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for
AIR COOLED CONDENSERS

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STANDARDS for **AIR COOLED CONDENSERS**

SECOND EDITION

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AIR COOLED CONDENSERS

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FOREWORD

The second edition Standards for Air Cooled Condensers has been developed by the Air Cooled Condenser Section of the Heat Exchange Institute, Inc. The technical information in these standards combines present industry standards, typical Purchaser requirements, and Manufacturer's experience. In addition, the standards outline the important design criteria for air cooled condensers. These standards provide practical information on nomenclature, dimensions, testing, and performance. Use of the standard will ensure a minimum of misunderstanding between Manufacturer and Purchaser, and will assist in the proper selection of equipment best suited to the requirements of the application.

The second edition of the Standards for Air Cooled Condensers includes updates, revisions and clarifications to most of the Sections in the standard. Metric unites have been added, including metric units for all three tables on exhaust casings.

The publication of the second edition of Standards for Air Cooled Condensers represents another step in the Heat Exchange Institute's continuing program to provide standards which reflect the latest technological advancements in the field of heat exchange equipment. The Standards for Air Cooled Condensers are continually reviewed by the Technical Committee at scheduled meetings under the direction of the Air Cooled Condenser Section. Suggestions for improvement of this standard are welcome and should be sent to the Heat Exchange Institute, Inc., 1300 Sumner Avenue, Cleveland, Ohio 44115, or via telephone at 216-241-7333, via fax at 216-241-0105, or email the HEI at hei@heatexchange.org. Additional information, such as tech sheets, member company profiles, membership information, and a complete listing of all HEI Standards, can be found at www.heatexchange.org

1.0 SCOPE AND PURPOSE

This Standard covers the specification and design recommendations along with the performance and operational issues associated with Air Cooled Condensers (ACC) for power plant applications. In addition, general field installation and commissioning practices are also discussed.

This Standard addresses common operational problems experienced during extreme ambient

conditions such as thermal performance effects in the summer, dead-zone formation, and freezing in the winter.

There are many different types of ACCs designed for various services. This Standard applies only to two-stage vacuum steam condensers predominantly utilized in power plant applications.

2.0 DEFINITIONS

2.1 A-Frame

Part of the steel structure above the fan deck, in the shape of the letter A, that may support the heat exchanger bundles. Although this is the most common configuration, alternative bundle arrangements are feasible (i.e. horizontal, vertical, V-frame, etc.)

2.2 Absolute Pressure

The pressure measured from absolute zero (0 inch HgA, 0 barA).

2.3 Air-Removal System

A system to remove non-condensable gases and maintain thermal capability of the ACC. The air-removal system may contain additional components to support the operation of a vacuum deaerator.

2.4 Air Cooled Condenser (ACC)

A heat exchanger that utilizes ambient air as the cooling medium to directly absorb heat from condensing exhaust steam, allowing the condensate to be collected and returned to the power generation cycle.

2.5 Air Inlet Height

The height from grade level to the air inlet, or bottom of the fan rings.

2.6 Air Inlet Temperature

The dry bulb temperature of the air entering the ACC, including the effect of recirculation and/or added heat sources.

2.7 Back Pressure

The absolute value of the static pressure at a prescribed location, typically at or near the steam turbine exhaust flange at which design and guaranteed performance are to be achieved.

2.8 Bundle

A heat exchanger element composed of a set of finned tubes sharing common tube sheets.

2.9 Bundle Face Area

The area measured at the face side of a bundle. The length of the bundle is equal to the length of the tubes excluding the tube sheets. The width corresponds to the width of the normal air flow plane on a per bundle basis.

2.10 Cell

Smallest sub-division in an ACC, sometimes referred to as module, which can function as an independent unit with regard to air and steam flow; it is bounded generally by either exterior walls or partition walls. Each cell may have one or more fans, although typically the number of fans per cell is limited to one.

2.11 Condensate Header

Collects the condensate from the finned tube bundles and conveys the remaining steam from the first stage to the second stage bundles.

