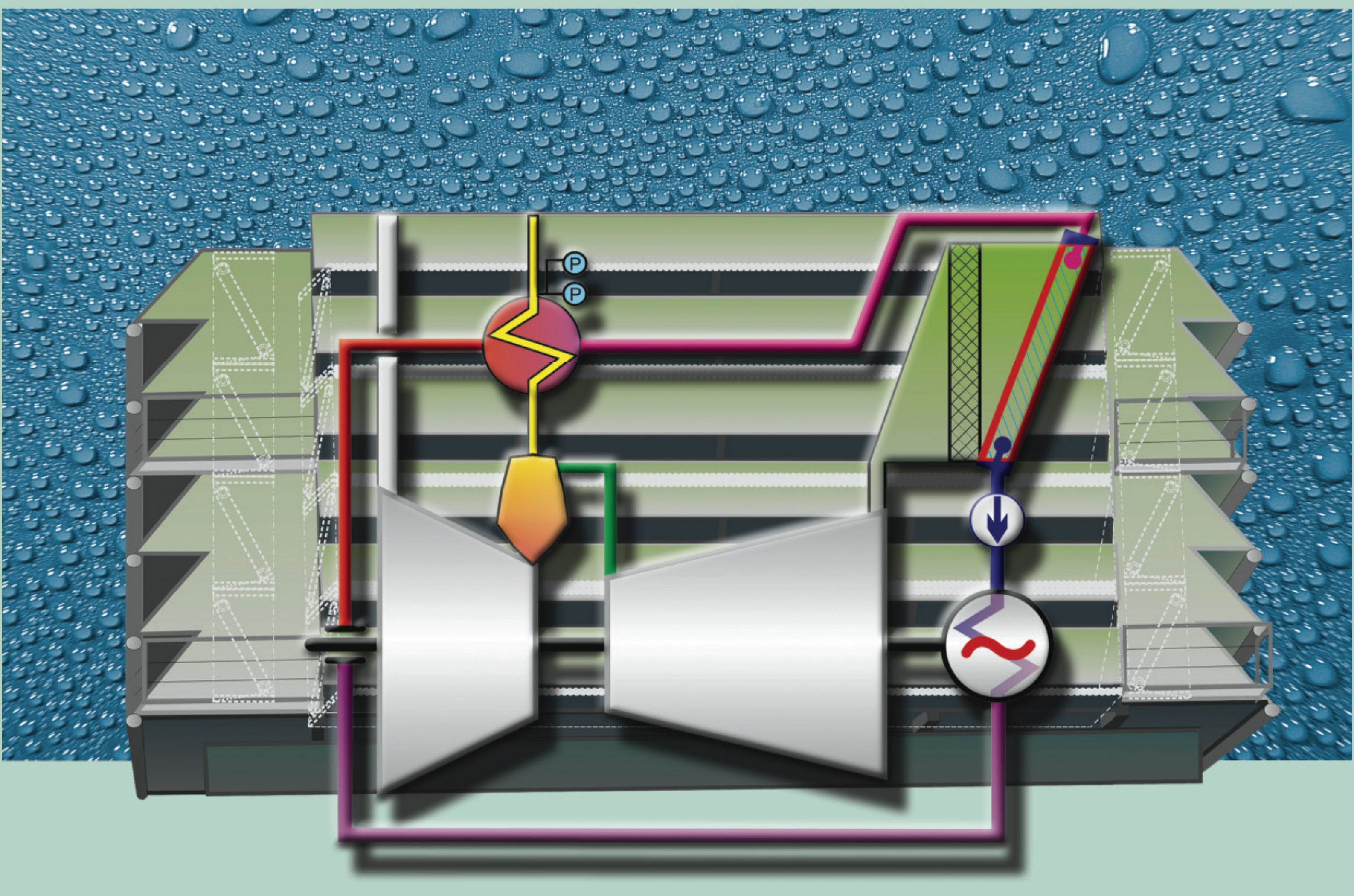
Thermo Integral

Innovative Solutions in the Service of Humans and the Environment

# HYBRID COMBUSTION AIR CONDITIONING



## A new method to optimise the operation of gas turbines

# Secondary processes on gas turbines

In steady-state operation, gas turbines serve to drive electrical generators, gas compressors and fluid pumps. Their advantage relates to simple design, an extremely high power density, a long service life and the option of operation with various calorific values, advantages not afforded by piston machines. In recent years, it has been possible to increase the output and efficiency of gas turbines and reduce pollutant gas emissions in the waste gases in line with more stringent legislation. However, secondary processes of gas turbines continue to have an important optimisation potential.

## Dependence of output and efficiency on intake air temperature

The output and effectiveness of gas turbines are greatly dependent on temperature of the process air at the compressor inlet, owing to the use of an axial-flow compressor. The air density and, consequently, the quantity of air inducted by the axial-flow compressor drop with increasing intake air temperature. The output and the efficiency of the gas turbine drop in proportion with this (see Figure 1).

The inducted air quantity, the output and the efficiency can be increased again by artificial cooling of the intake air in the summertime, and the following methods are already used in practice for this:

*Direct adiabatic cooling of the intake air with water:*

- Nozzle injection into the air stream using unitary high-pressure blast connections (can hardly be controlled)
- Nozzle admission into the air stream using binary blast connec tions (additional air consumption)
- Cascading or film humidification with water on fitted cooling devices (max. 65 - 80 % relative humidity)
- Direct flow through ice banks.

*Indirect cooling of the intake air by waste-heat exchanger, cooled with:*

- Absorption refrigerating units
- Adsorption refrigerating units
- Compression refrigerating units.

Refrigerating units are costly investments and are costly to operate. Compression refrigerating units require expensive electrical power to drive them. The drive energy converted to heat and the heat absorbed from the intake air stream must be dissipated to the ambient air. This, in turn, necessitates large recoolers that also consume water and electrical power.

## Anti-icing

The risk of icing up of the intake air filter and of the inlet diffuser of the axial-flow compressor occurs in cold regions in the wintertime at high intake air relative humidities. This is counteracted by artificially reducing the relative humidity by air preheating.

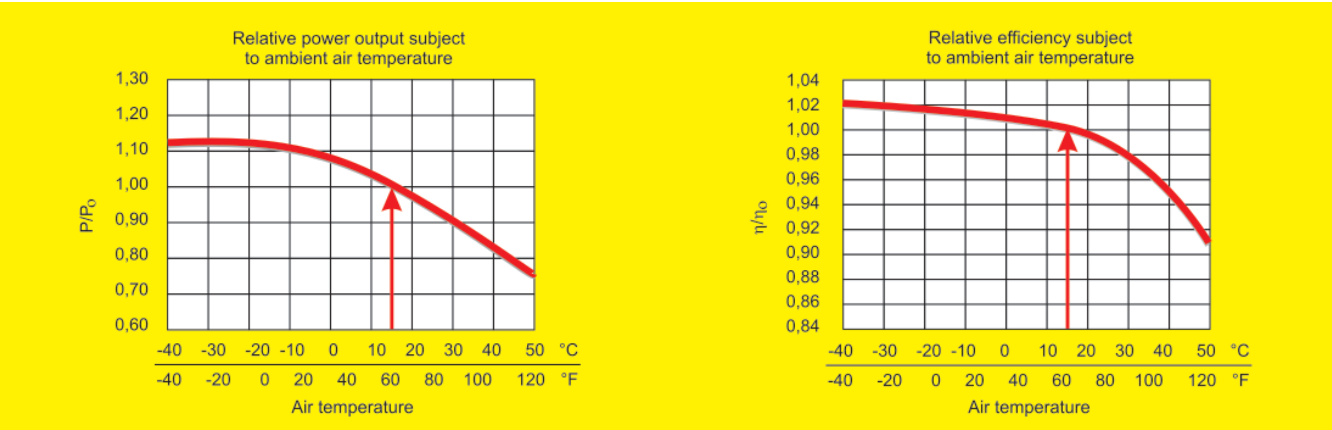



Figure 1: Example of the dependence of output and efficiency of a gas turbine on ambient temperature

