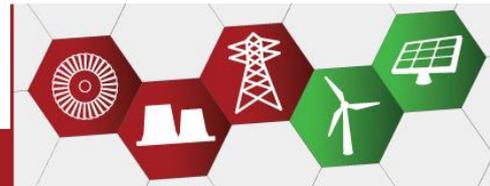




POWER-GEN
EUROPE

Conference & Exhibition
12 – 14 June 2012
KoelnMesse, Cologne, Germany



INTEGRATING THE **POWER SECTOR**

How to improve air cooler vacuum steam condensers performance in the field

By Marc Ellmer

ELFLOW BV – The Netherlands



Introduction

Air cooled vacuum steam condensers (ACC's) are used to condense exhaust steam from turbines in a closed cycle. They are mostly used in power plants (Waste Incineration Plants and Combined Cycle Plants). Axial flow fans located below heat exchanger bundles; sloped in an A-frame structure; force a stream of ambient cooling air through the system. In so doing, heat from the condensing steam is rejected to the environment via the finned tubes.

Steam flows down across the bundles. Condensates are recovered inside a manifold connected to a hot water tank. Non condensable goes up in a counter flow current through a secondary condenser part (dephlegmators) for final condensation.

The rejection capacity of an ACC is proportional to the air mass flow rate and the temperature difference between the ambient air and finned tubes. Therefore owing to the dynamic interaction between the steam turbines and the ACC, ambient conditions (e.g. dry bulb temperature, wind) and the flow rate delivered by the axial fans have a direct influence on the efficiency of such a direct air cooled power plant

Due to the fact that there is a clear dynamic interaction between the steam turbine and the ACC, a change in condensation capacity of the ACC will directly influence the efficiency of the steam turbines and hence have an important influence on electricity production.

As the design and manufacturing of ACC's has tended to be limited to a relatively select number of manufacturers mostly focussed on manufacturing and not assessing and optimizing its current performance, it is not uncommon to find new and old ACC's that do not perform to their full potential. This is also due to a lack in understanding of the end user and to a lack of cooperation of the ACC manufacturers in general.

This means there is almost always room for improvement on existing ACC's.

This technical paper aims at detailing a few practical examples of how to improve Your existing ACC in the field. Examples of ways to improve ACC performance are:

- Optimization of airflow system (higher efficiency)
- Installation of wind screens to counter negative effects of cross winds on ACC's
- Installation of fogging systems (adiabatic cooling)
- Elimination of hot air recirculation
- Leak detection of vacuum system
- Better and more efficient cleaning methods for finned tube bundles
- Other problems related to ACC performance loss

Optimization of airflow system (higher efficiency)



General rule of thumb

At 24°C; 1% more air corresponds to approximately 1 mbarA in vacuum improvement

More than 70% of the current installations are not performing optimally in terms of fan settings. This is caused by the fact that on the one hand there is a lack of practical field experience of OEM's in terms of fan optimization. Most OEM's are more focused on manufacturing the ACC than operating it. Furthermore, not a single ACC OEM has manufactured their own fans in Europe or in the USA over the last couple of years. Clearly, the latter situation does not help on acquiring expertise concerning fan behavior in the field.

This is why there is often room for improving airflow on an existing ACC by simply optimizing the fan settings or replacing it by a high efficiency fan. It has been observed that in most cases, an improvement of 10-20% increase in airflow was achieved with the same motor power resulting in improvement in electricity production for the power plant at the same steam load.



Pictures 1 & 2 - Illustration of an on-site fan setting optimization on a large ACC fan and replacement to high efficiency fan on another ACC

Installation of wind screens to counter negative effects of cross winds on ACC's



General rule of thumb

Experience has indicated that reducing the negative effects of crosswinds can reduce the turbine backpressure by as much as 15 mbarA with an average wind speed of 10 m/s

Crosswinds can result in a substantial reduction in fan performance of the upwind fans. This can result in loss in electricity production and reliability of related problems of the mechanical parts such as gearbox and fan failures. Crosswinds that hit an ACC will be deflected due the existence of a wind wall creating a jet stream under the fan (illustrated in figure 1). As the deflected winds are accelerated (due to the deflection), this creates a flow separation at the fan inlet which causes mal-distribution of airflow into the fan (vacuum under the fan illustrated in figure 2). Inlet flow distortions caused by structures (wind walls), wind and induced cross winds have an negative effect on fan performance, due to a combination of increased inlet flow losses (i.e. flow separation at the inlet section), mal-distribution of air into the fan (i.e. non uniform inlet profiles). The stronger the wind, the stronger the jet stream and in turn the more the fan starts to stall resulting in a loss of performance of the ACC and a potential risk of breaking down fans and gearboxes.