2.12 Condensate Tank/Receiver

A vessel at approximately the same pressure as the ACC that collects condensate returning from the heat transfer surfaces, system drains, and make-up water. It is equivalent to the hot well of a steam surface condenser.

2.13 Condensing Pressure

The absolute static pressure of the condensing steam at a defined location.

2.14 Condensing Steam Temperature

The saturation temperature corresponding to the absolute static pressure of the condensing steam at a defined location.

2.15 Deaerator

A mass transfer device that removes dissolved non-condensables from the condensate and/or makeup water.

2.16 Drain Pot

A vessel that is an integral part of the steam duct located at the lowest point that collects the condensate from steam duct. Alternatively, a separate collection vessel can be utilized with a gravity drain connection at the low point of the steam duct.

2.17 Exhaust Steam Flow Rate

Total mass flow rate of the steam exiting the low pressure steam turbine exhaust.

2.18 Exit Air Temperature

The average dry bulb temperature of the air leaving the heat exchanger bundles.

2.19 Face Air Inlet Velocity

The average air inlet velocity normal to the bundle face.

2.20 Fan Deck

Horizontal plane located at the top of the ACC substructure forming the lower air seal of the cell(s).

2.21 First Stage Cell

ACC cell with the steam and condensate flowing down concurrently; the first stage bundles are connected with the steam header at the top and the condensate header at the bottom. It is also referred to as a K, Primary or Condenser cell.

2.22 Hogging System

The portion of the air-removal system used during start-up to remove air from the ACC before admitting steam.

2.23 Holding System

The portion of the air removal system dedicated to continuous removal of non-condensable gases from the top of the second stage bundles.

2.24 Initial Temperature Difference (ITD)

The difference between the condensing steam temperature at the ACC inlet and the air inlet temperature.

2.25 Log Mean Temperature Difference (LMTD)

Since the condensing process in an ACC is not isothermal because of the significant steam-side pressure drop involved, a representative value for the LMTD can be defined as the total heat duty of condensation divided by the product of the overall heat transfer coefficient multiplied by the total airside heat transfer surface area.

2.26 Plot Area/Size

The area between all primary ACC support columns projected at grade level.

2.27 Recirculation

A condition in which a portion of the ACC's warm discharge air re-enters the air inlet along with fresh ambient air. Its effect is an elevation of the average air inlet temperature compared with the ambient dry bulb temperature.

2.28 Row (ACC Row)

Group of cells served by a common steam header. It is also referred to as a "street."

2.29 Second Stage Cell

ACC cell with the steam and condensate flowing in counter-flow; the second stage cell collects the remaining steam and non-condensables and is connected with the air-removal system at the top and the condensate header at the bottom. It is also referred to as a Dephlegmator, Secondary, or Reflux cell. It is possible to integrate secondary and primary bundles with the same cell, this is referred to as a Mixed cell.

2.30 Speed Reducer

A mechanical device incorporated between the driver and the fan, designed to reduce the speed of the driver to an optimum speed for the fan. A speed reducer can be either a gearbox or a V-belt.

2.31 Steam Distribution System

Conveys the flow of steam from the low pressure steam turbine exhaust to the bundles. The duct may include expansion joints, bypass spargers, drain pot, branch systems (risers), and isolation valves.

2.32 Steam Header

Conveys the steam from the risers to the inlet of all first stage bundles in an ACC row.

2.33 Steam Quality

The mass fraction of dry and saturated steam in a saturated water/steam mixture. A steam quality of zero indicates 100% condensate, while a steam quality of 1 indicates 100% dry and saturated steam.

2.34 Total Airside Heat Transfer Surface Area

The total area of the outside heat transfer surface exposed to air.

2.35 Turbine Exhaust

The interface between the low pressure steam turbine and the ACC steam duct.

2.36 Turbine Exhaust Pressure

See back pressure.

2.37 Windwall

The vertical perimeter walls above the fan deck, which typically extend to the top of the tube bundle elevation to minimize potential recirculation and shield the heat transfer surface from wind effects.