This process is referred to as anti-icing by specialists. The following methods and heat sources are used for this:

*Direct preheating of the intake air by mixing with:*

- Warm air from the compressor outlet
- Warm exhaust air of the package of the gas turbine
- Warm exhaust gas (more rarely)

*Indirect preheating of the intake air with heat exchangers in the intake air stream with:*

- Heat from a gas and steam circuit.

However, intake air preheating, as already mentioned above, causes a reduction in the inducted volumetric air flow, output and efficiency of the gas turbine. This reduction is particularly high if warm air from the condenser outlet is used for anti-icing since this air is taken from the process after compression has already occurred and is no longer available for performing work in the gas turbine and the steam process.

## Part-load operation

The intake air quantity through the system is reduced with priority on gas turbines for operation at part load. This is done by actuation of the fixed blades at the inlet of the axial-flow compressor. This increases the pressure loss at the suction end and consequently reduces the efficiency of the gas turbine. In addition, the air lost as the result of reduced flow rate is then not available in the downstream steam process of a combined gas and steam process, thus leading to a reduction in the parameters in this sub-process as well.

## Secondary cooling circuit

Gas turbines are extremely effective drives. Nevertheless, (waste) heat that must be dissipated to the environment via separate cooling systems is produced in secondary processes. This includes the (waste) heat of the generator, the waste heat of the lube oil of the bearings and any gearing mechanisms present and, depending on make, other (waste) heat sources. In warmer regions in particular and also as a consequence of global warming, these coolers frequently pose a problem in respect of operation of the gas turbines. The lube oil temperature can no longer be stabilised in the summertime and the gas turbine output must be reduced. In rare cases, it is also necessary to completely discontinue operation temporarily. The lube oil ages more quickly and other lube oil grades may need to be used.

## Fuel preheating

Fuel preheating is required on steady-state gas turbines operated with natural gas so as to compensate for the Joule-Thomson effect when relieving the pressure of the natural gas from pipeline pressure to combustion chamber pressure. The temperature reduction of the natural gas occurring in the isenthalpic restriction process may also be so great, depending on pressure ratio on regulator and inlet temperature of the gas from the pipeline, that there is a risk of the temperature dropping below the water vapour dew point and consequently, icing up inside and outside the gas pipe.

The effects on gas turbines can be at least just as far-reaching if the actual temperature drops below the carbon dew point in the natural gas. Propane, butane and other higher hydrocarbons contained in natural gas are precipitated to a certain extent in liquid phase at low temperatures and/or low pressures. If this liquid phase enters the gas turbine, burning in the form of large droplets, this may cause the dreaded damage to the turbine blades, also known as „flashback“.

Gas turbine manufacturers consequently demand a gas temperature at the combustion chamber inlet that is around 15 Kelvin above the hydrocarbon or water vapour dew point at every operating point. This combustion gas preheating is performed in gas pressure control stations in a separate heating building with a not insignificant fuel gas consumption from the turbine‘s own fuel.

Moreover, in power stations, the fuel gas is heated further, directly upstream of the gas turbine, temporarily up to temperatures as high as approx. 200 °C. This preheating is performed with heat from the gas and steam process. This results in a saving in fuel gas corresponding to the heat equivalent and an almost proportional increase in efficiency of the gas and steam system. Liquid fuels are also preheated, but, in this case, primarily to enhance flowability.