As the fan deck on large ACC's is mostly at 20-25 m in height, the wind at height is always a lot stronger than on the ground. the latter is also accentuated by the wind deflection caused by the bundles or wind walls. Therefore, it is not uncommon to see wind speeds of 12-15 m/s at the level of the fan ring whereas the ground wind speed (where the wind speed is mostly recorded) is only 3 m/s as illustrated in figure 3. This has also been registered by us during field surveys using a vane anemometer.

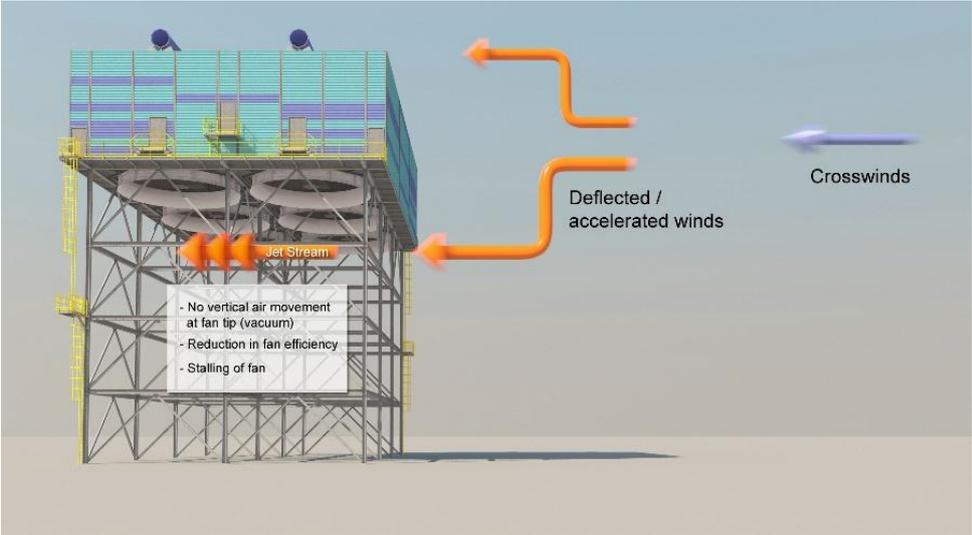


Figure 1 - Illustration of deflected wind resulting in jet stream under fan of ACC

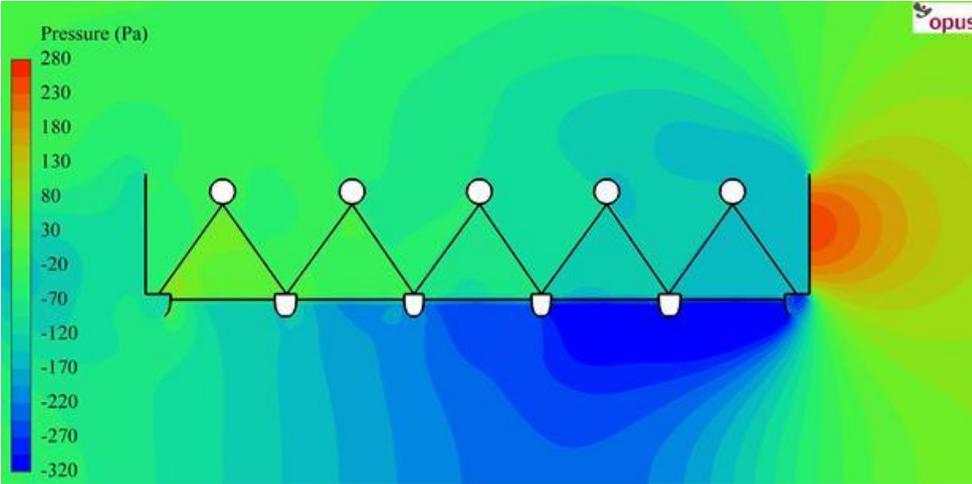


Figure 2 - Illustration of CFD modeling with strong winds (25 m/s) on ACC showing non uniform inlet profiles(source: GBR Industries)