3.0 SYMBOLS & UNITS

Abbreviation	Name	Typical Units
FV	Full Vacuum	inHg, (bar)
$P_{\text{mot,inst}}$	Installed Motor Power	hp, (kW)
$P_{\text{fan,shaft}}$	Fan Shaft Power	hp, (kW)
T_{design}	Design Air Inlet Temperature	°F, (°C)
T_{min}	Minimum Air Inlet Temperature	°F, (°C)
AIH	Air Inlet Height	ft, (m)
Q	Heat Load	Btu/hr, (W)
U_{service}	Overall Heat Transfer Coefficient, Service	Btu/ft ² hr °F, (W/m ² K)
A	Air-side Heat Transfer Surface Area	ft ² , (m ²)
LMTD	Logarithmic Mean Temperature Difference	°F, (°C)
ϵ	Heat Exchange Effectiveness	-
$\dot{m}_{\text{air}}$	Mass Flow Rate, Air	lb/sec, (kg/sec)
$C_{p,\text{air}}$	Specific Heat, Air	Btu/lb °F, (J/kg K)
ITD	Initial Temperature Difference	°F, (°C)
$T_{\text{steam,inlet}}$	Inlet Steam Temperature	°F, (°C)
$T_{\text{air,inlet}}$	Inlet Air Temperature	°F, (°C)
ΔT_{air}	Change in Temperature of the Air	°F, (°C)
$\dot{m}_{\text{in}}$	Inlet Mass Flow Rate	lb/sec, (kg/sec)
h_{in}	Inlet Enthalpy	Btu/lb, (kJ/kg)
$\dot{m}_{\text{out}}$	Outlet Mass Flow Rate	lb/sec, (kg/sec)
h_{cond}	Enthalpy, Condensate	Btu/lb, (kJ/kg)
$\dot{m}_{\text{vent}}$	Mass Flow, Vent	lb/sec, (kg/sec)
h_{vent}	Enthalpy, Vent	Btu/lb, (kJ/kg)
DO	Dissolved Oxygen	ppb
F	Fouling Factor	hr ft ² °F/Btu, (m ² K/W)
U_{clean}	Overall Heat Transfer Coefficient, New and Clean	Btu/ft ² hr °F, (W/m ² K)
W	Water Vapor Load	lb/lb, (kg/kg)
MW_{NC}	Molecular Weight, Non-Condensables	g/mol
P_{W}	Saturation Pressure of Steam at Mixture Temperature	psia, (bara)
P_{T}	Total Pressure of Mixture	psia, (bara)
A_{D}	Minimum Required Flow Area	in ² , (cm ²)
W_{s}	Discharge Flow Rate	lb/hr, (kg/hr)
K_4	Flow Coefficient	-
P_{A}	Relieving Pressure	psia, (bara)
η_{gearbox}	Gear Box Efficiency	-
$\rho_{\text{air, min}}$	Air Density at Minimum Operating Temperature	lb/ft ³ , (kg/m ³)
$\rho_{\text{air, design}}$	Air Density at Design Operating Temperature	lb/ft ³ , (kg/m ³)

4.0 GENERAL OVERVIEW / DESCRIPTION OF AN AIR COOLED CONDENSER (ACC) SYSTEM

4.1 Definition of an ACC

An ACC is a system that conveys exhaust steam to an array of heat exchangers that condense the steam by rejecting the heat to ambient air. The method of cooling is direct heat exchange because the heat is transferred from the primary source (exhaust steam) directly to the ultimate cooling media (ambient air). The ACC can use natural draft or mechanical draft (forced or induced) to drive ambient air across the heat exchange surface (tube bundles). The most common design is the A-Frame forced draft arrangement as seen in Figure No. 1.

