SwirlFlash® Gas turbine power augmentation and NOx reduction

Stork Thermeq

The Power of Water

The SwirlFlash® technology: More power, less pollution!

SwirlFlash technology is the state of the art water injection technology for gasturbine power augmentation and NOx reduction.

SwirlFlash® uses hot pressurised water to obtain a power increase of up to 15% in the output of a gas turbine and to obtain a NOx reduction of up to 45%.

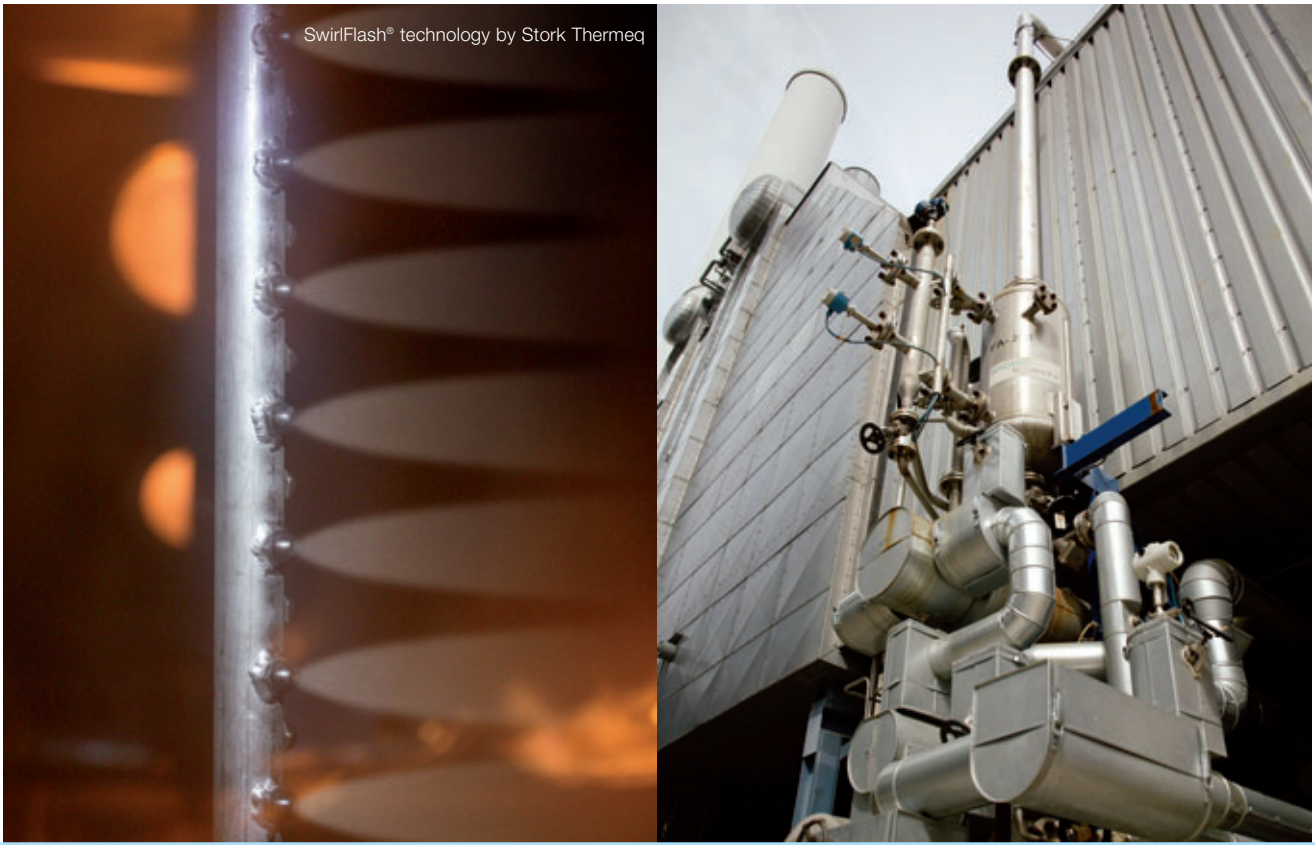
SwirlFlash®, the safe and reliable principle

