Combustion Turbine Inlet Cooling using Wet Compression

By Don Shepherd – Caldwell Energy Company

Sponsored by:

Turbine Inlet Cooling Association (TICA)

April 17, 2013; 1 PM (U.S. Central Time)

http://www.meetingzone.com/presenter/default.aspx?partCEC=4147918

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Introductions

Annette Dwyer

- Munters Corporation
- Chairman, TICA

Munters

Don Shepherd

Caldwell Energy Company
TICA Board Member

CALDWELL Since 1887
Water - Energy - Industrial

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Who is TICA?

- The Turbine Inlet Cooling Association (TICA) promotes the development and exchange of knowledge related to gas turbine inlet cooling
- The TICA website is one-stop source of TIC technical information, including Installation Database & Performance Calculator
- TICA is a non-profit organization.

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TICA Member Benefits

- Access to full/detailed version of TIC Installation Database
- Access to full/detailed version of the TIC Technology Performance Calculator
- GT Users get access to the TIC Forum
- Suppliers have access to information space on the TICA Website and access to booths at various electric power trade shows

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Turbine Inlet Cooling Technologies

Upcoming Webinar Schedule

- December 19, 2012: Chiller Systems
- February 13, 2013: Thermal Energy Storage
- ***April 17, 2013: Wet Compression***
- June 19, 2013: Hybrid Systems

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All Webinars start at 1 PM (U.S. Central Time)

Agenda:

- Why Cool Combustion Turbines (CT)
- How Wet Compression Works
- Components of Wet Compression systems
- Things to Consider before applying Wet Compression on CT's
- Quick Comparison to Other Cooling Technologies
- Why Apply Wet Compression on Combustion Turbines

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Unfortunate Fundamental Characteristics of All Combustion Turbine Power Plants

- During hot weather, just when power demand is at it's peak………….

1. CT Total Power output decreases up to 35% below rated capacity
   (Extent of the decrease depends on the CT design)

2. Efficiency decreases leading to increased fuel consumption (heat rate) and emissions per kWh……..up to 15% more fuel consumed
   (Extent of the decrease depends on the CT design)

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Why CT Power Output Capacity Decreases with Increase in Ambient Temperature?

- Power output of a turbine is proportional to the mass flow rate of hot gases from the combustor that enter the turbine
- Mass flow rate of combustor gases is proportional to the flow rate of the compressed air that enters the combustor
- Compressors provide compressed air and are volumetric machines, limited by the volumetric flow rate of inlet air they can pull or suck in
- As ambient temperature increases, the air density decreases. This results in a decrease of the mass air flow rate
- Reduced mass flow rate of inlet air reduces the mass flow rate of the combustor gases and hence reduced power out put of turbine

Why CT Efficiency Decreases with Increase in Ambient Temperature?

- Compressor of a CT system consumes almost two-third of the turbine's gross output
- Compressor requirement increases with increase in air temperature
- Increased power required by the compressor reduces the net electric power available from the CT system

