bundle. The space between the fan(s) and the tube bundle is enclosed by a plenum chamber which directs the air (flow field) over the tube bundle assembly thereby providing cooling. The whole assembly is usually mounted on legs or a pipe rack. The fans are usually driven by electric induction motors through some type of speed reducer. The speed reducers are typically V-belts, HTD drives, or right-angle gears. The fan drive assembly is supported by a steel mechanical drive support system. They usually include a vibration switch on each fan to automatically shut down a fan which has become imbalanced for some reason. Airflow is very important in ACHE cooling to ensure that the air has the proper "flow field" and velocity to maximize cooling. Turbulence and "choked-flow conditions can impair cooling efficiency. Therefore, mass airflow is the key parameter to removing heat from the tube and bundle system. ACHE cooling differs from "wet" cooling (i.e. wet cooling towers) towers in that ACHE systems do use water to cool the tube bundle and thus, do not benefit from the latent heat of vaporization or "evaporative cooling".

Prior art ACHE fan drive systems use any one of a variety of fan drive components. Examples of such components include electric motors, steam turbines, gas or gasoline engines, or hydraulic motors. The most common drive device is the electric motor. Steam and gas drive systems have been used when electric power is not available. Hydraulic motors have also been used with limited success. Specifically, although hydraulic motors provide variable speed control, they have relatively low efficiencies.

Fan-tip speed should not exceed 12,000 feet per minute for mechanical reasons, and may be reduced to obtain lower noise levels. Motor and fan speed are

shown in FIGS. 1 and 2, respectively, can be configured as any one of the prior art fan drive systems discussed in the foregoing discussion. FIGS. 3, 4, 5 and 6 show the commonly or widely used prior art fan drive systems. FIGS. 3 and 4 show the common gear-box type fan drive system. This fan drive system, which is generally referred to by reference number 28, comprises induction motor 29 and right-angle gear box 30. The shaft of motor 29 is coupled to right-angle gear box 30 by coupling 31. Shaft 32 extends from gear box 30. A coupling 33 is connected to shaft 32. Induction motor 29 and gear box 30 are mounted to support plate 34. Support plate 34 is mounted to machinery mount 35. Support plate 34 and machinery mount structure 35 are part of the structure of the ACHE system. Fan mount 36 is attached to coupling 33. The fan (not shown) is connected to fan mount 36. Fan mount support members 37 provide support to fan mount 36.

FIG. 5 shows a prior art fan-drive system that uses a belt-drive configuration to drive the fan in an ACHE system. This fan-drive system comprises induction motor 38 (shown in phantom), sprocket 39 and belt 40. Sprocket 39 is connected to a fan mount 42. Rotation of the shaft of induction motor 38 causes rotation of sprocket 39 which, in turn, causes rotation of the fan (not shown). Induction motor 38 is mounted to a support plate 43 which is adjustably attached to support member 44. Belt-tension adjustment device 45 can adjust the position of support plate 43 with respect to support member 44 in order to adjust the tension on belt 40.

FIG. 6 shows a prior art fan-drive system that uses a drive sprocket to drive the fan in an ACHE system. This fan-drive system comprises induction motor 46 (shown in phantom), driver sprocket 47 and driven sprocket 48. Driver sprocket 47 is

f) locks out a particular motor speed that creates resonance;

g) alerts the operator to imbalance such as ice accumulation on fan blades and automatically initiates corrective action.

h) sensor data is used by system logic and software algorithms to provide "cooling performance management" of the system. (Cooling performance management provides real-time operating, reliability and performance data and analysis of the cooling system to predict and schedule corrective action, maintenance intervals and provide cooling performance feedback to the operator for use in adjusting the process based on cooling performance).

Referring to FIG. 13, there is shown an ACHE system that is configured as an induced draft ACHE and has the same general structural components as the ACHE shown in FIG. 1, except for the prior art fan drive system which has now been replaced with the fan drive system of the present invention. In this configuration, variable frequency drive (VFD) device 50 and motor 52 are supported by support member 18. Motor 52 is located below tube bundle 12. Fan 15 is positioned above plenum 13 and rotates within fan ring 14 as described in the foregoing description. One end of vertical shaft 16 is coupled to hub 15A and the other end is coupled to shaft 56 with coupling 150. VFD device 50 is in electrical signal communication with permanent magnet motor 52 via cables or wires 54.

