Air-Cooled Heat Exchanger and Improved Performance

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Abstract:

In this paper, we present updated information on air-cooled heat exchangers (ACHE), including their advantages and disadvantages, classification, and main components. We then proceed to explain an experiment where we installed an ACHE in an oil production facility and discuss its impacts on operation. Subsequently, we discuss various methods for improving the performance of ACHE. Finally, we describe an experiment where we installed evaporative cooling pads on the ACHE as a pre-cooling system to enhance thermal performance in hot weather.

Keywords:

Air-cooled heat exchanger, Effect of ACHE in oil production facilities, improve performance of ACHE, Pre-cooling systems of ACHE.

Introduction:

Air-cooled heat exchanger (ACHE) is a type of heat exchanger that uses ambient air as the cooling medium to remove heat from a process fluid. It is designed to transfer heat between a fluid (such as a gas or liquid) and the surrounding air without the need for water or other external cooling fluids. These heat exchangers are also known as Air Fin Fan Coolers or Air Fin Coolers or Air Coolers or Fin-tube heat exchangers.

In oil and gas production facilities, as well as in situations where gas cannot be recovered, the use of ACHE as a condenser for condensing process fluids becomes necessary. This is particularly relevant in cases where oil and gas wells produce three-phase fluids consisting of gas, oil, and water. The primary objective is to minimize the amount of gas released to the flare, and ACHE plays a crucial role in achieving this goal by converting the gas phase into a liquid phase. Consequently, the implementation of ACHE leads to an increase in oil production. In this study, we present experimental evidence demonstrating the impact of installing ACHE on the crude oil well pipeline downstream of the choke before the separators process. Our findings reveal a notable increase in the oil rate by 3.5%, achieved through condensate recovery. Additionally, we observed a significant decrease in gas by 5% this study applied for two oil wells with total oil producing 22000 bbl./d and gas production 42 MMscf.

Air-cooled heat exchangers and performance improvement tools including pre-cooling systems are typically needed during hot weather, when the temperature difference between ambient air and process fluid is close to each other, necessitating maximum capacity operation. In winter, capacity can be reduced by adjusting fan speed, bypassing improvement tools, or even stopping the motor completely, depending on process requirements. In some cases, excessive cooling may have negative effects, so it should be carefully controlled.

By implementing various strategies, the performance of the air-cooled heat exchanger can be significantly improved, resulting in better heat transfer and reduced operational costs. Several of these strategies will be discussed, followed by Experiment installing evaporative cooling pads on ACHE to improve thermal performance in extreme hot weather.

Definition of Air-Cooled Heat Exchangers:

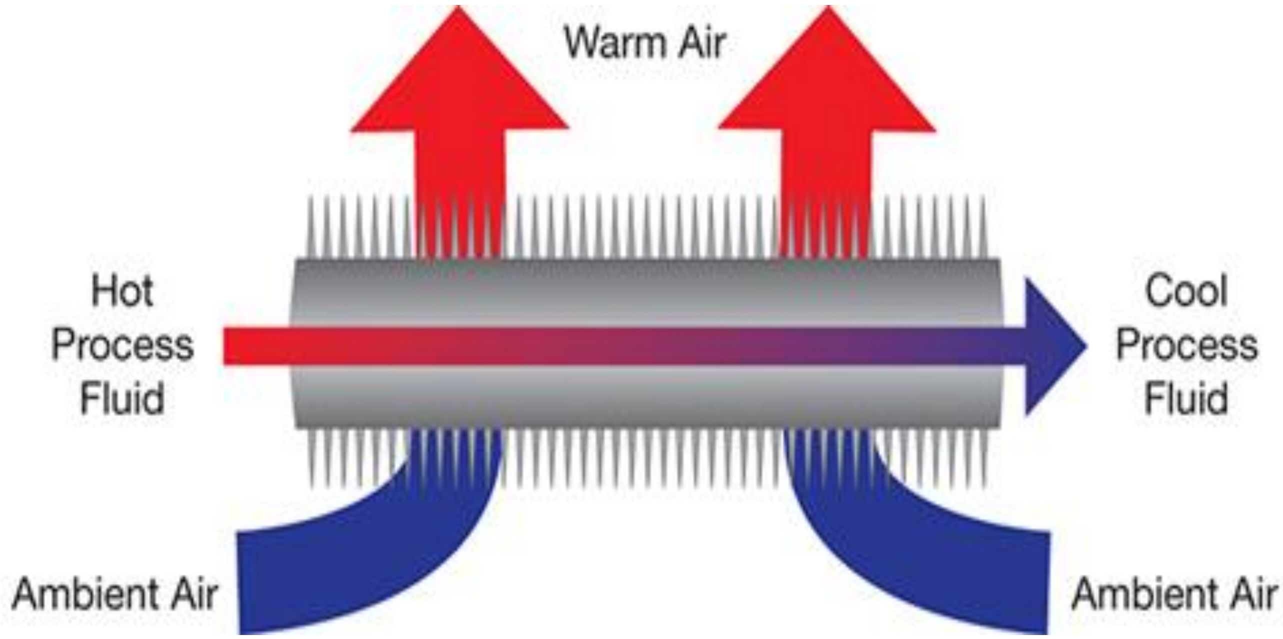


Figure 1. Air-cooled heat exchanger basic

Air cooled heat exchangers (ACHEs) are devices that transfer heat from a fluid to ambient air through convection and radiation. ACHEs consist of a bundle of tubes through which a fluid flows, with a series of fins attached to the tubes to increase the heat transfer area. Ambient air is forced over the fins and tubes by fans or natural convection, and heat is transferred from the fluid to the air (Figure 1). ACHEs are commonly used in applications where water is scarce, or the use of water for cooling is not desirable, such as in remote locations, arid climates, or where water quality is poor.

Advantages and Disadvantages:

Advantages of air-cooled heat exchangers (ACHEs) include:

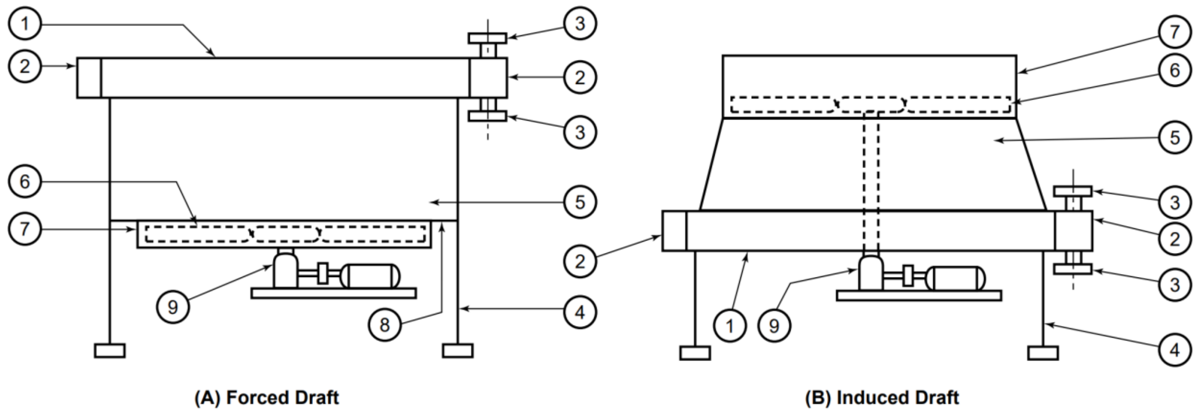
- No water requirement: ACHEs do not require a source of water for cooling, making them suitable for use in locations where water is scarce or of poor quality.
- Low maintenance: ACHEs do not have moving parts in the cooling medium, such as pumps or cooling towers, making them less susceptible to mechanical failure and requiring less maintenance.
- Lower operating cost: ACHEs do not require chemicals for water treatment or electricity for pumping, resulting in lower operating costs.
- Greater flexibility: ACHEs can be installed in a variety of locations, including remote areas, and can be used for a range of cooling duties.

Disadvantages of air-cooled heat exchangers (ACHEs) include:

- Higher capital cost: ACHEs require larger surface areas to transfer the same amount of heat as water-cooled heat exchangers, resulting in higher capital costs.
- Limited heat transfer capacity: ACHEs have limited heat transfer capacity due to the lower heat transfer coefficients of air compared to water, which can result in larger and more expensive units.
- Limited cooling capacity at high temperatures: ACHEs become less effective as the temperature difference between the fluid and the ambient air in-creases, which can limit their cooling capacity in high-temperature applications.
- Noise and vibration: ACHEs can generate noise and vibration from the fans, which can be a concern in some applications.

Parts of Air-cooled Heat Exchanger:

API STANDARD 661



Legend

1. Tube bundle
2. Header
3. Nozzle
4. Supporting column
5. Plenum
6. Fan
7. Fan ring
8. Fan deck
9. Drive assembly

Figure 2—Typical Components of an Air-Cooled Heat Exchanger

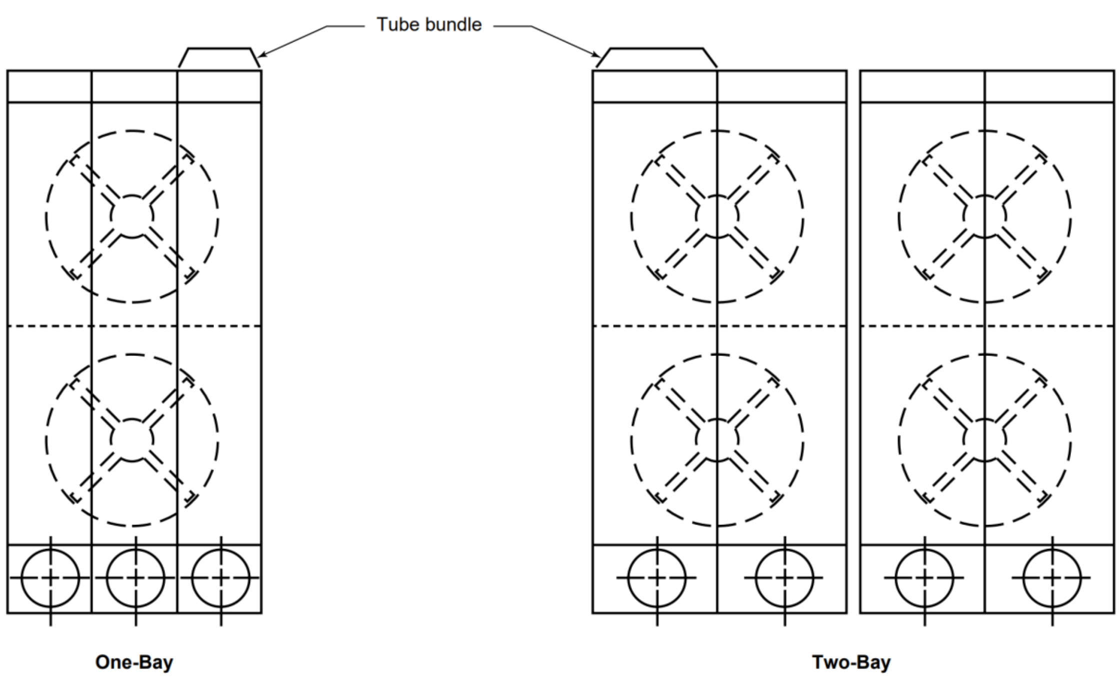


Figure 3—Typical Bay Arrangements

Air-cooled heat exchanger consists of following components:

- One or more bundles of heat-transfer surface consisting of finned or bare tubes connected by headers.
- A fan or blower that moves the air.
- Unless it is a natural draft application, a driver (usually an electric motor) and power transmission device (usually belt or gear) to mechanically rotate the air-moving device.
- A plenum
- A supporting structure
- Header and Fan maintenance platforms.
- Optional louvers and recirculation ducts
- Optional variable-pitch fan hub or variable-frequency drive for temperature control and power savings.

Bay Arrangement in Air Cooler:

One or more tube bundles, serviced by two or more fans, including the structure, plenum, and other attendant equipment is called a bay in an air-cooled heat exchanger. Refer to Fig. 3 for typical bay arrangements.

Header:

Headers distribute fluid from the source piping to the finned tubes. For most applications, a plug box header design is used for the tube bundle (Figure 4, top). A cover plate header design can be used if the inside of header boxes must be accessed (Figure 4, bottom). Although it is the more expensive alternative, the cover plate design allows full access to the inside of the headers for inspection and cleaning. The cover plate design is usually limited, however, to a maximum design pressure of 350 psig.

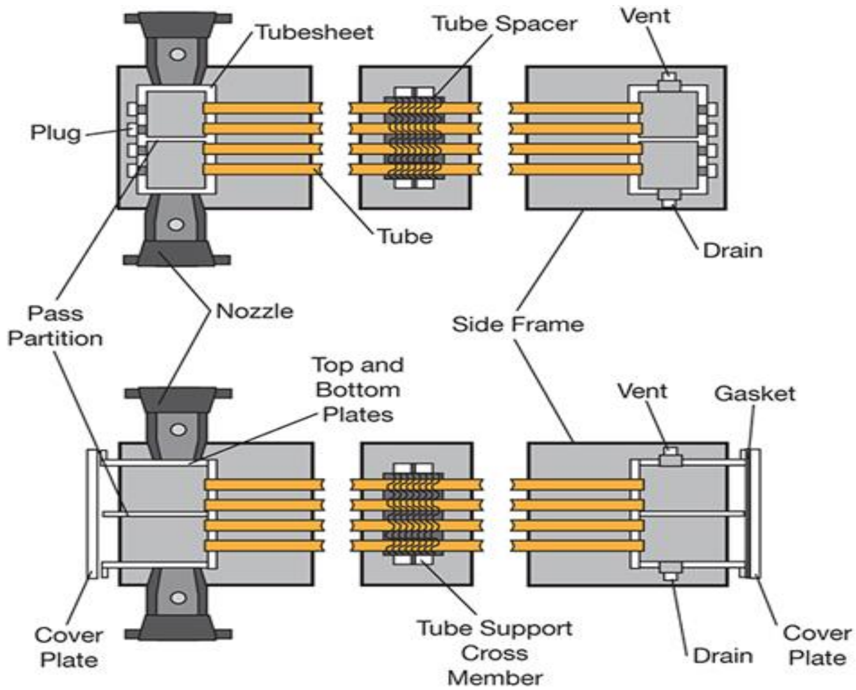


Figure 4. Tube bundles may be constructed with plug headers (top) or cover plate headers (bottom).

