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Frequently Asked Questions and Answers

regarding the

Optimize Evaporative Cooler

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Technical

1 General Questions, Cooling Potentials and Cooling Efficiency

Cooling potential varies with the specific climate existing in each country, depending on height above sea level, sea proximity, seasons etc.
Generally, the difference between dry and wet bulb temperature is the potential of evaporative cooling, i.e. the difference in temperature, and 90-95 % of this potential can be achieved by using a Optimize Evaporative Evaporative cooler. This means, that the Optimize Evaporative cooler can reduce a given ambient temperature by 90-95 % of the potential using the latent heat of the water which is evaporated.

Latent heat definition: Latent heat, defined as the quantity of heat absorbed or released by a substance undergoing a change of phase, i.e. from water to vapour or vice versa, at constant temperature and constant pressure.

By using the latent heat of water, air is cooled by evaporating water into the air. This means that energy from the air is transferred into the water to evaporate the water and to cool the air down towards the wet bulb temperature.

Generally, in the tropics, there is the smallest potential for evaporative air cooling technology, being in the night only 2-3°C, while over the day, the peak potentials are around 10-12°C at the hottest time of the day. On average, during daytime, 4-5°C can be assumed for countries like Indonesia, Malaysia, Thailand.

Northern of 55 ° latitude evaporative coolers for cooling inlet air of gas turbines are usually not employed. Countries in northern West Europe like Germany usually provide peak potentials up to 16°C in summer time while in spring it is more like 10-12°C. However, average during the summer on a 24 h basis, is not more than 4-4.5°C. In southern Europe like Spain, peak potentials are up to 20°C in southern Spain (inland), approximately 14-16°C in areas located close to the sea. Usually 26°C (or less) of cold air can be provided after cooling it with the Optimize Evaporative cooler during all climatic conditions throughout the year.

In North America, the situation is similar to southern Europe, potential is between 12°C in the North and more than 20°C in southern regions like Arizona, New Mexico, Texas.

The largest potential exists in the deserts, for example Saudi Arabia, or also in dryer spots of Australia, India and Pakistan. Cooling potentials are up to 30°C and it is possible to bring down temperatures from 55°C to around 25°C. Average cooling potentials of 6-7°C on a 24 h, 365 days basis are existing, so that also the average cooling potential, not only the peak cooling potential, is enormous.

How can an evaporative cooler work in countries, where the relative humidity is high, for example in the tropics, where the relative humidity is 80-90 %?

Relative humidity is not constant, it is rather fluctuating very much, and this depends very much on the absolute ambient temperature. Air of low temperature (5-10°C) can become saturated with a few grams of water/kg of air, air of higher temperatures (20-40°C) needs much more water to become saturated. With increasing temperatures, the potential gets always larger and larger, because the absolute portion of water in air does not exceed 23 g/kg air at the most humid conditions (Dubai) at 45°C, 38 % r.H. (wet bulb at 31°C) and very seldom exceeds 19 g/kg air (tropical countries, 27°C wet bulb temperature).

In a certain environment, at highest ambient temperatures, the r.H. is always low, i.e. always provides enough potential for at least 10°C anywhere on earth. To express that simply means that at high temperatures the relative humidity is always low.

The best example are the tropics, where the maximum difference between dry and wet bulb are the lowest on earth. Every night r.H. goes up to 85 –95 %, but over the daytime, at temperatures exceeding 32°C, it goes below 65 % r. H., often down to 55 %!

At relatively low temperatures, compared to the other temperatures at a certain place and at a certain period of the year, the likelyhood that the evaporative cooling potential is low, is relatively high. However, at low temperatures the gas turbines do not need additional cooling, because their capacities are near the design point or near the ISO output, i.e. they meet the design criteria.

Can the output of a gas turbine be kept constant at ISO output by using the Optimize Evaporative cooler?

Evaporative cooling can not keep the output constant, but is stops the continous loss of output towards higher ambient temperatures at a certain stage, typically it limits the maximum annual intake temperatures to 23-27°C in Europe, most parts of Asia and the US. In extreme cases, in Dubai, for a few days of the year 31°C have to be accepted, but for the rest of the year, even at extreme ambient conditions, the intake temperatures after evaporative cooling remain less than 29°C.

How is wet bulb temperature measured?

Wet bulb temperature is measured by using a wet wick, which is wrapped around a thermometer. Out of the wet wick, the water will evaporate and create thereby the cooling effect which cools the thermometer down to the wet bulb temperature. It has to be taken care that the thermometer is fully wrapped and the cloth is fully wet, otherwise the measuring result may not be correct.

When is a Evaporative cooler switched off?

The cooler is switched off either at very humid conditions with cooling potentials of less than 2°C, or at low ambient conditions of significantly lower than 10°C. Reason for the first is that at 2°C evaporative cooling is very little effective, i.e. the gas turbines do not provide much more power and since this climate conditions happens most likely in the night, where most of the time no peak power is required, the cooler can be switched-off. Lower than 6°C, the evaporative cooler should not be operated, because due to the chilling effect of the air which is expanded in the bellmouth of a gasturbine, icing can take place.

