Aspects of the GT inlet system that affect GT efficiency, including a focus on the correct application of power augmentation

ETN Global

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IGTC
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Gas Turbine Conference
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GT Efficiency - A Focus on the Air Inlet System

TODAY'S GOALS

- Reduce emissions
- Improve fuel consumption
- Increase available output
- Improve availability

→ ***Improved GT Efficiency***

GT EFFICIENCY LOSSES DUE TO INLET AIR

GT Efficiency

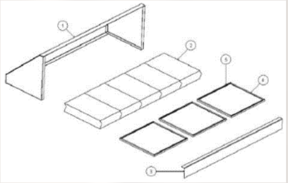
- GT Fouling – ***Minimise ingested contaminant***
- GT Corrosion – ***Minimise ingested corrosives***
- Pressure loss – ***Maintain low DP***
- Changes in air density – ***Control air temperature***

GT Fouling

Contaminants

- Solids → Media filters inc. HEPA →

- Liquids → Water removal stages and hydrophobic filters

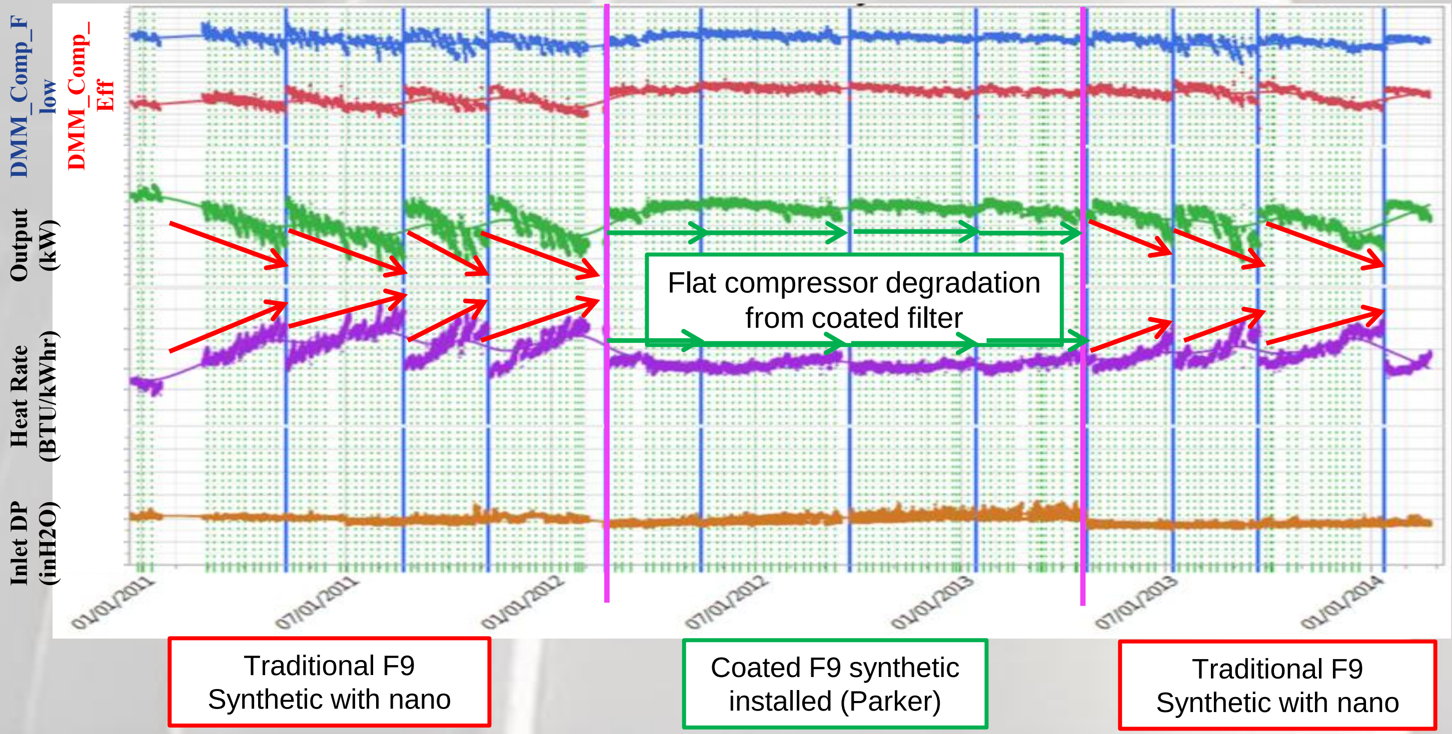


- Gases / Vapour → No filtration system

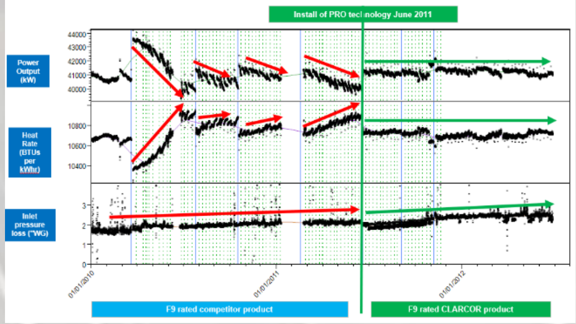
Two ways to reduce compressor fouling

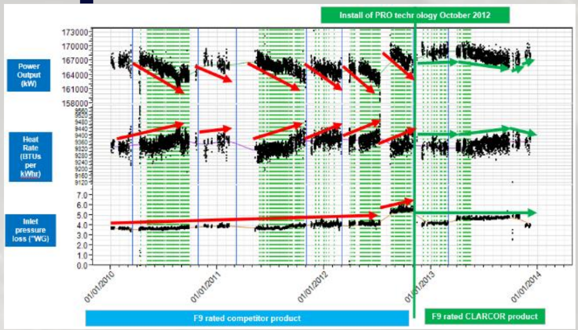
1. Install higher efficiency filters such as EPA / HEPA / E10-H12 – *Well documented*
2. Stop contaminants from sticking to the compressor blades
   - Sticky contaminants such as, salts and hydrocarbons etc. are much more likely to cause fouling by making the blades sticky which then enable them to foul with dry inert particulate.
   - Use of hydrophobic and advanced fibre coated filters can significantly reduce sticky contaminants getting to the GT even with same dust efficiency rating

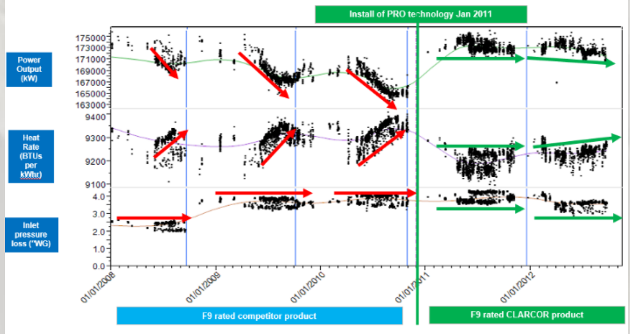
EXAMPLE FILED EXPERIENCE (GT RUNNING DATA)