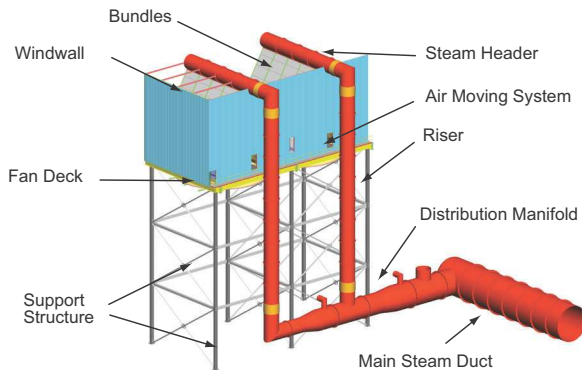


Figure 1

A - FRAME AIR COOLED CONDENSER

4.2 Major Components of an ACC System:

4.2.1 Air-Moving System – A typical forced or induced draft air-moving system consists of the following components:

- **Fan** – Axial fans provide ambient cooling air across the extended surface of the fin tube bundle to transfer the heat from the condensing steam within the tubes.
- **Fan Electric Motor** – Electric motors drive the fan.
- **Speed Reducer** – The gearbox or V belt reduces the rotational speed of the motor to the required speed of the fan.
- **Fan Ring** – The fan ring is a cylindrical shroud that surrounds the fan in order to optimize fan performance. It is typically constructed of steel, fiberglass or polypropylene.

4.2.2 Bundles – A bundle consists of multiple finned tubes welded into the tubesheets at either end. There are two types of bundles: first and second stage condensing bundles.

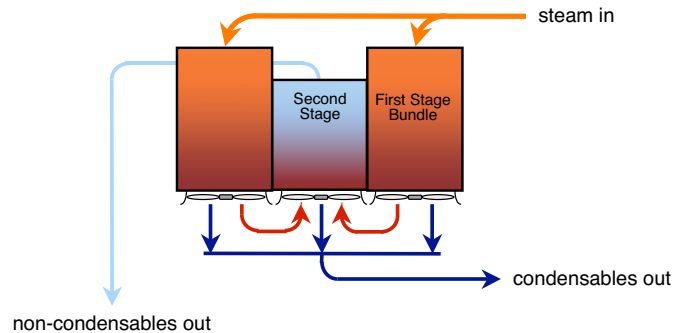


Figure 2

AIR COOLED CONDENSER BUNDLES

4.2.2.1 First Stage Bundle – These bundles are connected to the inlet steam header at the top and condensate header at the bottom. The steam flows concurrently through the tubes of the first stage bundles, where steam and condensate flow in the same direction. By design, steam velocities are maintained high enough to continually sweep non-condensable gases into the second stage bundle via the condensate header. Condensate is also collected within the condensate header and drained. The first stage bundles typically condense 60–90% of the total steam through the ACC.

4.2.2.2 Second Stage Bundle – The second stage bundles condense the remaining steam and collect non-condensable gases at the top of the bundle. These bundles are attached to the condensate header at the bottom and have air removal headers at the top for non-condensable extraction by the air removal system. Steam flows counter-currently through the tubes of the second stage bundles, where the steam and non-condensables travel up and condensate flows down into the condensate header.

4.2.7 Support Structure – The support structure is typically an arrangement of columns, beams, and bracing that supports the ACC components at the proper elevation above grade.

4.2.8 Fan Deck – The fan deck is the lower fan plenum boundary for the air-moving system.

4.2.9 Steam Distribution System – The steam distribution system consists of the following primary components:

- **Main Steam Duct** – The main steam duct interfaces with the steam turbine and serves to convey all exhaust steam to the steam distribution network. The main steam duct is also designed to provide connection points for steam turbine bypass, miscellaneous vents, drains, low point drain pot, etc.
- **Steam Distribution Manifold** – The steam distribution manifold is used to distribute steam between the main steam duct and the steam headers. This manifold includes vertical ducts referred to as risers. The risers will generally have expansion joints to accommodate the thermal expansion.
- **Steam Header** – The steam header serves to convey steam between the manifolds and the first stage bundles of an ACC row. Expansion joints may also be required in the steam header to accommodate thermal expansion.

4.2.10 Windwall – Windwalls are generally installed around the perimeter of the ACC and

extend from the fan deck to the top of the tube bundle elevation. The function of the windwall is to mitigate the negative wind effects, in order to normalize heat transfer, as well as to minimize potential for warm air recirculation.