Tube Bundle:

A tube bundle is an assembly of tubes, headers, side frames, and tube supports as shown in Figure 4. Usually, the tube surface exposed to the passage of air has extended surface in the form of fins to compensate for the low heat transfer rate of air at atmospheric pressure and at a low enough velocity for reasonable fan power consumption. The prime tube is usually round and of any metal suitable for the process, due consideration being given to corrosion, pressure, and temperature limitations. Fins are helical or plate type, and are usually of aluminum for reasons of good thermal conductivity and economy of fabrication. Steel fins are used for very high temperature applications.

Fins are attached to the tubes in a number of ways:

1) by an extrusion process in which the fins are extruded from the wall of an aluminum tube that is integrally bonded to the base tube for the full length.

2) by helically wrapping a strip of aluminum to embed it in a pre-cut helical groove and then peening back the edges of the groove against the base of the fin to tightly secure it, or

3) by wrapping on an aluminum strip that is footed at the base as it is wrapped on the tube. Figure 6 shows a cutaway view of these finned tubes.

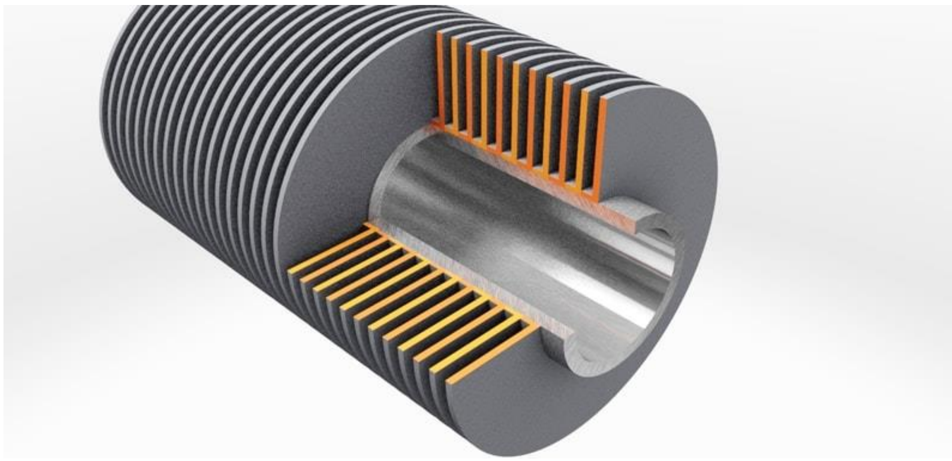


Figure 5. Airside tube surfaces in an ACHE have fins to compensate for the low heat-transfer rate of air.

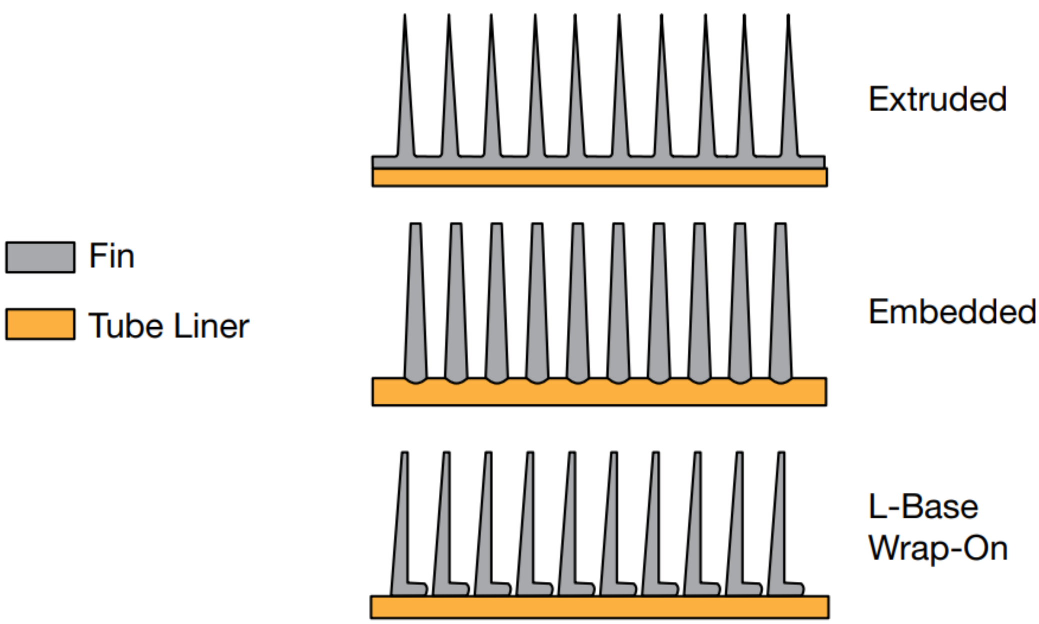


Figure 6. The three basic types of aluminum fins are extruded, embedded, and wrap-on.

Sometimes serrations are cut in the fins. This causes an interruption of the air boundary layer, which increases turbulence which in turn increases the air-side heat transfer coefficient with a modest increase in the air-side pressure drop and the fan horsepower.

The choice of fin types is critical. This choice is influenced by cost, operating temperatures, and the atmospheric conditions. Each type has different heat transfer and pressure drop characteristics. The extruded finned tube affords the best protection of the liner tube from atmospheric corrosion as well as consistent heat transfer from the initial installation and throughout the life of the cooler. This is the preferred tube for operating temperatures up to 600°F. The embedded fin also affords a continued predictable heat transfer and should be used for all coolers operating above 600°F and below 750°F. The wrap-on footed fin tube can be used below 250°F; however, the bond between the fin and the tube will loosen in time and the heat transfer is not predictable with certainty over the life of the cooler. It is advisable to derate the effectiveness of the wrap-on tube to allow for this probability.

There are many configurations of finned tubes, but manufacturers find it economically practical to limit production to a few standard designs. Tubes are manufactured in lengths from 6 to 60 feet and in diameters ranging from 5/8 inch to 6 inches, the most common being 1 inch. Fins are commonly helical, 7 to 11 fins per inch, 5/16 to 1 inch high, and 0.010 to 0.035 inch thick. The ratio of extended to prime surface varies from 7:1 to 25:1. Bundles are rectangular and typically consist of 2 to 10 rows of finned tubes arranged on triangular pitch. Bundles may be stacked in depths of up to 30 rows to suit unusual services. The tube pitch is usually between 2 and 2.5 tube diameters. Net free area for air flow through bundles is about 50% of face area. Tubes are rolled or welded into the tube sheets of a pair of box headers.

The box header consists of tube sheet, top, bottom, and end plates, and a cover plate that may be welded or bolted on. If the cover is welded on, holes must be drilled and threaded opposite each tube for maintenance of the tubes. A plug is screwed into each hole, and the cover is called the plug sheet. Bolted removable cover plates are used for improved access to headers in severe fouling services. Partitions are welded in the headers to establish the tube-side flow pattern, which generates suitable velocities in as near countercurrent flow as possible for maximum mean temperature difference. Partitions and stiffeners (partitions with flow openings) also act as structural stays. Horizontally split headers may be required to accommodate differential tube expansion in services having high fluid temperature differences per pass. Figure 4 illustrates common heat types.

Bundles are usually arranged horizontally with the air entering below and discharging vertically. Occasionally bundles are arranged vertically with the air passing across horizontally, such as in a natural draft tower where the bundles are arranged vertically at the periphery of the tower base. Bundles can also be arranged in an “A” or “V” configuration, the principal advantage of this being a saving of plot area. The disadvantages are higher horsepower requirements for a given capacity and decreased performance when winds on exposed sides inhibit air flow.

Mechanical Equipment of HEAC:

Fans may be driven by electric motors, steam turbines, gas or gasoline engines, or hydraulic motors. The overwhelming choice is the electric motor. Hydraulic motors are sometimes used when power from an electric utility is unavailable. Hydraulic motors also provide variable speed control, but have low efficiencies. The most popular speed reducer is the high-torque positive type belt drive, which uses sprockets that mesh with the timing belt cogs. They are used with motors up to 50 or 60 horsepower, and with fans up to about 18 feet in diameter. Banded V-belts are still often used in small to medium sized fans, and gear drives are used with very large motors and fan diameters. Fan speed is set by using a proper combination of sprocket or sheave sizes with timing belts or V-belts, and by selecting a proper reduction ratio with gears. Fan tip speed should not be above 12,000 feet per minute for mechanical reasons, and may be reduced to obtain lower noise levels. Motor and fan speed is sometimes controlled with variable frequency drives. Figure 7 provides a breakdown of the mechanical equipment and figure 8 shows typical drive arrangements according to API stander 661.

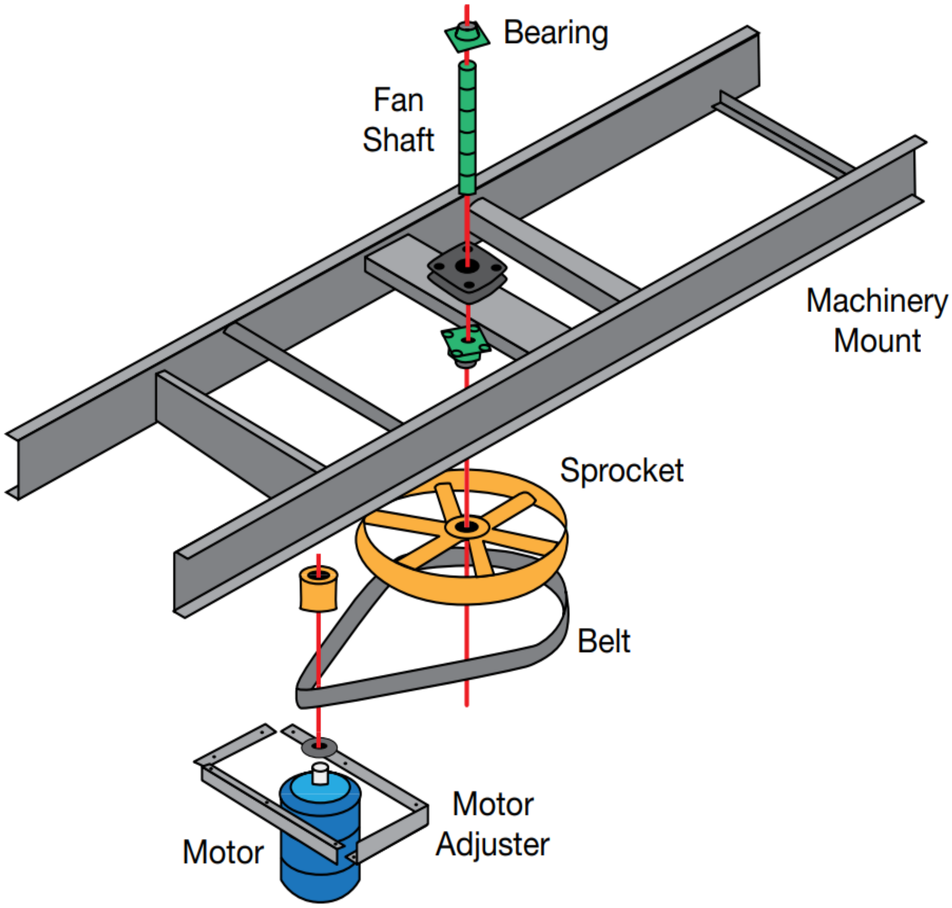
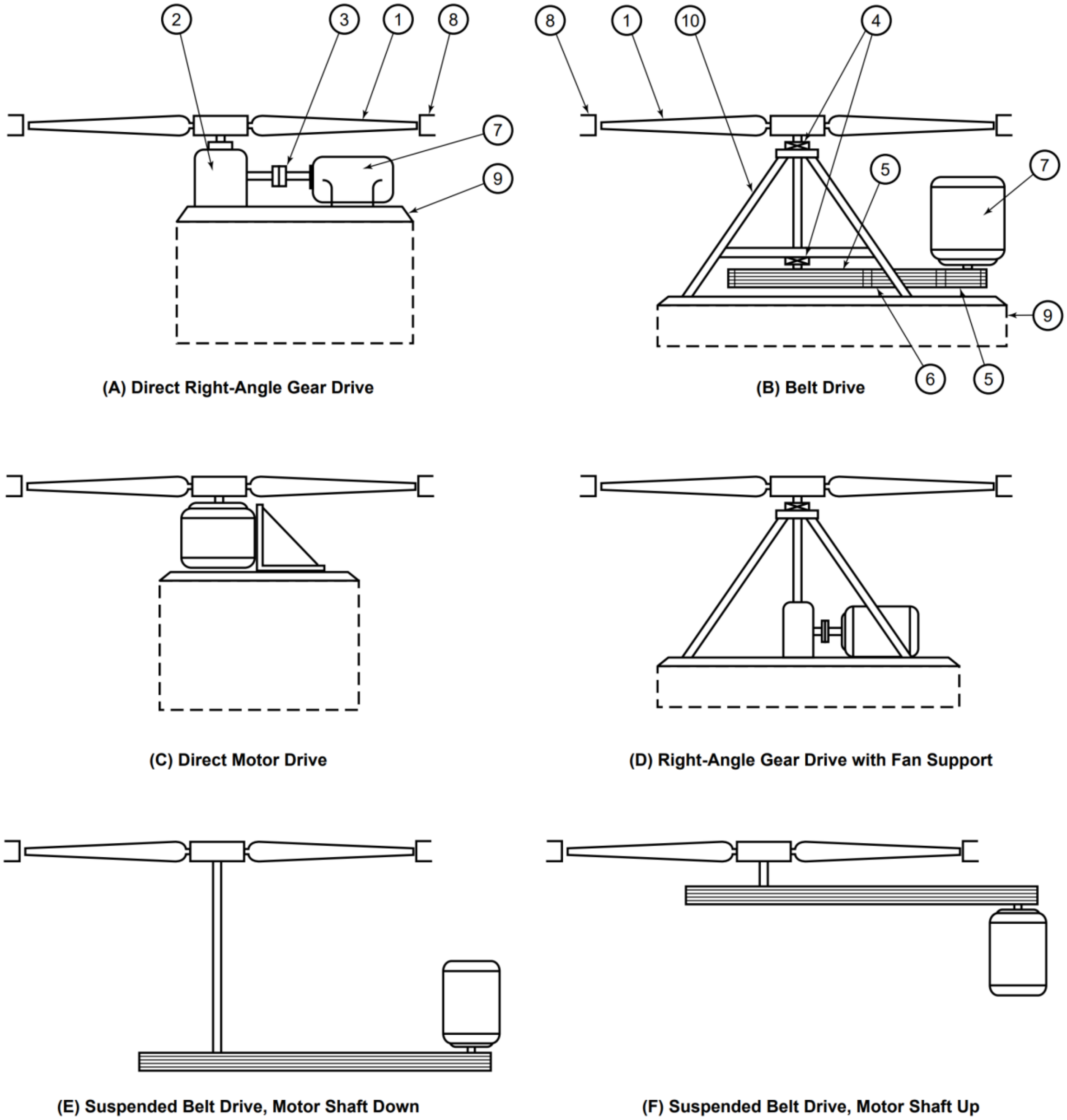


Figure 7. A typical mechanical drive system for an ACHE.