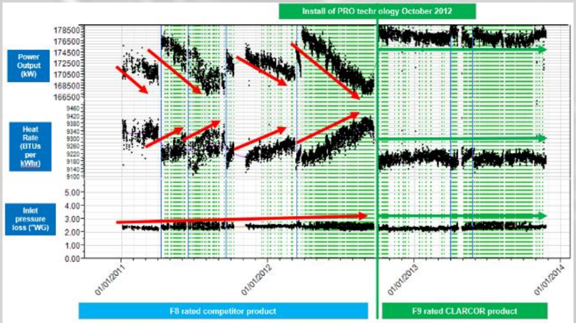


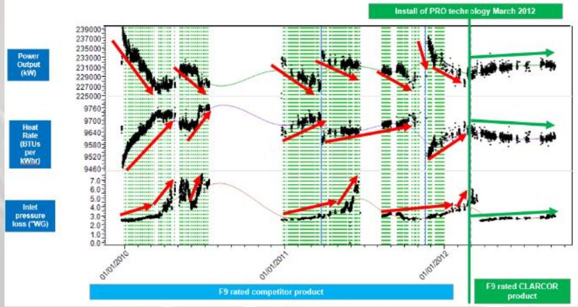
Many similar examples

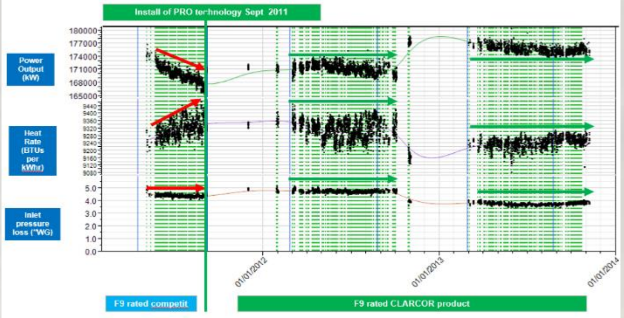


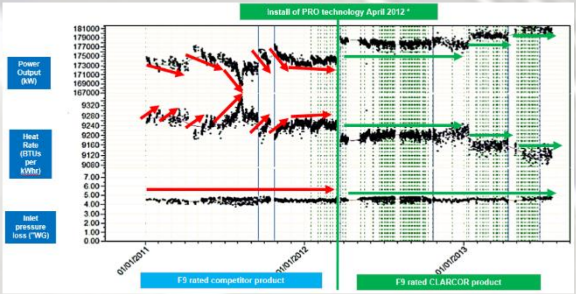


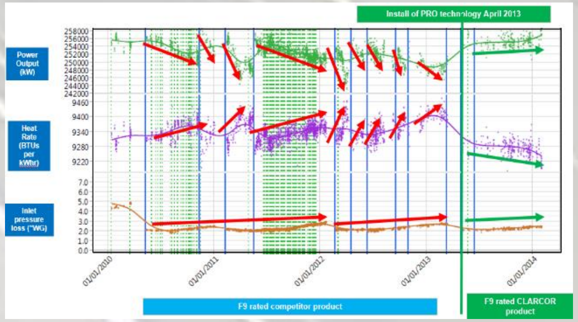


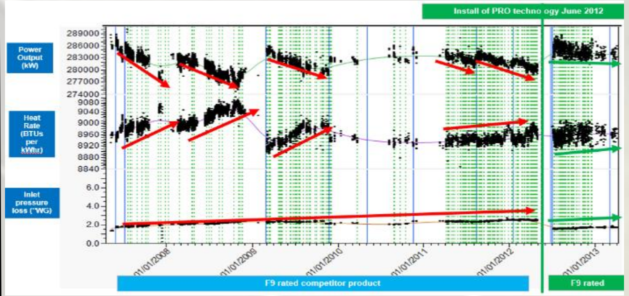






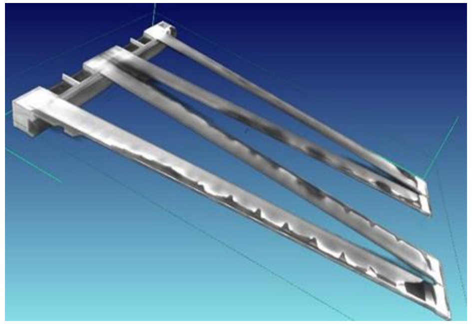


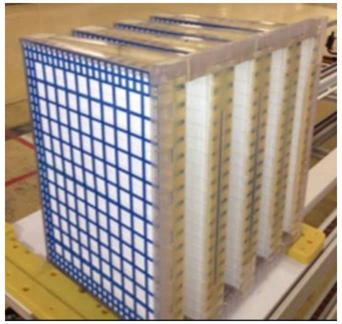


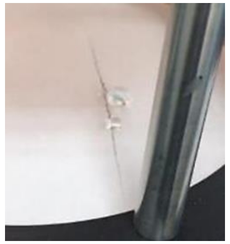


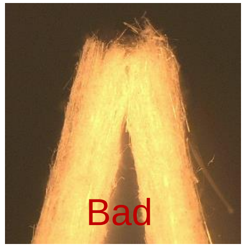
Good hydrophobic properties are not just about the filter media

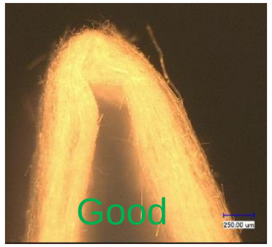
Filter potting adhesive flow optimised to eliminate possible leak paths and ensure 100% media pack to filter frame sealing.

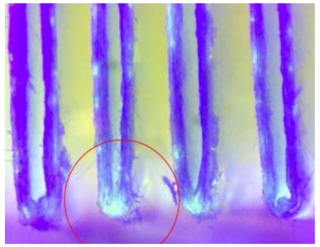






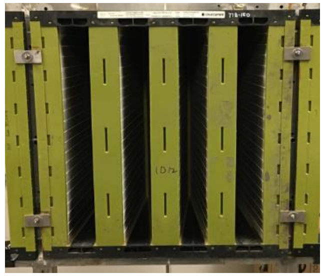






Optimised pleat settings and tooling to minimise media damage at pleat tips and maintain hydrophobic properties.

Vertical pleats with channels and other drainage enhancements.



