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for
AIR COOLED CONDENSERS

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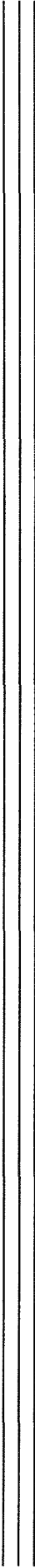
STANDARDS for **AIR COOLED CONDENSERS**

FIRST EDITION

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AIR COOLED CONDENSERS

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FOREWORD

The first 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 publication of the first 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 considerations 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 will also be discussed.

This Standard will address 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 the 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 using ambient air as the heat sink to absorb heat directly from steam at vacuum conditions, condensing the steam and recovering the condensate, as would be typically used in an electric power-generating station.

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 the 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 uncondensed 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 and 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 with access to the fans.

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 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 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 or Reflux 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 bundles 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)
W_{s}	Discharge Flow Rate	(lb/hr)
K_{A}	Flow Coefficient	
P_{A}	Relieving Pressure	psia

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.

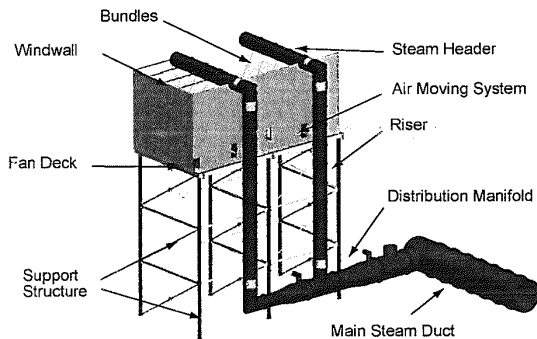


Figure 1
A - FRAME AIR COOLED CONDENSER

4.2 Major Components of an ACC System:

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

- **Fan** – Axial fans push ambient cooling air across the extended surface of the fin tube bundle to transfer the heat from the condensing steam within the tubes.
- **Electric Motor** – Electric motors drive the fan.
- **Speed Reducer** – The gearbox or V belt reduces the rotational speed of the fan and provides the fan with the required torque and speed.
- **Fan Ring** – The fan ring is a cylindrical structure 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.

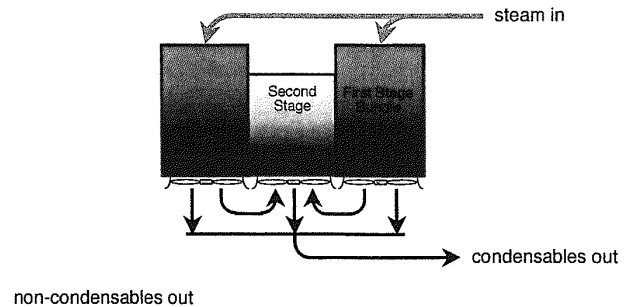


Figure 2
AIR COOLED CONDENSER BUNDLES

4.2.2.1 First Stage Bundle – These bundles are connected to the 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 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

bundles. The function of the windwall is to reduce the negative wind effects on the fan air flow and uniform 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 extract any 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 (SJAE) 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

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.

Table 1
TYPICAL CORROSION ALLOWANCE VALUES

ACC Equipment	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) can be used.

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.

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

$$P_{\text{mot,inst}} \geq (P_{\text{fan,shaft}} / 0.97) \times (273 + T_{\text{design}}) / (273 + T_{\text{min}})$$

with T_{design} and T_{min} in °C

Where T_{min} is 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.

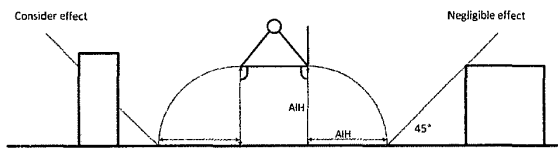


Figure 3
AIR INLET BLOCKAGE CONSIDERATIONS

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 with the manufacturer:

- 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; an 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.

Commercial 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:

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

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

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

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

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

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.

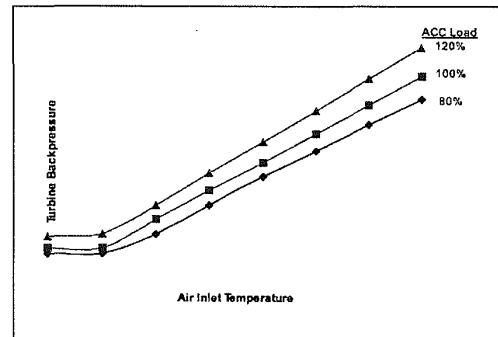


Figure 4
ACC OPERATING CHARACTERISTIC

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

Notes:

- a. The design capacity of the air-removal equipment should be in accordance with Section 9.
- b. These ratios are for air-removal equipment rated at 1 inch HgA.
- c. For air-removal equipment with design capacity exceeding 40 SCFM, the non-condensables removed should not exceed 20 SCFM for 50 ppb and 10 SCFM for 20 ppb.

6.3.2 There should be zero air leakage directly into the condensate below the condensate level in the condensate tank. The arrangement and location of all ingress points into the condenser for water vapor or other gases should be subject to the approval of the manufacturer. Examples of the potential sources of air are as follows:

- LP steam turbine casing and interface with the ACC.
- Leakage into the vacuum side of the system through leaks in welds, packing glands, gauge glasses, instrumentation leads, loop seals, steam traps, etc.
- Low pressure heater condensate drains and vents, particularly when operating below atmospheric pressure.
- Make-up water, which is usually saturated with oxygen.
- Condensate surge tank, when utilized in closed cycles.

6.3.3 Where condensate from processing systems and/or cogeneration systems is introduced to the ACC, it shall be assured that the oxygen content of the returned condensate is no greater than that specified for the dissolved oxygen guarantee. If this is not the case, special internal deaerating provisions may be required and/or returns shall be deaerated externally prior to being returned to the ACC. The specific oxygen level (ppb) in returning condensate and the quantity of condensate being returned must be specified for the manufacturer's consideration.

6.3.4 For all unspecified drains, it is the purchaser's responsibility to limit the DO level for all external streams to a value below the guarantee.

6.3.4.1 Although ACC systems that have virtually no air leakage may yield lower DO levels, for design purposes, vacuum deaerators should be utilized to obtain levels from 20 ppb down to 7 ppb.

6.3.4.2 Whether or not a vacuum deaerator is utilized, the above DO levels cannot be achieved during start-up conditions, low load operation (less than 25%), or in freeze protection control mode.

6.4 Condensate Subcooling

6.4.1 Condensate subcooling is casually defined as the difference between the saturation temperature of the steam at the steam turbine exhaust and the temperature of the condensate at the outlet of the condensate tank. This is not to be confused with the conventional subcooling definition, which is the local temperature difference at a given location between the steam and the condensate.

6.4.2 Due to the significant steam-side pressure losses, condensate subcooling will be much greater than the values observed in a steam surface condenser. Values up to 15°F are possible with ACCs unless a vacuum deaerator is used to reheat the condensate coming from the ACC. A vacuum deaerator should be able to reheat the condensate to within 4°F of the saturated steam temperature at the steam turbine exhaust. Extra consideration should be given to the steam-side pressure drop between the steam turbine exhaust and the vacuum deaerator.

6.5 Cleanliness Factors, Fouling Factors, and Performance Margins

6.5.1 A cleanliness factor is the ratio of the actual heat transfer coefficient to the clean heat transfer coefficient. Although a cleanliness factor is used with water-cooled condensers, it is not applicable to ACCs since the "service" value of the overall heat transfer coefficient (U_{service}) is provided by the manufacturer.

6.5.2 A fouling factor (F) is used to relate the "service" overall heat transfer coefficient to the "clean" overall heat transfer coefficient, and is defined by the following equation:

$$\frac{1}{U_{\text{service}}} = \frac{1}{U_{\text{clean}}} + F$$

6.5.2.1 A typical value for F is 0.003 hr ft²F/Btu or 0.0005 m²K/W based on the total air-side surface area, which accounts for both the steam-side and unrecoverable air-side fouling. Additional air-side fouling

may occur based on the location and the associated environmental conditions (plant material, debris, or any other air borne particulate matter). The ACC performance degradation associated with this type of additional external fouling can be recovered with a professional fin tube cleaning system or cleaning service.

6.5.3 If a performance margin is to be included in the ACC design, it is recommended that it be specified by the purchaser by increasing the design value of the steam flow rate. This is the preferred method that can be tested and verified by the existing performance test codes for ACCs. It is not recommended to include a performance margin in the form of extra cells, extra heat exchange surface area, or number of fans out of service during the performance test. The latter methods can result in unbalanced, non-uniform steam and air flows during the performance test, which are impossible to account for.

6.6 Steam-side Hydraulics

6.6.1 The steam-side pressure drop calculations are part of the thermal design of the ACC. The sizing and routing of the steam duct system is typically optimized for minimal overall ACC investment cost, subject to the following limitations:

- Maximum steam-side velocities (limit erosion, provide normalized steam distribution, allow for adequate range of operating pressure)
- Minimal obstruction in the duct system (heaters, bypass spargers, columns)
- Use of turning vanes to reduce the pressure drop coefficients
- Efficient header and manifold design

6.6.2 Maximum steam-side velocities in the duct system at the inlet of the tubes:

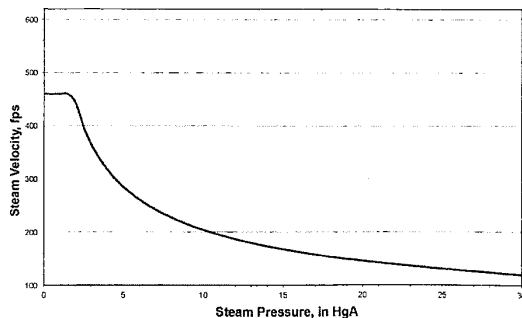


Figure 5
RECOMMENDED VACUUM STEAM VELOCITY
LIMITS (IMPERIAL UNITS)

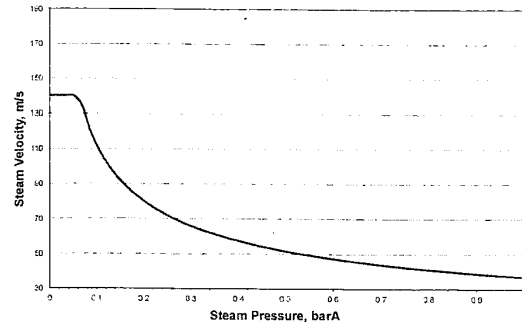


Figure 6
RECOMMENDED VACUUM
STEAM VELOCITY LIMITS (SI UNITS)

6.6.3 As a general guideline, a constant steam velocity should be considered to determine the size of the steam duct system components (steam duct, manifold, risers, and steam headers). It is not unusual, however, that specific physical limitations such as steam turbine exhaust arrangement, steam turbine supports or ancillary system component size and/or location may preclude such a design approach.

6.6.4 It is often necessary that components such as feedwater heaters, bypass spargers, or other sizable components need to be installed in the steam duct. Such internal components will affect the steam flow area, in turn affecting the steam-side pressure drop and steam turbine back pressure. Where internal components are supplied by the purchaser, it is incumbent upon the purchaser to coordinate the incorporation of such components in the steam duct design with the ACC manufacturer so that the effect of the components can be considered.

6.7 Air-side Pressure Losses

ACCs require large quantities of ambient air in order to reject the thermal load. The cooling air is drawn from the surrounding environment and forced through the heat exchanger bundles and around any obstacles that exist. The air-moving system must be designed to provide the required air flow rate while overcoming all of the associated air-side pressure losses.

6.7.1 The following air-side pressure losses shall be accounted for:

6.7.1.1 Air inlet – This is the pressure loss associated with drawing the air in from the ambient environment through the air inlet beneath the ACC along with the turning loss from a horizontal flow stream to a vertical flow stream. The air inlet height should be sufficient to provide uniform distribution of cooling air to all fans. This is typically determined by establishing an air inlet velocity such that the horizontal velocity pressure is sufficiently lower than the static pressure developed by the fan. A typical maximum value for the air inlet velocity is 5 m/s.