4.2.11 Condensate Tank – The condensate tank serves to collect the condensate that is formed within the ACC. Drain piping is routed from the condensate headers to the tank. Typically, the condensate tank is located beneath the ACC and supported at grade level.

4.2.12 Air Removal System – The primary purpose of the air removal system is to continuously extract non-condensable gases that accumulate at the top of the second stage condensing bundles. Air removal systems are typically either a two-stage steam jet air ejector (SJAЕ) or liquid ring vacuum pump (LRVP) system. Alternatively, hybrid systems may also be employed. Typically, the air removal system also contains a hogging system to rapidly evacuate the ACC volume for startup.

5.0 DESIGN CONSIDERATIONS

5.1 Design Pressure and Temperature

5.1.1 The maximum design pressure is the maximum pressure specified by the ACC supplier as a criterion for ACC design. The maximum design pressure is not the same as operating pressure; it is somewhat higher than the operating pressure for all operating conditions. Although the maximum and minimum design temperature and pressure could also be specified by the purchaser, the maximum limits are typically determined by the ACC tube technology. For single row tube technologies, the maximum design pressure of the ACC is typically set at 7.25 psig (0.5 barg).

The minimum design pressure for ACCs operating below atmospheric pressure is full vacuum (FV).

The design temperature is typically 250 °F (121 °C).

At certain locations of the steam duct, the local

temperature may exceed the maximum design temperature (at the bypass connections, for example), and the supplier typically imposes a limit on the enthalpy of the bypass steam entering the duct. A maximum value of 1170 Btu/lb (2720 kJ/kg) is typical. The value of 1170 Btu/lb (2720 kJ/kg) may result in a steam temperature > 250 F (121 C). However, experience has proven that this is a good practical upper limit and typically results in acceptable temperatures when the ACC is operated under vacuum conditions.

The design temperature is primarily used for selecting material suitability and thermal expansion calculations.

The design pressure is used for the design of steam ducting, tanks and, rupture discs, among other equipment.

5.2 Corrosion Allowance

Corrosion allowance is the incremental material

thickness above what is required to meet the structural and/or process requirements. A corrosion allowance is recommended for all surfaces exposed to the process fluid as per Table 1.

ACC Equipment	Typical Corrosion Allowance Values
---------------	------------------------------------

Table 1
TYPICAL CORROSION ALLOWANCE VALUES

Ducting	1 mm
Tubes	0 mm
Piping	3 mm
Tanks	3 mm

5.3 Air-Moving Equipment Selection Guidelines

The air-moving equipment of an ACC consists of a fan, speed reducer and motor.

5.3.1 Fan Selection – First, the fan is selected; axial flow fans are used for ACC applications. The duty point of the fan is determined by the required air flow rate and corresponding fan static pressure in order to meet the thermal capacity of the ACC. For large size fans (diameter ≥ 28 ft), a minimum of five fan blades is recommended with a maximum tip speed that should not exceed 60 m/s (12,000 fpm). The fan shaft power serves as the basis for determining the motor rating. The fan rotation speed is used in combination with the motor speed to determine the speed reduction ratio.

Additional fan selection parameters:

- Air flow margin
- Pressure margin
- Fan coverage
- Fan blade tip clearance
- Operating and natural frequency of fan blade
- Fan blade loading
- Low ambient temperature hardware
- Vibration limits
- Static efficiency
- Wind effect on the fan capacity
- Fan location with respect to obstacles
- Noise limitations

5.3.2 Motor Selection – Typically 460V/3 phase/60 Hz, NEMA, TEFC motors are used for ACC applications up to and including 250 hp. Such motors normally have a service factor of 1.15, Class F insulation with a Class B temperature rise.

For standard noise applications, 1800 rpm, single speed (with or without VFDs) or two-speed, single winding motors (1800/900 rpm) are typical.

Control of turbine back pressure and/or freeze protection will determine whether single speed, two-speed motors or VFDs are required in order to provide a sufficient number of control steps.

In the event VFDs are used, the motor should be suitable for such application.

Horizontal motors mounted vertically are typically used for ACCs, designed in accordance with NEMA B. Note, that electrical standards and practices are location specific and other international standards may be applied.