		TF18-150		TF18-168A			TF19-0011			TF19-0012			Avg gasket compression		
ID	Posn	85mm	65mm	85mm	65mm	10mm	85mm	65mm	10mm	85mm	65mm	10mm	85mm	65mm	10mm
BL	1	23.45	22.90	23.05	23.07	22.7	23.50	23.0	23.0	23.15	22.93	22.9	5.71	6.02	6.12
LEFT	2	25.40	25.73	25.25	25.70	26.7	25.05	25.5	26.4	25.15	25.50	26.3	3.79	3.40	2.54
TL	3	23.20	22.83	23.05	22.93	23.3	23.30	23.0	23.1	23.30	23.00	23.0	5.79	6.05	5.88
TOP	4	27.00	26.90	26.70	26.60	26.6	26.30	25.9	26.4	26.60	26.50	26.5	2.35	2.53	2.49
TR	5	22.95	22.97	23.15	22.93	23.3	23.45	23.1	23.0	23.10	23.17	23.1	5.84	5.97	5.86
RIGHT	6	25.95	25.97	25.35	25.53	26.7	24.70	25.0	26.3	24.55	25.07	26.3	3.86	3.61	2.56
BR	7	23.45	23.00	23.15	23.00	23.1	23.00	23.0	22.9	23.15	23.00	23.0	5.81	6.01	6.00
BOTTOM	8	27.35	27.13	27.40	27.00	26.9	26.70	25.9	26.7	27.25	27.30	27.1	1.83	2.17	2.10

Clamping design optimisation to ensure good seal around entire filter gasket.

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GT Corrosion

Corrosives

Dry Salt → **Media filters inc. HEPA** →

RH > 65 %
Rain, fog

Liquid Corrosive → **Hydrophobic filters**

Rain, fog, humidity

Gases / Vapour → **No filtration system**

Prevention of liquid passing through the inlet system using **hydrophobic filters** is key to preventing GT corrosion

Similar to a filter getting clogged with dust, hydrophobic properties wear off over time as the media fibres get coated with contaminants.

Filters should be changed on a regular basis to remain effective

Moisture Control

Leads to wet filters → DP spikes → Contaminate washed through → Degradation → Unscheduled outage

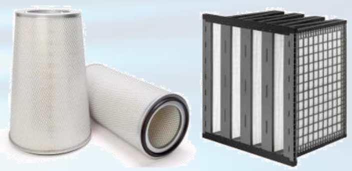
DROP SIZE RANGE (MICRONS) MEDIAN VOLUME	COMPARATIVE SUBJECT IN DROP SIZE	TIME FOR DROP TO FALL 3 meters (SECONDS)
5000 To 2000	Heavy Rain	0.85 0.9
2000 To 1000	Intense Rain	0.9 1.1
1000 To 500	Moderate Rain	1.1 1.6
500 To 100	Light Rain	1.6 11
100 To 50	Misty Rain	11 40
50 To 10	Wet Fog	40 1020
10 To 2.0	Dry Fog	1020 25400
1.0 To .01	Dust	"
.01 To .001	Smoke	"
Below .001	Molecular Dinemsions	