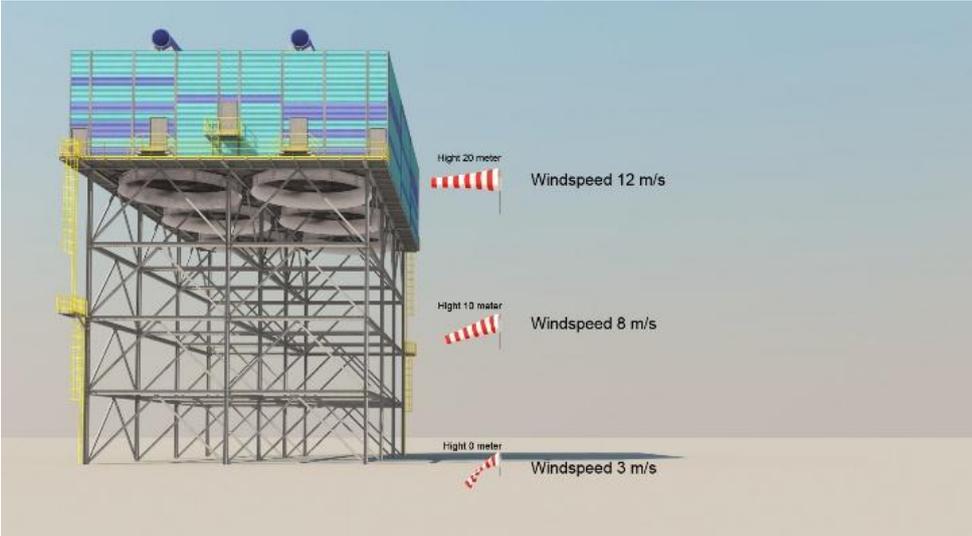


Figure 3 - Illustration of wind speeds just under fan deck versus ground wind speed

A solution for this problem can be to install wind screens in order to break up the jet stream as illustrated in pictures 3 &4 below.



Picture 3 - Illustration of a fixed wind screen system on an ACC to counter negative effects of cross winds



Picture 4 - Illustration of Rolling System wind screen on an ACC

Installation of fogging systems (adiabatic cooling)

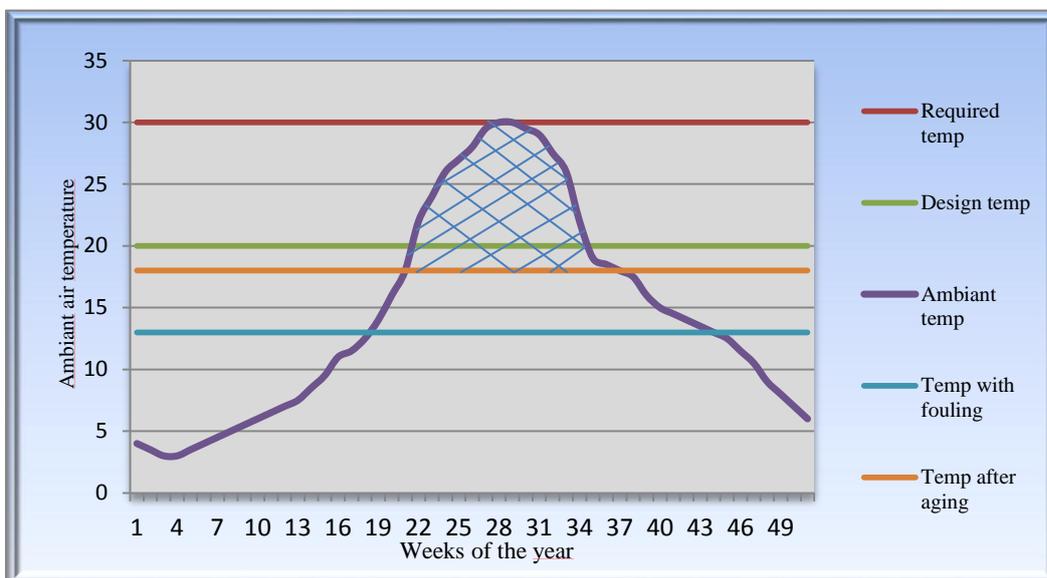


General rule of thumb

A properly installed fogging system will NOT damage your equipment with a potential improvement of turbine backpressure of as much as 55 mbarA at 30°C ambient air temperature

When designing new ACC's, one must always decide what ambient air temperature to use. Ambient air temperature will greatly affect ACC size.