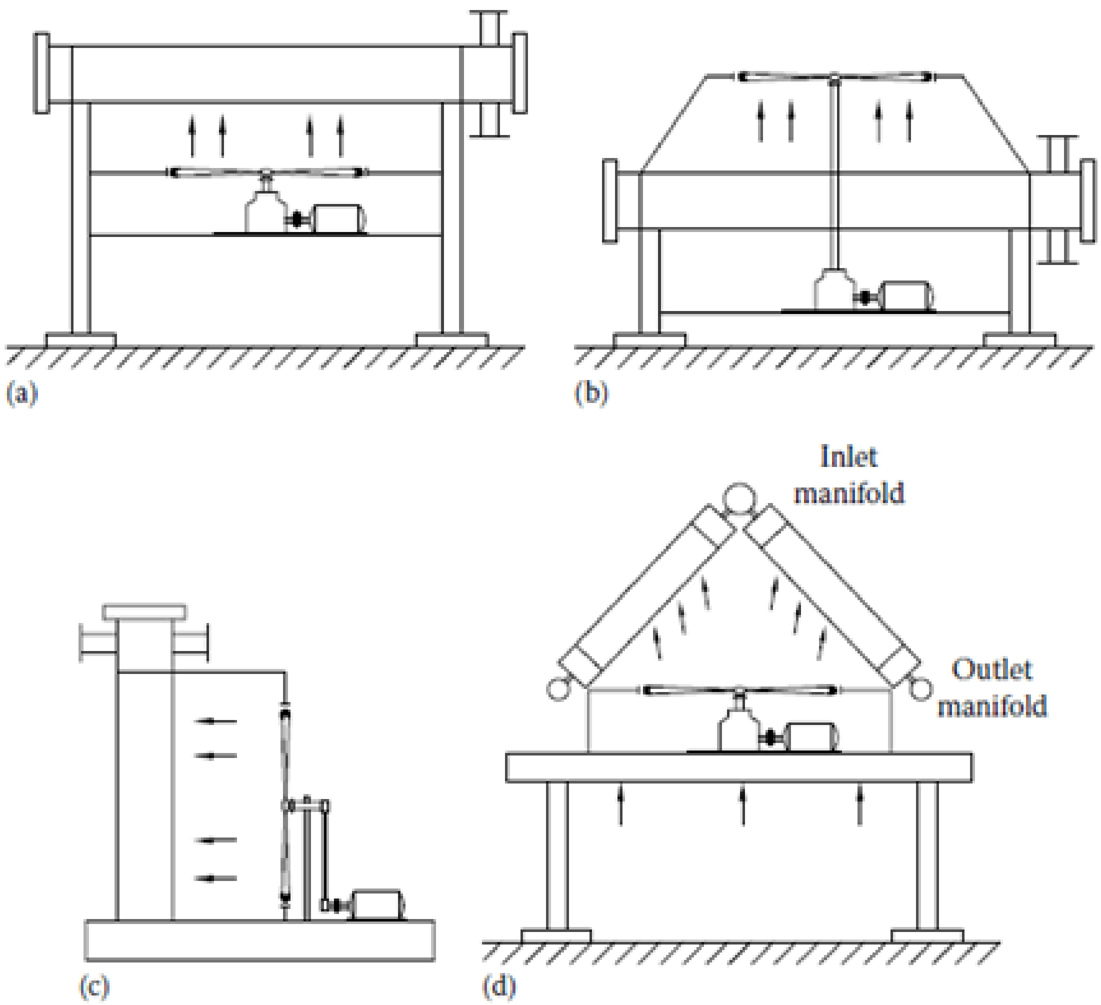
Legend

1. Fan
2. Gear
3. Coupling
4. Bearing
5. Sheave
6. Belt Drive
7. Motor
8. Fan ring
9. Base plate
10. Fan support

Figure 8–Typical Drive Arrangements

Air-cooled heat exchangers can be classification into below types.

1. Horizontal forced draft Air cooled heat exchanger
2. Horizontal induced draft Air cooled heat exchanger H
3. Vertical Air-cooled heat exchanger.
4. A frame air-cooled heat exchanger.



Orientation of ACHE tube bundle—(a) horizontal, forced draft, (b) horizontal, induced draft, (c) vertical, and (d) A-frame.

Figure 9- Orientation of ACHE tube bundle

Forced draft VS Induced draft:

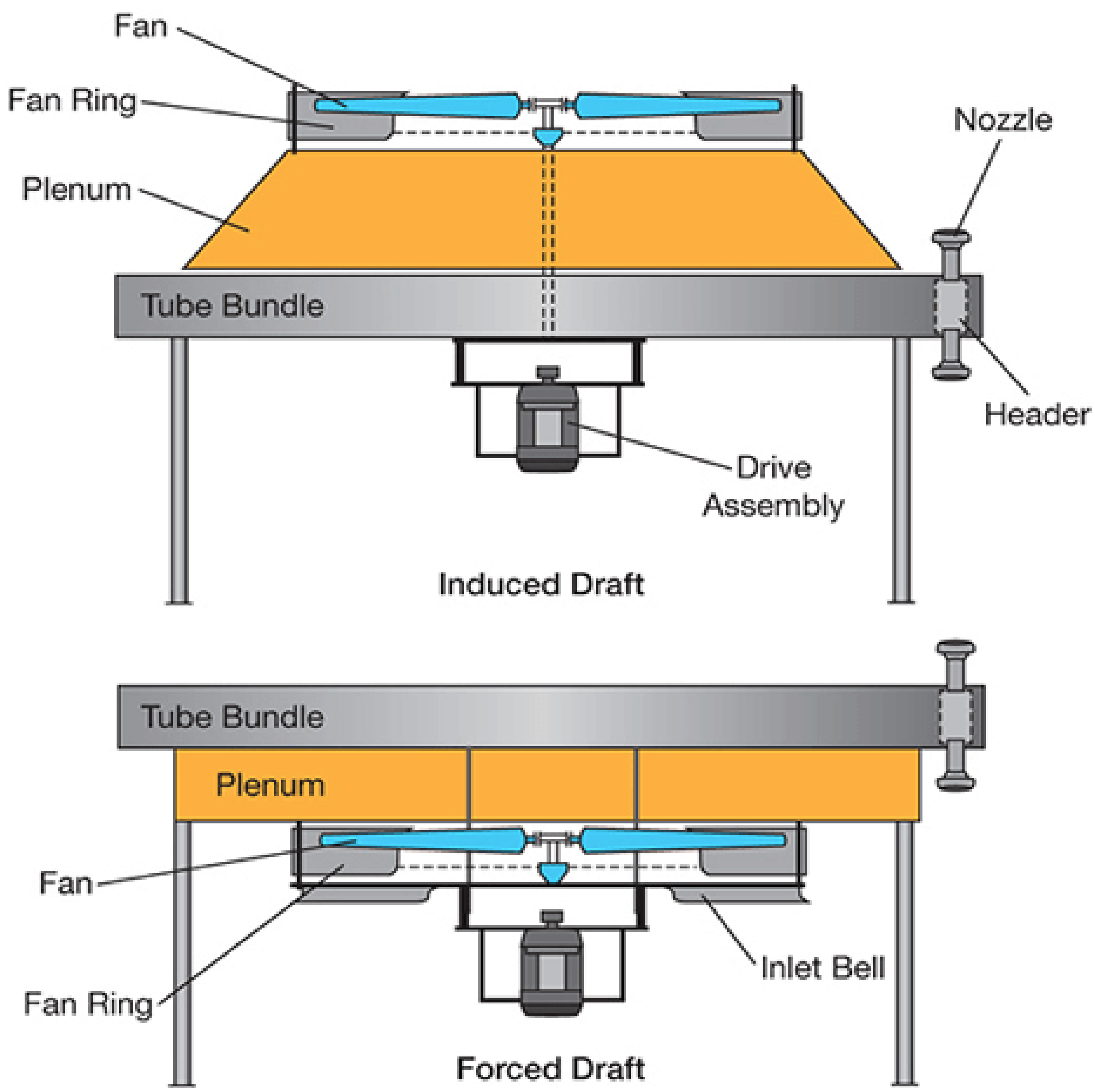


Figure 10. ACHE Forced draft and Induced draft

The moving of air across the tube bundle may be either forced draft or induced draft. Both arrangements are shown in figure 10.

Forced draft: in this arrangement fan is located below the tube bundle and air is forced through the fin tubes. The majority of air-cooled heat exchangers are forced draft type.

(A) As forced draft fans are at air inlet of ACHE, these have the advantage of handling cold air entering the exchanger.

(B) As air at outlet is hotter it has increased volume at outlet. Being at inlet forced draft requires moving smaller volumes of air and requires less horsepower than induced draft.

(C) It generally offers batter maintenance access as the tube bundle is mounted on top and can easily be removed.

(D) A common problem with forced draft coolers is accidental warm air recirculation.

Induced Draft: In this arrangement fan is located above the tube bundle and air is induced or pulled through the fin tubes.

Compared with forced draft design, induced draft design has the below advantages.

(A) Easier to shop assemble, ship and install.

(B) The hoods offer protection from weather and hailstone protection.

(C) Induced draft with fan above them can be mounted directly on the pipe rack, eliminating the structural steel support which results in lower material cost as well as simplified field installation.

(D) With the fan above cell, hot air exits the top of the unit at 2.5 times the velocity possible in the forced draft unit so it is less likely to be affected by hot air recirculation.

(E) Batter air distribution over the tube bundle.

And some of the disadvantages are:

(A) More difficult to remove bundle for maintenance.

(B) High temperature service is limited due to effect of hot air on the fans.

(C) More difficult to work on the fan assembly due to heat from the bundle and due to their location.

Natural Draft: Natural ventilation does not need a fan to operate. Air circulates because of the temperature difference between the inside and outside of ACHE and also due to difference in height. A chimney is provided above the tube bundle to create the draft necessary to suck and push air through the tube bundle. That's why it is called "chimney effect". One of the advantages of natural draft is that of a silent and economical unit.

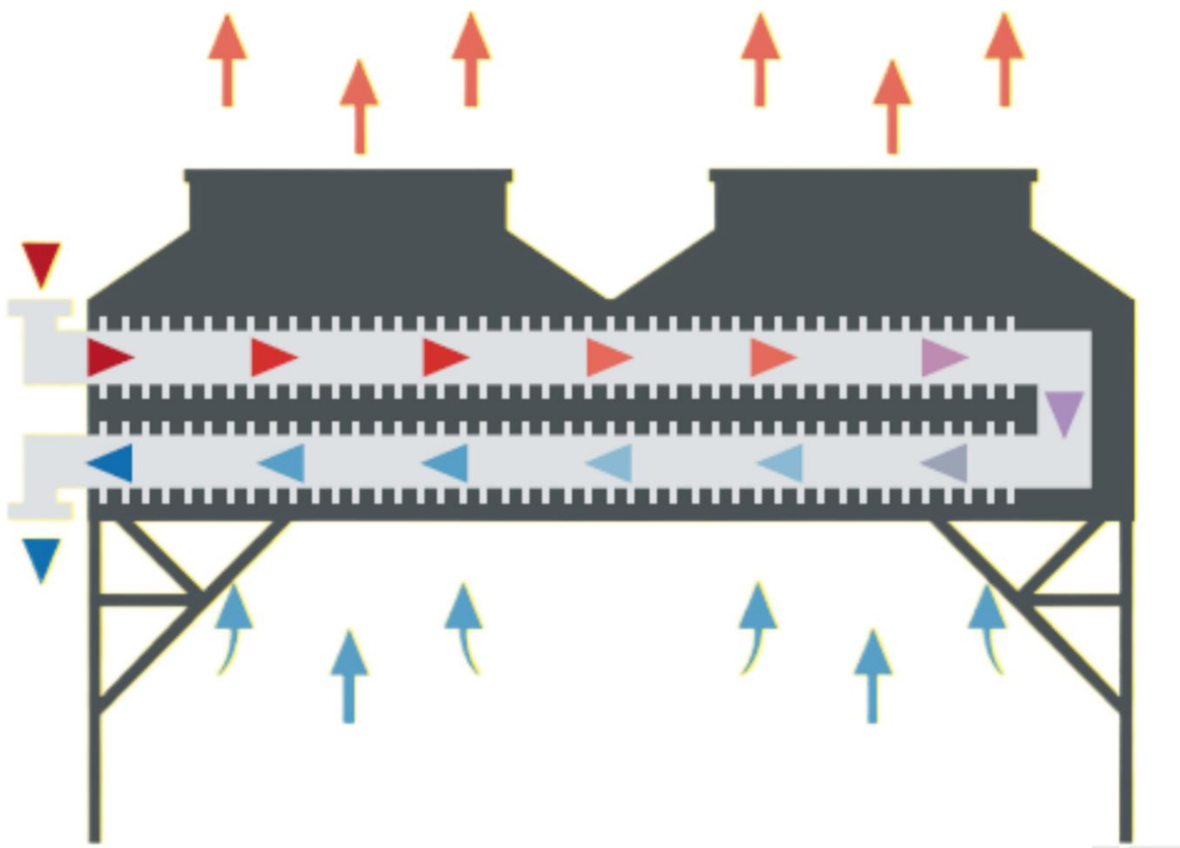


Figure 11-Natural draft air-cooled heat exchanger

Recirculation: Air cooled heat exchanger with internal recirculation systems is used in extremely cold climates. This system is used to control the cooling air temperature regardless of ambient air temperature. This prevents clogging of the fluids to be cooled. Internal recirculation system requires the use of positive and negative step auto variable fans.