The rated motor power shall be greater than the required motor output power at the design point, in accordance with the following equation:

$$P_{\text{mot,inst}} \geq \frac{P_{\text{fan,shaft}}}{\eta_{\text{gearbox}}} \frac{\rho_{\text{air,min}}}{\rho_{\text{air,design}}}$$

Where $\rho_{\text{air,min}}$ is the air density at the minimum inlet air temperature for which one of the motors is expected to be at full speed – this value is typically 5°C. For an aggressive motor selection and higher design ambient temperatures, T_{min} may be increased up to 10°C. Although the driven load may exceed the nameplate value at temperatures below this point, this is normally acceptable to the motor suppliers due to the additional cooling available. Confirmation should be obtained from the motor supplier; this applies only to forced draft configurations with the motor installed in the cold ambient air stream.

5.3.3 Speed Reducer Selection – Typically, the speed reducers are helical, multi-reduction, parallel shaft gearboxes. V-belts can also be used on smaller installations. The service factor for speed reducers (gearbox or belt) should be ≥ 2.0 based on the motor nameplate power for single and multi-speed motors and ≥ 1.75 for variable frequency drive applications. The thermal rating of the gearbox should be ≥ 1.0 at the maximum air temperature based on the motor nameplate power. Possible accessories for gearboxes are listed below:

- Backstops
- Oil pumps (shaft driven or electrical).
- Oil pressure/flow switches
- Oil heater & thermostat
- Input coupling

5.4 Air Flow Considerations

5.4.1 Cooling air flows into the ACC fans via the air inlet. In most cases, some of the air inlet area will be blocked by obstacles, like the steam duct, other equipment or buildings. Even if obstacles are not located under the ACC or at the air inlet, these can still be considered blockage.

As a rule of thumb, obstacles that fall below a 45 degree line originating at a point equal to 1 air inlet height (AIH) away from the ACC will have negligible effects on the air flow to the ACC. Any obstacle that extends above this line shall be considered in the manufacturer's design.

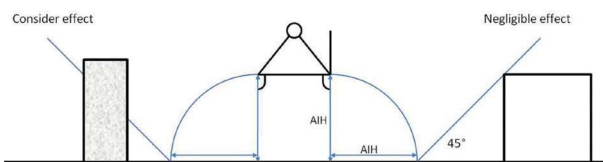


Figure 3
AIR INLET BLOCKAGE CONSIDERATIONS

5.4.2 To minimize warm air recirculation, it is recommended that the average air velocity at the ACC outlet be equal to or greater than the average air velocity at the ACC inlet, with both the average air inlet and air outlet velocities based on free flow area.

In addition, it is recommended to limit the average air inlet velocity to 5 m/s (based on the free flow area) and should be selected to promote uniform air distribution to all fans.

5.4.3 The total fan static pressure shall consider the following losses:

- Air inlet acceleration and turning
- Fan guard blockage
- Fan inlet bell shape
- Fan bridge blockage
- Plenum discharge
- Bundle
- Directional changes
- Discharge loss
- Natural draft correction
- Air inlet and air outlet louvers (if applicable)
- Air inlet and air outlet noise silencers (if applicable)

It is recommended that every cell shall be partitioned on the fan discharge side.

Equipment placement and obstacles underneath and besides the ACC shall be coordinated and accepted by the ACC supplier:

- Electrical or other buildings
- Condensate tank and vacuum deaerator
- Air removal equipment
- Condensate extraction pumps
- Other heat exchangers
- Cable trays
- Other obstacles

5.5 Fin Tube Cleaning System

5.5.1 The purpose of a Fin Tube Cleaning System (FTCS) is to clean the outside heat transfer surface in such a way that the thermal capacity of the ACC is restored close to the original capacity. External fouling of the heat transfer surface by airborne particulates can significantly reduce the performance of the ACC. Because the extent of external fouling is highly dependent on local environmental conditions, the frequency of cleaning will vary with the environmental conditions. At a minimum, the ACC should be cleaned once per year, typically before the warm season starts.