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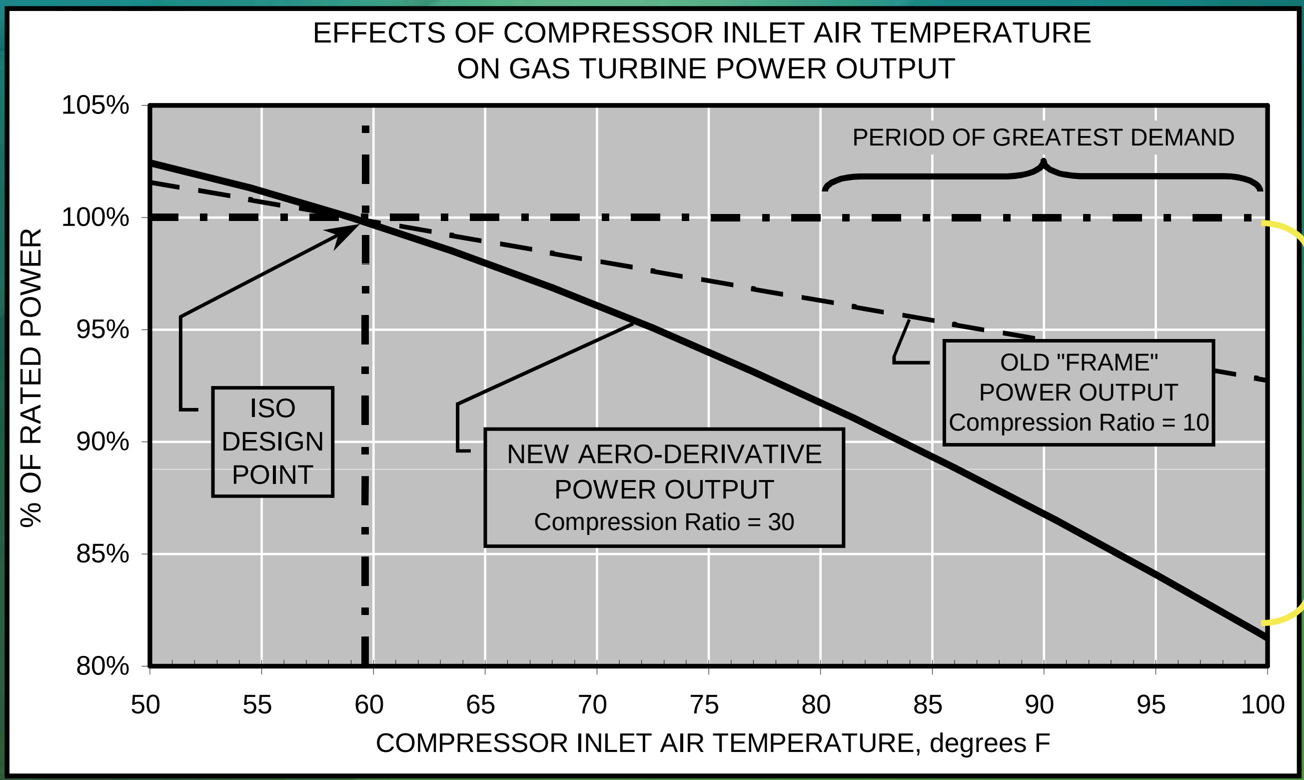
Effect of Hot Weather on CT Generation Capacity Depends on CT Design



Up to 19% capacity loss at peak demand for this CT