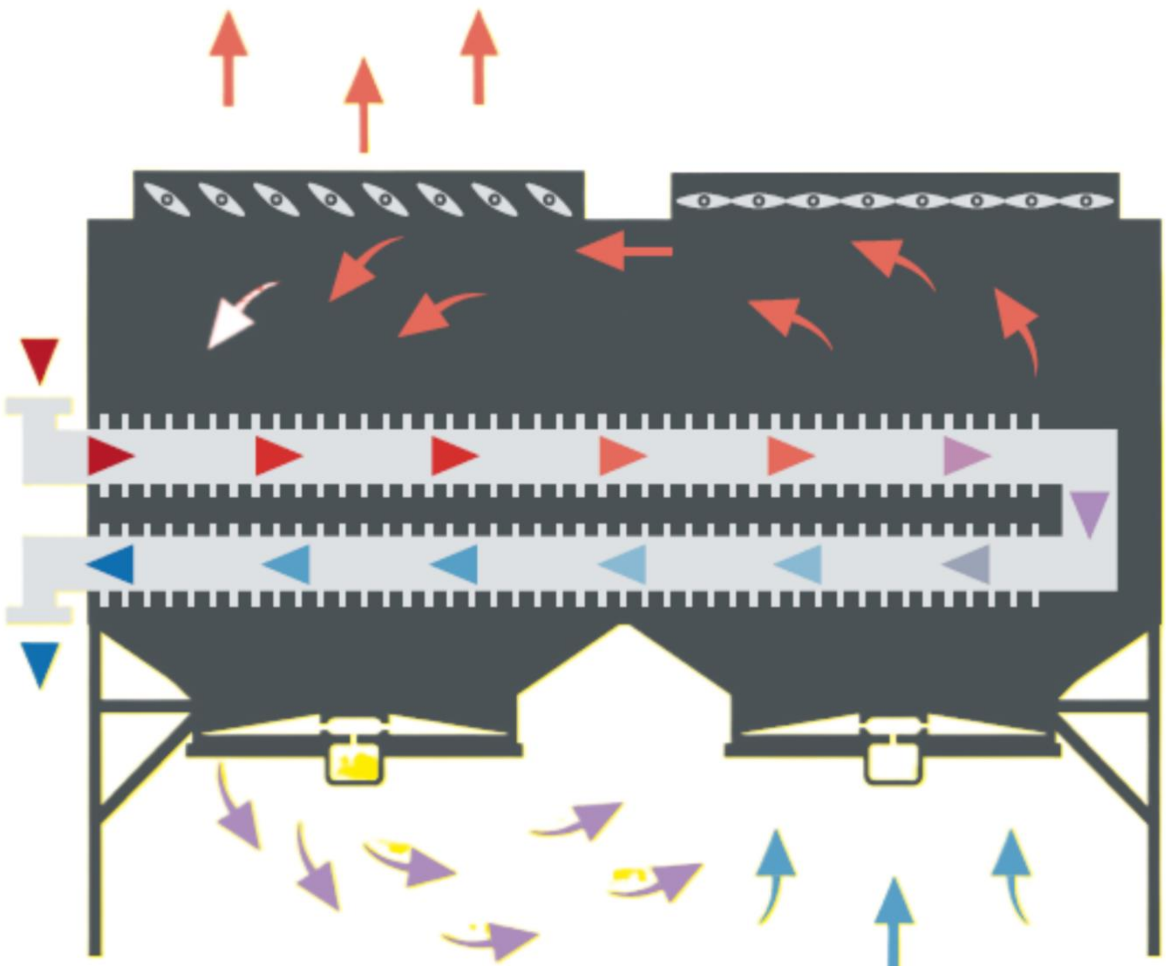


Figure 12- Recirculation-air cooled heat exchanger

Experiment installing ACHE in CPF oil production:

Our experimental research focuses on the impact of installing an ACHE on the crude oil well pipeline downstream of the choke, prior to the separators process. Through the cooling effect of the ACHE, the crude oil undergoes a phase conversion, resulting in the conversion of certain gases carbon pulse five (C+5) into the liquid phase. This conversion leads to an increase in oil production, while simultaneously reducing the gas rate and the gas oil ratio (GOR). The initial oil production rate is recorded at 22000 bbl/d, while the gas rate at 42 MMscfd. we observe that the implementation of the intervention results in a 3.5% increase in oil production and a 5% decrease in gas rate. Furthermore, this intervention proves effective in eliminating smoke emissions from the HP flare. Additionally, offers the benefit of improved equipment performance and extended lifespan of its components. One of the main drawbacks of this process is the formation of asphaltene and wax in pipelines and equipment. Additionally, it leads to an increase in the rate vapor pressure (RVP). To analyze the impact of this process, we conducted laboratory tests on oil well samples. By comparing the results before and after the installation of ACHE, we aim to gain a better understanding of the effects.

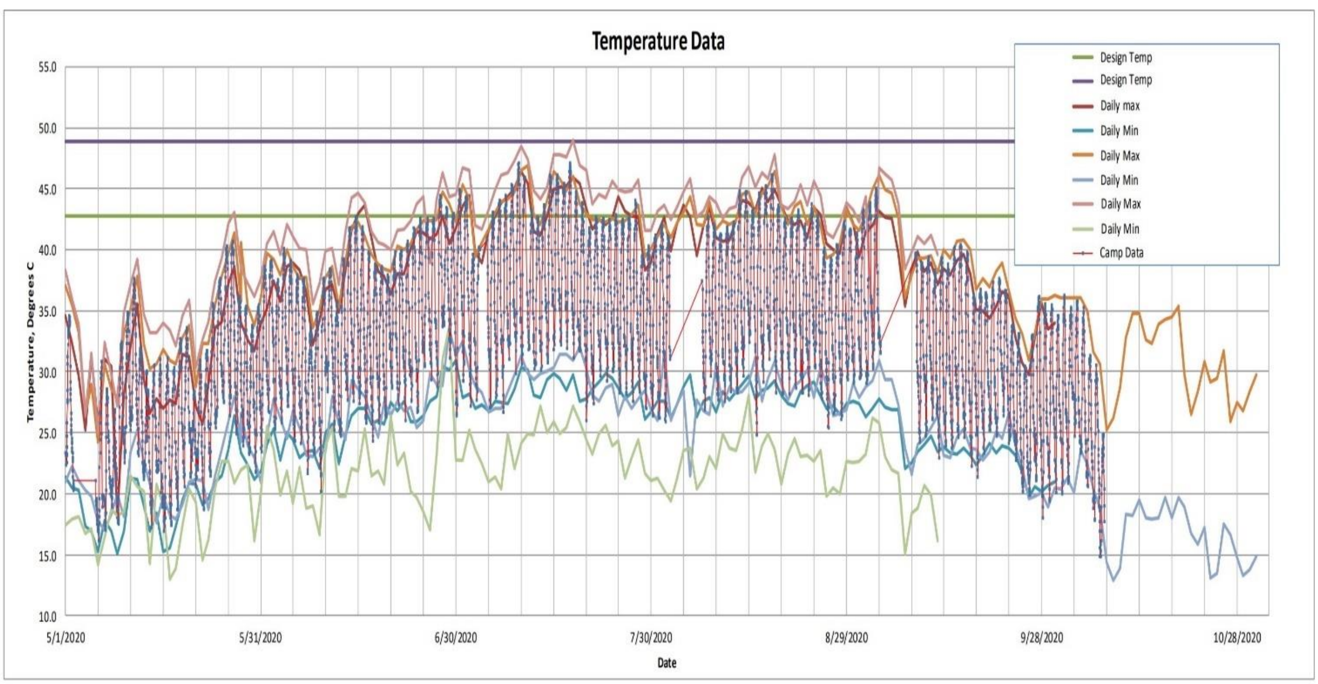
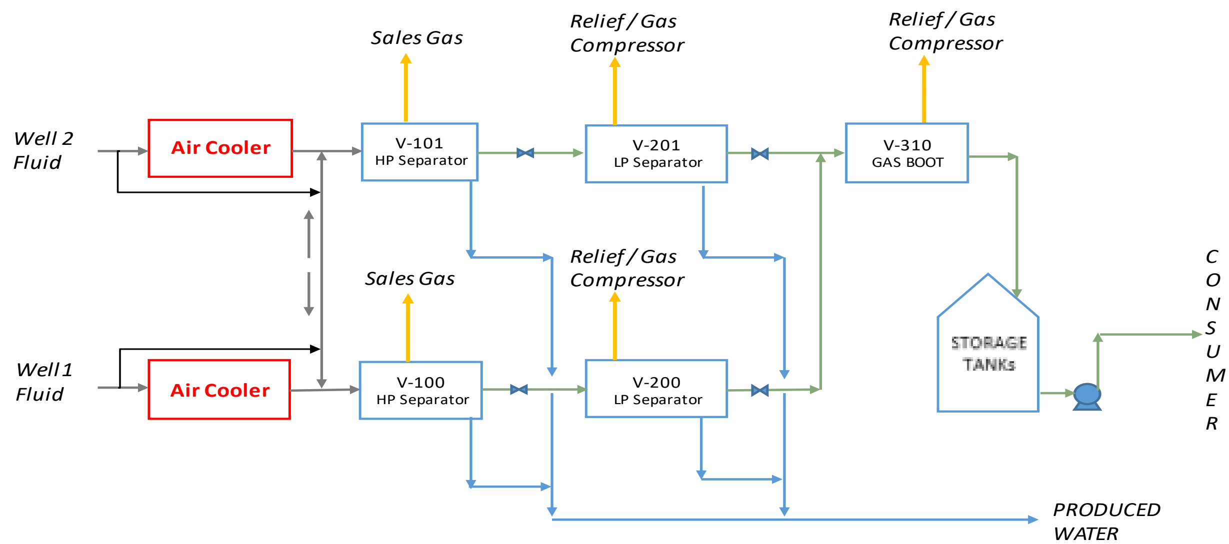


Chart 1- the chart displays ambient temp in CPF. Temp rises from May to peak in July & Aug, then starts to decrease in Oct this pattern repeats every year.

BLOCK FLOW DAIGRAM



In the diagram, ACHE is installed upstream of HP separators in an oil production facility. The correct location is important and must be carefully studied in order to maximize its potential. In this case, it has been installed before the separation process, which means it condenses some gases into liquid, which in turn increases the production of oil. Oil wells may be located many kilometers from CPF, so we have two options when installing ACHE, either within the oil well area or within the CPF. This depends on the condition of the oil well. However, it is recommended that we choose the closer distance from separation due to the following reasons:

-The cooldown of the process fluid from an oil well causes asphaltene and wax to form in the pipeline. In order to clean long pipelines, there is an additional cost and downtime associated with their maintenance.

- When a process fluid is cooled in an oil well, it causes slow down initial separation among the fluid components in the pipeline, and also leads to emulsion formation.

-When ACHE is installed in an oil well, it has difficult access for operation and maintenance.

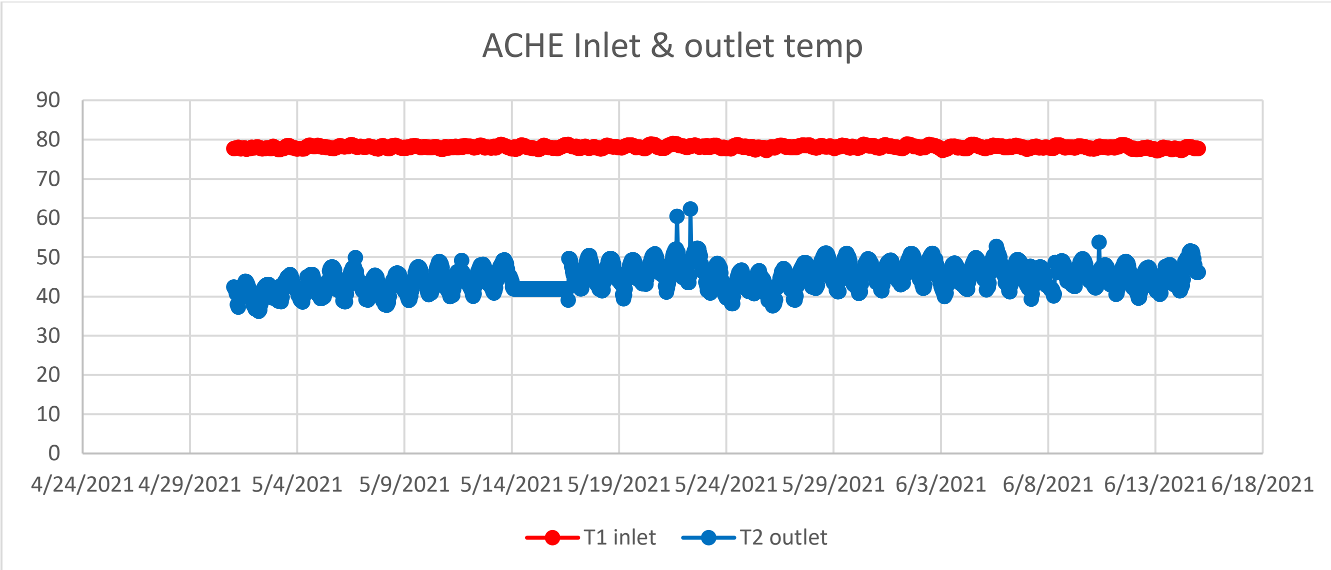


Chart 2 presents the process fluid temperature data for oil well #1 at the inlet and outlet of the (ACHE). The average temp at the inlet is recorded at 78°C, while at the outlet, it is 44°C. This results in a differential temp of 34°C. note that these values are subject to variation throughout the year. In the winter increases to 45°C, whereas in the summer, it decreases to 20°C. Consequently, during the summer months, we must focus on improving the thermal performance of the ACHE in order to increase this temperature difference.