Weather hoods

Moisture Eliminators

Coalescers

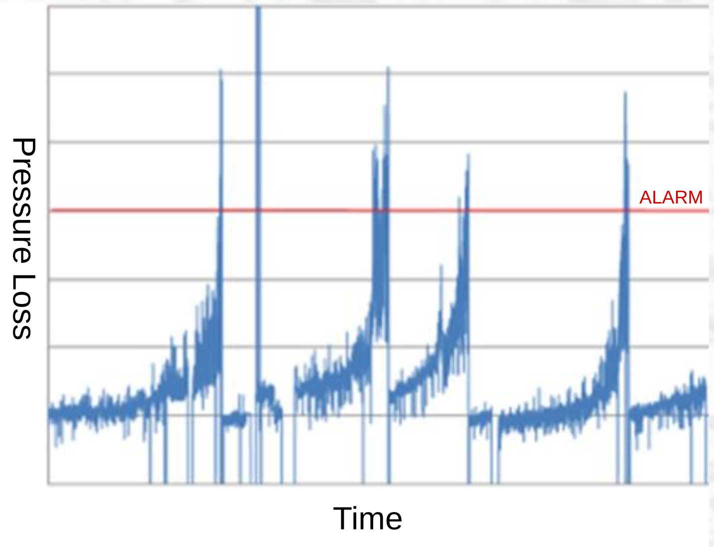
Dry, not droplets, removed by filters

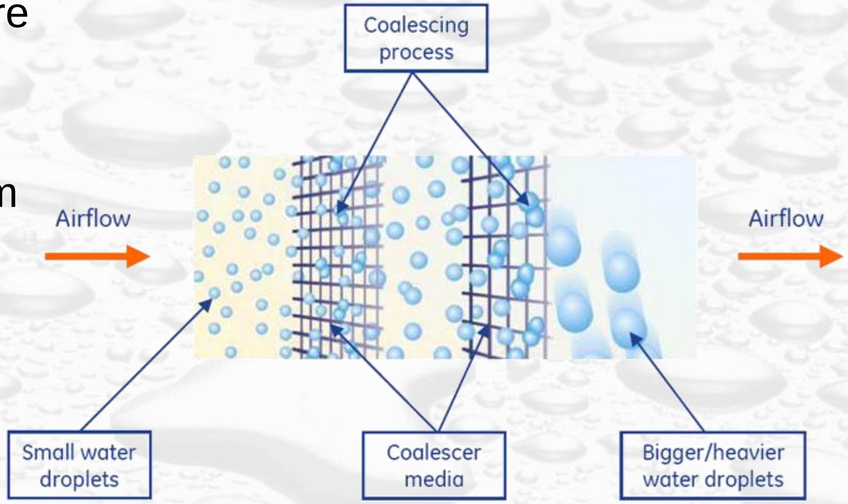


Vane separators

Mist and Fog

- In general moisture combines with dirt on filters, which swells increasing pressure loss and maybe blocking the filter.
- In high humidity when drops cannot evaporate, tiny mist and fog droplets act just like fine particulate and are filtered and block media pores.
- Higher efficiency filters such as EPA / HEPA are more sensitive to mist and fog as are more efficient at removing contaminants of this size.
- Need to prevent tiny mist and fog droplets from reaching high efficiency filter.
- **Use coalescers to change the droplets to a larger manageable size.**





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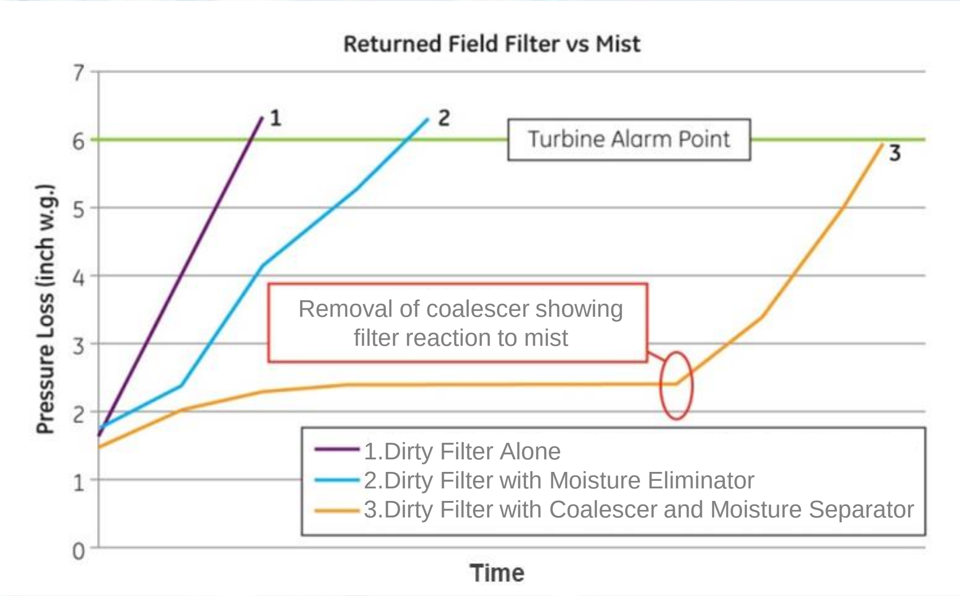
Coalescers in more detail



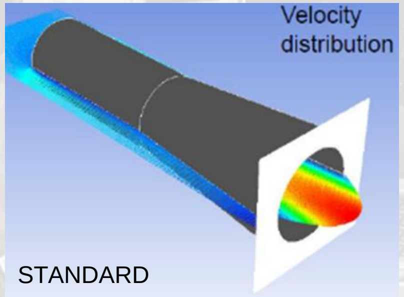

- Many different types used.
- Most still remove dust, so need regular maintaining by replacing or cleaning.
- More advanced designs are available that capture minimal dust, with extended life.
- Can be maintained with GT online.
- Some pre-filters also designed to operate effectively as a coalescer, particularly pocket filters.