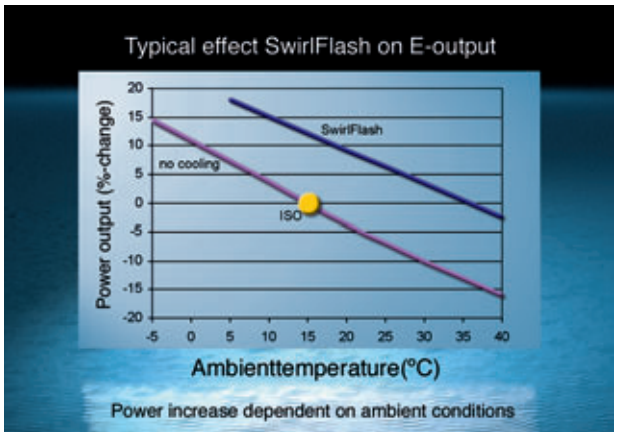
As SwirlFlash® technology uses hot water the water droplet size is considerably less then that possible with the conventional cold water systems with typical water-droplet size of 25 micron. Using SwirlFlash®, water droplet sizes are below 5 micron and thus behave like aerosols. With SwirlFlash® in operation, humidified combustion air enters the combustion chamber at a lower temperature thus reducing flame temperature as well as lower thermal NOx production.

Compressor improvement = GT improvement

Gas Turbines consist essentially of a power turbine, a combustor and a compressor. The power turbine drives the compressor which is required to supply the large volume of pressurized air for the combustion and power producing process. In modern gas turbines, more than 60% of the power produced by the power turbine is consumed by the compressor. Only 35 to 40% of the power turbines power production is available for driving a generator or other external load. The improvement of gas turbine performance as a result of the improvement of air compressor performance is therefore a logical, technological challenge for designers and operators alike.

The patented SwirlFlash® technology offers the simplest, most robust and most powerful solution available to this challenge.


SwirlFlash® technology by Stork Thermeq

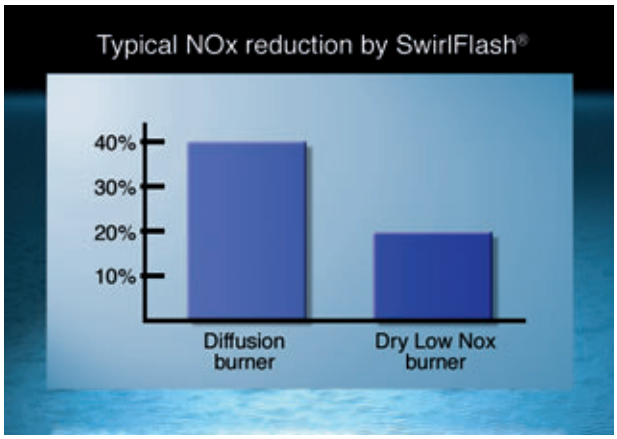


Cooling by heating?

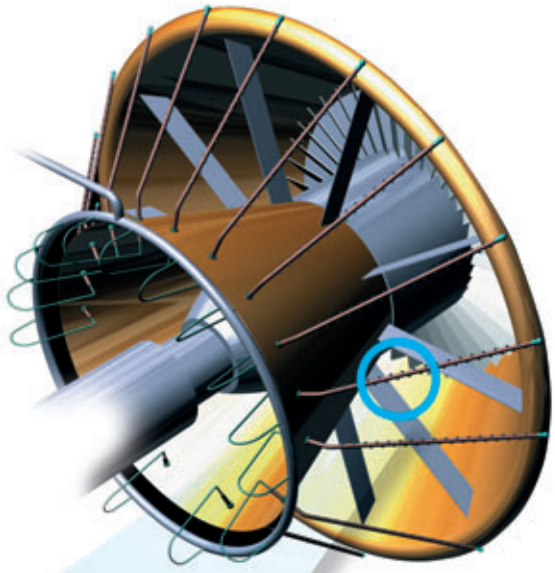
The idea of cooling air by adding hot water sounds strange. But the amount of heat extracted from the compressed air by means of evaporation is far greater than the amount of heat added by utilising the hot water spray. The result is a drop in compressed air temperature and a corresponding drop in compressor discharge temperature.