6.7.1.2 Fan guard and fan inlet bell – The fan guard is typically a form of screen that can vary from a light gauge material to prevent immediate access and slow falling debris to a heavier gauge material that can also serve as a working platform. The air-side pressure loss associated with the fan guard depends upon the location and geometry of this component. The fan inlet bell serves to create an efficient airflow guide into the fan. The inlet profile and overall geometry of the fan bell will affect the pressure loss. Fan vendor equipment rating programs utilized within the industry typically consider these factors.

6.7.1.3 Plenum discharge loss – As the air is discharged from the fan ring to the plenum, there is a sudden enlargement of the air flow path. This causes an expansion loss that is a function of the geometry and air-side properties (i.e., velocity and density). ACC manufacturers should consider this loss and other losses associated with the non-uniform airflow conditions that exist at the discharge of the fan.

6.7.1.4 Fan bridge – The fan bridge is the structural support of the air-moving system (i.e., fan, motor, and gearbox). Fan bridge designs vary and are manufacturer dependent. The air flow obstruction, type and distance from the fan affect this loss.

6.7.1.5 Bundle inlet – This is the pressure loss associated with air flow turning from the fan discharge into the heat exchanger bundles.

6.7.1.6 Bundle – This is the pressure loss associated with the airflow through the heat exchanger bundles. This loss includes the entrance loss to the heat exchange surface, loss through the heat exchange surface and the bundle outlet dumping loss. This is highly dependent on fin tube design and varies between manufacturers. This is also the predominant pressure drop within the system and typically represents 50 - 70% of the total air side pressure drop.

6.7.1.7 Bundle outlet – This is the pressure loss associated with air flow turning from the heat exchanger bundle exit to the discharge of the ACC.

6.7.1.8 Natural draft correction – This is the buoyancy contribution that the hot discharge air contributes to the air-side pressure losses. This will be reported as a negative pressure loss and is a function of the windwall/draft height and the difference in the air density between the ambient and the ACC discharge air.

6.7.1.9 Air inlet and air outlet louvers (if applicable) – Extreme ambient/operational considerations may necessitate air inlet or outlet louvers to enhance airflow control. This feature can generate significant additional air-side pressure losses.

6.7.1.10 Air inlet and air outlet noise silencers (if applicable) – Extreme noise restrictions may require air inlet or outlet silencers to reduce the noise emitted by the ACC. This feature can generate significant additional air-side pressure losses.

6.8 Air Inlet Temperature

6.8.1 The performance of an ACC is dependent upon the dry bulb temperature of the cooling air stream. It is important to note that the air temperature may vary around the power plant and not be consistent or representative of the air temperature entering the heat exchanger bundles. The temperature of the air entering the ACC may be negatively affected by the following:

- Warm air recirculation
- Discharge air from other heat exchangers
- Other sources of thermal energy

6.8.2 The plant designer should take into consideration the placement of additional sources of thermal energy with respect to the location of the ACC along with the prevailing summer wind conditions.

6.9 Auxiliary Power Consumption

6.9.1 Typically, when evaluating ACC designs, the ACC fan drive motors are the only loads to be considered.

6.9.2 In addition to the ACC fan motor power, the following additional system loads may exist:

- Gearbox oil pumps and heaters
- Vacuum pumps
- Drain pot pumps
- Condensate forwarding pumps
- Condensate tank heaters
- Motor operated valves
- Instrumentation
- Space heaters
- Heat tracing
- Lighting
- Cable losses, variable frequency drives, etc.

6.9.3 The auxiliary power consumption should be evaluated at the fan motor input terminals considering speed reducer efficiency (96 to 98%) and motor efficiency (91 to 95%). This can cause the electrical power consumption to exceed the fan shaft power by greater than 10%. Note that smaller motors (< 50 hp) and V-belt drives may have lower efficiencies.

6.9.4 The auxiliary power consumption will vary considerably due to the effects of temperature on air density. As the air temperature increases, auxiliary power will decrease, and as the air temperature decreases, the auxiliary power will increase based on constant fan speed. It is considered prudent to have a power margin (5 to 10%) on the installed motor capability at the design condition. However, it is not necessary to specify that this margin be available over the entire range of ambient conditions. Since most forced draft ACC designs place the motor in the discharge stream of the fan, the electric motor will benefit from a cooler operating environment as the air temperature decreases. It is not unusual to obtain an ambient air temperature correction factor from the motor manufacturers that will provide nameplate power corrections based on cooler operating environments.

6.9.5 The ACC control logic adjusts fan speed(s) in order to achieve the desired thermal

performance under various operating conditions. This typically involves:

- Single-speed motors – Switching fans on/off
- Two-speed motors – Switching between full speed/partial speed/off
- Variable-speed motors – Incremental adjustment

The various control scenarios will provide very different auxiliary power consumption profiles when evaluated on an annual basis and should be considered within the ACC specification.

6.10 Cold Weather Performance

6.10.1 As the air temperature decreases, the capability of the ACC increases based on a constant condensing pressure. However, it is quite common to allow the steam turbine back pressure to fluctuate with the air temperature within certain limitations:

- ACC manufacturer low pressure limit
- Steam turbine manufacturer low pressure limit
- Minimum operating pressure of the air-removal system
- Steam Velocities

6.10.2 Once one of the low pressure limitations has been achieved, further air temperature reductions must be accommodated with a control step. Typically, this is achieved by reducing fan speeds.

6.10.3 If the air temperature continues to decrease so that all fans are off, further control steps will be required to reduce air flow (inlet or exit louvers) or remove heat exchanger surface from operation (sectionalizing valves). Higher power density designs (higher fan power per unit of heat transfer surface area) will increase the ambient air temperature range that fan speed control can accommodate.

6.10.4 It is very important to ensure that the ACC has the capability to operate reliably and safely throughout the range of specified temperatures and, in particular, temperatures below freezing. Although control philosophies vary between the manufacturers, it is important to ensure that steps are taken to avoid the formation of dead zones (non-condensable accumulation). Dead zone formation during freezing conditions will result in depressed condensate temperatures. If this condition is not corrected, freezing of the condensate within the tubes and permanent damage of the ACC may result.

6.11 Low Load Operation

6.11.1 Low load operation is defined as a condition in which the ACC is operated at less than the design steam load. It is important that the low load and the corresponding minimum air temperature are clearly identified for the approval of the ACC manufacturer.

6.11.2 Low load operation presents similar challenges as the low temperature operation described in 6.10. The resulting situation is that more heat transfer surface is available than what is required. At air inlet temperatures above freezing, this is not a significant concern. Dead zone formation under these conditions will only affect the ACC operating efficiency along with an increase in DO potential.

6.11.3 Low load operation with air inlet temperatures below freezing will have the same concerns as described in 6.10. However, the low load operation will cause the concerns to develop more quickly or at higher temperatures.

6.11.4 The duration of the low load operation is important. What should be evaluated is the minimum load under sustained operation (greater than 4 to 6 hours) at the minimum air inlet temperature. ACC sectionalizing, louvers or enhanced control algorithms may be required in order to provide safe and reliable operation.

6.12 Performance Curves

6.12.1 Performance curves shall be provided by the ACC manufacturer in accordance with the specified performance test code.

6.12.2 Performance curves shall be generated with all fans running at the design fan speed. Supplemental curves may be generated for partial fan speed operation; however, such curves are generally not guaranteed.

6.12.3 Performance curves shall clearly identify the minimum operating pressure of the ACC and shall identify when the curves are subject to freeze protection control adjustments.

6.13 Performance Testing

6.13.1 For contractual compliance, the ACC should be tested in accordance with a specified industry-recognized performance test code such as ASME PTC 30.1 or VGB 131Me.

6.13.2 If specified by the purchaser, the ACC manufacturer shall include the necessary provisions within the ACC supply so that test instrumentation can be installed on the ACC to conduct the specified performance test.

6.14 Effects of Wind on ACC Performance

6.14.1 There are 2 primary effects that wind can have on the performance of an ACC.

6.14.1.1 (Warm air) recirculation – Will occur if the wind speed and direction are such that the ACC discharge air stream is brought within close proximity of the air inlet, whereby the two air streams mix. This will cause an increase in the air inlet temperature and a reduction in the performance of the ACC. The level of performance degradation will be function of the quantity and temperature of the recirculated air stream. Recirculating air can also cause an imbalance in condensing load from one section to another within the ACC. Windwalls reduce this phenomenon by separating the discharge air stream of the inlet air stream. Also, design practices such as keeping the air inlet velocity lower than the discharge velocity are often employed to mitigate the potential for recirculation. The placement of the ACC relative to other large structures or flow disturbances should be evaluated in order to understand their influence on the potential for recirculation.

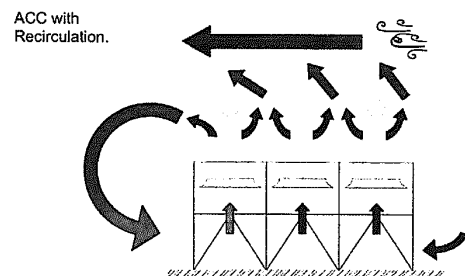


Figure 7
ACC WITH RECIRCULATION

6.14.1.2 Dynamic effects on the air flow – Elevated wind speeds can disturb the air flow of the ACC inlet, fans and ACC outlet.

- **ACC air inlet and outlet** – High wind speeds around the ACC structure and other plant structures or obstacles can cause localized vortices and flow disturbances that can reduce the air flow

through portions of the heat exchanger bundles. This will cause a reduction in performance of the ACC. Reduced air flow through the fans can also cause an imbalance in condensing load from one section to another within the ACC. Depending on the severity of the flow disturbance, this may cause unexpected spikes in back pressure that could result in steam turbine back pressure alarms or trips.

- **Fans** – High wind speeds will cause an increase in the velocity pressure of the inlet air stream of the ACC. This will increase the static pressure loading on the fan causing the fan's duty point to shift. The result will be a higher operating static pressure at a reduced air flow rate, reducing the performance of the ACC. Typically, the fans that are subjected to the greatest degradation in performance are those on the leading face (upwind) of the ACC. Windscreens or other devices may be employed to mitigate these effects.

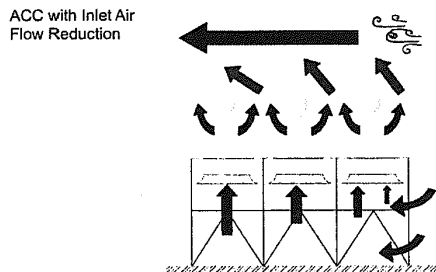


Figure 8
ACC WITH INLET AIR FLOW REDUCTION

6.14.2 As a general rule, the higher the absolute value of the pressure margin of a fan, the less susceptible to wind effects the ACC will be. This is why lower noise ACCs (with slow turning, low pressure fans) are generally more sensitive to wind effects.

6.15 Effects of Solar Radiation

6.15.1 The amount of solar radiation incident on an ACC is determined by the maximum solar flux for a given location. A value on the order of 1000 W/m² is typical for areas of concern, which are closer to the equator or in a desert climate. This solar flux is applied to the plot area of the ACC, not the heat transfer surface area. If an ACC were to absorb 100% of the solar energy incident upon its plot area, it would equate to less than 1.5% of the ACC's heat rejection capacity. Although the emissivity of the tube and fin materials varies between ACC manufacturers, when it is considered, the maximum impact due to solar radiation has been calculated to be less than 0.5% on an instantaneous basis. If this effect is integrated over the daylight hours, the impact is considered negligible.

6.15.2 Operators of ACCs have observed back pressure reductions as large clouds block solar radiation. It is believed that this has more to do with the reduction in air inlet temperature rather than the temporary blockage of solar radiation on the ACC heat transfer surface.

7.0 INSTRUMENTATION AND CONTROL

7.1 Recommended Instrumentation

7.1.1 The ACC shall be equipped with sufficient instrumentation to monitor the process conditions. Both local instrumentation and transmitters, switches, and other devices shall be included. Some of the instrumentation will be involved in the control and protection of the ACC over the specified range of operating conditions. The following process conditions shall be monitored as a minimum:

7.1.1.1 Back pressure and corresponding steam temperature: At least one pressure transmitter and one temperature element should be installed near the steam turbine exhaust interface or other prescribed location.