What other controls does a Optimize Evaporative cooler consist of?

One of the most important controls is the conductivity control, i.e. the water quality. Water quality needs to be kept under control, i.e. the minerals shall not fall out, because this will damage the evaporator pads and will cause deterioration.

What are the typical dimensions of a Optimize Evaporative Cooler and what is the maximum air velocity possible?

Due to some new pad developments of Optimize, the allowable air velocities have gone up to 3.5 m/s, which decreases the necessary cross-sections for certain air flows.

Evaporative coolers can be built between 1 ft x 1 ft and 20 m x 20 m depending on the airflow through the cooler. It is recommended to design levels between 3.5 m and 4 m, any width can be taken care of. The depth of the design is, depending on access and depending on droplet separator type, between 0.42 m and 1.5 m.

How much power is required to operate the Evaporative cooler?

Power consumption depends on the design of the Evaporative cooler, but is typically between 0.5 kW for small 4 MW gas turbines and 11 MW for big 240 MW gas turbines. Depending on the height difference between tank and media banks, up to 18 kW are necessary for the biggest Evaporative coolers in front of the biggest gas turbines on the market today (240 MW).

Typical Misconceptions

The highest humidity happens at the highest ambient temperature

It is easy to assume the above, but actually, as explained earlier, at highest ambient temperatures, the relative humidities are the lowest and vice versa. At lowest ambient temperatures, the highest relative humidities occur. If weather data seem to indicate more than 23 g water in 1 kg of air, it cannot be correct.

Difference in achieving wet bulb and dew point temperature (from a given ambient temperature and given relative humidity)

Wet bulb temperature is achieved by humidifying air of certain condition by evaporating water until the air is 100 % saturated, without any further exchange of energy.
Dew point temperature is achieved by cooling air of a certain conditions by means of sensible heat exchange (at no exchange of phase) until the air is 100 % saturated. Pls see also psychrometric diagram in the literature.

How is the relative humidity controlled by an evaporative cooler?

With a Optimize evaporative cooler, the relative humidity is not controlled at all. The evaporative cooler operates by its principle at an efficiency of 90-95 %, depending on thickness of media, media type etc. The evaporative cooler will always cool the air proportionally to its efficiency, i.e. provide maximum 90-95 % of the existing cooling potential, which depends on the intake air. However, we can also design coolers with lower efficiencies, if desired.
For example, if air of 32°C, 60 % r.H., is taken into the cooler, it will leave with 96-98 % r.H. and with 5.8-6.1°C lower temperature than 32°C. The efficiency remains constant between 10-60°C.

2 Air Velocity through Optimize Evaporative cooler and Pressure Loss

What are the maximum velocities acceptable and what are the maximum pressure losses associated?

Net average velocity (deducting the cross-sections for bracings, flanges etc.) should be lower than 3.2 m/s. For higher average velocities, Optimize can

provide specially designed media up to 3.6 m/s in special cases.
Pressure loss mainly depends on the air velocity and on the thickness (efficiency) of the media. Low pressure losses are 50 Pa at coolers with approximately 2.5 m/s air velocity and reach up to approximately 140 Pa at 3.5 m/s. However, this also depends on the droplet separator, if and of which type installed.

3 Erection, New Units and Retrofits

What are the retrofit cost for a Evaporative cooler?

Erection cost strongly depend on type and size of Evaporative cooler and location. Typically, for retrofits, only for the erection 10-40 % of the ex-works price can be assumed, not including those cost for adaption of the filterhouse, access etc. Erection cost for Evaporative cooler for new gas turbines are only about two thirds of this amount.

4 Water Water Consumption

Water consumption depends on the cooling potential, i.e. the difference between wet bulb and dry bulb temperature, the efficiency of the Evaporative cooler, which is generally between 90-93 %, and the air flow of the respective turbine.
It is possible to cool with 1 g of water 2.4 kg of air by 1°C, or 1 kg of air by 2.4°C, so for example a gas turbine with 125 kg/s of air operated in an environment with a cooling potential of 12°C needs 581 g/s of water to cool the 125 kg/s of air by 11.2°C (93 % efficiency).
Depending on the water quality, the bleed-off needs to be considered, because it usually means a water demand of additional 15-100 % of the evaporated water demand. This has to be added to the evaporated water.
Peak demands for big units with 500 kg/s of air and cooling of 16°C lead to an evaporation rate of 12 tons/h. Very small units (4.5 MW, 30 kg/s of air) do run on a couple of hundred liters/h.

Water quality

What water quality is necessary to operate the evaporative cooler?