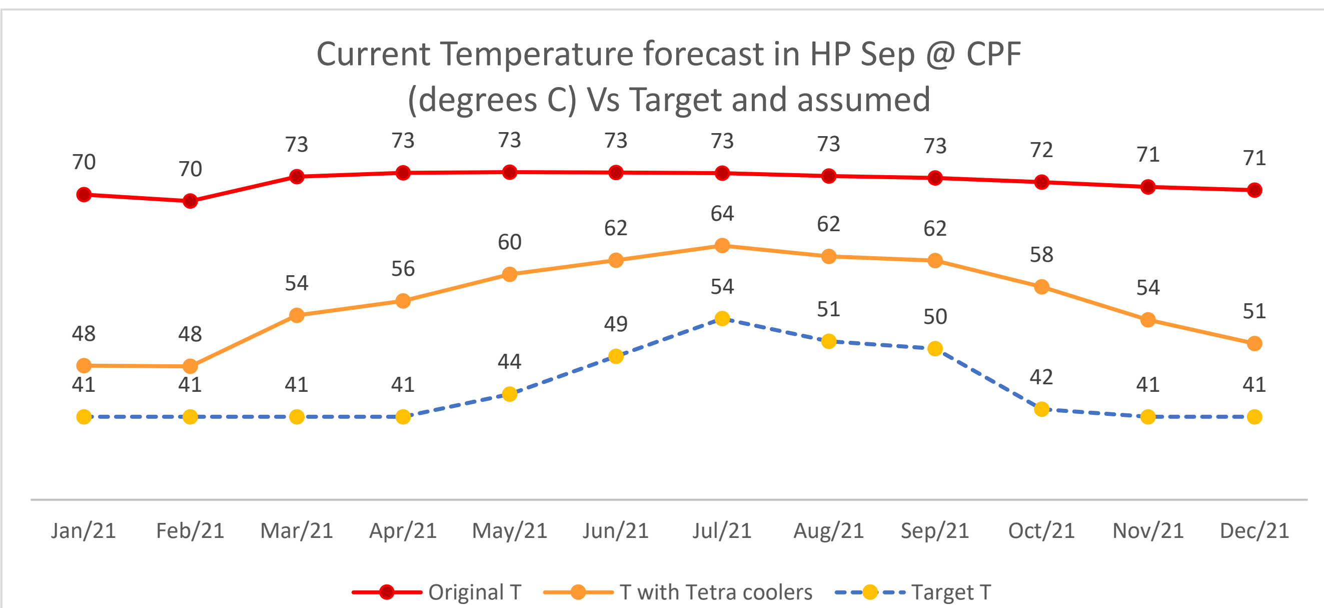


Chart 3. Present the fluid temp in HP separator, The red line represents the temp without the presence of an ACHE. The orange line corresponds to the temperature with one ACHE in operation, while the blue line represents the temp with two ACHE's in operation

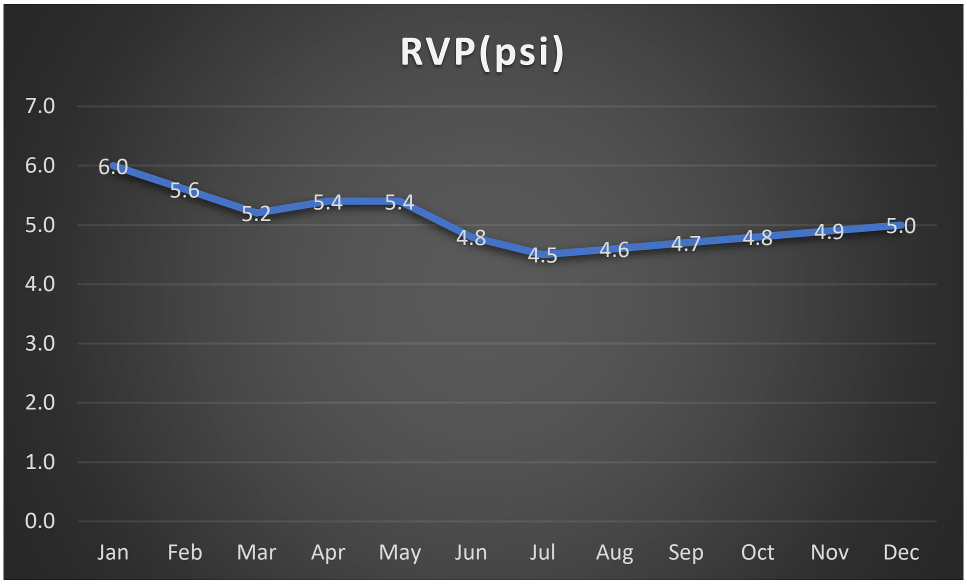


Chart 4. Present oil RVP without the presence of an ACHE in 2020.

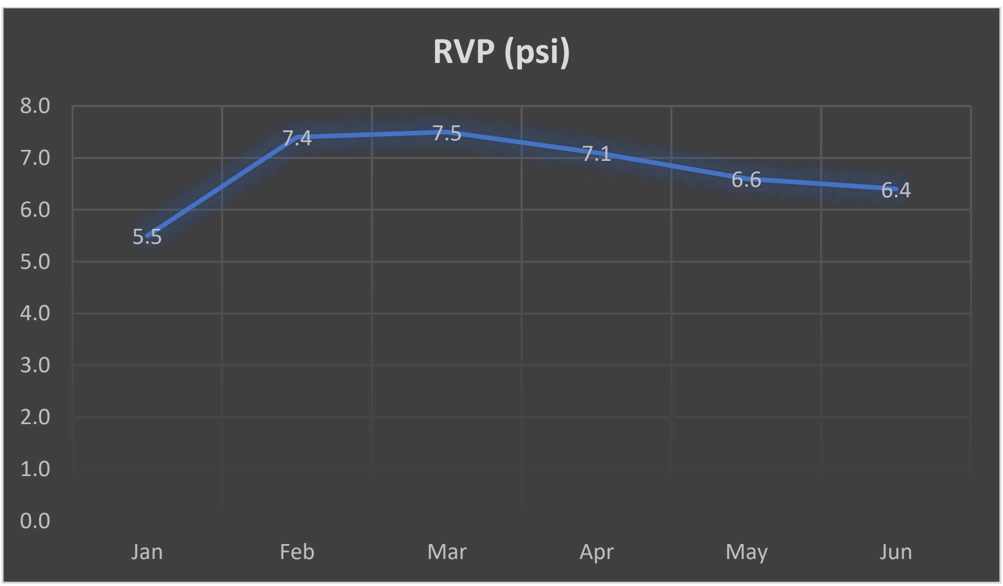


Chart 5. Present oil RVP with the one ACHE in operation in 2021.

In charts 4 and 5, we observe that the cooling process fluid exhibits a slight increase in the Reid Vapor Pressure (RVP) of the product oil. This observation suggests that the cooling process has an impact on the volatility of the oil, potentially leading to changes in its vapor pressure.

Calculating the effect of ACHE on daily produced oil

Crude oil specification is:

API 39 @60F, BS&W <1% and RVP 6 psi @100F.

Date	Calculation period	ACHE in Operation	Oil Rate bbl./day
2021	00:00 - 24:00	No	22303
2021	00:00 - 24:00	Yes	23082
Balance			**+ 779**

Table 1. Effect of ACHE on oil production.

Date	ACHE in Operation	Separator Temp.C
2021	No	~ 50
2021	Yes	~ 67
Balance		**- 17**

Table 2. Effect of ACHE on Separator fluid Temperature

Fluid cooling impact on process operation and control it:

The maximum effect of ACHE observation in a hot climate due to the temperature difference between the process fluid and ambient air temperature is close to each other. However, it does not have any adverse effect on process operation, whereas, in cold climates, it can negatively impact the process, which should be addressed carefully in order to minimize or avoid it.

Asphaltene and wax formation in process pipelines and equipment are our major problems. In certain temperatures and pressure conditions, asphaltene and wax are formed. In cold weather, these conditions are suitable for the formation of asphaltene and wax.

Asphaltene deposition inside ACHE tubes leads to a decrease in tube diameter, resulting in increased resistance to process fluid flow. This, in turn, creates back pressure in the oil well flowline, leading to a reduction in oil production. The impact of asphaltene deposition is more pronounced in the ACHE compared to other equipment due to its smaller tube diameter.

To effectively manage the effects of asphaltene and wax, it is crucial to closely monitor the pressure diffraction through the ACHE. If an increase in pressure diffraction is observed, it is necessary to implement the following stages in order to normalize the situation. These stages are aimed at mitigating the impact of asphaltene and wax and ensuring optimal operational conditions.

1. In instances where the cooling of process fluid is deemed unnecessary, it is possible to reduce the capacity of the ACHE by discontinuing the use of the pre-cooling system, decreasing the fan speed, and closing the ACHE louvers. By doing so, the fluid can be maintained at a higher temperature within the tube bundle, effectively preventing the formation of asphaltene and wax.

2. In the event that step one does not resolve the issue at hand, it is recommended to proceed with the injection of asphaltene/wax inhibitor at the inlet of the ACHE. This measure is undertaken to effectively control and ensure the smooth operation of the system.

3. When differential pressures through the ACHE suddenly rise, it is imperative to open the bypass line of the ACHE, when the problem has been resolved so that the system can be normalized.

Wax deposition can result in the restriction of crude oil flow in the pipeline and equipment, creating pressure abnormalities and causing a blockage of the pipeline, pump strainers, flowmeter, and instrumentation devices. also, it obstructs the pump's work. There is a problem associated with wax accumulation in the storage tank, which makes disposal difficult.

The cooling process fluid has a side effect of slightly increasing the RVP of the product oil, as shown in charts 4&5. This, in turn, leads to an increase in lower explosive limit (LEL) gas during truck loading. To address this issue, is installed a gas blower on the truck vent flare line as a result, the process of ventilating the vaper will be accelerated.

Improvement Thermal Performance of ACHE

ACHEs utilize ambient air to cool process fluids that are susceptible to extreme temperatures. However, in hot weather, the cooling capacity of ACHEs diminishes as the temperature difference between the outside and inside of the tubes decreases. Therefore, without optimization or a pre-cooling system, the ACHE unit becomes ineffective.

We can describe improvement thermal performance of ACHE in three stages:

1- Revert ACHE to its original design condition.
2- Upgrade ACHE components.
3- Utilize Pre-cooling system.

These stages are executed sequentially until cooling capacity of the unit is meet with the process requirement.

1- Revert ACHE to its original design condition.

To revert ACHE to its original condition you need to obtain the original manufacture specification datasheet for the unit which contains all information about thermal and mechanical design Table 1 is an example of this datasheet. Then compare datasheet parameters with the current condition considering the lifetime of the unit, normally all equipment loses their efficiency over time.

Cooling issues should be resolved or better if the current duty requirement is equal to or less than the original design condition. If the current duty is greater than the original design condition, there are some methods that can be taken to upgrade the unit.

In order to return the unit to its original design and before you can initiate any improvements, you must perform a detailed visual inspection of the units. Start with easy and more effective unit components:

a) **Louvers**: are they fully open or partial open or close, in some time strong wind can close them if not locked properly or may lover actuator control have failed
b) **Fan**: Measure fan shaft RPM (revolution pre mints) by Tachometer if it's at the maximum limit as per specification datasheet. If RPM was lower than designed speed then inspects Mechanical components for any abnormal conditions. if the unit belt drive inspects condition and tension of the Belt, drive and driven Sprockets condition and alignment, if the unit gear drive inspects condition of Gearbox and Shaft Coupling between motor and gearbox then inspect Motors, if the motor current draw meet to the designed horsepower. Inspects condition of Blade Pitch and Tip clearance if they are match with designed datasheet.

General check for Vibration, it has many reasons usually accrue due to fan unbalance, and check for abnormal sound which has also more reason mostly accrue due to fan shaft bearing frailer.

c) Tube Bundle

• **Finned Tubes:** check if finned tubes are dirty or fouled (Figure 13). Check condition of tubes and fin it's not destroyed or crashed. Inspects condition of Air seals, Headers, Tube supports, Frame.

Clean the finned-tube bundle:

Clean fined tube is most effective way to optimizing unit efficiency while has low cost if compared with another method so will describe cleaning method in following steps:

Brush the fins: Using a soft-bristled brush, gently brush the fins to remove any dirt, debris, or dust. Make sure to brush in the direction of the fins, not across them, to avoid bending or damaging them.

Vacuum the fins: After brushing, use a vacuum cleaner with a soft brush attachment to remove any loose debris or dust from the fins.

Clean the fins with a fin comb: For more stubborn dirt or debris, you can use a fin comb to gently comb the fins. Be careful not to apply too much pressure or force, as this can damage the fins.

Rinse the fins: Use a hose to rinse the fins with water, being careful not to use too much pressure, which can also damage the fins.

Allow the fins to dry: After rinsing, allow the fins to air dry completely before turning the power back on.