7.1.1.2 Condensate temperature in the condensate tank: At least one temperature element should be installed below the lowest operating condensate level.

7.1.1.3 Condensate temperature in the condensate headers: At least one temperature element should be installed in each condensate header. It is important that these thermowells are installed properly such that the temperature of the condensate flowing in the bottom of the header is measured and not the steam space temperature. Where freezing conditions exist, temperature elements may be installed to measure temperature on both sides of the condensate header drain pipe.

7.1.1.4. Temperature of the non-condensables: At least one temperature element should be installed in each air removal line per row.

7.1.1.5 Inlet air temperature: At least one temperature element should be installed in the air inlet stream of the ACC and shielded from solar radiation.

7.1.1.6 Level of condensate in the tank: At least one level transmitter should be installed in the condensate tank.

7.1.1.7 Level of condensate in the drain pot: At least one level transmitter should be installed in the drain pot.

7.1.1.8 Gearbox oil pressure or flow: One pressure or flow switch per gearbox is the standard.

7.1.1.9 Fan speed: Fan motor speed status shall be monitored for each individual fan via feedback from the Motor Control Center.

7.1.1.10 Valve positions of automated valves: The valve position of each automated valve within the ACC should be monitored via the limit switches or valve positioners.

7.1.1.11 Vibration of air-moving equipment: At least one vibration switch or transducer should be installed for each fan drive assembly.

7.2 ACC Control and Freeze Protection Considerations

7.2.1 General control concepts

- The back pressure can be controlled by modifying the air flow rate of the ACC, achieved by adjusting fan speeds unless air inlet/outlet louvers are supplied. The number

of air flow control steps available is only a function of the number ACC fans and the type of motor control (single, two speed or variable speed).

- For example, a 100-cell ACC with single speed fans can provide up to 100 airflow control steps, which, in many cases, will be sufficient for proper ACC operation. However, a 4-cell ACC may require VFDs in order to provide sufficient air flow control
- The range of steam flow rate and inlet air temperatures will determine the quantity and magnitude of control steps required.

7.2.2 ACC Freeze Protection Considerations

It is very important to ensure that the ACC has the capability to operate reliably and safely throughout the range of specified temperatures and, in particular, temperatures below freezing. Although control and freeze protection philosophies vary among manufacturers, it is important to ensure that steps are taken to reduce the risk of low condensate temperatures and potential for freezing:

- Enhanced monitoring of process conditions and control
- Modified air flow control (fan speed, louvers, controlled recirculation, etc.)
- Reduce heat transfer area (use of sectionalizing valves)

7.3 Selection of Number of Isolation Valves

7.3.1 If the ACC must be operated at low steam flow rates at air inlet temperatures below freezing and the suction pressure at the vacuum equipment is too low when all fan control steps are exhausted, the heat transfer area of the ACC must be reduced. This can be achieved by removing heat transfer surface from operation using sectionalizing valves.

7.3.2 The number of sectionalizing valves is determined by the amount of heat transfer surface that must be isolated in order to maintain a sufficiently high suction pressure at the air-removal skid at the minimum sustained steam flow rate and coincident minimum design air inlet temperature. The minimum sustained steam flow rate and coincident minimum design air inlet temperature shall be specified by the purchaser.

7.4 Drain Pot Capacity

7.4.1 The capacity of the drain pot is a function of the quality of the steam entering the ACC, the number of drains entering the drain pot, and the steam duct condensing capacity. The drain pot capacity shall be sized for at least five minutes between the low and high operating level using the maximum continuous condensate flow rate entering the drain pot. If the condensate collected in the steam duct is drained by gravity to the condensate return system, a drain pot is not required.

7.5 Condensate Tank Capacity

7.5.1 The condensate tank is typically a horizontal cylindrical tank sized using the design steam turbine exhaust steam flow rate, unless specified otherwise by the purchaser. Typical condensate tank capacity is the volume sufficient to contain all of the condensate produced in the ACC in a period of five minutes between normal operating level and low operating level at the design steam turbine exhaust steam flow rate. Normal operating level is typically 50% of the tank diameter.

8.0 SERVICE CONNECTIONS

8.1 General Considerations

8.1.1 This section serves as a guide to provide information on the location and design of the various types of connections on an ACC to permit the dispersion of fluid energies at steady-state operation without causing detrimental effects on the internals, steam duct, drain pot, and condensate tank.

8.1.2 Specific recommendations are provided, since each connection will have different flows and fluid energies in order to achieve the most effective dispersion. Required connection service will range from high-energy large volume steam dumps (in some cases requiring multi-stage breakdowns and desuperheating) to relatively low flow and low energy level connections.

8.1.3 An ACC is significantly different from a steam surface condenser and requires unique design considerations. Connections on the ACC are typically at a significant distance from the heat exchange surface. Due to nominal steam duct system expansion design provisions, the design temperature of the ACC system is typically 250°F (121 C). The enthalpies of the various inlet connection flows, particularly steam turbine bypass flow, shall be limited to approximately 1,170 Btu/lb (2720 kJ/kg).

8.2 Flow Data

8.2.1 It is imperative that the ACC manufacturer is furnished with reliable flow data required for designing the connections and internals. The energy levels and flows will have a bearing

on the acceptable location and orientation of connections. Incorrect or incomplete information can result in improper location, orientation, and possible operational issues. Similarly, conditions of service (e.g., start-up, continuous) shall be specified, because problems may occur if actual service differs from that originally specified.

8.2.2 All thermal and hydraulic design conditions of the connections provided to the manufacturer shall be at the connection on the ACC (not upstream of control valve, etc.).

8.3 Connection Locations

8.3.1 Locating connections on the steam duct, drain pot, condensate tank, and/or flash tank must be given high priority and be integrated into the plant layout during preparation of the specifications to avoid compromising ACC performance. It is recommended that high energy or flashing drains be routed to a separate flash tank as to condition the fluids to an acceptable enthalpy. The flash tank shall be vented to the ACC steam space and drained to the ACC condensate return system.

8.3.2 In order to ensure that all connections on the ACC are located so that the integrity and operation of the ACC is not compromised, and to ensure that required deaeration is obtained, the following requirements on the placement of connections and acceptable conditions of flows in the connections shall be provided. The following table indicates the preferred locations for some categories of connections usually installed on the ACC system. Numbers indicate the order of preference.

Table 3
PREFERRED LOCATIONS OF CONNECTIONS
USUALLY INSTALLED ON THE ACC SYSTEM

	Steam Duct	Drain Pot	Condensate Tank	Deaerator	Flash Tank
Low Temperature Drains Requiring Deaeration	Not Recommended (NR)	NR	NR	1	NR
Low Temperature Drains Not Requiring Deaeration	2	2	1	NR	2
Make-Up	3	3	2	1	NR
Condensate Pump Recirculation	NR	NR	1	NR	NR
Drain Pot Pump Recirculation	NR	1	NR	NR	NR
Boiler Feed Pump Turbine Exhaust	1	NR	NR	NR	NR
Gland Seal Drain	2	NR	NR	NR	1
High Temperature Steam Drains	2	NR	NR	NR	1
High Temperature Water Drains	2	NR	NR	NR	1
Steam Turbine Bypass Dumps	1	NR	NR	NR	NR
Continuous Feedwater Heater Drains	2	NR	NR	NR	1
Miscellaneous Drains and Vents	Determine location based upon similar application above				

*1 = Best choice, 2 = Good, 3 = Acceptable

8.4 Connection Design Guidelines

8.4.1 Complete design conditions (pressure, temperature, enthalpy and flow) must be provided at each connection. In addition, service conditions shall be supplied (i.e., continuous, intermittent, start-up, etc.).

8.4.2 Limit the enthalpy of entering steam to 1,170 Btu/lb (2720 kJ/kg). Acceptance of flows with enthalpy greater than 1,170 Btu/lb (2720 kJ/kg) may be considered depending on specific conditions of service.

8.4.3 Limit connection pressures to a maximum of 50 psia (3.44 bara). Pressures should be lower where possible, especially for liquid flows. Special considerations for higher pressures should be reviewed with individual manufacturers.

8.4.4 Ventilator valve (and other high energy short duration sources) discharges should be to the atmosphere; however, if they are directed to the ACC, limitations as described above will apply.

8.4.5 Where conditions exceed the above requirements, external desuperheating must be provided by the purchaser for all connections that are in operation when exhaust steam flow is absent. Desuperheating shall be accomplished in a manner such that the above enthalpy limits are not exceeded.

8.4.6 It is recommended that drains requiring deaeration have a pressure of at least 5 psi (0.34 bar) greater than the ACC operating pressure.

8.4.7 Design of ACC connections and/or locations should be such that the steam release volumes from the additional steam loading will not result in steam velocities in excess of those indicated in Section 6.6.

8.4.8 Thermal sleeves should be provided on process connections designed for temperatures in excess of 450°F (232 C).

8.4.9 Under no circumstances should steam flashing drains be admitted to the ACC unless cooling air flow is established and non-condensable gas removal equipment is in operation.

8.4.10 Connections as indicated in the above table should not be located below the water level, near field weld lines, internal bracing, corners or near any expansion joints, rupture discs, instruments or internal apparatus.

8.4.11 Do not locate a series of connections, except gauge and control, in close proximity so that high flow concentrations and/or interferences from discharges from all of the connections will result. High energy drain effluent lines must be kept away from liquid return lines to prevent droplet transport and associated erosion.

8.4.12 If sufficient flow area is not available within the steam duct for the introduction of steam turbine bypass sparger(s), integral bell housing(s) located on the steam duct should be considered.

8.4.13 The use of external flash tanks is recommended for high temperature, high pressure drain flows prior to being admitted to the ACC. This would usually apply to systems where a large number of small connections with high energy levels exist. Minor steam drains or vents may exceed specified conditions in paragraphs 8.4.2 and 8.4.3, provided flow from the main steam turbine exists and the locations are acceptable to the manufacturer.

8.4.14 Piping upstream of all flowing connections shall be properly trapped and drained to prevent damaging water slugs being introduced into connections.

8.4.15 The external location shall be such that re-routing of internal piping is not required, since internal piping may interfere with normal steam flow within the ACC.

8.5 Steam Turbine Exhaust Interface

8.5.1 Orientation, Location, and Dimensions

8.5.1.1 The purchaser shall provide sufficient details depicting the overall steam turbine arrangement, particularly the orientation and location of the steam turbine interface, relative to the ACC. Additionally interface dimensions and shape details shall be provided so that the ACC manufacturer can develop and engineer interface connection details.

8.5.1.2 Typical steam turbine exhaust orientations include bottom exhaust, axial exhaust, lateral/side exhaust and top exhaust. Multiple exhaust openings may exist.

8.5.1.3 Location and orientation of the steam turbine interface(s) must be given high priority and be integrated into the plant layout during preparation of the specifications to avoid compromising the main steam duct design and performance of the ACC. The location and orientation shall facilitate the efficient interconnection, installation, support and routing of the main steam duct

from the steam turbine exhaust interface to the ACC. This involves designing the steam turbine foundation surrounding equipment and structures to accomplish these requirements.

8.5.2 Connection Types

8.5.2.1 The two (2) main types of steam turbine interface connections are welded and bolted. The purchaser shall provide sufficient details depicting the interface so that the ACC manufacturer can develop and engineer interface connection details.

8.5.2.2 A welded connection is preferred over a bolted connection to mitigate air leakage into the ACC. A landing bar welded connection is recommended, as it allows for adjustment during installation to compensate for manufacturing and installation tolerances. Welding methods, access, and details shall be considered when developing the equipment arrangement.

8.5.2.3 Bolted flange connections shall be of the O-ring or gasket type. This connection shall be properly installed and maintained to provide a leak-free seal. Appropriate tolerance in this connection shall be specified. Metal-to-metal interfaces shall be avoided.