# Connection between secondary cooling, fuel preheating, anti-icing and air humidification

A new system that performs the following tasks with little-known and tried-and-tested components has been developed for conditioning the intake air on gas turbines:

- Recooling of the secondary cooling circuit (lube oil and generator)
- Fuel preheating
- Combustion air conditioning of the gas turbine:
  - Indirect preheating of the intake air in the event of the risk of sub-zero temperatures
  - Direct humidification of the intake air in the case of positive ambient temperature
  - Indirect preheating of the intake air in order to achieve part-load operation.

This involves interconnecting the (waste) heat sources of generator and lube oil etc. with a double-pipe safety heat exchanger to be installed in the fuel line and hybrid coolers to be installed in the intake air by the closed secondary cooling circuit filled with water or water-glycol mixture, to form a system of hybrid combustion air conditioning (see Figure 2).

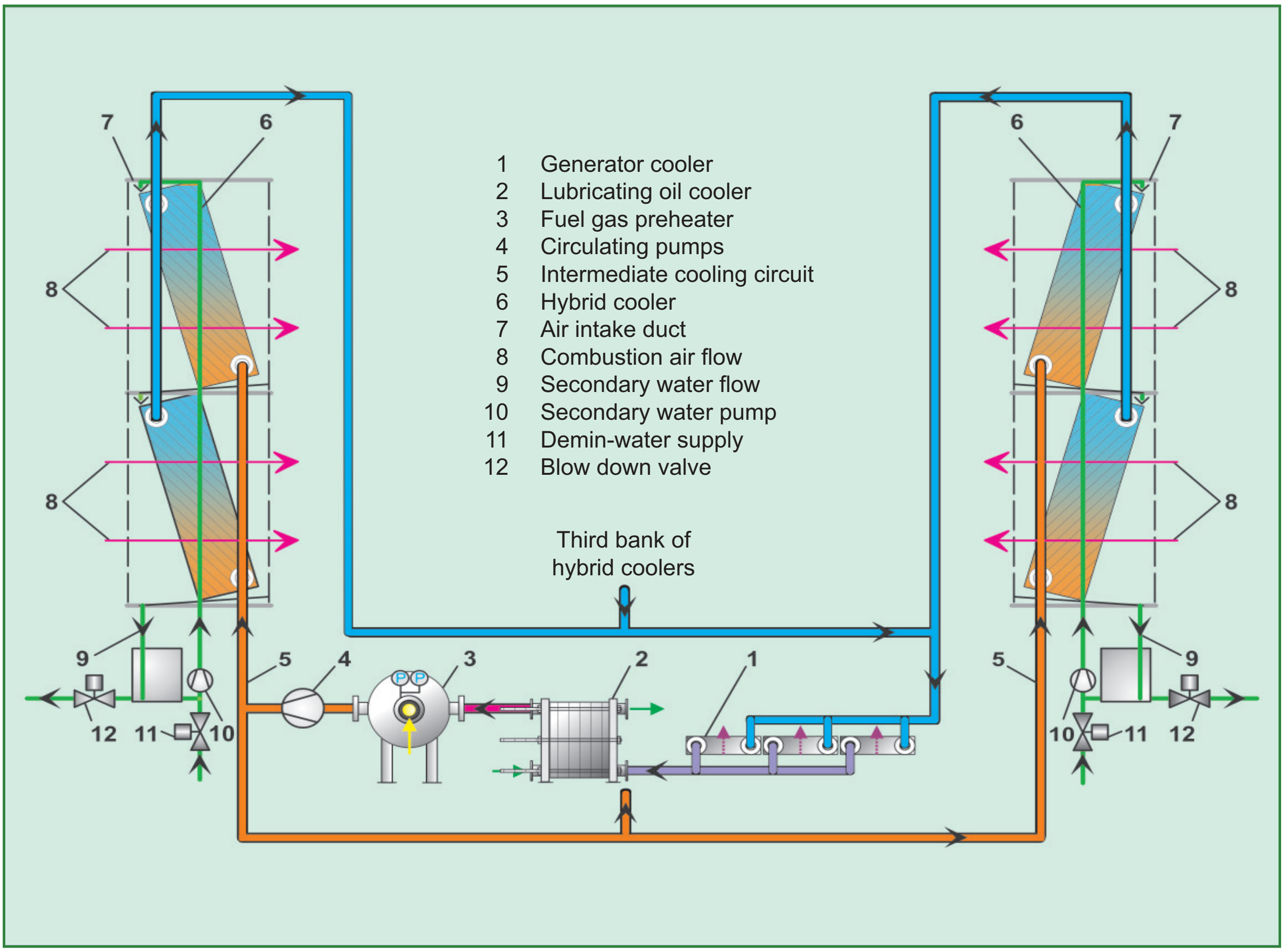



Figure 2: Schematic of a hybrid combustion air conditioning system for gas turbines

## Hybrid cooler

Hybrid coolers have been used for recooling to date. They are operated only dry up to outside temperatures of approx. 7 to 18 °C depending on design. Recooling is then performed via a finned tube matrix. If the outside temperature is beyond these limits, it is humidified externally so that a water film wets the entire matrix with secondary water. Partial evaporation of the wetting water results in indirect additional cooling. The excess water is caught in a sump beneath the cooler or in a separate tank and fed back to the wetting circuit until the permitted concentration is reached and automatic blow-down/desludging occurs. Wetting is performed with excess water so as to reliably flush out contamination from the ambient air and in order to avoid drying of the fins during wetting. Air is circulated with variable-speed fans. Hybrid coolers thus feature economical use of water and electrical power. Cooler elements derived from the sector of hybrid cooler construction are now also used for combustion air conditioning and are installed directly in the intake air stream (see Figure 3).

Air washing relieves the load on the downstream air filters in humidification mode, thus leading to a far longer service life of the filter elements.