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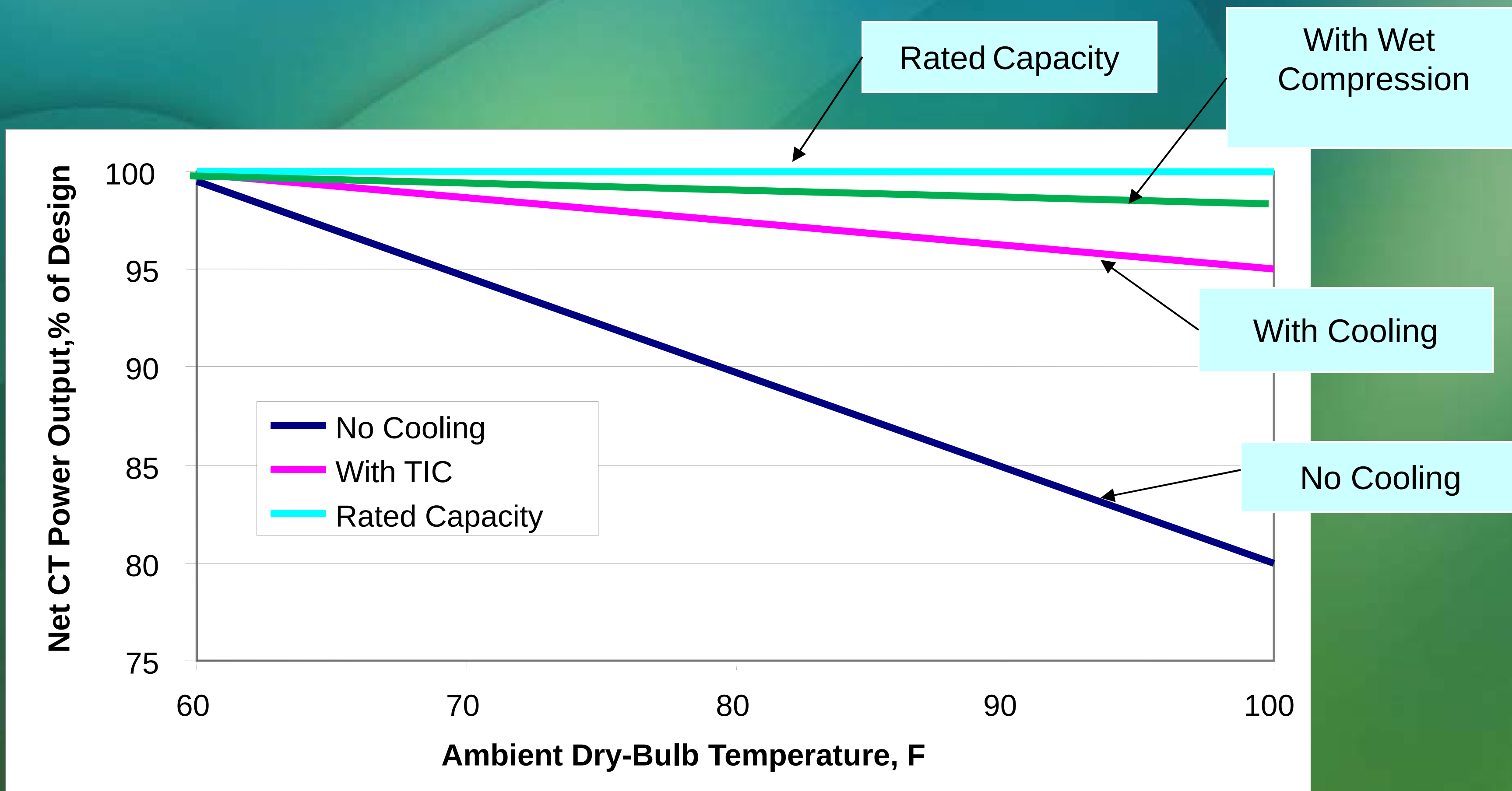
Turbine Inlet Cooling Overcomes the Effects of the CT Characteristic During Hot Weather