- Flanged steam turbine connections shall be faced and drilled per the steam turbine suppliers guidelines.
- Expected flange face finishes shall be indicated.
- Cast iron flange connections shall be flat faced.
- General geometric dimensioning and tolerance should be reasonable and state the functional requirements.
- Careful design and planning are essential, and customer specifications must clearly outline all expected dimensions, tolerances, and finishes.

8.5.3 Displacements and Settlement

Steam turbine exhaust interface displacements and differential settlement between the steam turbine interface, the steam duct supports, and the ACC structural supports due to any factors shall be specified by the purchaser and shall be less than 0.125 inch (3 mm), unless otherwise acceptable by the ACC manufacturer.

It is imperative that the purchaser cooperates with the ACC manufacturer to ensure that all conditions are examined prior to the ACC initial design. Careful design and planning are essential, and customer specifications must clearly outline all expected settlement and displacements.

8.5.4 Interface Force and Moments

8.5.4.1 Consideration of the interaction of forces and moments at the steam turbine exhaust interface are of paramount importance. The purchaser must specify reasonable allowable external forces and moments at the interface location.

8.5.4.2 In no case shall the ACC steam duct be required to support the steam turbine.

8.5.4.3 It is imperative that the purchaser cooperates with the ACC manufacturer to assure all conditions are examined prior to the ACC initial design. Careful design and planning are essential and customer specifications must clearly outline all expected forces and moments.

8.5.4.4 Unless specified otherwise, the purchaser understands that the steam turbine is capable of accepting the internal vacuum forces associated with the incorporation of an unrestrained expansion joint near the steam turbine interface. The internal vacuum force is in addition to those forces and moments specified under 8.5.4.1. The purchaser's steam turbine foundation design shall consider the resultant vacuum forces and moments. In the event that the steam turbine is not able to accept vacuum forces, it is incumbent upon the purchaser to advise the ACC manufacturer so that alternate design considerations should be explored.

8.5.5 Steam Turbine Exhaust Expansion Joint

8.5.5.1 In order to accommodate the allowable external forces and moments (loads) and displacements at the steam turbine interface, an expansion joint is routinely required. Usually an unrestrained expansion joint is utilized.

8.5.5.2 If unusual design temperature, displacement, or load conditions are

specified, then alternate expansion joint types, materials, and arrangements may be considered. In this event it is incumbent upon the purchaser to advise the ACC manufacturer so that alternate design considerations can be explored.

8.5.6 Steam Turbine Exhaust Duct Structural Design

8.5.6.1 The main steam duct is a thin-walled, externally pressurized vessel. Accordingly, external and/or internal stiffeners are required to provide the necessary structural integrity. The purchaser's design of its turbine support structure, internal piping, and components shall consider the ACC manufacturer's stiffening requirement.

8.5.6.2 Unless specified otherwise, support of the purchaser's components (feedwater heaters, piping, spargers, platforms, etc.) is not considered. If support of such components is required, then it is incumbent upon the purchaser to advise the ACC manufacturer of such details that may be required for the ACC manufacturer to consider in its design.

8.5.7 Steam Turbine Exhaust Steam Flow Profile

Unless specified otherwise, it is assumed that the steam flow velocity, pressure, and density profile exiting the steam turbine are uniform in nature. This assumption shall be considered by the ACC manufacturer in its structural hydraulic designs.

8.6 Steam Turbine Bypass Guidelines

8.6.1 General

8.6.1.1 Complete evaluation of the design parameters for main steam bypass lines is important for the safe operation of the ACC. Operating requirements and special customer requirements could affect the ACC design. It is imperative that the purchaser cooperates with the ACC manufacturer to assure all conditions are examined prior to the final design.

8.6.1.2 Operation of steam turbine bypass should occur with all ACC systems capable to operate at full capacity. For start-up conditions, to achieve maximum condensing capacity, all non-condensable

must be extracted from the ACC system. During sustained steam turbine bypass operation, non-condensable extraction shall be maintained at the required holding rate. Careful design and planning are essential, and customer specifications must clearly outline all expected operational modes.

8.6.1.3 The total amount of conditioned bypass steam admitted to the ACC can vary over a wide range. ACC manufacturers do not guarantee performance for steam turbine bypass service, but rather make accommodations for the condensation of the bypass steam flow.

8.6.1.4 Noise abatement measures, such as the use of special noise attenuating valves, spargers, or noise attenuating insulation, should be considered by plant designers in accordance with specified noise requirements. ACC manufacturers shall not be required to provide noise guarantees during steam turbine bypass operations.

**8.6.1.5 Bypass Connection
Allowable Loads:**

Location and orientation of the steam turbine bypass interface(s) must be given high priority and be integrated into the plant layout during preparation of the specifications to avoid compromising the main steam duct design and performance of the ACC. The location and orientation shall facilitate the efficient interconnection, installation, support, and routing of the main steam duct from the steam turbine exhaust interface to the ACC. This involves designing the steam turbine bypass surrounding equipment and structures to accomplish these requirements.

Consideration on the interaction of forces and moments at the steam turbine exhaust duct interfaces are of paramount importance. The purchaser must specify the external forces and moments at the interface location. The forces and moments shall be reasonable, considering the arrangement to the steam turbine exhaust duct.

It is imperative that the purchaser cooperates with the ACC manufacturer to assure all conditions are examined prior to the ACC initial design. Careful design and planning are essential, and customer specifications must clearly outline all expected forces and moments.

If unusual design temperature, displacement, or load conditions are specified, then alternate connection types, materials, and arrangements may be considered. In this event it is incumbent upon the purchaser to advise the ACC manufacturer so that alternate design considerations can be explored.

8.6.2 Bypass Steam Conditioning

8.6.2.1 ACC bypass steam inlet enthalpy values shall not exceed 1,170 Btu/lb (2720 kJ/kg) and 50 psia (3.44 bara) to ensure the discharge does not exceed the ACC design temperature. External desuperheating devices that reduce enthalpy to 1,170 Btu/lb (2720 kJ/kg) must be located sufficiently upstream of the ACC to ensure adequate mixing and evaporation of the attenuation fluid.

8.6.2.2 The steam turbine manufacturers may set specific guidelines for maximum temperature at the interface of the steam turbine with the ACC. Main steam turbine exhaust expansion joint suppliers also have temperature limits that need to be considered. When such limitations are encountered, a cooling water spray curtain may be required near the steam turbine exhaust duct transition area to reduce local temperature excursions. The purchaser shall design and supply the spray curtain components, which shall be integrated within the steam turbine exhaust duct. Water loading, pressure, connection size, and components shall be specified by the purchaser. Careful design and planning are essential and must be coordinated with the ACC manufacturer. In no event shall the ACC manufacturer be required to provide guarantees with regard to the spray curtain performance.

Table 4
TYPICAL ALLOWABLE NOZZLE LOADS

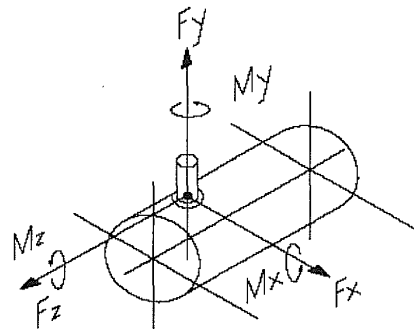
Maximum allowable nozzle loads and moments							
SIZE		Forces (N)			Moments (N*m)		
NPS	DN	FX	FY	FZ	MX	MY	MZ
2	50	800	800	800	160	160	160
3	80	1800	1800	1800	540	540	540
4	100	3200	3200	3200	1280	1280	1280
6	150	7200	7200	7200	4320	4320	4320
8	200	12800	12800	12800	10240	10240	10240
10	250	14000	14000	14000	11000	11000	11000
12 and over	300	14000	14000	14000	11000	11000	11000

Maximum allowable nozzle loads and moments							
SIZE		Forces (lbf)			Moments (ft*lbf)		
NPS	DN	FX	FY	FZ	MX	MY	MZ
2	50	180	180	180	120	120	120
3	80	405	405	405	400	400	400
4	100	720	720	720	945	945	945
6	150	1620	1620	1620	3185	3185	3185
8	200	2880	2880	2880	7550	7550	7550
10	250	3145	3145	3145	8110	8110	8110
12 and over	300	3145	3145	3145	8110	8110	8110

8.7 Feedwater Heater Considerations

8.7.1 The installation of feedwater heater(s) within the ACC steam duct will affect the performance of the ACC. As such, the inclusion of feedwater heater(s) requires the purchaser to specify the location, orientation, dimensions, pipe routing, and quantity. If all of the above information is not provided, the guaranteed back pressure shall be measured downstream of the feedwater heater(s).

8.7.2 Additional thermal loads, if any, are not considered by the ACC manufacturer unless specified otherwise by the purchaser.



9.0 VENTING EQUIPMENT CAPACITIES

9.1 Venting Requirements

9.1.1 Venting equipment must be capable of removing all non-condensables and associated water vapor from the ACC to produce the minimum steam condensing pressure consistent with physical dimensions and heat transfer. The sources of the non-condensables to be removed include but are not limited to:

- Low pressure steam turbine casing, seals and associated drains.
- Air leakage into all system components operating at sub-atmospheric pressure.
- Gases released from feedwater drains and vents admitted to the ACC.
- Gases released from makeup admitted to the ACC.
- Condensate surge and flash tanks, when vented or drained to the ACC.
- Disassociation of feedwater into oxygen, hydrogen, and other non-condensables in certain types of nuclear fueled cycles.

9.1.2 Unless specified by the purchaser and accepted by the ACC manufacturer, the ACC manufacturer shall not be responsible for the effect that additional sources of non-condensables have on ACC performance.

9.1.3 In addition to non-condensables, a quantity of associated water vapor will also be vented. This quantity will be a function of the quantity, temperature, and pressure of the non-condensable flow.

9.2 Design Suction Pressure

In order to coordinate the performance of the venting equipment to be installed with an ACC serving a turbine, it is recommended that the design suction pressure be in accordance with the following:

9.2.1 Electric generating service – The venting equipment design suction pressure is 1.0 inch HgA or the minimum suction pressure (as measured at the inlet to the air removal equipment) based on the specified range of operating conditions for the ACC. Final selection should consider compatible operation of the ACC and its venting equipment over the full range of anticipated operating pressures and loads. In addition, the physical location of the equipment should be considered when the design suction pressure is selected.

9.2.2 Pumps, compressors, and other mechanical drives – The venting equipment design suction pressure is that for which the ACC is designed minus 1.0 inch Hg or the lowest required suction pressure. Minimum shall be 1.0 inch HgA.

9.3 Design Suction Temperature

9.3.1 The temperature of the gas vapor mixture shall be considered as 7.5°F below the steam saturation temperature at the effective suction pressure.

9.3.2 The 7.5°F temperature differential is a design value utilized to physically size the venting equipment. The actual temperature of the vapor at the vent outlet during operation is influenced by the operating characteristics, the non-condensable load, and the capacity characteristics of the venting equipment and may not necessarily be equal to the 7.5°F differential.

9.4 Calculation of Water Vapor Load Component

The amount of water vapor to saturate the non-condensables can be calculated from the following formula:

$$W = \frac{18}{MW_{NC}} \times \frac{P_w}{P_T - P_w}$$

When the non-condensable is dry air ($MW_{NC}=29$), the weight of the water vapor can be obtained from the above equation. P_w is the saturation pressure of steam at the mixture temperature and P_T is the total pressure of the mixture.

9.5 Minimum Recommended Capacities

It is recommended that the capacity of the venting equipment not be less than the values shown in Tables 5 thru 7 at the design suction pressure to insure adequate removal capacity under commercial operating conditions.

9.5.1 Procedure for Sizing Venting Equipment

9.5.1.1 Determine the total steam flow of the unit by adding the main turbine exhaust flow and any auxiliary turbine exhaust flows entering all main ducts of the ACC.

9.5.1.2 Determine the total number of LP turbine exhaust openings. Do not include auxiliary turbine exhaust openings.

9.5.1.3 Divide flow obtained in 9.5.1.1 by exhaust opening number obtained in 9.5.1.2. The resultant number is the effective steam flow for each LP turbine exhaust opening.