The hybrid heat exchangers are designed on the basis of the permitted additional pressure loss in the air-intake, e.g. 100 Pa. This means that they are so generously dimensioned that cooling of the intermediate cooling circuit is performed with very slight temperature differences between the air and the cooling water.

Figure 3: Hybrid coolers installed in a building

A relative humidity of around 90 % is achieved at the inlet of the gas turbine in humidification mode with no appreciable discharge of droplets. Humidification mode is possible as of an outside air temperature only slightly above 0 °C. No other humidification method can be controlled as well or is as effective.

As-rolled aluminium, electrophoretically coated, is used as the standard material for the fins. The fin spacing is 2.85 mm and the fin thickness is 0.3 mm.
This solution is insensitive to corrosion and consequently affords a long service life.

Atmospheric contamination is generally washed out by the wetting water. In the case of high contamination, a soft water jet suffices to spray off the cooler. In particularly stubborn cases, a high-pressure cleaner with a nozzle pressure up to 120 bar can be used. Experience has shown that it is advisable to wash the cooler regularly every 1 to 2 months during the wetting period in the case of sustained, long-duration wetting and heavy occurrence of long-fibred blossoms. If there are doubts in respect of the strength of the aluminium fins, e.g. in desert regions subject to permanent sand contamination of the intake air, the hybrid cooler elements should be arranged between the prefilters and fine filters of the gas turbine (see Page 6, Figure 4).

Copper is used as the pipe material. If necessary, pipes made of stainless steel may also be used, but this does not appear to be absolutely necessary since the intermediate circuit is designed as a closed circuit. Stainless steel pipes have a wall thickness of 0.75 mm.

Fully demineralised water should be used to wet the hybrid coolers. Desludging that is then required far less frequently is controlled as a function of the measured conductivity in the secondary water circuit, thus contributing towards economical use of additional water.
The thermal output and the air temperature at the outlet of the hybrid coolers can be controlled to a certain extent on the basis of the quantity of wetting water. The wetting bandwidth is approx. 30 - 100 %.