The incoming water should fulfil the following water quality:

Water specifications

Designation	Lower	Upper	Unit
Conductivity	50	450	µSiemens/cm
Calcium Hardness (as $CaCO_3$)	45	170	ppm
Chlorides (as Cl)	<50 ppm		
Total Alkalinity (as $CaCO_3$)	45	170	ppm
pH	7	8.5	-
Silica (as SiO)	<25 ppm		
Iron (as Fe)	<0.2 ppm		
Oil and grease	<2 ppm		
Total dissolved solids	<550 ppm		
Suspended solids	<5 ppm		

The analysis of water which does not fulfill this specification shall be given to Optimize in order to determine whether or to which extent the water can be used for operating the Optimize evaporative cooler. Demin water can also be used to operate the Optimize evaporative cooler, but we do´issue special instructions case by case in order to ensure that media does not suffer.

5 Output increase of the gas turbine

The maximum output increase of turbines is between 0.5 %/°C cooling of the ISO output and more than 1 %/°C of cooling of the ISO output. This depends on the GT type and the absolute temperature. The coefficient usually increases slightly with the absolute temperature. Most of the turbines used for stationary power plants have an coefficient of 0.63-0.7 %/°C, the aeroderivatives around 1.

What is the incremental power output of my turbine?

Pls determine the above coefficient of the turbine from the output correction curve which comes with the GT documentation. Determine the maximum or the typical cooling possible and multiply ISO output x temperature difference x coefficient. For example, for a Frame 6: 39.5 MW x 10°C x 0.63 %/°C of cooling leads to 2.49 MW output increase compared to an operation without cooler.

If you do not have climatic data of your turbine available, pls contact Optimize for a performance calculation at your location.

6 Efficiency increase of the gas turbine

Efficiency is also increased at full load operation of the turbine, the typical reduction of the heat rate is 0.18 %/°C. However, this depends also on the turbine type. Firstly, the heat rate corretion curve has to be used to determine the factor, secondly, as in section 6, the multiplication has to be done with the ISO heat rate x the reduction in temperature. For example: Turbine with 10,500 kJ/kWh, correction factor 0.18, _T = 10°C >> 10,500 kJ/kWh x 0.18 %/°C x 10°C leads to 189 kJ/kWh improvement in heat rate at full load condition.

7 Degradation

Is the efficiency of the Optimize Evaporative cooler reduced after a period of time?

If the media is in contact with water according to the specifications, the media has a long operating life – we have few examples of more than 10 years, whether for glasfibre media (non combustible quality) or for cellulose media (inflammable quality).

But if the media is in contact with water out of the specification (usually containing to much calcium or magnesium), the media can be destroyed within weeks by accumulating magnesium or calcium which blocks the structure, so that the humidification and cooling process is prevented and the pressure loss is increased.

Typically, the media lasts for 5-7 years, if the water quality is within the limits.

8 Droplets – Droplet separators

At velocities higher 2.5 m/s, we do install a droplet eliminator, also called droplet separator or mist eliminator, in order to protect the air intake from drops. There is a variety of different Optimize droplet separator types, depending on where the cooler is installed (before/after air filters) and depending on the air velocity through the cooler.

9 Where to integrate the cooler – before or behind the air filter?

The Evaporative cooler can be installed before or after the air filter, but in case it is installed before, it has to be checked that the air filter behind does not contain paper fibres which would swell and increase the pressure drop over the filters. Also, their life lengths would be reduced. Fully snythetic filters are suitable for a cooler operation before the air filters.

10 Erection time, Erection procedure – new units and retrofits

Erection time depends on the size of the units. Small units of 4-10 MW are usually retrofitted within 1-2 days while bigger units for 170-240 MW gas turbines do require a week.
At installations before the air filter, no downtime is required. If the cooler is installed behind the air filter, a downtime of 1-4 days is required in order to install the Evaporative cooler.

11 Operation and Maintenance manpower

Optimize does build fully automatic or semi-automatic evaporative coolers, which do not require additional manpower to operate. Maintenance and service does also not require much manpower, because only regular checks and some cleaning (at least once per year) have to be done, however, total manhours for maintenance and service of a cooler should be between 10-50 manhours/year, if the pads are not taken out during the cold season (if any). Mainly, the water quality has to be checked regularly.

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12 Output increase and increased peak power capacity

Due to the increased output at higher ambient temperatures, the gas turbine operator is in the position to produce/sell more output which is the main benefit for him. 1 MW of additional capacity is usually worth between US$ 50,000/year and US$ 200,000/year so that the Optimize evaporative coolers do often earn the investment back within months.

13 Additional production of power

Further to the increased capacity available at higher ambient temperatures, the total power production over the year is typically increased by 2-6 %, depending on how often the turbine and how often the Evaporative cooler is operated.

14 Operation cost - Water cost

Water cost do form over 90 % of the operation cost. Water is the main consumable, the cost for it vary usually worldwide between 0.5 US$/$m^3$ and 1 US$/$m^3$ for cleaned river water or potable water. Pls see our website calculations how much water is consumed at continous operation at different locations with a variety of turbines.
Demineralized water can also be used, but is of higher cost compared to before. However, total water cost are usually negligible against the profits created by an Optimize evaporative cooler.

15 Maintenance cost - spare part cost

Spare part cost mainly consist of new media every few years. Other cost are negligible. Very little manpower is necessary to check the cooler regularly and to maintain it.