NOx emission

Today large numbers of gas turbines are originally equipped or retrofitted with steam or water injection in the combustors. This reduces the NOx emission significantly



and increases power output only due to increased mass flow. Steam injection is expensive since steam is valuable. Water injection is cheaper, but this results in lower turbine efficiency and can cause expensive repairs due to cracking of the hot components. Employing SwirlFlash® allows for NOx reduction at much lower costs with substantial increased power output.

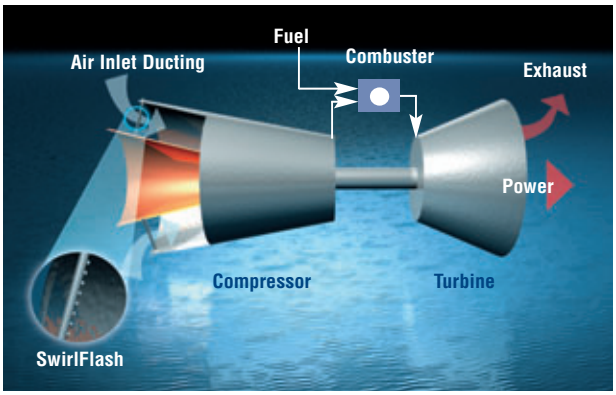


SwirlFlash® technology

The flame stability is not affected by introducing humidified air in the combustor, not even for a dry low-NOx combustor. The NOx-reduction for a conventional diffusion burner can be more than 40%, for a dry low-NOx burner it is typically 20 to 25%.

The ambient conditions of temperature and humidity

SwirlFlash® technology performs very favourably in varying ambient conditions. Classical inlet air chillers require high investments and operate effectively at high ambient temperatures and low relative humidity. The cold water



over-spray injection systems require ambient temperatures above 10°C in order to avoid ice formation in areas of compressor inlet ducting with high air velocities. The SwirlFlash® system, how-ever, is applicable over a much wider range of temperature conditions from 5°C upwards and at relative humidities up to 100%.

Flexibility

Flexibility is an increasingly important asset for power generators. The introduction of power exchanges and price volatility in a liberalised electricity market increase the need for flexibility of the power plants. The SwirlFlash® technology creates an extra degree of freedom in the operation of the facility. The power increase of about 10% is available instantaneously so providing the operator with new capabilities to meet the demands for power markets and from individual customers.

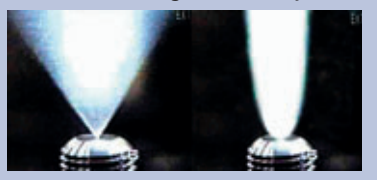
Why SwirlFlash®?

SwirlFlash® is superior to any other nozzle design in creating small droplets. Where swirl or impact nozzles can reach an average droplet size of 25 µm, the SwirlFlash® nozzle creates droplets with an average size of 3 µm. This means that the mass of a SwirlFlash® droplet is almost 1000 times smaller than a droplet of a non-flashing nozzle.

This results in the energy being released on impact to be reduced by the same factor. Also because of the small size, the droplets become aerosol, making it possible for the droplet to enter several compressor stages without impacting on the blades.

The SwirlFlash® principle was accidentally discovered during research on steam spray cooling systems. When the spray water temperature was raised above a certain temperature, the shape of the spray changed dramatically. The pictures below show the effect of raising the temperature (right picture) compared to a cold flow (left picture).