Optionally, a biocide metering device is available for avoiding biological growth in the secondary water circuit.

# Arrangement of the hybrid cooler elements in the air intake of the gas turbine

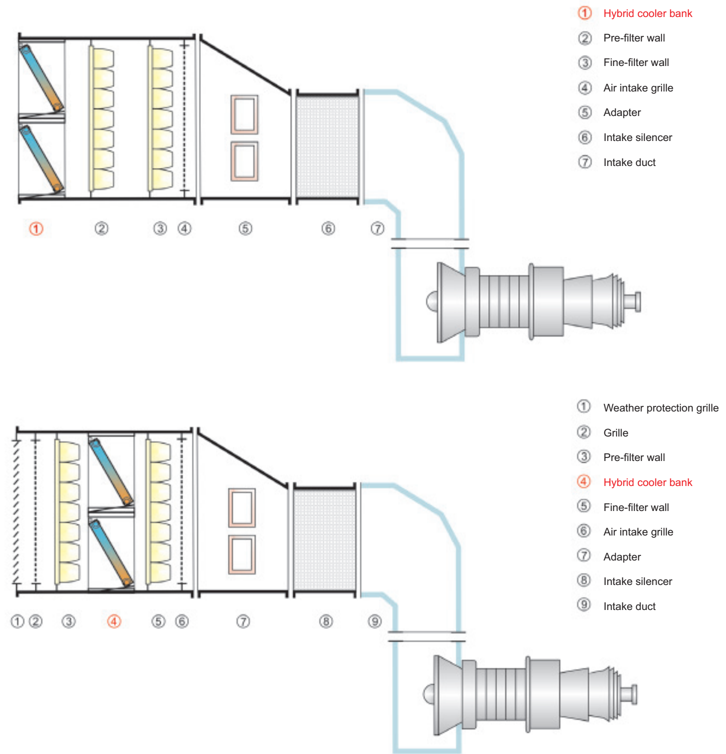



Figure 4: Options for arrangement of hybrid cooler elements in the intake tract of a gas turbine

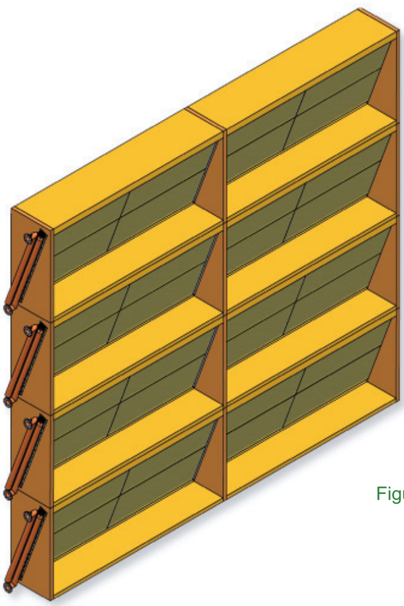


Figure 5: Hybrid cooler bank comprising four hybrid cooler elements arranged one above the other

## Fuel preheating

Fuel preheating with the (waste) water of the gas turbine is practical if the fuel itself has adequately low temperatures. This will be the case with natural gas that is taken from a pipeline at high pressure and that cools down substantially when relieved to combustion pressure as the result of the Joule-Thomson effect.

If the combustion gas pressure in the pipeline does not suffice for gas turbine operation and if the natural gas consequently needs to be compressed specifically for this, this causes the gas temperature to increase to such an extent that, in most cases, it is no longer suitable for the purpose of recooling.

Cold combustion gas can be used with the new method also for indirect cooling of the intake air via the intermediate cooling circuit in the hybrid coolers. Fresh water for replenishment of boiler and cooling circuit, also required in the process, may serve as another source of low temperature.