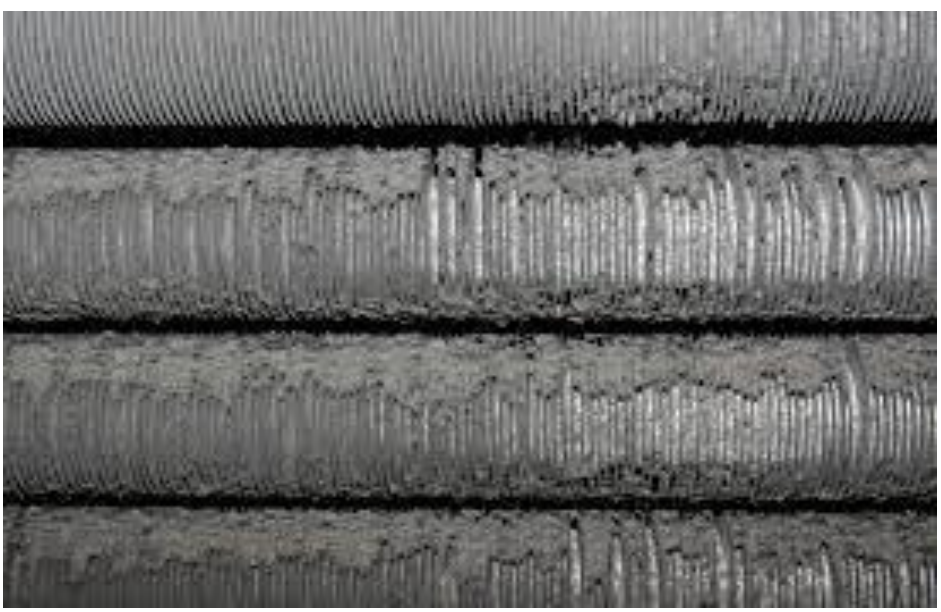


Figure 13- Air-cooled heat exchanger Fouling

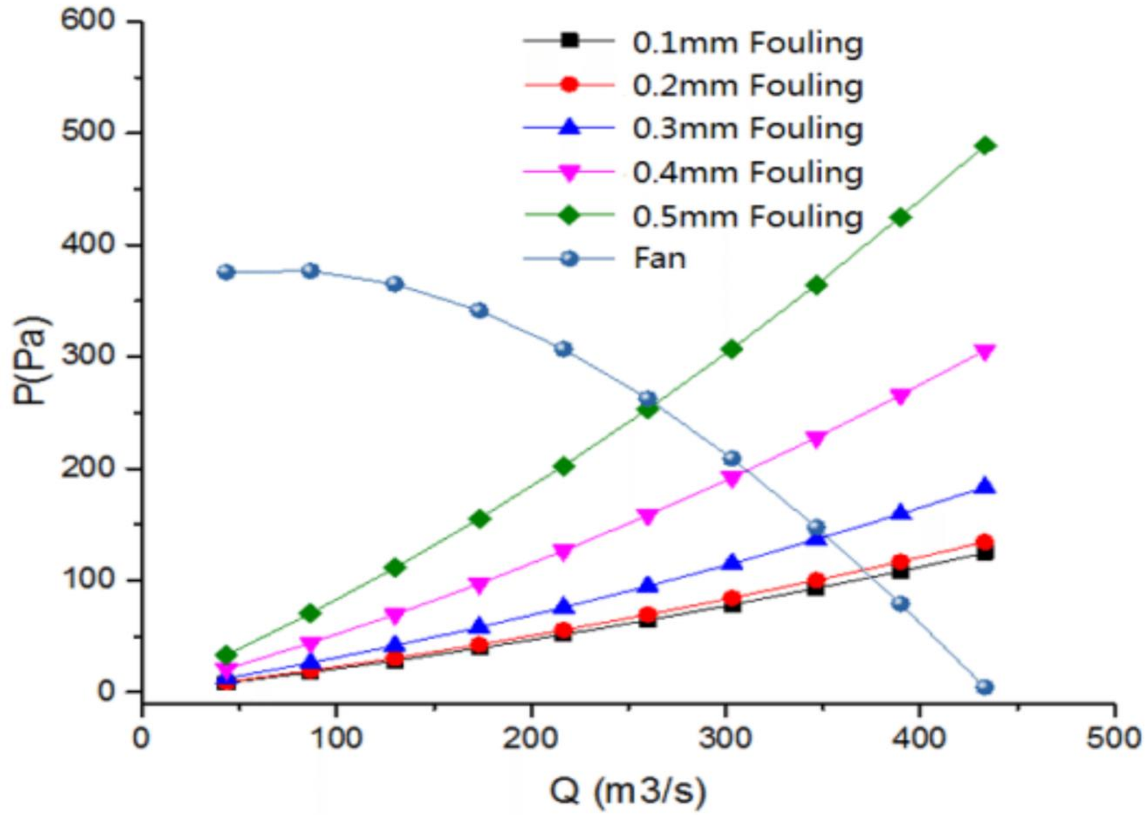


Chart 6. The performance of the fan and the ACHE under various fouling thickness, the heat transfer coefficient with the finned tube fouling thickness showed a slightly increasing, but the fan performance reduced greatly. The decrease of flow rate of the cooling air resulting to reduce efficiency of the unit.

Once this mechanical inspection is complete, steps should be taken as necessary to bring the ACHE back to the as-built condition. In some instances, simple bundle cleaning and fan adjustments, repairs, and/or modifications can bring the unit back to near-design performance.

THERMAL & MECHANICAL DESIGN	
Service	AC *
Flow	47MMSCFD
Fluid	.622SPGR
Temp. In / Out, °F	188.0 / 110.0
Pressure, PSI	1489PSIG
Pressure Drop, PSI	9.3
Heat Load, BTU/HR	4946323
True LMTD	31.5
Overall Rate, U	112.2
Fouling Factor	.0020
Surface, Tube / Total, Sq Ft	1393 / 29805
Sections, #	(1)
Design Temp, °F Max / Min	350 / -49
MWP / Test Press, PSIG	1932 / 2512
Pass Arrangement	CROSSFLOW
# Tube Rows	3
# Tube Passes	4
Tubes, OD x BWG	1X14
Material	SA179 STEEL
# Per Section / Length, Ft	224 / 24
Turbulators	
Accelerators	
Fins, Type	HI-EFF
Material	AL
Nozzles, Rating / Type	900RF
Material	SA350LF2
#-Inlets / Size In	(1) 6
#-Oulets / Size In	(1) 6
Headers, Type	BOX
Material	SA516-70N
Corrosion Allow, In	.1250
Grooved Tubesheet	DBL
Plugs, Type	SHOULDER
Plugs Material	SA350LF2
PWHT	YES
ASME Code & Nat'l Board	YES
CRN	AB, BC
Add'l Specs & Options	
API	661
Louvers / Hail Screen	AUTO / INT
Inspection / NDT	BX, UT, H

FX= *100% X-Ray of all header seam, attachment & nozzle butt welds.* ***SX=*** *Spot X-Ray of 1 long seam & 1 end closure, per header*
BX= *100% X-Ray of all nozzle butt welds.* ***UT =*** *100% UT of all header seam, attachment & nozzle butt welds.* ***H*** *= Hardness testing.*

AIR-SIDE PERFORMANCE		FAN DATA		DRIVER DATA	STRUCTURAL	
Ambient Air Temp, In °F	95	*Fan(s)*	(1) MOORE-10K-60VT	*Type*	*Guards*	FAN / DRIVE
Elevation, Ft	2964	*Blade Material*	ALUMINUM	RIGHT ANGLE DRIVE BY (1)		INTEGRAL HAILGUARD
Air Flow, SCFM	199,951	*HP / Fan*	36.4	50HP, 1200RPM, 575/60/3,		SOFT BUGSCREEN
Outlet Air Temp, °F	117.6	*Dia, In / # Blades*	156 / 12	TEFC, VFD COMP. MOTOR		AUTOMATIC WARM AIR
Min Air Temp, °F	-40	*RPM*	193	(CSA) 1.15SF		RECIRCULATION SYSTEM
		Tipspeed, FPM	7882	IEEE-841		
Est. Noise Data:	81 dBA @1m, 64 dBA @ 15m	*Pitch, Deg*	14			
Additional Info.	* - INCLUDES 10% EXCESS HEATLOAD AND FLOW RATE					

Table 3. Example of ACHE specification datasheet.

2- Upgrade ACHE components.

If the ACHE does not provide sufficient cooling duty after being returned to its original design condition, there are several options available to improve and optimize it. The following sections outline the typical strategies that can be employed for this purpose:

a) **Increase Airflow**

Enhance the airflow across the heat exchanger by increasing the speed or volume of air passing through it. This can be achieved by adding more fans or blowers, increasing fan speeds, or optimizing the air distribution system.

- **Increase the fan speed.** This will also increase airflow and prevent the fan from stalling, as long as the motor horsepower is high enough. If you are currently using V-belt drives, upgrading to cog belt drives will increase power transmission efficiencies as well as maintain design fan speeds. However, as the fan speed is increased, noise will increase as well, and cog belts emit slightly more noise near the drives (within 3 to 10 ft). If you have a gearbox, a new one with a different ratio will be necessary to increase speed. Note that when you increase either fan pitch or speed, it is strongly recommended that the fan performance be checked against the fan manufacturer's rating software to ensure the existing fan will operate properly at the new setpoints.
- **Increase the fan blade pitch.** Increasing the fan blade pitch will increase airflow as long as the fan does not begin to stall and it has enough motor horsepower. If the fan is horsepower-limited, a motor upgrade will be required to achieve the needed airflow. Remember, for every 10% increase in airflow, there is a 21% increase in static pressure and a 33% increase in required horsepower.
- **Install high-efficiency fans.** Some installations have low-efficiency straight-chord aluminum fan blades. Typically, straight-chord blades have total efficiencies between 35% and 55%. Today, more modern fans (constructed of fiberglass and aluminum) are available that are more aerodynamic, with a tapered chord and an increasing pitch or twist from the blade tip to the hub. This tapered-twisted shape allows for a more uniform airflow off the fan blades, which produces significantly greater efficiency normally 75% to 85% total efficiency. It is not uncommon to obtain 25% to 40% more airflow

with high-efficiency fans at the same or slightly higher motor horsepower.

- **Reset tip clearances.** Check unit manufacture specification data sheet for minimum clearance allowed, reducing the clearance can increase airflow by 2–5% and reduce noise by 0.5 dBA.
- **Install inlet bells.** Many ACHEs have entrances with sharp edges at the fan inlet. The addition of an inlet bell (usually made out of fiberglass or galvanized sheet steel) can increase total airflow by 2–3% and can reduce noise by as much as 1 dBA.
- **Improve Airflow Management:** Optimize the air inlet and outlet design to minimize restrictions and maximize the uniform distribution of air across the ACHE surface. This prevents recirculation and ensures efficient cooling.

b) Improve Heat Transfer

- **Clean inside the tubes:** Sometimes fouling is more severe inside the tubes. This is most common in process coolers handling viscous fluids or fluids that precipitate solids or waxes when the temperature falls below the minimum design point. Chemical flushes, as well as high-temperature and high-pressure steaming and pigging, are the most common methods of cleaning. Viscous-fluid coolers benefit more from cleaning the inside of the tubes than do condensers. As with airside cleaning, tube side cleaning can improve ACHE duty anywhere from 5% to 50%.
- **Retube the bundle:** If the condition of the finned tubes has significantly degraded due to overheating or excessive corrosion retubing the bundle with an equivalent or higher-grade type of fin will be required (page 10). Overall, a 10% to 50% increase in ACHE duty can be achieved by retubing the bundle, depending on the level of finned tube deterioration.
- **Replace the bundle:** Severe finned-tube corrosion is sometimes an indication that the headers and bundle frame may have reached the end of their useful life. The new tube bundles can be fabricated in advance of the turnaround so that the existing bundles can be removed and the new bundles immediately installed. This also allows the user to add tube rows, modify tube pitch, or upgrade fin type to increase the amount of duty without

increasing footprint. As with retubing, 10% to 50% increases in ACHE duty can be achieved.

- **Utilize External Factors:** Leverage natural factors such as wind direction and ambient temperature. Position the heat exchanger to take advantage of prevailing winds or consider shade structures to minimize exposure to direct sunlight.
- **Consider Coatings:** Applying special coatings to the heat exchanger surfaces can enhance heat transfer efficiency. These coatings can improve surface roughness, reduce fouling, and promote better heat dissipation.

3- **Utilize Pre-Cooling system of ACHE**

In situations where applying a previous stage is not feasible due to factors like cost, unit downtime, lack of materials and techniques, implementing stage three improvements becomes a viable option. This is because certain strategies may be lower cost or can be executed while the unit is in operation or with readily available techniques and materials.

In this stage, the cool down of ambient air is achieved before it is pulled by the fan. This is accomplished by increasing the humidity of the air through the implementation of various systems:

a) **Pre-Cooling with Misting:**

For certain extreme cases in hot climate with a process fluid temperature very close to the ambient air temperature, it is necessary to use Pre-Cooling system to improve thermal performance of ACHE's.

The basic idea behind this system is to feed the inlet air with fine water droplets. Depending on ambient conditions and expected evaporation time, these droplets can be of any size, but usually between 20 microns and 40 microns**.** Fog forms once high pressure demineralized water passes through the atomizing nozzles. Once the water is ejected from the nozzles, it strikes impaction pins, creating billions of water droplets, then these droplets directed to the tube bundle by the power of fan. This system generally operates without a recovery tank. Figure 13 shows simple layout of misting system.

Figure 14- Practical misting system

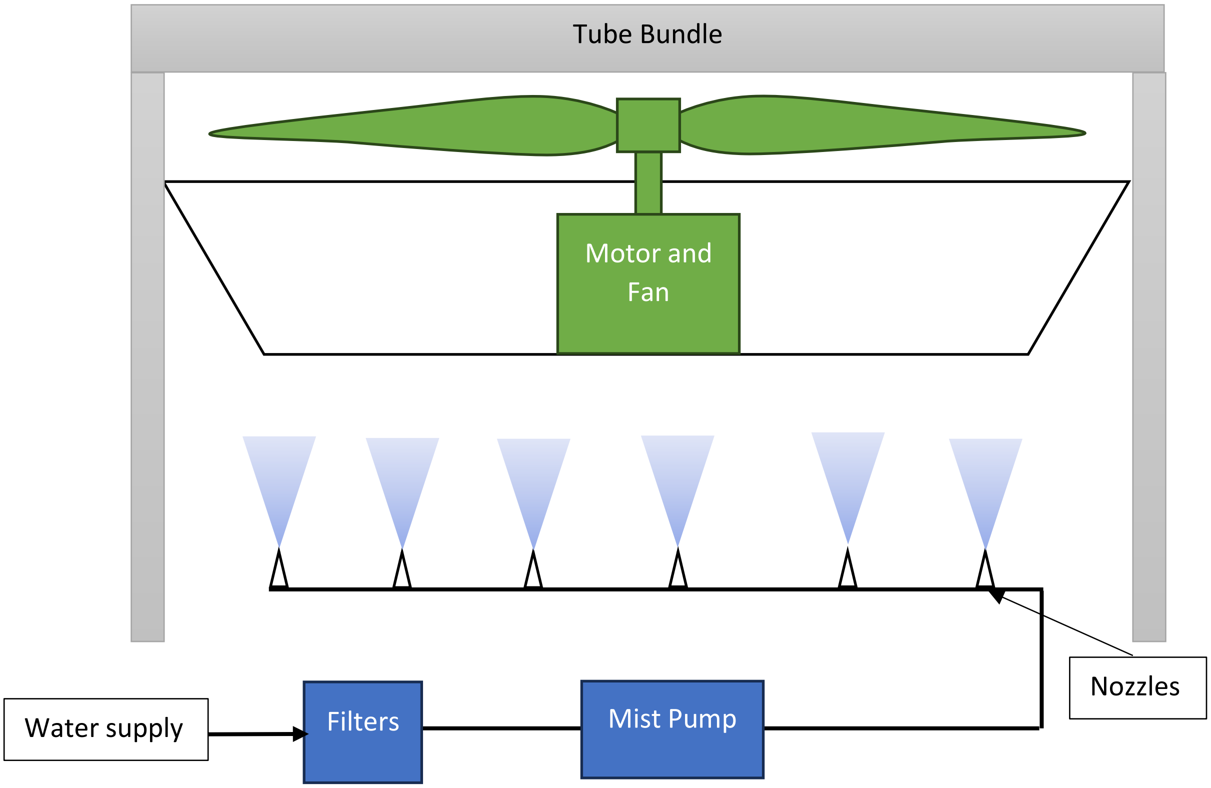


Figure 15- Simple layout of misting system.