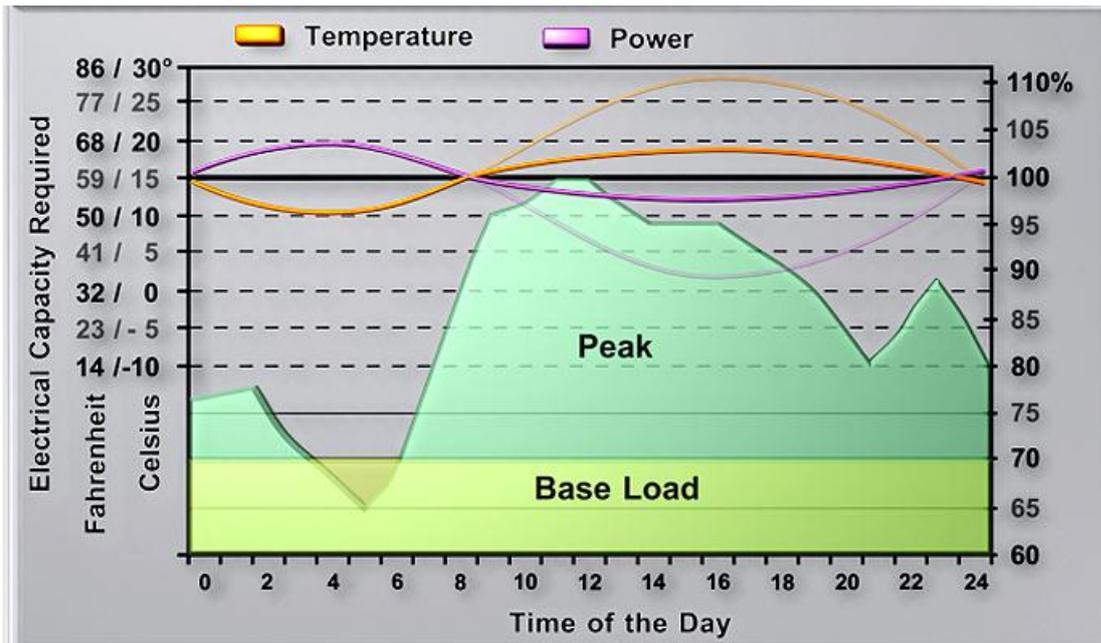
There is always the trade-off between high capital expenditure (high ambient air temperature) or limitations in production during the hot summer days if one decides to use lower ambient air temperatures in the design stage. In most cases, the design ambient air temperature is far lower in comparison to hot summer days as illustrated in Graph 1 below



Graph 1 – Different design points determined by real temperature, design points and after aging and external fouling

Because air is used as cooling medium, the heat rejection capacity is strongly influenced by ambient conditions such as dry bulb temperature and other meteorological phenomena.

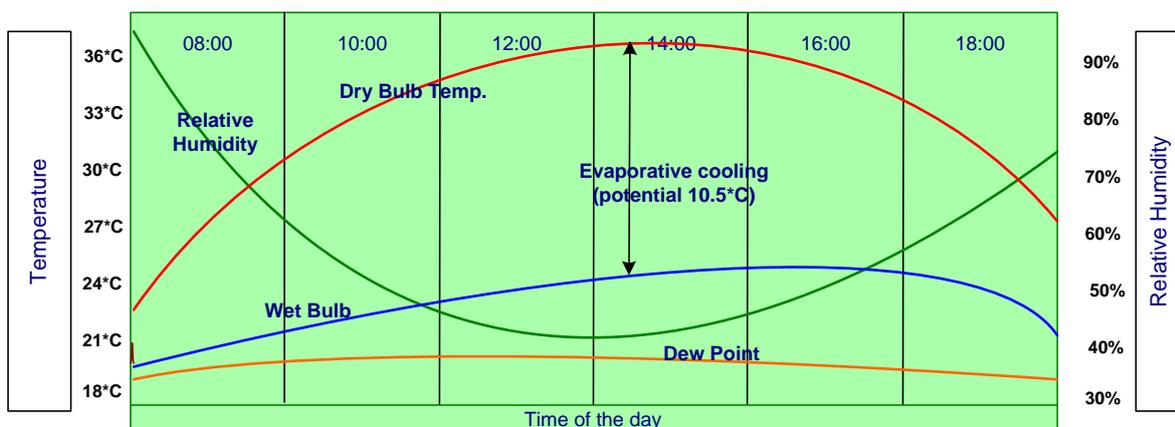
This means that in most cases, ACC's are always coping with serious vacuum problems during the entire summer period (and sometimes even in the spring and autumn). Moreover, electricity prices fluctuate on a daily basis and follow the temperature curve as illustrated in Graph 2 on the following page. This is especially true for peak load power plants!