Referring to FIG. 14, there is shown another ACHE system that is configured as an induced draft ACHE and which uses the fan drive system of the present invention. ACHE system ~~200~~ generally comprises a support structure that comprises a plurality of support columns ~~202~~. Tube bundle ~~204~~ is supported by the ACHE

~~support structure. Plenum 206 is located above tube bundle 204. Fan ring 208 is attached to plenum 206 and to the support structure of ACHE 200. Fan 210 rotates within fan ring 208. Fan 210 includes hub 212. Plenum 206 has an upper portion to which motor 52 and VFD 50 are mounted. Shaft 56 of motor 52 is directly coupled to hub 212 of fan 210. VFD device 50 is in electrical signal communication with permanent magnet motor 52 via cables or wires 54.~~

Thus, the fan drive system of the present invention provides many advantages and benefits, including:

a) elimination of many components found in the prior art fan drive systems, such as gear boxes, pulleys, belts, sprockets, drive shafts, couplings, bearings, shaft seals, etc.;

b) elimination of oil changes;

c) significant reduction in service and maintenance;

d) ability to vary the speed of the permanent magnet motor over a relative wide range of speeds;

e) ability to reverse direction of the permanent magnet motor without any additional components;

f) consumption of significantly lower amounts of energy in comparison to prior art fan drive systems;

g) easy retrofit with existing fan thereby eliminating need to construct new ACHE cooling towers or structures;

h) significant reduction in the occurrence of cell outages; and

i) provides significantly more cooling capacity in comparison to prior art

gearbox-type fan drive.

The operational logic and ~~current~~ system architecture of the present invention will provide the ability to optimize the cooling tower for energy efficiency (e.g. at night when it is cold) and to maximize cooling on hot days or when the process demands additional cooling or to avoid fouling of auxiliary systems such as condenser and heat exchangers.

Other significant advantages of the fan drive system of the present invention are improved reliability, in comparison to prior art fan drive systems, "more air flow per ampere" improves electrical efficiency in comparison to prior art systems, and has a relatively smaller footprint due to the elimination the gear train offset thereby providing more space for airflow per envelope and less structural obstructions and passing flow frequency issues. The present invention provides direct-drive simplicity with a simple, two-bearing, robust design. The fan drive system of the present invention is relatively easier to install, maintain and remove. The simple, low-part count design of the fan drive system of the present invention allows it to be "dropped in" existing ACHE installations and eliminates tension-alignment devices that are required by prior art fan drive systems using shafts, belts and pulleys.

The permanent magnet motor 52 is capable of providing constant high-torque with infinitely variable speed control that allows an existing installation envelope to be optimized for cooling effectiveness and high energy efficiency. The permanent magnet motor 52 provides high, constant torque and electrical efficiency through-out the entire variable speed range. Thus, with the fan drive system of the present invention, it is easier to match the required mass airflow of a particular application with

In accordance with the invention, permanent magnet motor 52 is a sealed motor unlike prior art motor drive systems which are open to the environment and susceptible to contamination from water, chemicals, dust and foreign particles..

~~Although the foregoing discussion is in terms of the applicability of the present invention to the petroleum industry, it is to be understood that the present invention provides benefits to any industry using ACHE cooling systems. Thus, the present invention has applicability to many industries that consume large amounts of energy and are process intensive, such as the power generation, petro-chemical, pulp and paper, and chemical, glass, mining, steel, and aluminum industries. Other examples of systems, industries and applications to which the present invention may apply include air cooler fans, process coolers /condensers, gas coolers, gas compressor inter/after coolers, steam condensers, seal/lube oil cooler, closed loop cooling water system coolers, HVAC, geothermal plant condensers, inter-coolers and after-coolers, HVAC and Refrigeration Condensers, Air Cooled Condensers, Air Cooled Radiators for large stationary power applications such as gensets as well as transportation applications such as rail road locomotives, marine power, mining and large earth moving equipment.~~

It will thus be seen that the objects set forth above, among those elucidated in, or made apparent from, the preceding description, are efficiently attained and, since certain changes may be made in the above construction and/or method without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawing figures shall be interpreted as illustrative only and not in a limiting sense. It is also to be understood that the

bundle. The space between the fan(s) and the tube bundle is enclosed by a plenum chamber which directs the air (flow field) over the tube bundle assembly thereby providing cooling. The whole assembly is usually mounted on legs or a pipe rack. The fans are usually driven by electric induction motors through some type of speed reducer. The speed reducers are typically V-belts, HTD drives, or right-angle gears. The fan drive assembly is supported by a steel mechanical drive support system. They usually include a vibration switch on each fan to automatically shut down a fan which has become imbalanced for some reason. Airflow is very important in ACHE cooling to ensure that the air has the proper "flow field" and velocity to maximize cooling. Turbulence and "choked-flow conditions can impair cooling efficiency. Therefore, mass airflow is the key parameter to removing heat from the tube and bundle system. ACHE cooling differs from "wet" cooling (i.e. wet cooling towers) towers in that ACHE systems do not use water to cool the tube bundle and thus, do not benefit from the latent heat of vaporization or "evaporative cooling".