9.5.1.4 Enter the appropriate section of Table 5 and locate the flow obtained in Step 9.5.1.3.

9.5.1.5 Determine total number of exhaust openings by adding the total number of LP turbine exhaust openings to the total number of auxiliary turbines exhausting into the ACC.

9.5.1.6 Determine the recommended capacity by using the number obtained in 9.5.1.5.

9.5.2 If the ACC is separated into individual blocks or split configurations (i.e., parallel condensers) so that the suction pressures at full performance can be different, then the venting system capacity of each block shall be per Table 5.

The following is an example of sizing the venting equipment:

Example No. 1: The condenser design parameters are the following:

- One LP Exhaust Casing
- Total steam flows from LP turbine exhausts = 1,600,000 lb/hr
- Total steam flows from auxiliary turbine exhausts = 0 lb/hr
- Number of LP turbine exhaust openings = One (1)
- Number of auxiliary turbine exhaust openings = Zero (0)

The total steam flow of the unit is the sum of the LP turbine exhaust and auxiliary exhausts. [This value is 1,600,000 lb/hr.]

The number of LP turbine openings is one (1).

Divide 1,600,000 lb/hr by one (1). The result is 1,600,000 lb/hr, which is the effective steam flow for each LP exhaust opening.

Enter Table 5 and use the row listed for the Effective Steam Flow Each LP Exhaust Opening of 1,500,001 to 2,000,000 lb/hr.

The total number of exhaust openings is one (1). This is determined by the sum of the total number main exhaust openings and auxiliary turbine openings.

The intersection of this column and row results in a venting capacity of 22.5 SCFM.

Example No. 2: The condenser design parameters are the following:

- One LP Exhaust Casing
- Total steam flows from LP turbine exhausts = 950,000 lb/hr
- Total steam flows from auxiliary turbine exhausts = 200,000 lb/hr
- Number of LP turbine exhaust openings = Four (4)
- Number of auxiliary turbine exhaust openings = Two (2)

The total steam flow of the unit is the sum of the main turbine exhaust and auxiliary exhausts. [This value is 1,150,000 lb/hr.]

The number of LP main turbine openings is four (4).

Divide 1,150,000 lb/hr by four (4). The result is 287,500 lb/hr, which is the effective steam flow for each main exhaust opening.

Enter Table 5 and use the row listed for the effective steam flow [for] each LP exhaust opening of 250,001 to 500,000 lb/hr.

The total number of exhaust openings is six (6). This is determined by the sum of the total number LP exhaust openings and auxiliary turbine openings.

The intersection of this column and row results in a venting capacity of 25 SCFM.

9.5.3 Steam Dump (Bypass) Application –

When sustained steam dump operation is required, venting equipment must also be suitable to handle the design quantities of non-condensables saturated at a temperature 7.5°F below that corresponding to the saturation steam pressures at the highest condensing pressure likely to occur with full steam dump load with all or a partial number of fans operating at the maximum inlet air dry bulb temperature.

9.6 Rapid Evacuation (Hogging) Equipment

When starting the steam turbine, it is desirable to reduce the ACC pressure from atmospheric to some lower value. This can be done by means of single stage ejector or mechanical vacuum pump. The capacity of the device is dependent on the effectiveness of the turbine gland seals, the volume of the ACC, turbine casings, and associated ducting, as

well as the time desired for such reduction. Where specific values are not listed, the industry standard has been established at 10"HgA (0.338 bara) in 30 minutes based on a fixed volume. Depending on overall plant design, bypass steam flow rates may require modulation in order to prevent pressure spikes that may burst rupture discs. Therefore, lower evacuation pressures or longer evacuation periods may be desired.

Table 5
ONE LP EXHAUST CASING

Effective Steam Flow <i>Each</i> Main Exhaust Opening, lbs/hr		Total Number of Exhaust Openings							
		1	2	3	4	5	6	7	8
Up to 25,000	*SCFM	3.0	4.0	5.0	5.0	7.5	7.5	7.5	10.0
	Dry Air, lbs/hr	13.5	18.0	22.5	22.5	33.8	33.8	33.8	45.0
	Water Vapor, lbs/hr	29.7	39.6	49.5	49.5	74.3	74.3	74.3	99.0
	Total Mixture, lbs/hr	43.2	57.6	72.0	72.0	108.0	108.0	108.0	144.0
25,001 to 50,000	*SCFM	4.0	5.0	7.5	7.5	10.0	10.0	10.0	12.5
	Dry Air, lbs/hr	18.0	22.5	33.8	33.8	45.0	45.0	45.0	56.3
	Water Vapor, lbs/hr	39.6	49.5	74.3	74.3	99.0	99.0	99.0	123.8
	Total Mixture, lbs/hr	57.6	72.0	108.0	108.0	144.0	144.0	144.0	180.0
50,001 to 100,000	*SCFM	5.0	7.5	10.0	10.0	12.5	12.5	15.0	17.5
	Dry Air, lbs/hr	22.5	33.8	45.0	45.0	56.3	56.3	67.5	78.8
	Water Vapor, lbs/hr	49.5	74.3	99.0	99.0	123.8	123.8	148.5	173.3
	Total Mixture, lbs/hr	72.0	108.0	144.0	144.0	180.0	180.0	216.0	252.0
100,001 to 250,000	*SCFM	7.5	12.5	12.5	15.0	17.5	20.0	20.0	25.0
	Dry Air, lbs/hr	33.8	56.3	56.3	67.5	78.8	90.0	90.0	112.5
	Water Vapor, lbs/hr	74.3	123.8	123.8	148.5	173.3	198.0	198.0	247.5
	Total Mixture, lbs/hr	108.0	180.0	180.0	216.0	252.0	288.0	288.0	360.0
250,001 to 500,000	*SCFM	10.0	15.0	17.5	20.0	25.0	25.0	30.0	30.0
	Dry Air, lbs/hr	45.0	67.5	78.8	90.0	112.5	112.5	135.0	135.0
	Water Vapor, lbs/hr	99.0	148.5	173.3	198.0	247.5	247.5	297.0	297.0
	Total Mixture, lbs/hr	144.0	216.0	252.0	288.0	360.0	360.0	432.0	432.0
500,001 to 750,000	*SCFM	12.5	20.0	20.0	25.0	30.0	30.0	35.0	40.0
	Dry Air, lbs/hr	56.3	90.0	90.0	112.5	135.0	135.0	157.5	180.0
	Water Vapor, lbs/hr	123.8	198.0	198.0	247.5	297.0	297.0	346.5	396.0
	Total Mixture, lbs/hr	180.0	288.0	288.0	360.0	432.0	432.0	504.0	576.0
750,001 to 1,000,000	*SCFM	15.0	22.5	22.5	27.5	32.5	35	40.0	45.0
	Dry Air, lbs/hr	67.5	101.3	101.3	123.8	146.3	157.5	180.0	202.5
	Water Vapor, lbs/hr	148.5	222.8	222.8	272.3	321.8	346.5	396.0	445.5
	Total Mixture, lbs/hr	216.0	324.0	324.0	396.0	468.0	504.0	576.0	648.0
1,000,001 to 1,250,000	*SCFM	17.5	25.0	27.5	32.5	37.5	40.0	45.0	50.0
	Dry Air, lbs/hr	78.8	112.5	123.8	146.3	162.5	180.0	202.5	225.0
	Water Vapor, lbs/hr	173.3	247.5	272.3	321.8	357.5	396.0	445.5	495.0
	Total Mixture, lbs/hr	252.0	360.0	396.0	468.0	520.0	576.0	648.0	720.0
1,250,001 to 1,500,000	*SCFM	20.0	27.5	30.0	35.0	40.0	45.0	45.0	50.0
	Dry Air, lbs/hr	90.0	123.8	135.0	157.5	180.0	202.5	202.5	225.0
	Water Vapor, lbs/hr	198.0	272.3	297.0	346.5	396.0	445.5	445.5	495.0
	Total Mixture, lbs/hr	288.0	396.0	432.0	504.0	576.0	648.0	648.0	720.0

Effective Steam Flow <i>Each</i> Main Exhaust Opening, lbs/hr	Total Number of Exhaust Openings							
1,500,001 to 2,000,000 *SCFM	22.5	30.0	35.0	37.5	45.0	50.0	50.0	55.0
Dry Air, lbs/hr	101.3	135.0	157.5	162.5	202.5	225.0	225.0	247.5
Water Vapor, lbs/hr	222.8	297.0	346.5	357.5	445.5	495.0	495.0	544.5
Total Mixture, lbs/hr	324.0	432.0	504.0	520.0	648.0	720.0	720.0	792.0
2,000,001 to 2,500,000 *SCFM	25.0	32.5	37.5	40.0	50.0	55.0	55.0	60.0
Dry Air, lbs/hr	112.5	146.3	162.5	180.0	225.0	247.5	247.5	270.0
Water Vapor, lbs/hr	247.5	321.8	357.5	396.0	495.0	544.5	544.5	594.0
Total Mixture, lbs/hr	360.0	468.0	520.0	576.0	720.0	792.0	792.0	864.0
2,500,001 to 3,000,000 *SCFM	27.5	35.0	40.0	45.0	50.0	55.0	60.0	65.0
Dry Air, lbs/hr	123.8	157.5	180.0	202.5	225.0	247.5	270.0	292.5
Water Vapor, lbs/hr	272.3	346.5	396.0	445.5	495.0	544.5	594.0	643.5
Total Mixture, lbs/hr	396.0	504.0	576.0	648.0	720.0	792.0	864.0	936.0
3,000,001 to 3,500,000 *SCFM	30.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0
Dry Air, lbs/hr	135.0	180.0	202.5	225.0	247.5	270.0	292.5	315.0
Water Vapor, lbs/hr	297.0	396.0	445.5	495.0	544.5	594.0	643.5	693.0
Total Mixture, lbs/hr	432.0	576.0	648.0	720.0	792.0	864.0	936.0	1008.0
3,500,001 to 4,000,000 *SCFM	32.5	45.0	50.0	55.0	60.0	65.0	70.0	75.0
Dry Air, lbs/hr	146.3	202.5	225.0	247.5	270.0	292.5	315.0	337.5
Water Vapor, lbs/hr	321.8	445.5	495.0	544.5	594.0	643.5	693.0	742.5
Total Mixture, lbs/hr	468.0	648.0	720.0	792.0	864.0	936.0	1008.0	1080.0

*14.7 psia at 70°F

Note: These tables are based on air leakage only and the air vapor mixture at 1 inch HgA and 71.5°F