5.5.2 The fin tube bundles are cleaned using high pressure water; a nominal operating pressure of at least 750 psi is recommended. Higher pressures can result in a more effective cleaning, and reduce cleaning time and water consumption. The quality of the water for the fin tube cleaning system should be specified by the ACC manufacturer to avoid corrosion and scaling of the outside heat exchange surface.

5.5.3 Different fin tube cleaning systems are on the market and can be categorized by the level of automation of the cleaning device.

5.5.3.1 Manual fin tube cleaning systems consist of one or several spray headers mounted on a support that runs along both sides of the A-frame. Because there are no motorized parts, the spray headers must be moved manually.

5.5.3.2 Semi automatic fin tube cleaning systems have a reduced number of spray nozzles mounted on an automated spray carriage that traverses the bundles. Some degree of manual operation is required with this system.

6.0 AIR COOLED CONDENSER PERFORMANCE / OPERATION

6.1 General Considerations

The performance of an ACC cannot be exactly predicted under all possible operating conditions. Consequently, curves or tabulations of ACC performance data are only approximate, except for one specific condition termed the “Design Point.” Performance checks should be made only when the system has been stabilized and reproducible values are attainable.

Typical operating conditions are recognized as involving uncontrollable variations in air leakage into the ACC and its related system under vacuum. These variations, while negligible under some conditions, render the exact prediction of the ACC performance impractical for air/non-condensable inlet rates exceeding 50% of the values specified in Section 9.

ACC performance information is based on venting equipment having a capacity specified in Section 9.

Due to the effect on ACC performance, the location of feedwater heaters and/or extraction piping and by-pass spargers or related equipment should be subject to the ACC manufacturer's approval after the turbine flow distribution diagram (velocity map) has been made available.

It should be recognized that the ACC performance becomes unpredictable at reduced heat duty, ambient temperatures below freezing and low turbine back pressures.

6.2 Thermal performance – relationship between turbine back pressure, steam flow, $T_{air,inlet}$, altitude, and fan power.

The design of an ACC must consider the effects of non-condensable gases that are present in the ACC and pressure drop of the steam as it flows through the duct system and through the tubes of both stages of the ACC.

The heat transfer coefficient of a typical commercial operating ACC is less than that attainable in laboratory tests. The “service” heat transfer coefficient compared with a new and clean heat transfer surface area should be taken into account in the design of the ACC.

The general heat transfer equations are:

$$Q = U_{service} A LMTD$$

$$Q = \epsilon \dot{m}_{air} c_{p,air} ITD \text{ with } \epsilon = 1 - \frac{UA}{\dot{m}_{air} c_{p,air}} \text{ and}$$

$$ITD = T_{steam,inlet} - T_{air,inlet}$$

$$Q = \dot{m}_{air} c_{p,air} \Delta T_{air}$$

$$Q = \sum \dot{m}_{in} h_{in} - \dot{m}_{out} h_{cond} - \dot{m}_{vent} h_{vent}$$

It should be noted that the term $\dot{m}_{vent} h_{vent}$ is quite small and is generally considered negligible; therefore, for the purpose of the thermal performance calculations, the above equation can be reduced to:

$$Q = \sum \dot{m}_{in} h_{in} - \dot{m}_{out} h_{cond}$$

The overall service heat transfer coefficient ($U_{service}$) combines the convective heat transfer coefficient at the inside of the tube, conduction through the tube wall and fins, and the convective heat transfer coefficient at the outside of the fins. The governing resistance for heat transfer is the air-side resistance, which is dependent on the tube and fin geometry. Therefore, $U_{service}$ is a function of the tube characteristics and will vary for each manufacturer.

The steam temperature is related to the steam pressure, which is a known relationship for saturated steam conditions. Therefore, for a given ITD, the back pressure will vary with the air inlet temperature.

From the equations above, it can be demonstrated that if the load (Q) is increased, then the ITD will increase proportionally, ignoring the effect of the steam-side pressure losses.