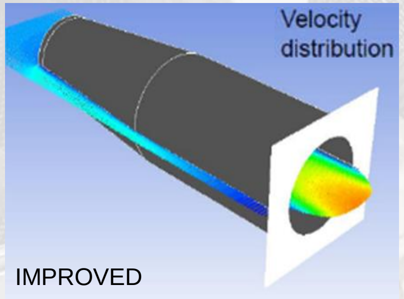


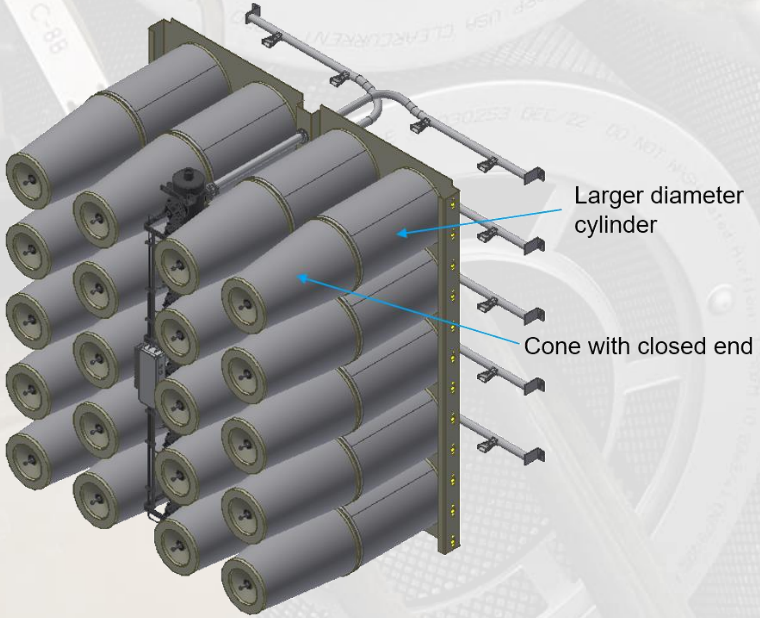
Pressure Loss

- **Expect about a 0.4% reduction in power output plus 0.1% increase in heat rate for each inch Water Gauge (250Pa) of pressure drop.**
- Aerodynamic filter design can improve pressure loss and therefore GT efficiency.

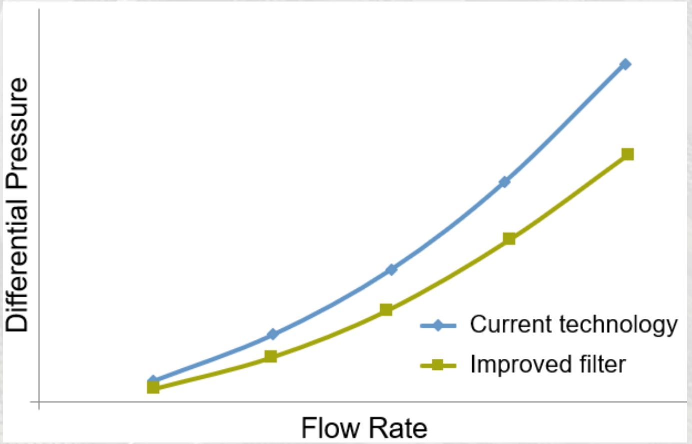
EXAMPLE





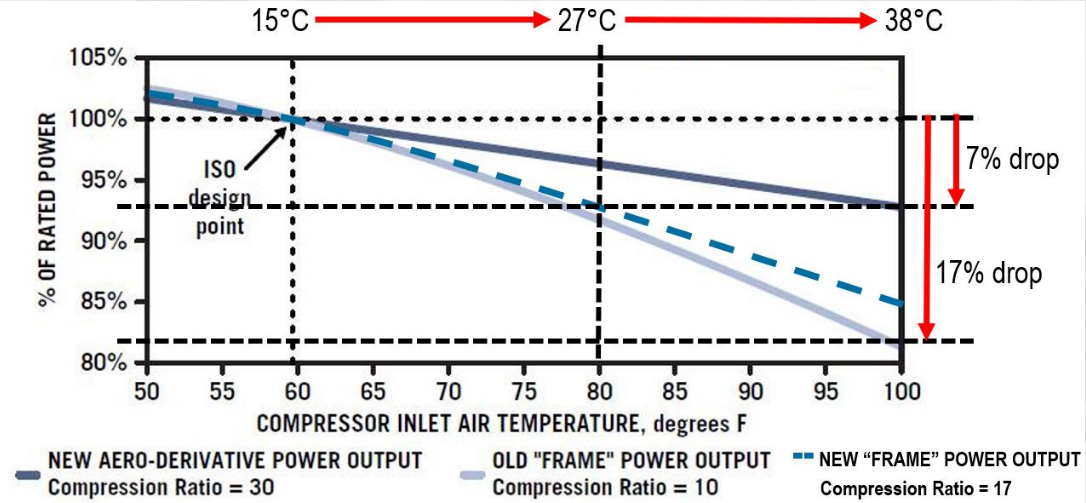


- Fits existing filter house hardware.
- Reduced differential pressure by up to 25% vs. standard.
- Extended filter life.
- Provides the ability to upgrade GT rotor using the existing filter house.
- Similar improvements can be had with static filters.



Why do we cool GT Inlets?