Table 6
TWO LP EXHAUST CASINGS

Effective Steam Flow <i>Each</i> Main Exhaust Opening, lbs/hr	Total Number of Exhaust Openings						
	2	3	4	5	6	7	8
100,001 to 250,000 *SCFM	15.0	20.0	20.0	22.5	25.0	27.5	30.0
Dry Air, lbs/hr	67.5	90.0	90.0	101.3	112.5	123.8	135.0
Water Vapor, lbs/hr	148.5	198.0	198.0	222.8	247.5	272.3	297.0
Total Mixture, lbs/hr	216.0	288.0	288.0	324.0	360.0	396.0	432.0
250,001 to 500,000 *SCFM	20.0	22.5	25.0	30.0	32.5	37.5	40.0
Dry Air, lbs/hr	90.0	101.3	112.5	135.0	146.3	162.5	180.0
Water Vapor, lbs/hr	198.0	222.8	247.5	297.0	321.8	357.5	396.0
Total Mixture, lbs/hr	288.0	324.0	360.0	432.0	468.0	520.0	576.0
500,001 to 750,000 *SCFM	25.0	27.5	32.5	37.5	40.0	45.0	50.0
Dry Air, lbs/hr	112.5	123.8	146.3	162.5	180.0	202.5	225.0
Water Vapor, lbs/hr	247.5	272.3	321.8	357.5	396.0	445.5	495.0
Total Mixture, lbs/hr	360.0	396.0	468.0	520.0	576.0	648.0	720.0
750,001 to 1,000,000 *SCFM	27.5	30.0	35.0	40.0	45.0	50.0	55.0
Dry Air, lbs/hr	123.8	135.0	157.5	180.0	202.5	225.0	247.5
Water Vapor, lbs/hr	272.3	297.0	346.5	396.0	445.5	495.0	544.5
Total Mixture, lbs/hr	396.0	432.0	504.0	576.0	648.0	720.0	792.0
1,000,001 to 1,250,000 *SCFM	32.5	35.0	40.0	45.0	50.0	55.0	60.0
Dry Air, lbs/hr	146.3	157.5	180.0	202.5	225.0	247.5	270.0
Water Vapor, lbs/hr	321.8	346.5	396.0	445.5	495.0	544.5	594.0
Total Mixture, lbs/hr	468.0	504.0	576.0	648.0	720.0	792.0	864.0
1,250,001 to 1,500,000 *SCFM	35.0	37.5	45.0	50.0	55.0	60.0	65.0
Dry Air, lbs/hr	157.5	162.5	202.5	225.0	247.5	270.0	292.5
Water Vapor, lbs/hr	346.5	357.5	445.5	495.0	544.5	594.0	643.5
Total Mixture, lbs/hr	504.0	520.0	648.0	720.0	792.0	864.0	936.0
1,500,001 to 2,000,000 *SCFM	37.5	40.0	50.0	55.0	60.0	65.0	70.0
Dry Air, lbs/hr	162.5	180.0	225.0	247.5	270.0	292.5	315.0
Water Vapor, lbs/hr	357.5	396.0	495.0	544.5	594.0	643.5	693.0
Total Mixture, lbs/hr	520.0	576.0	720.0	792.0	864.0	936.0	1008.0
2,000,001 to 2,500,000 *SCFM	40.0	45.0	55.0	60.0	65.0	70.0	75.0
Dry Air, lbs/hr	180.0	202.5	247.5	270.0	292.5	315.0	337.5
Water Vapor, lbs/hr	396.0	445.5	544.5	594.0	643.5	693.0	742.5
Total Mixture, lbs/hr	576.0	648.0	792.0	864.0	936.0	1008.0	1080.0
2,500,001 to 3,000,000 *SCFM	45.0	50.0	55.0	65.0	70.0	75.0	80.0
Dry Air, lbs/hr	202.5	225.0	247.5	292.5	315.0	337.5	360.0
Water Vapor, lbs/hr	445.5	495.0	544.5	643.5	693.0	742.5	792.0
Total Mixture, lbs/hr	648.0	720.0	792.0	936.0	1008.0	1080.0	1152.0
3,000,001 to 3,500,000 *SCFM	50.0	55.0	60.0	70.0	75.0	80.0	85.0
Dry Air, lbs/hr	225.0	247.5	270.0	315.0	337.5	360.0	382.5
Water Vapor, lbs/hr	495.0	544.5	594.0	693.0	742.5	792.0	841.5
Total Mixture, lbs/hr	720.0	792.0	864.0	1008.0	1080.0	1152.0	1224.0
3,500,001 to 4,000,000 *SCFM	55.0	60.0	65.0	70.0	80.0	85.0	90.0
Dry Air, lbs/hr	247.5	270.0	292.5	315.0	360.0	382.5	405.0
Water Vapor, lbs/hr	544.5	594.0	643.5	693.0	792.0	841.5	891.0
Total Mixture, lbs/hr	792.0	864.0	936.0	1008.0	1152.0	1224.0	1296.0

*14.7 psia at 70°F

Note: These tables are based on air leakage only and the air vapor mixture at 1 inch HgA and 71.5°F

Table 7
THREE LP EXHAUST CASINGS

Effective Steam Flow <i>Each</i> Main Exhaust Opening, lbs/hr	Total Number of Exhaust Openings					
	3	4	5	6	7	8
250,001 to 500,000 *SCFM	30.0	32.5	37.5	40.0	45.0	50.0
Dry Air, lbs/hr	135.0	146.3	162.5	180.0	202.5	225.0
Water Vapor, lbs/hr	297.0	321.8	357.5	396.0	445.5	495.0
Total Mixture, lbs/hr	432.0	468.0	520.0	576.0	648.0	720.0
500,001 to 750,000 *SCFM	32.5	37.5	45.0	50.0	55.0	60.0
Dry Air, lbs/hr	146.3	162.5	202.5	225.0	247.5	270.0
Water Vapor, lbs/hr	321.8	357.5	445.5	495.0	544.5	594.0
Total Mixture, lbs/hr	468.0	520.0	648.0	720.0	792.0	864.0
750,001 to 1,000,000 *SCFM	37.5	45.0	50.0	55.0	65.0	70.0
Dry Air, lbs/hr	162.5	202.5	225.0	247.5	292.5	315.0
Water Vapor, lbs/hr	357.5	445.5	495.0	544.5	643.5	693.0
Total Mixture, lbs/hr	520.0	648.0	720.0	792.0	936.0	1008.0
1,000,001 to 1,250,000 *SCFM	40.0	50.0	55.0	65.0	70.0	75.0
Dry Air, lbs/hr	180.0	225.0	247.5	292.5	315.0	337.5
Water Vapor, lbs/hr	396.0	495.0	544.5	643.5	693.0	742.5
Total Mixture, lbs/hr	576.0	720.0	792.0	936.0	1008.0	1080.0
1,250,001 to 1,500,000 *SCFM	45.0	55.0	60.0	70.0	75.0	80.0
Dry Air, lbs/hr	202.5	247.5	270.0	315.0	337.5	360.0
Water Vapor, lbs/hr	445.5	544.5	594.0	693.0	742.5	792.0
Total Mixture, lbs/hr	648.0	792.0	864.0	1008.0	1080.0	1152.0
1,500,001 to 2,000,000 *SCFM	50.0	60.0	65.0	75.0	80.0	90.0
Dry Air, lbs/hr	225.0	270.0	292.5	337.5	360.0	405.0
Water Vapor, lbs/hr	495.0	594.0	643.5	742.5	792.0	891.0
Total Mixture, lbs/hr	720.0	864.0	936.0	1080.0	1152.0	1296.0
2,000,001 to 2,500,000 *SCFM	55.0	65.0	70.0	80.0	85.0	95.0
Dry Air, lbs/hr	247.5	292.5	315.0	360.0	382.5	427.5
Water Vapor, lbs/hr	544.5	643.5	693.0	792.0	841.5	940.5
Total Mixture, lbs/hr	792.0	936.0	1008.0	1152.0	1224.0	1368.0
2,500,001 to 3,000,000 *SCFM	60.0	70.0	75.0	85.0	90.0	100.0
Dry Air, lbs/hr	270.0	315.0	337.5	382.5	405.0	450.0
Water Vapor, lbs/hr	594.0	693.0	742.5	841.5	891.0	990.0
Total Mixture, lbs/hr	864.0	1008.0	1080.0	1224.0	1296.0	1440.0
3,000,001 to 3,500,000 *SCFM	65.0	75.0	80.0	90.0	95.0	105.0
Dry Air, lbs/hr	292.5	337.5	360.0	405.0	427.5	472.5
Water Vapor, lbs/hr	643.5	742.5	792.0	891.0	940.5	1039.5
Total Mixture, lbs/hr	936.0	1080.0	1152.0	1296.0	1368.0	1512.0
3,500,001 to 4,000,000 *SCFM	70.0	80.0	85.0	95.0	100.0	110.0
Dry Air, lbs/hr	315.0	360.0	382.5	427.5	450.0	495.0
Water Vapor, lbs/hr	693.0	792.0	841.5	940.5	990.0	1089.0
Total Mixture, lbs/hr	1008.0	1152.0	1224.0	1368.0	1440.0	1584.0

*14.7 psia at 70°F

Note: These tables are based on air leakage only and the air vapor mixture at 1 inch HgA and 71.5°F

10.0 ATMOSPHERIC RELIEF DEVICES

10.1 General

10.1.1 The size of atmospheric relief devices is dependent upon the specified operating conditions. It is understood that they must be of sufficient size to pass all of the steam, which can be admitted to the ACC, except from the lines that are already protected by relief devices set to open at pressures not exceeding the ACC relief pressure. Typically, the maximum steam flow rate is defined by a steam turbine bypass condition.

10.1.2 The size and location of atmospheric relief devices should be based on the following criteria:

- Relief device size and associated piping should be selected to prevent pressure in ACC from exceeding the ACC design pressure.
- Relief devices should be located and installed so they are accessible for inspection and repair. The protective devices need not be directly installed on the ACC but may be installed on the steam turbine exhaust hood, provided they are properly sized.
- Exhaust from all relief devices must be properly vented by the purchaser to avoid injury to personnel or damage to equipment.

10.2 Vacuum Breaker Valves

10.2.1 Valves shall be designed for full vacuum service. A water seal may be required of ample depth around the valve disc to ensure proper sealing of the seat with provision for adequate fill and drainage.

10.2.2 The following table represents the suggested vacuum breaker sizes for ACCs. This methodology considers breaking full vacuum to atmospheric pressure (0.0 bara to 1.013 bara) in six minutes. Purchaser shall confirm scope and sizing criteria.

Table 8
VACUUM BREAKER SIZE FOR ACCS

Total Steam-Side Volume, ft ³	Vacuum Breaker Size, in
0 to 10,000	4
10,000 to 23,000	6
23,000 to 39,000	8
39,000 to 62,000	10
62,000 to 88,000	12
88,000 to 108,000	14
108,000 to 145,000	16

If the system volume exceeds 145,000 ft³, then multiple devices of the same size should be used.

10.3 Rupture Device

10.3.1 A rupture disc is a non-reclosing pressure relief diaphragm actuated by static pressure differential and designed to function by the bursting of a pressure-containing non-fragmenting disc.

10.3.2 Every rupture disc shall have its burst pressure tagged in accordance with the design requirements. The selected burst pressure shall take into account manufacturing tolerances. Under no circumstances shall the burst pressure plus all associated tolerances exceed the ACC design pressure.

10.3.3 The total installed rupture disc capacity shall be sufficient to relieve the maximum ACC steam flow at or below the ACC design pressure.

10.3.4 The following equation may be used to estimate the size of the rupture disc based on dry and saturated steam:

$$A_D = \frac{70W_s}{K_4 P_A 3600}$$

Where,

A_D = Minimum required flow area, in²

W_s = Discharge flow rate, lb/hr

K_4 = Flow coefficient, use value of 0.62

P_A = Relieving pressure, psia

10.3.5 If the required rupture disc diameter exceeds 30", then multiple rupture discs of equal size shall be utilized.

10.3.6 Rupture discs are usually located on the ACC main duct or distribution header. Location for ease of replacement as well as personnel protection and the avoidance of accidental disc damage should be considered.

10.3.7 Rupture discs shall be designed to operate satisfactorily and without leakage under full vacuum.

11.0 INSPECTION, QUALITY AND FIELD INSTALLATION

11.1 Leakage Testing

11.1.1 A pneumatic leak test is performed to verify the leak tightness of the fin tube bundles, steam distribution headers, and miscellaneous piping. Typically, testing of the main steam duct is optional for multi-row ACCs. When the main steam duct is tested, the main steam duct and the tube bundle drain nozzles must be blanked; an engineered blanking plate must be used to blank the main steam duct. If the main steam duct is also tested, the duct blanking plate is installed as close as possible to the steam turbine exhaust interface.

11.1.2 An air compressor is used to put the system under pressure; a typical testing pressure is 4.35 psig (0.3 barg). The acceptance criterion for the pressure test is to limit the air leakage expressed in lb/hr (kg/hr) to 25 % of the holding capacity of the air-removal system associated with the tested section. The pressure and the temperature of the air inside the ACC should be monitored on an hourly basis. The duration of the test should be up to 24 hours or as required to demonstrate leak tightness.

11.1.3 A temporary pressure-relief device should be installed to prevent over-pressurization of the ACC. The capacity of the relief device shall be at least equal to the capacity of the compressor utilized for the pressure test. During the pressure test, it is recommended to blank off the rupture disc to prevent accidental activation.