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FIG. 5 shows a prior art fan-drive system that uses a belt-drive configuration to drive the fan in an ACHE system. This fan-drive system comprises induction motor 38 (shown in phantom), sprocket 39 and belt 40. Sprocket 39 is connected to a fan mount 42. Rotation of the shaft of induction motor 38 causes rotation of sprocket 39 which, in turn, causes rotation of the fan (not shown). Induction motor 38 is mounted to a support plate 43 which is adjustably attached to support member 44. Belt-tension adjustment device 45 can adjust the position of support plate 43 with respect to support member 44 in order to adjust the tension on belt 40.

FIG. 6 shows a prior art fan-drive system that uses a drive sprocket to drive the fan in an ACHE system. This fan-drive system comprises induction motor 46 (shown in phantom), driver sprocket 47 and driven sprocket 48. Driver sprocket 47 is

f) locks out a particular motor speed that creates resonance;

g) alerts the operator to imbalance such as ice accumulation on fan blades and automatically initiates corrective action.

h) sensor data is used by system logic and software algorithms to provide "cooling performance management" of the system. (Cooling performance management provides real-time operating, reliability and performance data and analysis of the cooling system to predict and schedule corrective action, maintenance intervals and provide cooling performance feedback to the operator for use in adjusting the process based on cooling performance).

Referring to FIG. 13, there is shown an ACHE system that is configured as an induced draft ACHE and has the same general structural components as the ACHE shown in FIG. 1, except for the prior art fan drive system which has now been replaced with the fan drive system of the present invention. In this configuration, variable frequency drive (VFD) device 50 and motor 52 are supported by support member 18. Motor 52 is located below tube bundle 12. Fan 15 is positioned above plenum 13 and rotates within fan ring 14 as described in the foregoing description. One end of vertical shaft 16 is coupled to hub 15A and the other end is coupled to shaft 56 with coupling 150. VFD device 50 is in electrical signal communication with permanent magnet motor 52 via cables or wires 54.

Referring to FIG. 14, there is shown another ACHE system that is configured as an induced draft ACHE and which uses the fan drive system of the present invention. ACHE system 400 generally comprises a support structure that comprises a plurality of support columns 400. Tube bundle 404 is supported by the ACHE

support structure. Plenum 406 is located above tube bundle 404. Fan ring 408 is attached to plenum 406 and to the support structure of ACHE 400. Fan 410 rotates within fan ring 408. Fan 410 includes hub 412. Plenum 406 has an upper portion 414 to which motor 52 and VFD 50 are mounted. Shaft 56 of motor 52 is directly coupled to hub 412 of fan 410. VFD device 50 is in electrical signal communication with permanent magnet motor 52 via cables or wires 54.

Thus, the fan drive system of the present invention provides many advantages and benefits, including:

a) elimination of many components found in the prior art fan drive systems, such as gear boxes, pulleys, belts, sprockets, drive shafts, couplings, bearings, shaft seals, etc.;

b) elimination of oil changes;

c) significant reduction in service and maintenance;

d) ability to vary the speed of the permanent magnet motor over a relative wide range of speeds;

e) ability to reverse direction of the permanent magnet motor without any additional components;

f) consumption of significantly lower amounts of energy in comparison to prior art fan drive systems;

g) easy retrofit with existing fan thereby eliminating need to construct new ACHE cooling towers or structures;

h) significant reduction in the occurrence of cell outages; and

i) provides significantly more cooling capacity in comparison to prior art

In accordance with the invention, permanent magnet motor 52 is a sealed motor unlike prior art motor drive systems which are open to the environment and susceptible to contamination from water, chemicals, dust and foreign particles..

Although the foregoing discussion is in terms of the applicability of the present invention to the petroleum industry, it is to be understood that the present invention provides benefits to any industry using ACHE cooling systems. Thus, the present invention has applicability to many industries that consumer large amounts of energy and are process intensive, such as the power generation, petro-chemical, pulp and paper, chemical, glass, mining, steel, and aluminum industries. Other examples of systems, industries and applications to which the present invention may apply include air cooler fans, process coolers/condensers, gas coolers, gas compressor inter/after coolers, steam condensers, seal/lube oil coolers, closed-loop cooling water system coolers, HVAC, geothermal plant condensers, inter-coolers and after-coolers, HVAC and Refrigeration Condensers, Air-Cooled Condensers, Air Cooled Radiators for large stationary power applications such as gensets as well as transportation applications such as railroad locomotives, marine power, mining and large earth moving equipment.

It will thus be seen that the objects set forth above, among those elucidated in, or made apparent from, the preceding description, are efficiently attained and, since certain changes may be made in the above construction and/or method without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawing figures shall be interpreted as illustrative only and not in a limiting sense. It is also to be understood that the