cooling tower duty motors also operate in harsh conditions with high humidity, which necessitates utilizing a cast iron frame, bracket and conduit box with seals for IP55 protection. Image courtesy Nidec Corp.

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