11.1.4 ACC structures are not designed to withstand the loads associated with a hydrostatic test after installation. Therefore, hydrostatic testing shall not be performed.

11.2 Inspection and Quality of Welding

This section establishes minimum standards for visual inspection of ACC welds performed in the shop and field. The visual acceptance criteria are developed using recognized codes and standards such as ASME codes, ANSI standards, AWWA, and AWS as a guide. More stringent requirements may be specified by the purchaser and will take precedence.

11.2.1 Supplemental non-destructive examination (i.e., dye-penetrant, magnetic particle testing, radiography, etc.) is typically not required.

11.2.2 The welding shall be performed using welders and written weld procedures, which have been qualified in a manner comparable to that defined in Section IX of the ASME Unfired Pressure Vessel Code.

11.2.3 All welds shall be examined in the "as welded" condition preceded only by normal cleaning.

11.2.4 Weld inspection methods and equipment

- Personnel performing visual inspections shall be qualified to eye examinations in accordance with ASME or AWS.
- All measuring equipment shall be maintained and calibrated in accordance with the manufacturer's approved quality control manuals and procedures.

11.2.5 Weld Categories – The following categories are established considering the service requirements of specific types of welds. These criteria apply to shop welds and to field welds in the apparatus except for pipe welds made to connection stubs.

- Category I includes pressure boundary welds: Those welds which provide a separation of atmospheric pressure and ACC internal pressure.
- Category II includes structural welds: Those welds which are associated with the primary support structure of the ACC, platforms, stairways, ducting, vessels and piping.
- Category III includes all other welds: Those welds associated with dirt collars, vortex breakers, internal shielding, lagging, personnel grating, ladder rungs, grab bars, instrument/ accessory support, temporary erection and shipping members, nameplates/brackets, etc.

11.2.6 Acceptance levels – Acceptance levels for various types of welds in Categories I, II, and III are to be identified by the equipment supplier with ASME used as a guide for Category I and AWS for Category II.

11.3 Surface Preparation Requirements

11.3.1 General requirements – Surfaces shall be prepared by the manufacturer to assure that the equipment will be acceptable from the following aspects:

11.3.1.1 Surfaces to be coated (painted or galvanized) will be suitably free from deleterious materials that may affect the adhesion of the coatings.

11.3.1.2 In any case, the surface preparation shall meet the requirements of the coating system to be utilized.

11.3.1.3 Loose scale, weld spatter, or other materials shall be removed by suitable methods.

11.3.1.4 Surfaces will have a workmanlike appearance and freedom from scars and protrusions that could cause bodily injury.

11.3.1.5 The preparations required by this section may be performed at any time in the manufacturing cycle. Rust that develops during manufacture shall be removed prior to painting if it would be detrimental to the paint application. Rust on non-painted

surfaces need not be removed. Pre-cleaned material such as pre-blasted plates may be painted prior to fabrication. All accessible paint scars and blemishes shall be retouched prior to shipment. It must be recognized that some touch-up will be required after unloading or installation.

11.3.2 General Requirements

11.3.2.1 Table 9 contains the recommended acceptable preparations for various areas and components of the ACC. Each area is evaluated on the basis of preparation required for coatings as well as the ultimate destination of the contained fluids and any particles that may be carried with the flow.

11.3.2.2 The requirements as written apply to the preparation of components and assemblies as built in the manufacturer's facilities. Final assembly of the apparatus by the erection contractor should meet the applicable sections of Table 9.

11.3.2.3 The purchaser should assure that parts of the components supplied by other than the condenser manufacturer, but which are connected to or installed in the condenser, are prepared in similar fashion.

Table 9
RECOMMENDED ACCEPTABLE PREPARATIONS OF COMPONENTS
AND ASSEMBLIES BUILT IN MANUFACTURER'S FACILITIES

Characteristic	Bundles	Ducting	Tanks	Piping	Auxiliary Equipment
Weld Surfaces	Per Manufacturer's standard	Per the applicable welding procedure			Per Manufacturer's standard
General Surface Condition	Per Manufacturer's standard	Internal surface per SSPC-SP2 or better External surface per SSPC-SP6			Per Manufacturer's standard
Indentations	Minor tube indentations and fin deformation is acceptable. Tube indentions should not compromise the pressure boundary	Depth to be the smaller of 0.2*thickness or 1/8" (3mm)			Per Manufacturer's standard
Residual Weld Metal and Protrusions	Per Manufacturer's standard	Max. height = 1/8" (3mm); Dress as necessary to assure good paint coverage			Per Manufacturer's standard
Arc Strikes	Remove all Arc Strikes				
Weld Spatter	Remove spatter per SSPC-SP2 or better				Per Manufacturer's standard
Mill Scale	Remove spatter per SSPC-SP2 or better				Per Manufacturer's standard
General Condition of Components or Sub-Assemblies	Loose dirt, particles, excessive rust, oils, and general contaminants shall be removed by brushing, air blowing, and/or water to produce a workmanlike appearance. (per SSPC-2)				

11.3.3 Special Requirements – The requirements of this section represent good practices recommended by the ACC manufacturer, the paint/coating manufacturers, applicators and, in general, meet the intent of specifications by engineering firms, owners, and purchasers of this equipment. However, there may be exceptions requiring special preparation. There are two basic groups of special requirements.

11.3.3.1 Purchaser-specified requirements – If the purchaser or his agent desire any preparation more stringent (i.e., abrasive blasting) than this Standard, it must be clearly stated in the procurement documents.

11.3.3.2 Manufacturer-specified requirements – The manufacturer may at any time prepare the equipment in a manner superior to the requirements of Table 9. This improvement is discretionary and could be done to suit the manufacturer's economic evaluation and/or his processing equipment and schedules. As a minimum, the manufacturer is required to provide preparation as dictated by the requirements of the painting or coating process.

11.4 Painting, Coating and Corrosion Protection

11.4.1 External surfaces of carbon steel ACC components (steel structure, ducting, piping and vessels) are to be cleaned and either hot dip galvanized or painted with one coat of primer. Touch-up of the primer and application of the finish paint are performed after final field installation by the purchaser.

11.4.2 Internal ACC surfaces do not require primer, paint, or rust inhibitors for normal shipment and storage. Oxidation of these surfaces is acceptable and is to be expected. Any internal surface preparation activities should use ferrous materials that are silica free.

11.4.3 Mechanical equipment shall be provided with the manufacturer's standard factory finish.

11.4.4 These Standards do not cover the application of any coatings. All such applications shall be done to the requirements of the applicable process.

11.5 Quality Assurance

The manufacturer shall have a Quality Assurance program for ACCs. This program shall be outlined in a Quality Assurance manual, which will be available to the purchaser and his representatives upon request. The system shall provide for control of quality in both the manufacturer's plant and that of any subcontractor fabricating parts. Field Quality Assurance is the responsibility of the purchaser and/or installing contractor. The party responsible for the field installation should have a quality assurance program comparable to that of the ACC manufacturer. Review of this quality assurance program shall be the responsibility of the purchaser.

The Quality Assurance program shall provide for assurance of compliance with, but not limited to, the manufacturer's and HEI Standards, which provide as a minimum:

- Project controls (i.e., engineer, procurement, installation)
- Material controls
- Fabrication controls
- Quality control
- Document control
- System for audit of control of procedures

11.6 Erection Advisor Duties

The manufacturer may provide the services of an erection advisor to counsel the purchaser in the proper installation of the ACC and accessories in accordance with the erection drawings and installation procedures.

In the event of any conflict between the manufacturer's requirements and site practice, the erection advisor will bring such conflicts to the attention of the purchaser's designated representative.

The erection advisor shall not be responsible for the following:

- The supervision of the erection crew
- Fit-up and weld quality
- Lifting and rigging plans
- The health and safety of the erection crew
- The schedule of erection and work progress

11.7 Erection Cleanliness

11.7.1 Due to the relatively large internal volume and confined spaces within an ACC, it is important that the erection contractor exercises a heightened level of housekeeping effort. As ACC row sections are completed,

the erection contractor shall inspect the upper steam headers and remove all construction debris (i.e., tools, weld rods, slag, tool boxes, lights, etc.) so that it does not enter the fin tubes or other areas.

11.7.2 The erection contractor shall sequence the installation of the ACC to provide opportunities to remove any debris prior to closure. A practical approach to clean the interior of the ACC from the top to the bottom shall be followed. In particular, the condensate headers shall remain open for cleanout until the steam headers are completely installed and cleaned.

11.7.3 Other ACC components (steam ducting, drain pot, condensate tank, and piping systems) shall be cleared of debris and broom cleaned as each component is installed or prior to final closure.

11.7.4 Appropriate cleanouts or means of collecting debris within the condensate drain system shall be provided for during the hot commissioning phase by the commissioning contractor. It is very common to have surface rust form on the internal surfaces of the carbon steel materials (i.e., ducting, piping, tubes, etc.).

This is not detrimental to the performance of the ACC and is removed during the hot commissioning phase.

11.7.5 External debris and construction materials must be removed from all surfaces of the ACC prior to the start of the cold commissioning process. This includes but is not limited to the following:

- Heat transfer surfaces
- Walkways and platforms
- Mechanical equipment (fans, motors, etc.)
- Fan guards and cable trays

11.8 Post-Erection Walkdown

Upon completion of the erection activities, it is recommended that a representative from the ACC manufacturer and the purchaser (or purchaser's agent) perform a post-erection walkdown. The following activities shall be performed:

- Visually inspect all installed ACC components
- Review inspection and testing records associated with the erection activities
- Review and modify punch list items as required

12.0 COMMISSIONING

12.1 Cold Commissioning

Typical cold commissioning or "dry run" activities are completed after construction. Normal prerequisites include that the field pressure test is complete and successful, punch list items are satisfied, all electrical and instrumentation connections are completed, and power is available to fan motors and other electrical components.

12.1.1 Typical pre-start inspections include but are not limited to the following:

12.1.1.1 Confirm that the erection cleanliness requirements as described in section 11.7 are met.

12.1.1.2 Confirm that pre-operational checks of all mechanical equipment have been performed in accordance with the ACC manufacturer's O&M manual, which include but may not be limited to:

- Confirm gearbox oil type and level
- Install gearbox breathers

- Verify proper lubrication of all rotating equipment
- Calibrate instruments and perform functional check
- Megger all motors
- Remove blanking plate(s) and install rupture disk(s)
- Remove shipping braces from all expansion joints

12.1.1.3 Proceed with the cold commission activities per the ACC manufacturer's O&M manual, which include but may not be limited to:

- Bump motors and check fan
- Perform fan run test and adjust vibration switches and gearbox flow/pressure switches, as necessary
- Adjust fan blade pitch as necessary
- Note any unusual vibrations (record if necessary) and noises from rotating equipment

- Test valve function (stroke valve and set or adjust limit switches as necessary)
- Perform vacuum equipment functional test
- Commissioning of ACC Electrical System
- Commissioning of ACC Instrumentation and Control systems
- Heat Tracing Functional Check
- Grounding System Functional Check

12.2 Hot Commissioning

12.2.1 Hot commissioning activities can commence once steam becomes available. It is recommended that all cold commissioning activities be successfully completed.

12.2.2 The ACC manufacturer's O&M Manual shall be used in conjunction with the following checklist for reference.

12.2.3 Commissioning activities for equipment supplied by others are not the responsibility of the ACC manufacturer. Some typical hot commissioning activities include:

- Conduct internal steam cleaning of the ACC until the purchaser's water chemistry requirements are met. The purchaser shall provide and install temporary provisions to collect, condition or dispose of the initial condensate.
- During the steam cleaning, inspect steam duct, heat exchanger, and piping movements to confirm free expansion.

Once steam cleaning has been completed, the ACC is ready for normal operation and the following hot commissioning activities should be conducted:

- Verify pressure control at DCS and tune as necessary, verify valve control.
- Verify air removal system operation.
- Verify freeze protection functions (subject to ambient temperature conditions).
- Check and record the non-condensable gas temperatures, condensate temperatures and fin tube bundle temperatures.
- Perform a vacuum decay test of the system and check for ACC system leaks, as necessary.