Graph 2 – Illustration of price of electricity versus temperature

An efficient chilling system (also called fogging, misting, peak cooling) is a high pressure fogging system used to influence ambient climatic conditions. By evaporating billions of micro fine droplets in the inlet air of an ACC, adiabatic cooling is attained and the evaporative effect results in a drop in inlet air temperature, resulting in an increase in efficiency of the ACC. The evaporative cooling system effect on an ACC will have a direct positive effect on Process production.

A proper chilling system can reduce air temperature by as much as 10°C in dry climates (Steppes and desert) and up to 8°C in continental, Mediterranean and temperate climates.



Graph 3 – Illustration of adiabatic cooling

A proper chilling system is also designed and installed in such a way that all of the water sprayed in the air is completely evaporated before reaching the mechanicals and/or finned tube bundle, as illustrated in the pictures 1 and 2 below. This is attained by using special nozzles and high pressure (80-100 Bar) in order to create microscopic droplet sizes (20-25 μ). By doing so, the evaporation time is reduced to almost nothing (instant evaporation) and will therefore maximize system efficiency, minimum water waste and no damage to your mechanicals and/or finned tube bundles.

In the pictures 3 and 4 below, one can see that the mist is completely evaporated before reaching the fans/finned tube bundles. These systems are also multi stage systems for improved control.