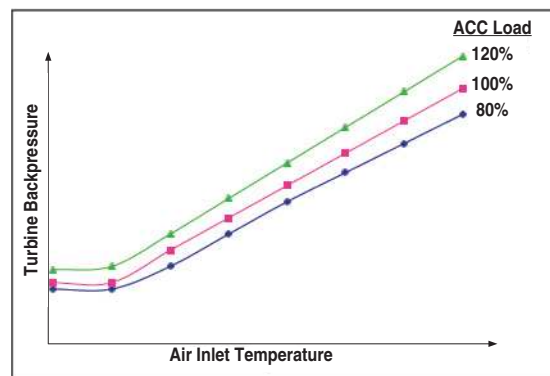


Figure 4
ACC OPERATING CHARACTERISTICS

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6.2.1 Other factors influencing the ACC performance are listed below:

6.2.1.1 Face air velocity – The face air velocity is directly proportional to the air mass flow rate through the heat exchanger and has a significant impact on the overall heat transfer coefficient. For a given ACC, higher face air velocity results in an increased overall heat transfer coefficient, albeit against increased fan power.

6.2.1.2 Air density – The air mass flow rate is proportional to the air density, and has an impact on the overall heat transfer coefficient as well. The air density is a function of the dry bulb temperature, atmospheric pressure, and, to a much lesser extent, of the relative humidity. Since the impact of the relative humidity on the thermal performance of the ACC is rather small, it is usually omitted in the thermal calculations.

6.2.1.3 Fouling – Refer to Section 6.5.

6.2.1.4 Steam properties – Usually, the steam leaving the steam turbine exhaust is saturated with a steam quality greater than 85%. Under bypass or start-up conditions, superheated steam may enter the ACC. ACC manufacturers usually impose limitations on the enthalpy of the steam entering the ACC that are lower than those for steam surface condensers. This is related to the relatively long travel distances of the steam prior to reaching the heat transfer surfaces and the associated large thermal expansion of the steam ducting. A typical maximum steam enthalpy entering the duct is 1170 Btu/lb (2720 kJ/kg).

6.2.1.5 Non-condensables – Non-condensables must be removed from the ACC to avoid accumulation, which will result in reduced ACC capability. There are two major effects of non-condensables: a reduction in available heat transfer area (when non-condensables are accumulating to form a dead zone or air pocket) and a reduction in overall heat transfer coefficient (reduced condensation rate), especially in the second stage, where the concentration of non-condensables becomes significant. During warm weather operation, accumulation of non-condensables would primarily affect

the ACC performance. However, under freezing ambient conditions, accumulation of non-condensables (dead zones) may also result in damage to the heat transfer surface due to freezing of the condensate inside the tubes.

6.2.1.6 Noise: ACCs designed for low noise levels usually have lower face velocities and lower speed fans. Consequently, these ACCs typically have greater surface area and are more sensitive to wind effects.

6.2.1.7 Wind – Refer to Section 6.14.

6.2.1.8 Precipitation – Precipitation may have a beneficial effect on the thermal performance as a consequence of evaporative cooling. However, in some cases the precipitation can increase the air-side resistances, leading to a reduction in performance.

6.2.1.9 Solar radiation – Refer to Section 6.15.

6.3 Deaeration and Dissolved Oxygen

Under practical operating conditions, without a deaerator, a reasonably airtight ACC can be expected to produce condensate with a dissolved oxygen (DO) content not exceeding 50 ppb. Refer to Table 2 below.

With certain conditions of stable operation and suitable construction, an oxygen content not exceeding 20 ppb may be obtained as follows:

6.3.1 The ratio of the actual non-condensable load removed from the system to the design capacity of the air-removal equipment should be no greater than the values in the table below.

Table 2
RATIO OF THE ACTUAL NON-CONDENSABLE LOAD REMOVED FROM THE SYSTEM TO DESIGN CAPACITY

Venting equipment design capacity ^a	Ratio actual venting load to design load ^b	Expected DO content in condensate
0 - 20 SCFM	50% 35%	50 ppb 20 ppb
20 - 40 SCFM	50% 25%	50 ppb 20 ppb
> 40 SCFM	See note c	See note c