There are at least two popular locations of nozzles in relation to the ACHE tube bundles. Often, they are placed upstream the fan, as shows in Fig.15 This arrangement has more advantage than others where:

- The amount of water evaporation is more, faster, and more comprehensive. The distance between nozzles and tube bundles gives sufficient time for evaporation process. It offers the droplets more time to evaporate.
- It is crucial to note that only a limited number of drops can reach the finned tubes and other components, resulting in them typically remaining dry.
- Consumed of water is less.
- The nozzles can be easily accessed for cleaning and maintenance purposes.

Alternatively, the placement of the nozzles upstream of the tubs bundles allows for the direction of water mist towards the finned tubes. This method requires more water and additional mist nozzles. While it is more efficient than the previous method, it has a significant long-term side effect. Wetting the finned tube surface can lead to damage, corrosion of ACHE components, and the formation of fouling in the finned tubes.

Controls and water quality for this system:

The system can increase relative humidity up to 95%, it can be monitored by a humidity sensor and humidity sensor output can control the pump speed with a frequency controller VFD.

Reverse Osmosis water should be used to purify raw water from salt and other contaminants.

No recommended to use normal water because has strong side effect on finned tube, ACHE components and mist nozzles it will destroyed/clogged them and difficult to clean them so it cost you to replace them.

b) Pre-Cooling inlet air using evaporative cooler pad:

Introduction about evaporative cooling pads:

Direct evaporative cooling process:

is one of the most efficient techniques used in air conditioning applications including industrial and residential sectors, swine building, poultry, greenhouses, as well as storage warehouses, cooling towers, humidifiers and evaporative coolers.

In this process, water and air are in contact with cross-flow arrangement, vertical channels for water flow and horizontal channels for air. First, warm air is drawn by fan into a dwelling through a porous wetted material or pads. Then, the water absorbs heat and evaporates from porous wetted medium. Finally, the air leaves the system at a lower temperature (Figure 16). During the cooling process, the wet bulb temperature of the air remains constant and the porous pad are wetted continuously by dripping water onto the upper edge of vertically mounted pads

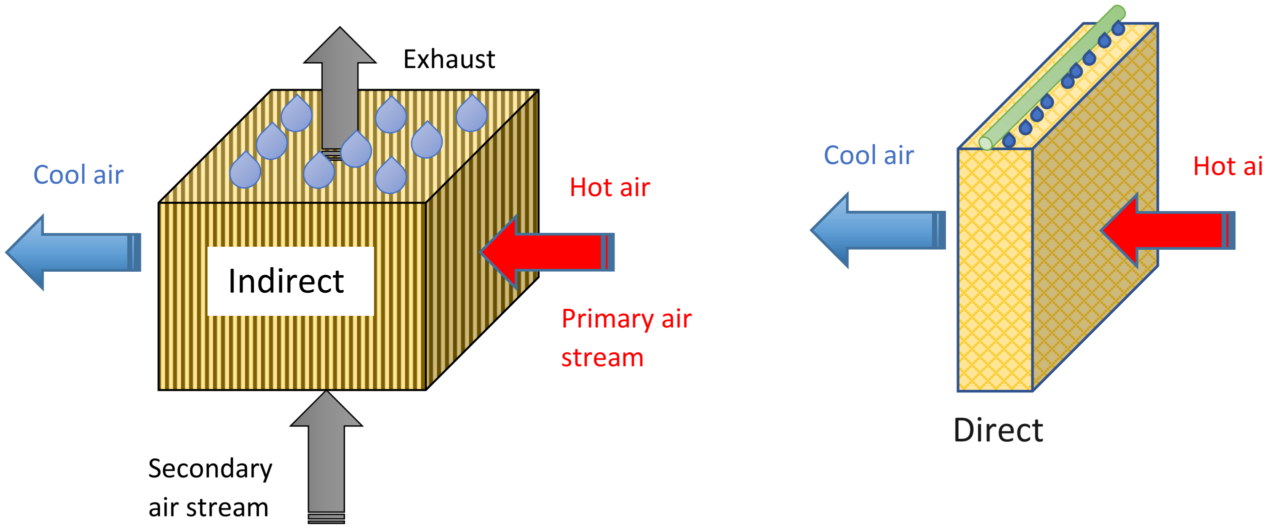


Figure 16 Direct and indirect evaporative cooling pad working principle.

The efficiency of evaporative pad systems is affected by many factors including surface area and thickness of pad, the type of material used in the pad, the size of perforations, flow rate and relative humidity of air passing through the pad, and volume of water used.

Evaporative pads have made from different materials such as metal, wood, plastic, and glass.

Indirect evaporative cooling:

Indirect evaporative cooling is a cooling process that uses direct evaporative cooling in addition to some heat exchanger to transfer the cool energy to the supply air. The cooled moist air from the direct evaporative cooling process never comes in direct contact with the conditioned supply air. The moist air stream is released outside or used to cool other external devices such as solar cells which are more efficient if kept cool. This is done to avoid excess humidity in enclosed spaces, which is not appropriate for residential systems.

Advantages and disadvantages of evaporative cooling pads in general:

- Initial cost is less than 1/2 the cost of refrigerated air conditioning and the operating costs is less than 1/3 rd. the cost of refrigerated air conditioning to run.
- Maintenance costs are minimal requiring simpler procedures and lower skilled maintenance people.
- The frequent and high volumetric flow rate of air traveling through the building reduces the age of air in the building dramatically.
- Evaporative cooling increases humidity. In dry climates, this may improve comfort and decrease static electricity problems.

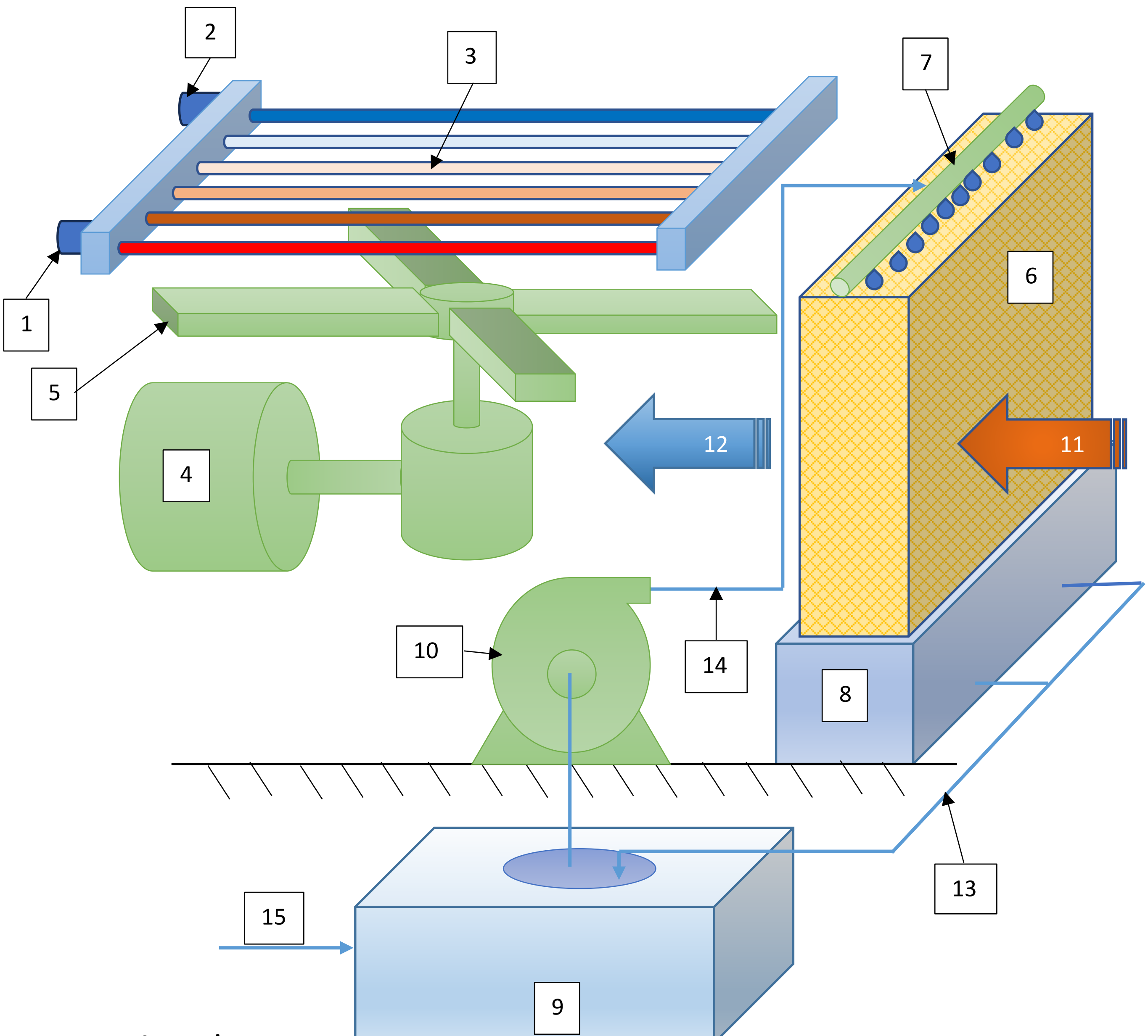
Disadvantages:

- Most evaporative coolers are unable to lower the air temperature as much as refrigerated air conditioning can. It has limited cooling capacity.
- High dewpoint (humidity) conditions decrease the cooling capability of the evaporative cooler. So, it’s not suitable for humidify places.
- Any mechanical components that can rust or corrode need regular cleaning or replacement due to the environment of high moisture and potentially heavy mineral deposits in areas with hard water.
- Evaporative media must be replaced on a regular basis to maintain cooling performance.

Experiment installing evaporative cooling pads on ACHE to improve thermal performance in hot weather.

Why select the evaporative cooling pad instead of a misting system for pre-cooling of ACHE?

- The misting system poses a risk as water droplets can come into direct contact with the finned tubes and mechanical components, causing damage, corrosion, and fouling.
- Because the water in the evaporative cooling pad is not atomized but evaporated, no (contaminated) aerosols are released into the air.
- The performance of a misting pre-cooler is affected by wind. At relatively low wind speeds, the mist may be carried away, limiting the efficiency of the pre-cooler.
- The performance pre-cooling with an evaporative cooling pad, is not affected by wind because the wind has no impact on the evaporation media. And although the wind does, of course, still bring dust that collects on the wet media, there is no chance of clogging. The dust on the evaporation pad is washed away and disposed of by the system when the water is changed. In addition, the wet walls of the evaporation media also provide protection from dust. In effect, the evaporation media acts as an air filter.
- The initial cost for a misting system is lower than evaporative cooling pad. but the evaporative cooling pad materials are available while some materials for misting the system have to be ordered from outside of the country
- Misting system effected more if not used RO water while evaporative cooling pad can be operated by row water however, evaporative media must be replaced frequently.



Legend:

1- Process fluid Inlet.
2- Process fluid Outlet.
3- Finned Tubs.
4- Motor.
5- Fan.
6- Evaporative cooling pad.
7- Water distribution header.
8- Water sump
9- water reservoir
10-Recycle water Pump
11- Hot air
12 Cool air
13- Water return lines
14- Water supply lines
15- Fresh water supply

Figure 17. ACHE with pre-cooling evaporative cooling pad layout

Major components of the evaporative cooling pads systems:

- **Cooler Pad:**
  Cooler pads (sometimes called media) come in two alternatives (figure 18). The **Aspen Wood Fiber Pads** encased in chemically treated cheesecloth is a widely used option because it's cheap, available anywhere and has low resistance of air but its inefficient.
  The newest and most efficient media is **Honeycomb Pad** (Rigid Cooling Media). It is available in several thickness up to 24" which performs at (up to) 99% cooling efficiency. The construction of this media is unique in that it has alternating, transverse flutes of 45 degrees and 15 degrees. The 45-degree flutes carry the water (introduced over the top of the media) to the front of the media where the oncoming air forces it back into the media assisting in the thorough wetting of the media. The air flows through the 15-degree flutes. This media is made from a cellulose material with wetting agents and rigidifying saturants. The useful life of this media is usually 2 to 5 years depending on maintenance and water quality used.

  Note: The cooler pad used in this experiment is honeycomb type 20 cm of thickness.

Figure 18- Type of cooler pad

- **Recycling Water Pump:**
  In order to supply the cooler pads with water, any type of pump can be utilized to extract water from the water reservoir and transfer it to the top header. It is crucial that this pump operates continuously to ensure a consistent flow of water to the cooler pads.
  Note: in this experiment Used 2” 2Hp submersible pump Max.head 14.5M and Max. flowrate 20 M3/H
- **Water Reservoir:**
  In order to ensure the return of water by gravity, it is essential that the height of the tank is lower than that of the water sump. To regulate the water level, a float valve has been installed in the inlet nozzle of the tank. Additionally, the submersible pump is situated inside the tank.
- **Water Distribution Header (Pipe and guide headers):**
  The pipe header serves the function of receiving water from the water pump and distributing it equally over the cooling pads. Equipped with valves, it allows for the control of the water amount as required. However, it is important to note that the pipe and guide header nozzles tend to clog frequently. Therefore, daily monitoring is necessary to ensure proper cleaning of these nozzles. Failure to do so can have a detrimental effect on the cooling efficiency of the system.
- **Water sump:**
  It is a water tank designed to collect the residual water that does not evaporate from the cooling pads. This water is then returned to the water reservoir through the force of gravity. The header guide and sump of the tank are constructed using either 304 stainless steel or galvanized sheet materials. These materials have a thickness of 2mm and are reinforced with intermediate support channels. Furthermore, the seams and joints of the tank are fully welded, ensuring structural integrity.