The use of double-tube safety heat exchangers for fuel preheating means that there is absolute certainty that the fuel is unable to enter the intermediate cooling circuit in the event of any fuel leakage. Any fuel leakage is signalled by a fail-safe leakage switch. Double-tube safety heat exchangers require no maintenance and can also be operated for a limited period after any leakage event owing to the pressure-resistant design of the two double-tube chambers.

# The benefits of hybrid combustion air conditioning

## Benefits

Process-engineering coupling of recooling for secondary processes, fuel preheating and combustion air conditioning result in very interesting options for gas turbine construction overall:

- Extremely effective **recooling of the generator, the lube oil and other (waste) heat sources** without additional demand for fan power or secondary water, universally at any outside air condition; no need for the conventional recooling unit.

- Boosting output and efficiency of the gas turbine for long parts of the year thanks to **combustion air humidification** to approx. 90 % required humidity - other humidification method cannot be controlled in this way. This means that combustion air humidification can also be used in moderate climatic zones and achieves operating times of over 5000 hours per annum. The use of fully demineralised water alone pro-duces additional electrical power in this case („water to electricity!“).

- Boosting output and efficiency of the gas turbine in the case of **anti-icing** thanks to the use of (waste) heat.

- Boosting the efficiency of gas and steam system in **part-load operation**, resulting from artificial combustion air preheating with (waste) heat. This makes part-load operation of gas and steam system efficient.

- **Prefiltering of the intake air** in the hybrid cooler in the case of prehumidification - this greatly prolongs the service life of the downstream air filter elements.

- **Reduction in installation space** required by gas turbine installation owing to the fact that there is no recooler in the secondary cooling circuit.

- **Fuel saving** thanks to fuel preheating with (waste) heat - an additional fuel saving of approx. 0.1 % per 20 K gas preheating, no need for the conventional heating boiler installation.

- Use of the fuel for **indirect intake air cooling** - the natural low temperature of natural gas is the cheapest refrigeration energy available.

- **Reduction in $NO_x$ emissions** midification.

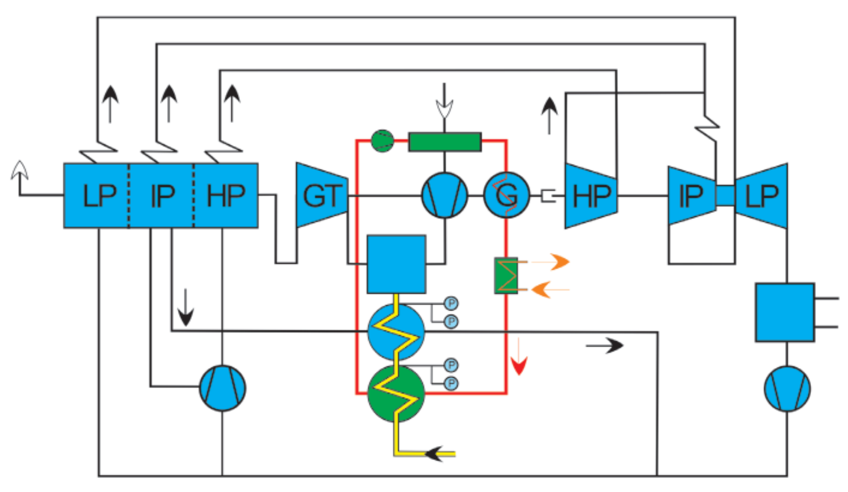



Figure 6: Integration of a hybrid combustion air conditioning system in a gas and steam process

Return-on-investment times of around 1.7 years have been determined in economic feasibility studies for retrofitting a combustion air conditioning system on existing gas turbine installations. In the case of new installations, savings are even possible with the investment by comparison with conventional solutions. We must also consider the substantial benefits achieved when operating the installation.

The new method of combustion air conditioning thus represents an important advance in the sector of gas turbine construction. The use of tried-and-tested standard elements means that there are no obstacles to widespread application.

An industrial property right application has been filed for the method of hybrid combustion air conditioning. It is offered exclusively by the Thermo Integral company.