12.3 Duties of Commissioning Advisor

12.3.1 The manufacturer may provide the services of a commissioning advisor to counsel the purchaser in the proper commissioning and initial operation of the ACC and accessories in accordance with the ACC manufacturer's O&M manual.

12.3.2 In the event of any conflict between the manufacturer's requirements and site practice, the commissioning advisor will bring such conflicts to the attention of the purchaser's designated representative.

12.3.3 The commissioning advisor shall not be responsible for the following:

- The supervision of the commissioning crew or plant operators.
- Installation or removal of temporary components required during the cold or hot commissioning.
- The schedule of commissioning and work progress.

APPENDIX A

HEI AIR COOLED STEAM CONDENSER DATASHEET - IMPERIAL UNITS

1	Manufacturer:		
2	Customer / Project Name:		
3	Location:		
4	Customer Ref:	Date:	
5	Manufacturer Ref:	Revision:	
Design Conditions (Thermal)			
6	Steam-side		Air-side
7	Steam flow rate:	lb/hr	Total air mass flow: lb/s
8	Non-condensable flow rate:	lb/hr	Temperature in / out: F
9	Turbine exhaust pressure:	"Hg(A)	Bundle face velocity: ft/s
10	Inlet enthalpy:	Btu/lb	Fan static pressure: "H ₂ O
11	Steam quality:		Airflow per fan: cfm
12	Temperature in / out:	F	Total motor input power: kW
13			Barometric pressure: psi(a)
Heat Transfer Data			
15	Heat transfer rate:	Btu/hr ft ² F	Extended surface: ft ²
16	Heat duty:	MMBtu/hr	LMTD: F
17	Bundle face area:	ft ²	Bare tube surface: ft ²
Bundle Design Data			
19	Design pressure:	psi(g)	Design temperature: F
20	Test pressure:	psi(g)	
Construction (Mechanical)			
21	Plot area, W x L:	ft x ft	Number of tube rows:
22	Overall height:	ft	first stage tube length: ft
23	Cell arrangement:	rows x (cells/row)	second stage tube length: ft
24	Number of cells:	1 st / 2 nd stage	Tube dimensions: in x in
25	Cell size, W x L:	ft x ft	Tube pitch: in
26	Main duct length:	ft	Tube wall thickness: in
27	Main duct diameter:	in	Tube material:
28	Duct corrosion allowance:	in	Fin material:
29	Distribution header diameter:	in	Fin dimensions: in x in
30	Bundles per cell:		Fin thickness / fpi: in / -
31	Tubes per bundle:		
Fans			
33	Fans per cell:		Diameter: ft
34	Speed:	RPM	Number of blades:
35	Hub material:	Blade material:	
36	Fan shaft power:	hp	SPL @ 3' dBA
Motors			
38	Type:		Number per cell:
39	Speed:	RPM	Enclosure type:
40	Motor rating:	hp	Volts / Phase / Cycle:
Speed Reducers			
42	Type:		Number per cell:
43	Reduction ratio:		AGMA service factor:
Condensate Tank			
45	Wall thickness:	in	Volume: gal
46	Normal level:	in	Normal level capacity: ft ³
47	Max level:	in	Max level capacity: ft ³
48	Dimensions (diameter x length):	ft	Corrosion allowance: in
Miscellaneous Equipment			
50	Vacuum system type:		Holding steam use: lb/hr
51	Holding capacity:	SCFM	Hogging steam use: lb/hr
52	Hog time to 10" HgA:	min	Turbine expansion joint type:
53	Motive steam pressure / T:	psi(g) / F	
Weights			
55	Empty weight:	lbs	Operating weight: lbs
56	Notes:		

APPENDIX A

HEI AIR COOLED STEAM CONDENSER DATASHEET – METRIC UNITS

1	Manufacturer:		
2	Customer / Project Name:		
3	Location:		
4	Customer Ref:	Date:	
5	Manufacturer Ref:	Revision:	
Design Conditions (Thermal)			
6	Steam-side		Air-side
7	Steam flow rate:	T/hr	Total air mass flow: kg/s
8	Non-condensable flow rate:	T/hr	Temperature in / out: C
9	Turbine exhaust pressure:	bar(A)	Bundle face velocity: m/s
10	Inlet enthalpy:	kJ/kg	Fan static pressure: Pa
11	Steam quality:		Airflow per fan: m³/s
12	Temperature in / out:	C	Total motor input power: kW
13			Barometric pressure: bar(a)
14	Heat Transfer Data		
15	Heat transfer rate:	W/m² C	Extended surface: m²
16	Heat duty:	MW	LMTD: C
17	Bundle face area:	M²	Bare tube surface: m²
18	Bundle Design Data		
19	Design pressure:	bar(g)	Design temperature: C
20	Test pressure:	bar(g)	
Construction (Mechanical)			
21	Plot area, W x L:	m x m	Number of tube rows:
22	Overall height:	m	first stage tube length: m
23	Cell arrangement:	rows x (cells/row)	second stage tube length: m
24	Number of cells:	1 st / 2 nd stage	Tube dimensions: mm x mm
25	Cell size, W x L:	m x m	Tube pitch: mm
26	Main duct length:	m	Tube wall thickness: mm
27	Main duct diameter:	mm	Tube material:
28	Duct corrosion allowance:	mm	Fin material:
29	Distribution header diameter:	mm	Fin dimensions: mm x mm
30	Bundles per cell:		Fin thickness / fpm: mm/ -
31	Tubes per bundle:		
32	Fans		
33	Fans per cell:		Diameter: m
34	Speed:	RPM	Number of blades:
35	Hub material:		Blade material:
36	Fan shaft power:	kW	SPL @ 1 m dBA
37	Motors		
38	Type:		Number per cell:
39	Speed:	RPM	Enclosure type:
40	Motor rating:	kW	Volts / Phase / Cycle:
41	Speed Reducers		
42	Type:		Number per cell:
43	Reduction ratio:		AGMA service factor:
44	Condensate Tank		
45	Wall thickness:	mm	Volume: m³
46	Normal level:	mm	Normal level capacity: m³
47	Max level:	mm	Max level capacity: m³
48	Dimensions (diameter x length):	m	Corrosion allowance: mm
49	Miscellaneous Equipment		
50	Vacuum system type:		Holding steam use: kg/hr
51	Holding capacity:	m³/hr	Hogging steam use: kg/hr
52	Hog time to 0.34 bar(A):	min	Turbine expansion joint type:
53	Motive steam pressure / T:	bar(g) / C	
54	Weights		
55	Empty weight:	T	Operating weight: T
56	Notes:		

APPENDIX B

CONVERSION FACTORS

Area	1 m ²	= 1550.0 in ²
		= 10.7639 ft ²
Heat transfer rate	1 W	= 3.4123 Btu/h
Heat flux	1 W/m ²	= 0.3171 Btu/h·ft ²
Heat transfer coefficient	1 W/m ² ·K	= 0.17612 Btu/h·ft ² ·°F
Enthalpy	1 kJ/kg	= 0.42995 Btu/lb _m
Length	1 m	= 39.3701 in.
		= 3.2808 ft
Mass	1 kg	= 2.2046 lb _m
Mass density	1 kg/m ³	= 0.062428 lb _m /ft ³
Mass flow rate	1 kg/s	= 7936.6 lb _m /h
Pressure and stress	1 Pa	= 1.4504 x 10 ⁻⁴ lb/in. ²
		= 1.0197 x 10 ⁻⁵ ata
		= 1.0197 x 10 ⁻⁵ kg/cm ²
		= 4.015 x 10 ⁻³ in. water
		= 2.953 x 10 ⁻⁴ in. Hg
	1.0133 x 10 ⁵ Pa	= 1 standard atmosphere
	1 x 10 ⁵ Pa	= 1 bar
Specific heat	1 kJ/kg·K	= 0.23886 Btu/lb _m ·°F
Temperature	1 K	= (5/9)·°R
		= (5/9)·(°F+459.67)
		= °C+273.15
Temperature difference	1 K	= 1°C
		= (9/5)·°R = (9/5)·°F
Volume	1 m ³	= 35.314 ft ³
		= 264.17 gal
Volume flow rate	1 m ³ /s	= 2.1189 x 10 ³ ft ³ /min
		= 1.5850 x 10 ⁴ gal/min
Velocity	1 m/s	= 196.85 ft/min
Power	1 kW	= 1.341 hp
Fouling factor	1 m ² ·K/W	= 5.678 h·ft ² ·°F/Btu
Normal atmospheric pressure	101,325 Pa	

APPENDIX C

ACC TROUBLESHOOTING GUIDELINES

This troubleshooting guide has been prepared to assist operators of air cooled condensers. The guide provides general guidance, and operators are advised to consult with the manufacturer when necessary for specific instructions regarding their equipment. Many of the items listed below are not in the scope of the condenser manufacturer; however, these items do affect operation and must be considered by operators.

Symptoms	Possible Causes	Possible Solutions
Air In-Leakage	Gasket failure	Replace gasket
	Expansion joint failure	Replace or repair expansion joint
	LP Turbine	Check all LP turbine seals
	Weld failure	Locate weld failure and repair
	Tube leak	Locate and repair
	Leaks from vent or drain connections	Check all potential sources connected to vacuum space
	Instrumentation	Check all instrumentation connections to vacuum space
	Manhole or blind flange gaskets	Repair gasket seating surface
Condensate Chemistry (High Conductivity)	Corrosion products or weld slag in condenser	Check and clean condensate headers, deaerator trays and condensate tank
	Incoming drains	Check drain sources
False Instrument Reading	Instruments out of calibration	Check calibration
	Damaged instruments	Repair or replace as necessary
	Improper installation	Check manufactures recommendations including valve manifold and pigtail requirements
	Incorrect range	Check process requirements and correct as required
	Isolated instrument connection	Check connection

APPENDIX C

ACC TROUBLESHOOTING GUIDELINES

High Absolute Back pressure	Air in-leakage	See air in-leakage section
	Excessive air-side fouling	Clean external heat transfer surface
	Air blanketing within the fin tube bundles	Consult equipment operations manual on recommended purging actions
	Hot air recirculation	Consult OEM supplier for recommended solutions for plant specific arrangements
	Hot air ingestion into ACC air inlet from outside sources	Remove, shield or redirect hot air effluent away from the ACC's air inlet
	High winds	Consult OEM supplier for recommended solutions for plant specific arrangements
	Condensate holdup within ACC	Clean debris that may be obstructing condensate drainage (i.e., strainers, DA spray valves, etc.)
	Control logic set pressure too high	Reduce set pressure
	False instrument readings	See False Instrumentation Reading section
	Air-moving system failure	Consult O&M manual or OEM supplier
	Vacuum equipment failure	See HEI Vacuum Equipment Troubleshooting Guide
High Dissolved O ₂ in Condensate	Air In-Leakage	See Air In-Leakage section
	High dissolved O ₂ in process or plant drains	Check return stream sources
	Vacuum equipment failure	See HEI Vacuum Equipment Troubleshooting Guide
	Air blanketing within the fin tubes causing condensate to subcool	Consult equipment operations manual on recommended purging actions
	Low load operation	Consult HEI design standards
Local Overheating	Operating conditions exceeding design parameters	Check for proper desuperheating of drain connection
		Re-evaluate internal dispersion design
Low Hotwell Temperatures	Make up to condensate tank exceeding design parameters	Check and adjust make up flow
	Operation off design/low load operation	Expected at low load/low back pressure. Possibly alleviated with steam sparging in condensate tank
Tube failures	Frozen tubes	Replace or repair tubes and consult OEM for revised operating conditions to avoid freezing
	Tube inlet erosion	Consult OEM for repair techniques and approved methods for shielding
	Maintenance or construction damage	Repair or replace as required
High Vibration of Air-Moving System	Fan imbalance	Check fan balance in accordance with O&M manual
		Check for broken/cracked blades
		Check for ice on fan blades
	Lost fan blade	Replace according to O&M manual
	Excessive air-side fouling	Clean fin tube bundles

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