- Gas Turbines are mass flow machines.
- Lower air density means less mass flow to the GT which results in;
    - Decreased engine efficiency
    - Increased fuel consumption
    - Higher emissions
    - Lower engine output
- Air density entering a GT is determined by the ambient temperature and altitude. The higher the ambient air temperature or altitude, the lower the air density.
- Expect around 0.4% reduction in power output plus 0.1% increase in heat rate for each 1°F (0.55°C) rise in ambient temperature above 59°F (15°C).
- Altitude has a minimal effect on heat rate but for each 1000ft (305m) increase in site elevation above sea level, there is about a 3.5% loss in power output.
- **Gas turbine air inlet cooling increases air density by cooling the air and recovers some of these losses.**



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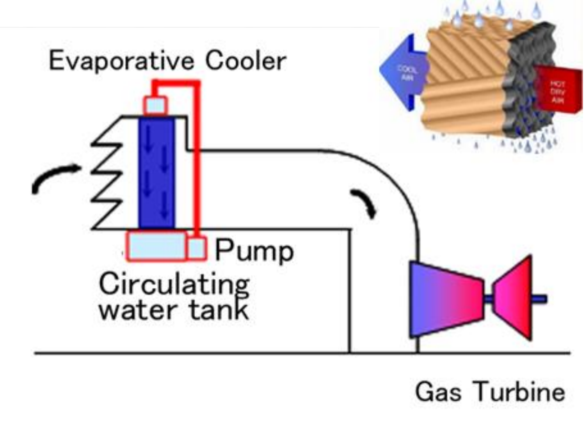
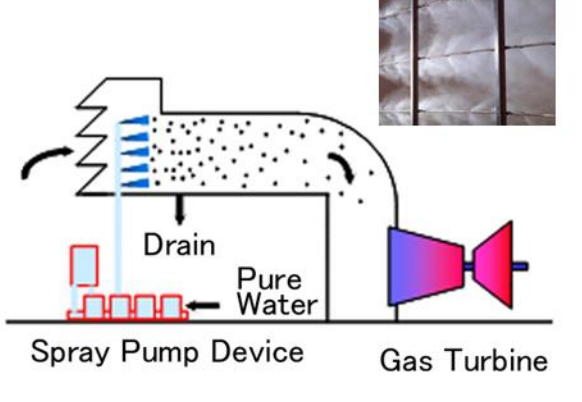
Evap cooler working principal and design



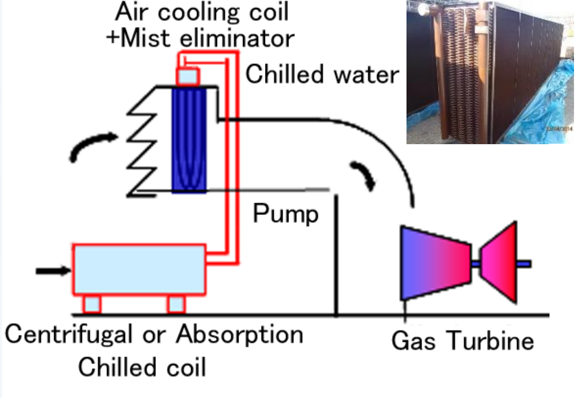
- GT inlet air passes through a bank of water-soaked evaporative cooler media. Evaporation of water contained in the media lowers the temperature of the air.
- A drift eliminator is mounted downstream to capture any free droplets that may bypass the evap media.
- A sump with pumping system is installed at the base to recirculate unused water to a spray system at the top of the evap cooler and to contain new water continually added to the system.
- Water quality is automatically controlled through draining and refilling based upon the status of a conductivity sensor.
- Disolved minerals from the supplied water will build up on the evap media overtime requiring it to be changed.
- An evap cooler should only be mounted downstream of filters to prevent them getting wet.

Fogging working principal and design



- An array of very high pressure fogging nozzles is mounted in the duct which the GT air passes through.
- A high volume very fine fog of pure water is injected downstream, which evaporates lowering the temperature of the air.
- The pure water is supplied via a water purification plant and very high pressure pumps.
- The volume of water fed to the nozzles is strictly controlled based upon readings from a locally mounted ambient humidity sensor, to minimise overspray of more water than is possible to evaporate.
- The fogging system should be mounted downstream of filters to prevent them getting wet.
- Fogging nozzles wear or get blocked which can affect droplet size and prevent full evaporation.
- Drops inevitably coalesce into larger droplets which do not fully evaporate.
- A sufficiently long duct is required downstream to provide residence time to evaporate.
- Biggest concern is compressor erosion from remaining or large droplets.