  Connection and pipelines:
  We utilized a 2" polypropylene random copolymer pipe (PPR) for the entire hole system, with the exception of the heater, which required a 1" pipe. Additionally, we installed a 1" pipe for the bypass line, connecting the discharge of the pump to the Water Reservoir. This bypass line serves the purpose of controlling the overall water flow.

The amount of cooler pad used:

Length =7.5 (left side) +4(back side) +7.5(right side) =19m

Hight =2m

Total cooler pad surface area= 19X2= 38 m2.

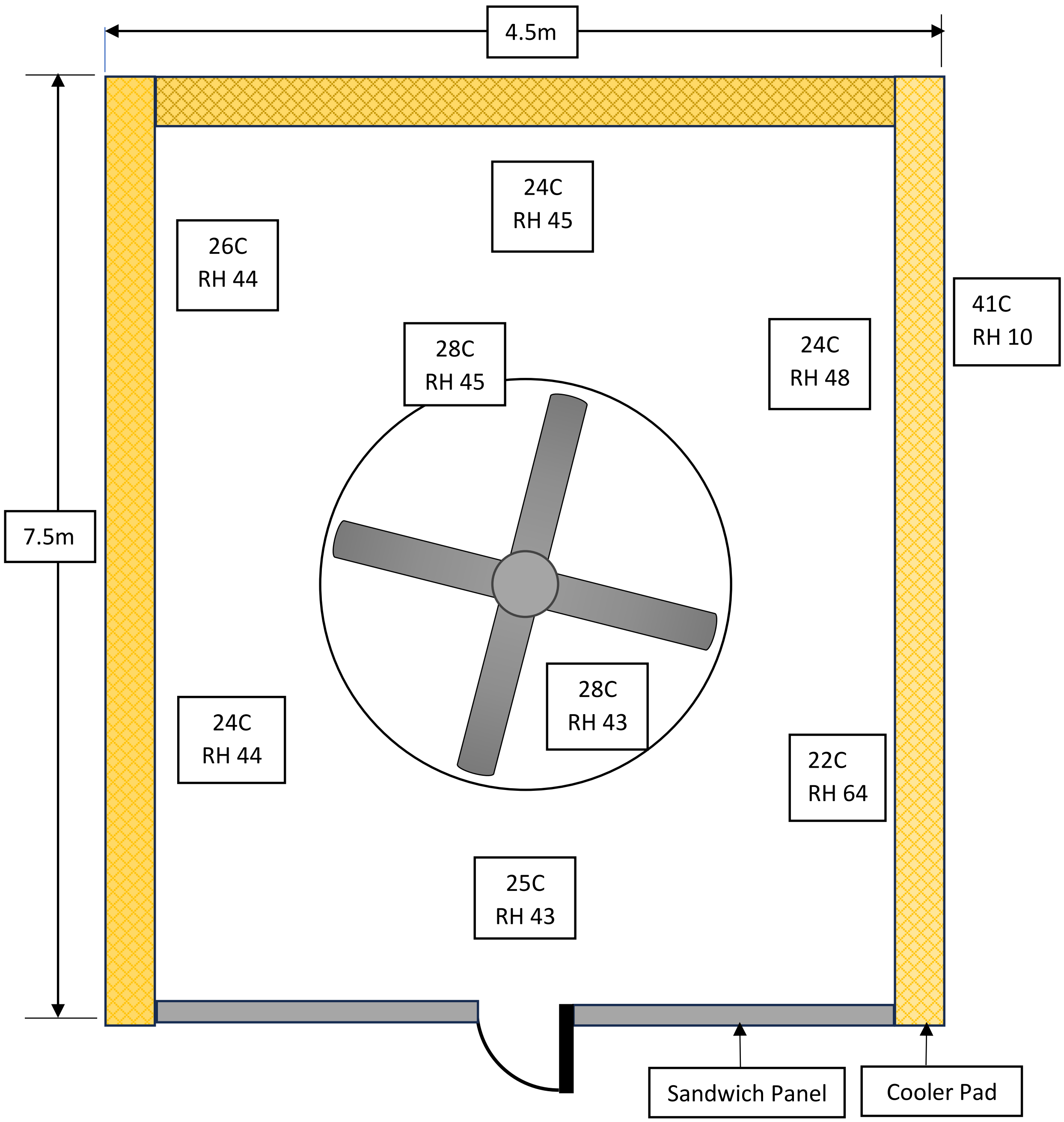


Figure 19. Top view of evaporative cooling pad system and how distribute the temp and RH inside.

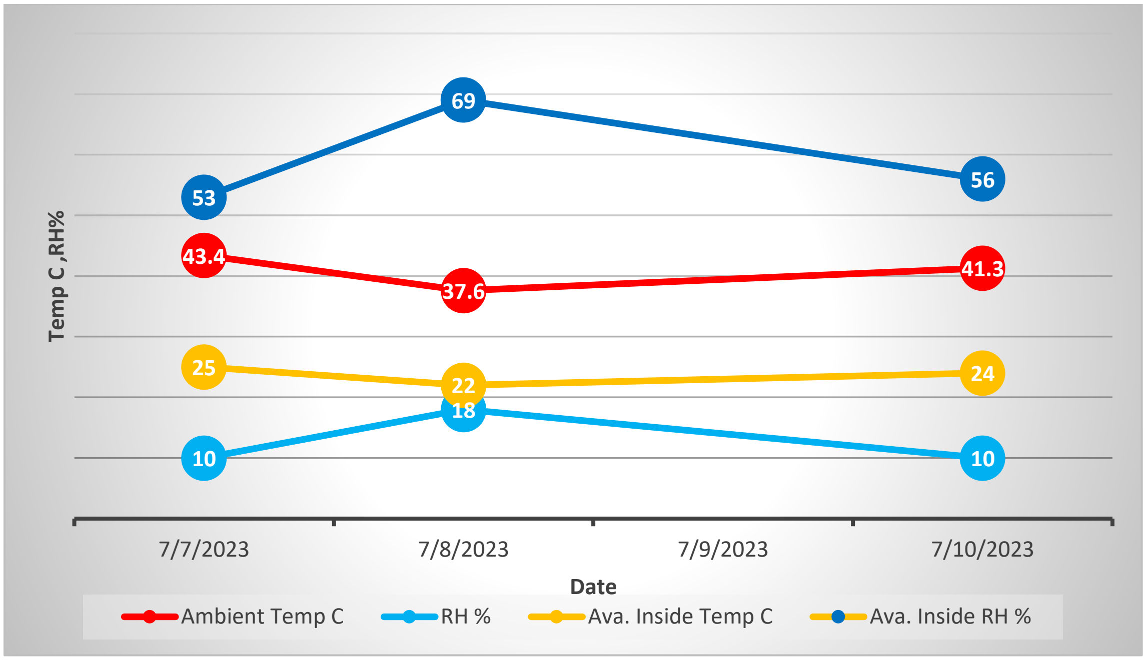


Chart 7-temp and RH outside and inside of the system

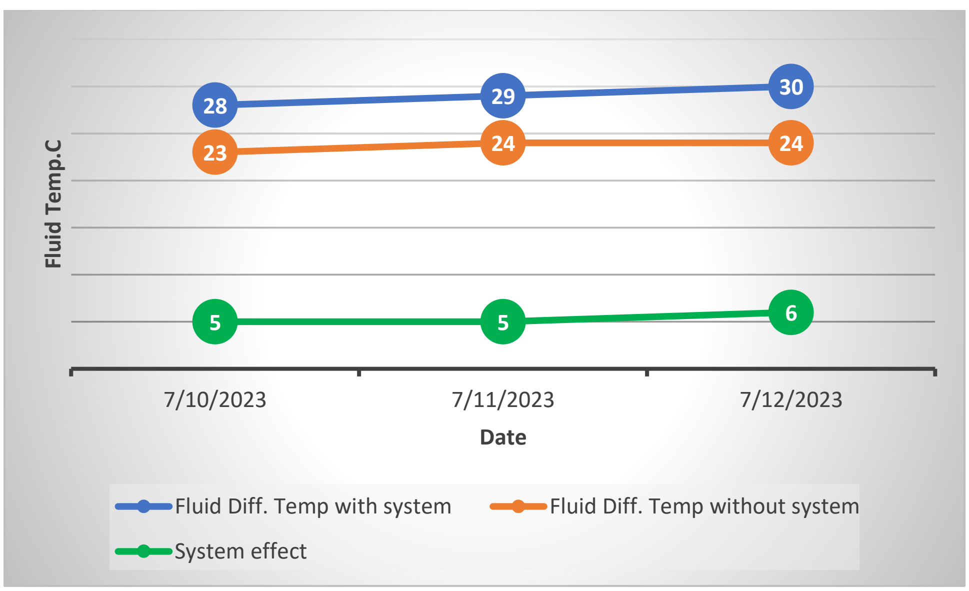


Chart 8-System temp. effect on fluid process

Temperature reduction achievable using direct evaporative cooling:

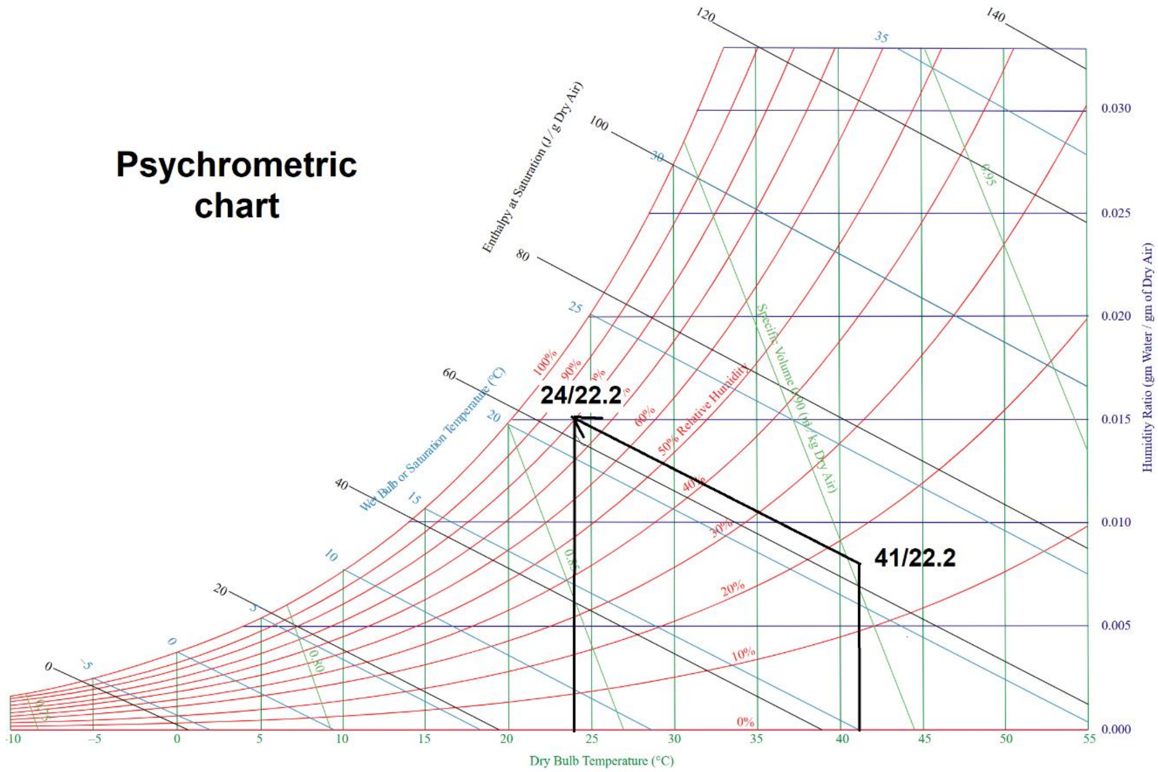


Chart 9- Adiabatic direct evaporative cooling pad

1. Temp drop achievable = (dry bulb – wet bulb) x (efficiency of the media)
Example: (41 C – 22.2 C) x .9 = 16.92 C
2. Achievable temp = dry bulb – temp drop achievable
Example: 41C – 16.92 C = 24 C
3. Starting DB: 41 C
Ending DB: 24 C
Note: Efficiency is usually 90%, Because cooling is achieved by adding moisture to the supply air stream, the new dry bulb/web bulb temperatures are found on the wet bulb gradient. With direct evaporative cooling, the dry bulb temperature is reduced while the web bulb temperature remains the same.

Conclusion:

- Based on chart 8, pre-cooling by evaporative cooling pads reduces ambient air temperature by approximately 17 degrees Celsius and increases relative humidity by approximately 46%. These values can be affected by various factors including, weather conditions (wind speed, rain, cloudy day, etc.), season change, amount of water over cooling pads, and cleanliness of cooling pad.

- Pre-cooling with evaporative pad system is reduces process fluid temperature about 5 degrees Celsius as shown in chart 9. And this value also depending on factors mentioned above point.

- The temperature distribution within the system is non-uniform, as depicted in Figure 16. Notably, the temperature near the fan, located in the middle, exhibits an increase, while the relative humidity (RH) experiences a decrease. This phenomenon can be attributed to the escalating velocity of the air and the concurrent decrease in atmospheric pressure.
  This phenomenon arises due to inadequate surface area. We observe that the absence of a cooler pad in front of the ACHE leads to a decrease in the overall surface area of the entire system. To address this issue, we propose increasing the total area of the cooling pad.
  Temperature distribution in a given area is influenced by various factors, including the presence of shade and the direction of the wind. When shade is present, the temperature on the shaded side is generally lower compared to the side that is directly exposed to sunlight. Additionally, the direction of the wind also plays a role in temperature distribution. The side that is exposed to the wind tends to have a lower temperature, as the wind carries away heat from the surface and transfer it to opposite side.

Wordbook:

Word details	Abbreviations	Word details	Abbreviations
Central Production Facility	CPF	Meter	m
Air cooler heat exchanger	ACHE	Horse Power	HP
Barrel per day	bbl./d	Meter Cubic/hours	M3/H
Rate vapor pressure	RVP	Temperature (°C)	T
Gas oil ratio	GOR	Reverse Osmosis	RO
Million square cubic food per day	MMscfd		
Revolution per minute	RPM		
Dry Bulb Temperature	DBT		
Wet Bulb Temperature	WBT		
Relative Humidity (%)	RH		
Variable Frequency Drive	VFD		

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