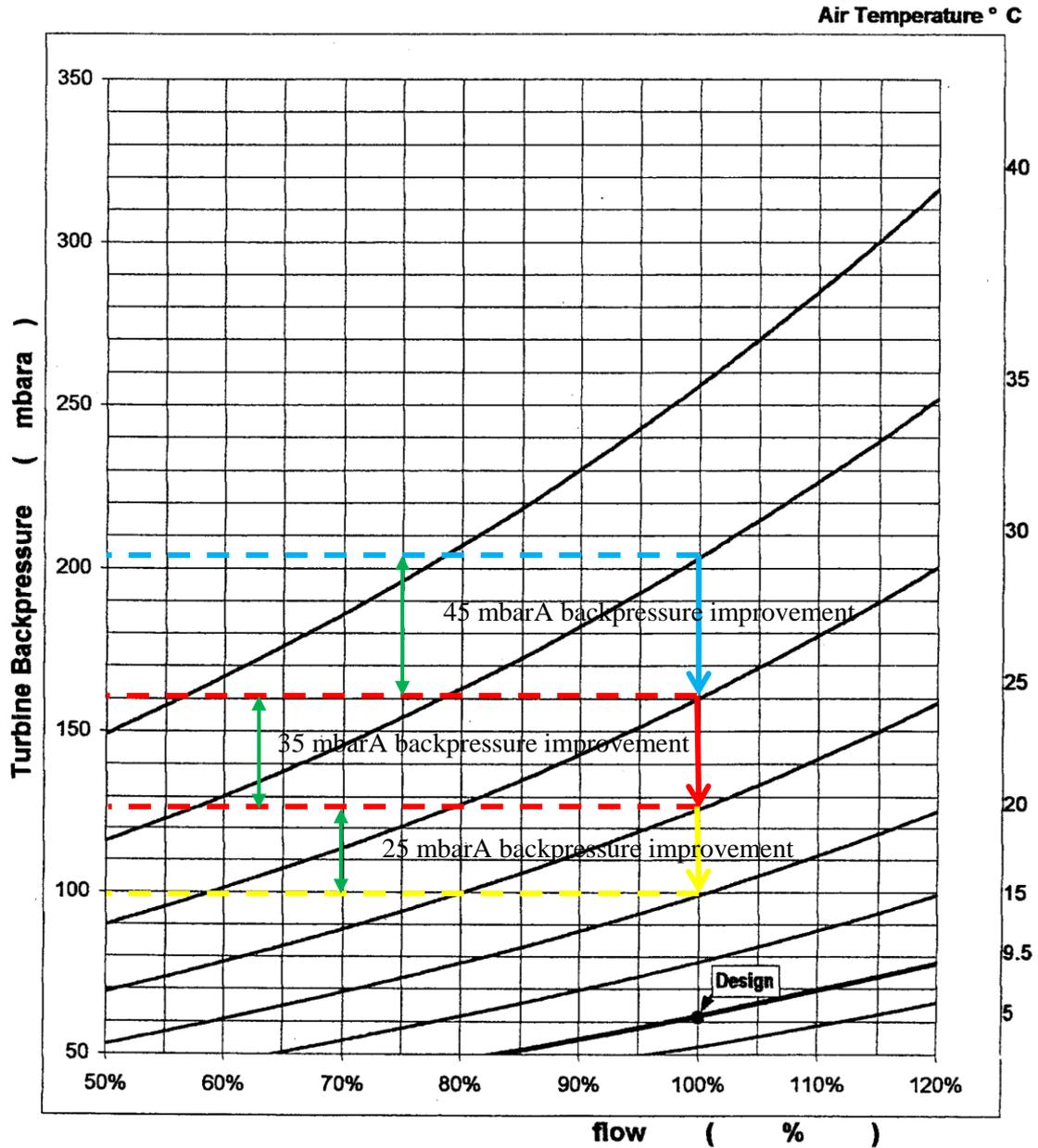


Pictures 6 & 7 - Illustration of a multi stage fogging system in action with complete evaporation

The effects of installing a fogging system under the ACC can be enormous as illustrated in the following ACC performance curve (graph 4), of an ACC installed in Northern Europe

DESIGN CONDITIONS

Steam Flow	DG	100.00	kg/s	Steam Dryness	xG	0.920	kg/kg
Back Pressure	PG	61.00	mbara	Barom. Pressure	bG	978.85	mbara
Air Temperature	tLG	9.5	C				



Graph 4 – Illustration of gains in Turbine Back pressure using Fogging Systems

Elimination of hot air recirculation



General rule of thumb

Hot air recirculation can increase the turbine backpressure by as much as 35 mbarA at a ambient air temperature of 24°C

It is essential that the ACC is equipped with a wind wall in order to prevent hot air recirculation. If this is not the case, the hot outlet air can recirculate back into the inlet of the fan such as illustrated in the picture below putting into evidence the hot recirculation by using smoke bombs. The tricky thing about hot air recirculation, is that the hotter it gets, the higher the turbine back pressure. The higher the turbine backpressure, the higher the inlet steam temperature at the ACC and hence the higher the outlet air temperature, thereby ultimately resulting in a worsened hot air recirculation. For example, at a vacuum of 100 mbarA the steam temperature should be around 45.8°C whereas the steam temperature would be 60.1°C at a vacuum of 200 mbarA resulting of course in a far higher outlet air temperature.



Picture 8 - Illustration of hot recirculation on ACC using smoke bombs

Leak detection of vacuum system

In order to check your ACC performance, it is important to carry out a so called “vacuum drop test” which will enable you to check whether the system is leaking and therefore causing severe loss in performances. The test is very simple and immediately shows if there is a leak, and where one should check for the leaks. Once it has been determined that there is a leak, a leak detection study should be carried out using helium combined with a helium detector.

The vacuum drop test consists of 3 tests which are described below. The leaking rate should in theory not exceed 0.5 mbarA per minute.

Test 1

Isolate the complete vacuum system by closing the isolation valve to the holders. (operational vacuum ejectors)

Test 2

Isolate the vacuum system as per test 1 but with both double ejector systems operational by opening the steam valves to the holders.

Test 3

Isolate the vacuum system as per test 2 but with the hogger (start-up ejector) in operation by opening the steam valve to the hogger.