The effect can be explained by the fact that flashing occurs in the droplets as they leave the nozzle and the pressure is reduced. The steam generated by flashing causes the droplets to "explode". This results in a radial velocity of part of the droplets, causing the base of the spray pattern to be wider. Further down stream the sprayer, the spray bundle is smaller. This is caused by the fact that the very small droplets rapidly lose their relative velocity to the air flow.



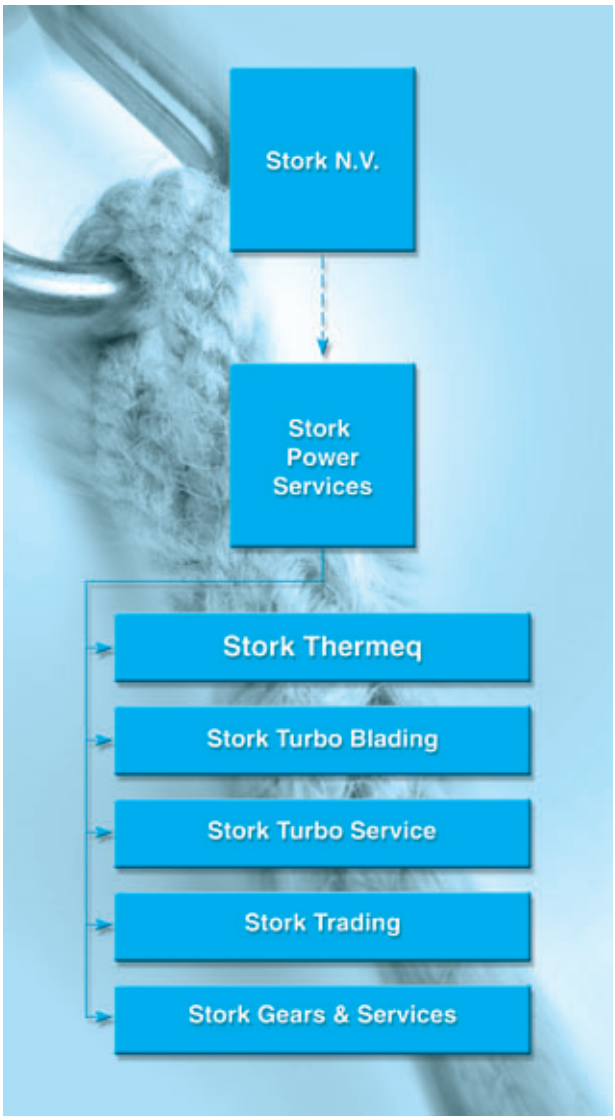
The normal operating condition for the SwirlFlash® system is a pressure of 130 bar and a temperature of 180 °C.

Main features	SwirlFlash	Wet compression (cold water)	Evaporative cooling	Chilling
Power increase	10 to 15%	10 to 15%	5 to 10%	15 to 20%
Use at high humidity	Excellent	Excellent	Poor	Good
Use at low temperature	Excellent	Poor	Neutral	Neutral
Risk of blade erosion	Low	High	Low	None
NOx emission reduction	High	High	Medium	Minor effect
Additional kWh/year	High	Medium	Low	Medium / high
Complexity	Medium	Medium / low	Low	High
Investment (%)	100	70	50 to 70	500 to 800

Features & Advantages

- Increased power output by 10-15% instantaneously.
- NOx reduction of more than 40% at diffusion burners
- Improved efficiency by 1-2% in simple cycle mode.
- No efficiency degradation in combined cycle service.
- Highly attractive costs per additional kW.
- Applicable in moderate climate and in colder seasons too, meaning more operating hours compared to competing systems.
- Simple robust technology based on thermodynamics rather than complex components.
- No moving parts in water injection nozzles.
- Integration in existing water-steam cycles give extra room for optimization.
- Applicable on any gas turbine.
- No mechanical or functional changes in compressor behaviour.
- Short outage time of gas turbine necessary for installation.

The Stork Network



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