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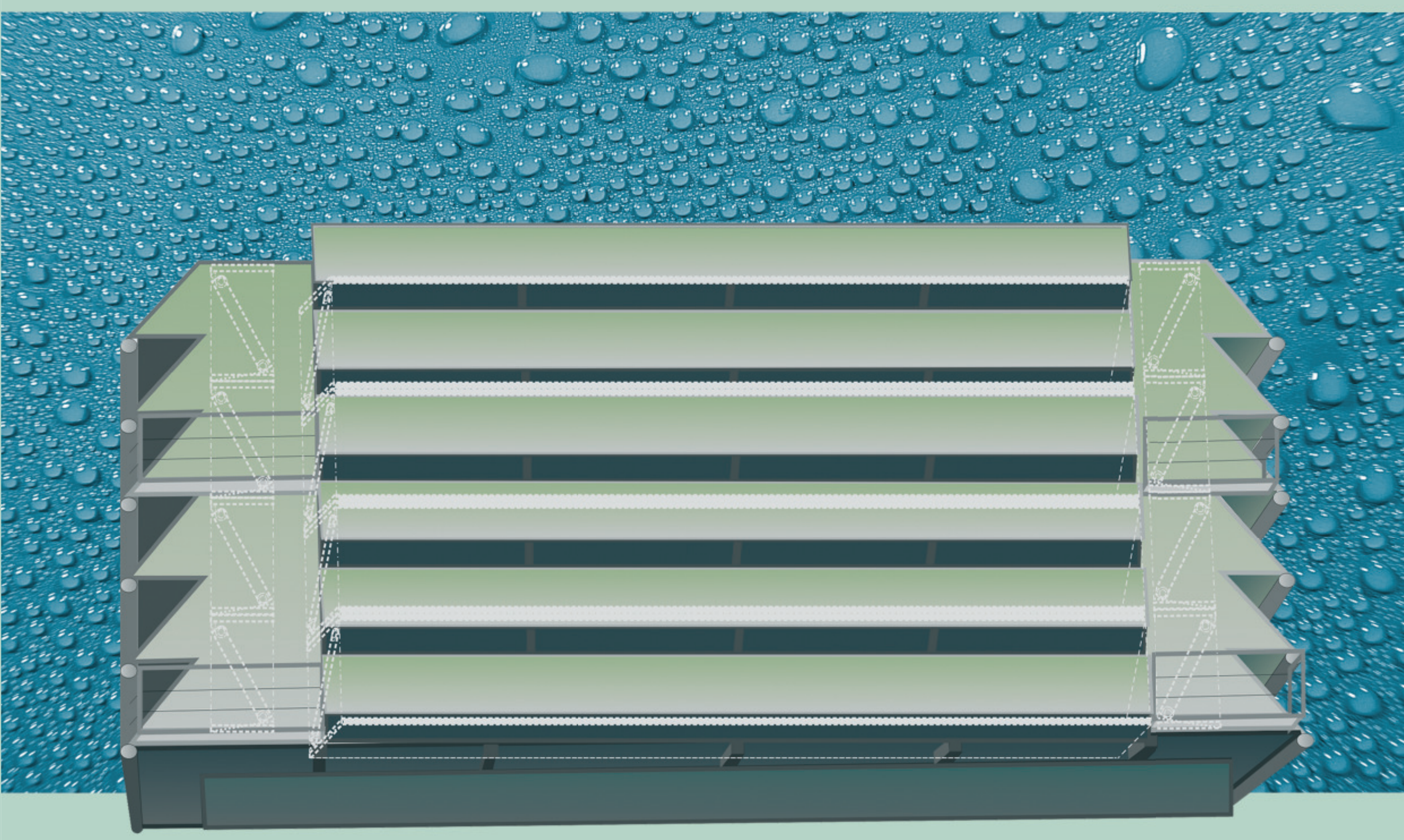

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