Better and more efficient cleaning methods for finned tube bundles



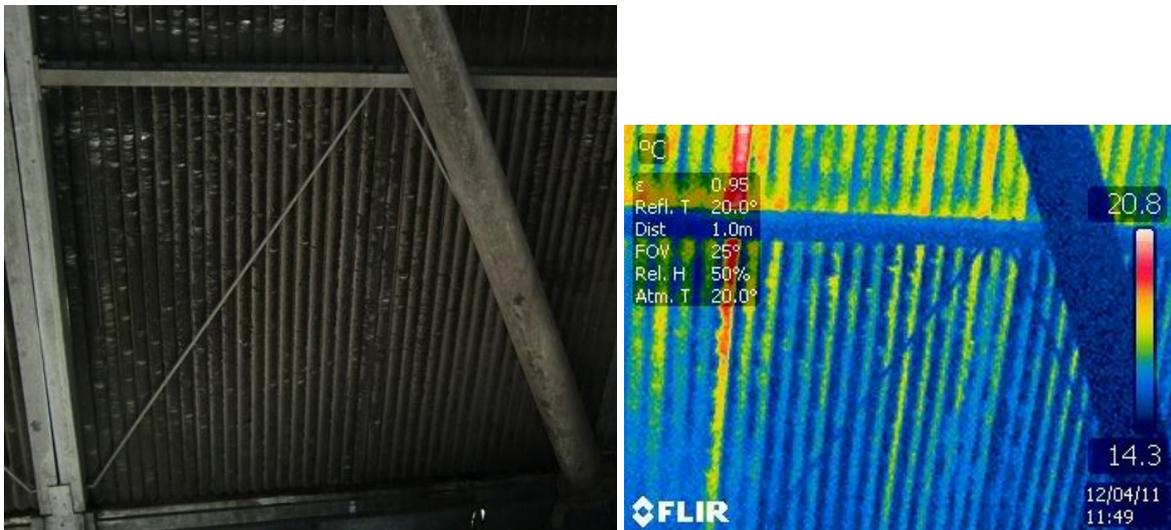
General rule of thumb

A good cleaning can generate an average vacuum improvement at the turbine backpressure of as much as 60 mbarA depending on fouling degree

External fouling of finned tubes can reduce the capacity of the ACC by as much as 40% as it not only restricts the air of going through the finned tube bundles, but also thermally isolates the fins making up a large portion of the finned tube surface as illustrated in picture 1 below. Therefore it is very important to clean the ACC regularly and as well as possible. There are a few challenges in cleaning an ACC quickly and safely.

As one (1) ACC fan covers a large portion of heat transfer surface, the impact of having to shut the fan down for cleaning is enormous on the steam turbine backpressure, and therefore electricity production. This is especially true in the late spring when most ACC's are cleaned right after the period of the pollens. Therefore it is very important to clean the ACC as quickly as possible in order to limit the loss in electricity production.

It is also not easy to clean an ACC safely due to the fact that the bundles are built in an A-frame configuration. This means that access to the top of the finned tube bundle is very difficult and delicate, and therefore potentially dangerous.



Pictures9 & 10 - Illustration of external fouling on lower row of finned tube bundle and thermal isolation of fouling on fins

This is why most ACC's are cleaned by using a permanent cleaning rig on the bundles, which allow fast and safe cleaning of the finned tube bundles. When using such a system, it is important to use as large a pump capacity as possible, to be able to clean faster than with a low capacity pump. We therefore recommend a pump system of at least 220 l/min with a minimum of 20 nozzles. The pump pressure should also be at least 120 bar in order to have the maximum impact on the finned tube bundle cleaning.



Picture 11 - Illustration of high capacity cleaning head versus normal capacity head. High capacity increases speed of cleaning by 2 x

The cleaning system of an A-frame steam condenser consists of a support frame, which can be a ladder or an aluminum space frame, a cleaning rig and rails via which the support frame moves along the heat exchanger bundles. The cleaning rig is suspended from the support frame to allow a traveler with spray-head move in vertical direction. Picture 2 illustrates the permanent cleaning machine specially designed for ACC application which allows for fast and safe cleaning of the finned tube bundles.