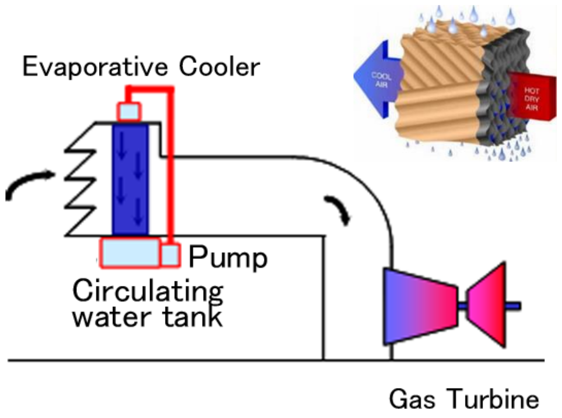
Coils working principal and design



- A finned, liquid to air heat exchanger coil is mounted directly in the GT inlet duct and supplied with cold water/glycol mix from an externally sited chilled water refrigeration plant, through insulated pipework.
- The GT air is cooled as it passes over the fins of the heat exchanger, which also condenses any water vapour present in the air.
- A vane separator is mounted downstream to capture water condensate removed from the air flow by the cooling process.
- It is possible but unusual to use the same coil for heating as well as cooling.
- Mounting of the heat exchanger is flexible and can be upstream of the filters, but fouling of the fins should then be considered.

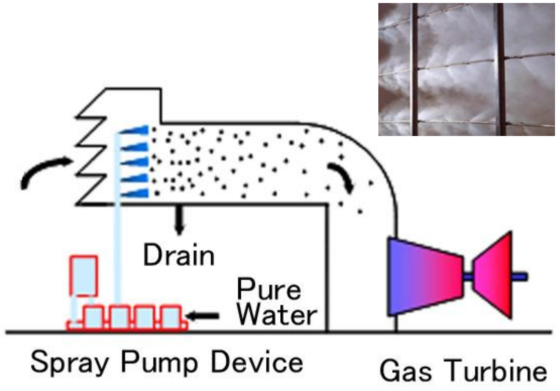
Comparison of cooling technologies

Wetted media Evap cooling



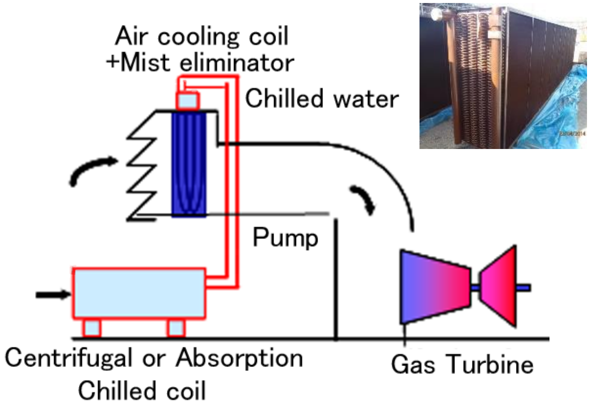
- Air temperature **cannot** be lowered below the wet-bulb temperature.
- The cooling effect is small in high humidity conditions.
- Potable water with potentially some treatment required.
- Added DP due to evap components (which can/should be removed when not in use).
- System must be drained during low ambient temperatures.
- Downtime associated with retrofitting is high.
- Most common GT cooling system.

Atomising water Evap cooling (Fogging)



- Air temperature **cannot** be lowered below the wet-bulb temperature.
- The cooling effect is small in high humidity conditions.
- Pure/RO water is required.
- Minimal DP impact.
- Limited downtime associated with retrofitting.
- Water flow rate needs to be constantly adjusted to minimise overspray.
- Compressor erosion concerns.
- System must be drained during low ambient temperatures.

Chiller coil



- Air temperature **can** be lowered below the wet bulb temperature.
- The cooling effect is independent of ambient humidity.
- Pure/RO water/glycol mix but no evaporation – closed system.
- The initial investment cost is high.
- Added DP is present all year round.
- Downtime associated with retrofitting is high.
- High parasitic load ~1/3 of power gain.

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Overall Conclusions

- The GT inlet system offers worthwhile opportunities to improve GT efficiency leading to; reduced emissions, improved fuel consumption, increased available output and improved availability.
- Increasing filter particulate efficiency is valuable, but other changes can lead to improvements.
- A filter's hydrophobic properties play an important role in keeping the GT compressor clean and are critical in reducing GT corrosion.
- The appropriate removal of moisture in all forms is vital to keep operating pressure loss low and avoid unplanned outages.
- The addition of inlet air cooling can significantly improve GT efficiency, but care must be taken to the application of the most appropriate cooling technology as each has a different balance of compromises.

THANK YOU

50+ Years of GT inlet filtration

1966 Altair Ventilation Products

1986 Altair Filters International

1997 Altair Filter Co. (USA)

1999 Altair Filter Technology Ltd/Inc.

2006 General Electric

2013 Clarcor Industrial Air

2016 PARKER Hannifin

ENGIN