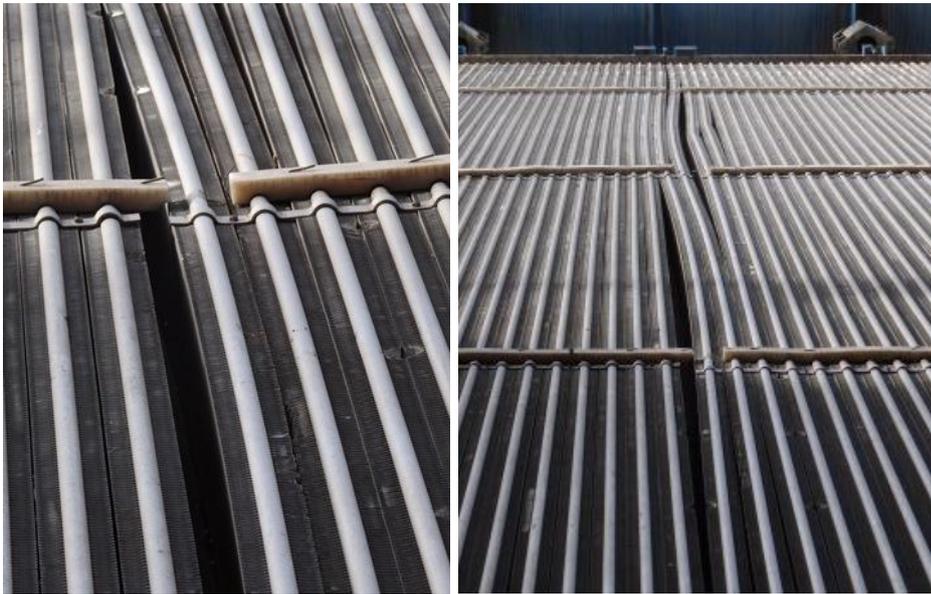


Pictures 12 &13 - Illustration of high flow & pressure permanent cleaning system in action

Other problems/solutions related to ACC performance loss

a. Distance keepers for Single Row Bundles

During our many site surveys, we noticed that there were certain ACC's with large gaps between certain tubes being created by different thermal expansions of the different tubes. These gaps allow for air to pass through as it chooses the path of least resistance reducing ACC capacity considerably. This is caused by the distance keepers not doing the job correctly. We would recommend placing stainless steel distance keepers more apt to perform the job, instead of the originally installed PE distance keeping that get eroded by UV lighting and break after a while, and thus creating gaps.



Pictures 14 &15 - Illustration of creation of gaps between certain tubes caused by failing distance keepers



Pictures 16 - Illustration of newly installed stainless steel distance keepers

b. Variable frequency drives on electrical motors

Many ACC fans are not equipped with variable frequency drives. Variable frequency drives have many advantages and should in our view always be installed on ACC fans due to the following:

Noise

There is a European noise directive 2002/49/EG relating to the assessment and management of environmental noise where they differentiate noise levels between day time, evening and night-time. Between noise restrictions during the (hotter) day time and the (cooler) evening and especially (even cooler) night time, there is a large difference. Indeed evening noise levels need to be day noise level – 5dB and the night-time noise levels need to be day noise level – 10dB which is a huge difference. This means that in order to reduce existing noise level of a plant according to European legislation, one can install variable frequency drives on the existing fans. One must first of all realize that fans will turn faster (thus produce more noise) during the hot part of the day which is day time and to a lesser extent the evening time. During night time (when the price of electricity is also lower), the fans can easily turn at lower RPM as the air temperature is lower than during the day. ACC fans are sources of low frequency noise as a normal ACC 30 ft. fan will turn at about 60-70 RPM. The low frequency noises go further away (so not good for overall plant noise level) and are impossible to filter.

Optimization of fan performance

Most motor loadings of the ACC fans are about 80% of nominal current. This is to be able to run at 100% during cold winter periods when the air is denser than during hot summer days. By installing a variable frequency drive on these units, one can load up the motors to 100% nominal current at for instance 15°C which would be the theoretical value where the fans would have to run given the maximum load. By using thermal simulation programs, one can simulate this set point and set the fan to full load current at that particular air temperature. If the temperature would get lower, the fans would run slower anyhow (pulling less current as a result) and thus the motors would not trip anyhow???. The motors can be loaded to full current by increasing pitch angle until full load current is obtained. A preferred (provided noise level allows for this!) way to load the motors to full load current, is to increase the frequency of the variable frequency drives to over 50 Hz. This will increase fan RPM and thus increase motor loading. We prefer to carry out the latter method as in most cases, this will increase fan efficiency and also pressure capability of a fan. We have experienced average increases in airflow of 10-15% by carrying out this “trick” without breaking the rules of plant noise level restrictions. Increasing fan RPM will also increase the AGMA rating for the gearbox which will in turn increase MTBF of your mechanical equipment.

Mechanical reliability

Due to the fact that fans do not have to be shut down and started again to regulate the plant load, this will of course have a very positive effect on the MTBF of your fans and gearboxes. A variable frequency drive will regulate the plant load in a much smoother way which will only have positive effects on the MTBF of your mechanics.