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Why Use Wet Compression for Turbines

- Wet Compression (WC) provides a cost-effective and energy-efficient mean to increase a CT's output during hot weather
- Wet Compression is an environmentally beneficial means to enhance power generation capacity.
- Wet Compression is complementary to all other inlet cooling technologies
- Wet Compression is highly reliable, available when needed, with very low maintenance requirements

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How it works: Four-fold effect

- COMPRESSOR EFFICIENCY DRAMATICALLY IMPROVED
  - Water Inter-cools the CT compressor
- Mass flow enhancement
- Lower CDT allows more fuel to be fired (at constant firing temperature)
- Cools air to very near WBT @ bell-mouth
  - Adiabatic Cooling of inlet air
  - Usually operated with an existing fogger, evap cooler, or chiller upstream

Overall net impact: 12-15 MW on a GE 7EA, simple cycle

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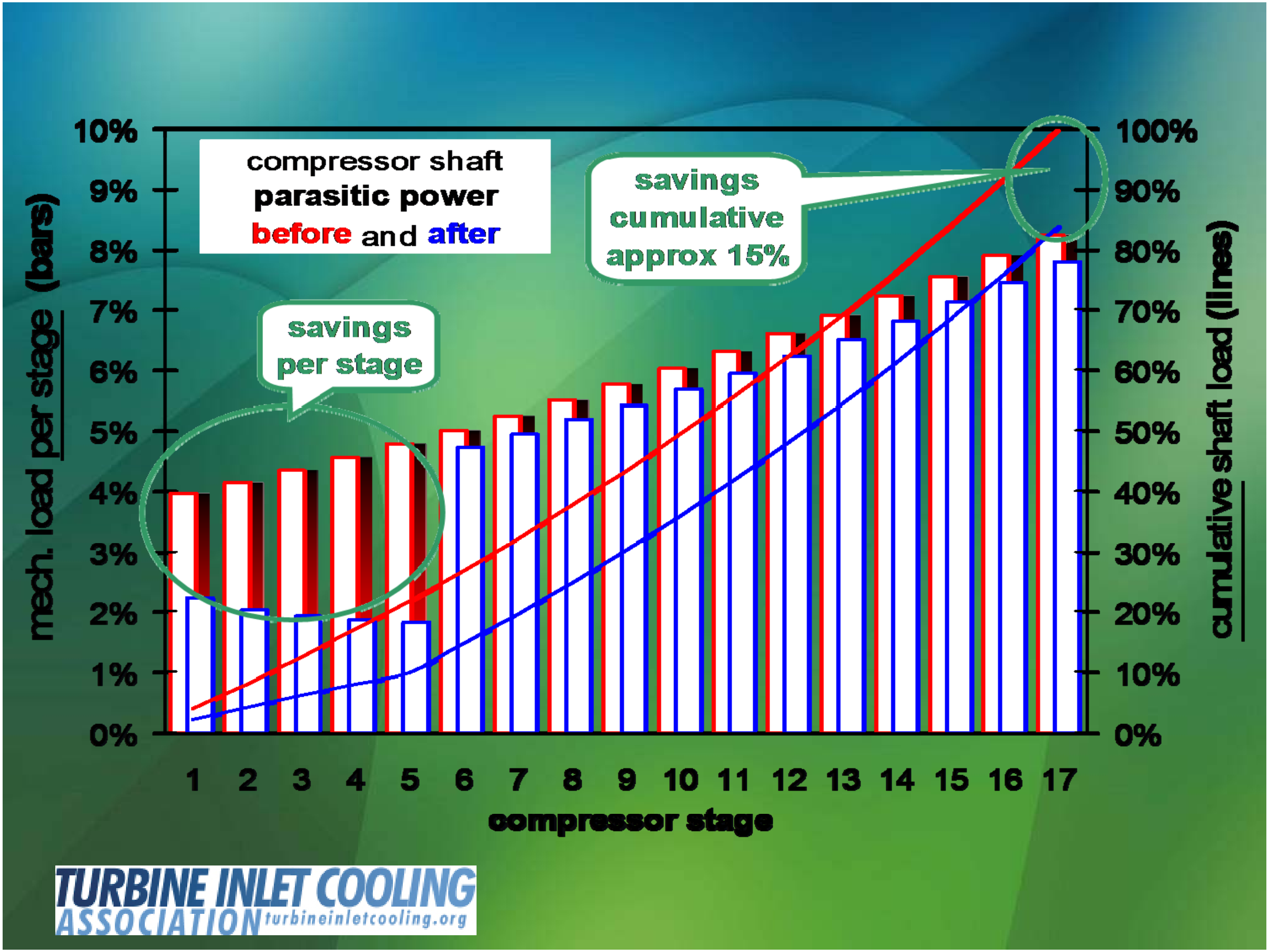

compressor shaft
parasitic power
before and after
savings
cumulative
approx 15%
savings
per stage
10%
9%
8%
7%
6%
5%
4%
3%
2%
1%
0%
mech. load per stage (bars)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
cumulative shaft load (lines)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
compressor stage
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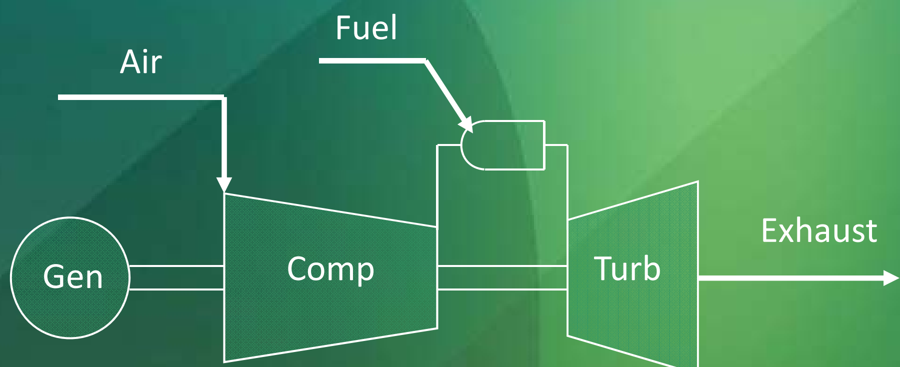
WC Performance Effects

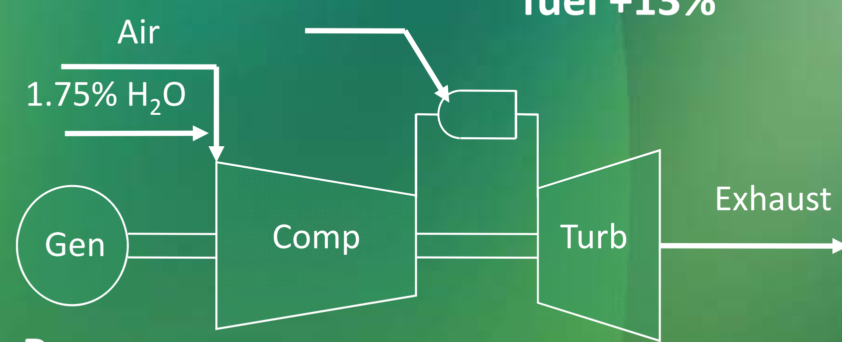
Base Case: 85% fogging @ 95 / 75°F



NOx 42 ppm

1.75% Wet Compression:

fuel +13%



Power +18%

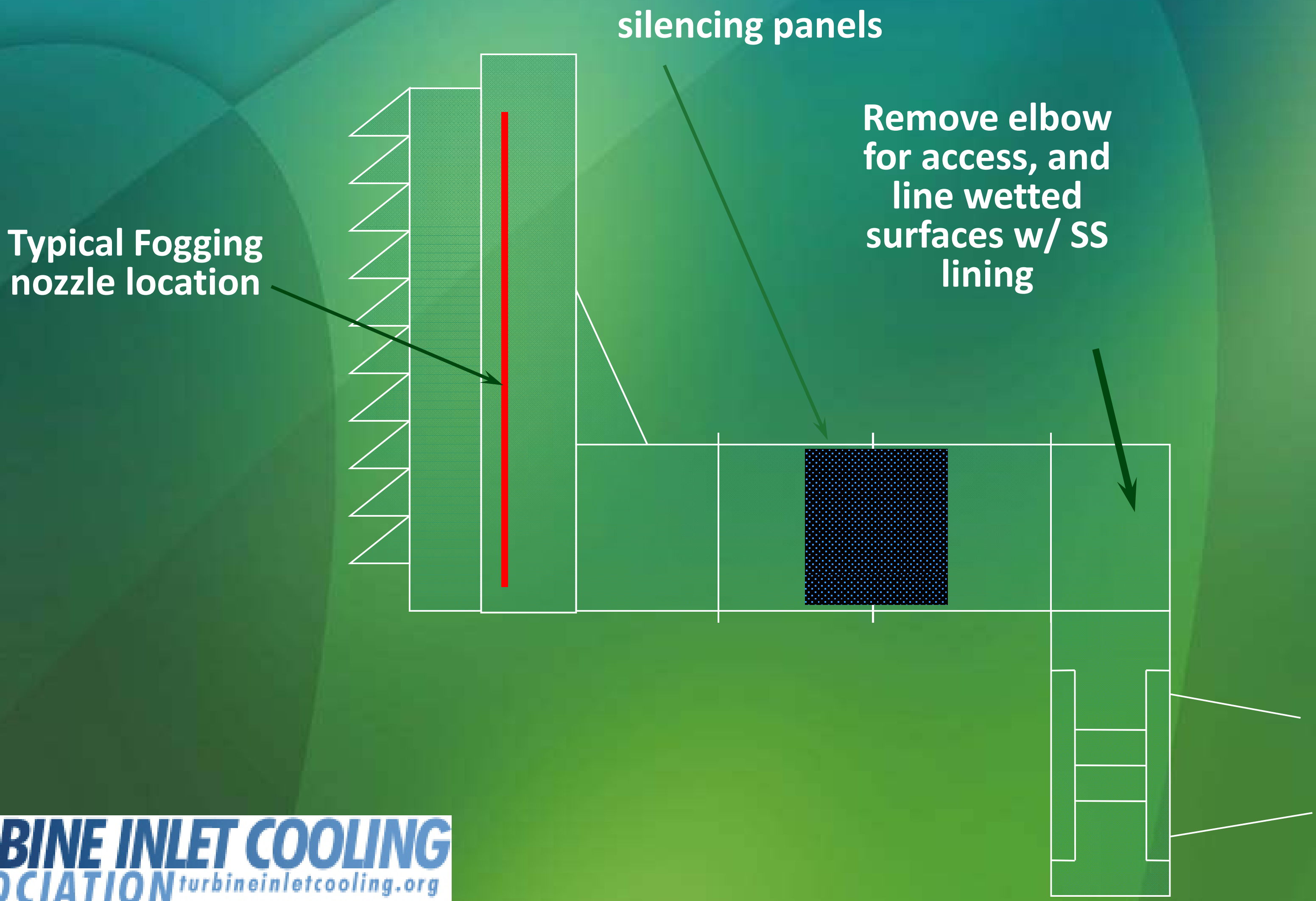
NOx 38 ppm

Flow + 2.5%

Enthalpy + 10%

Most plants will not exceed 40 tons per year of "Criteria Pollutants" (NOx, SOx, CO, UHC), therefore not triggering NSR / PSSD

Wet Compression Nozzle Location



Array Manifold 7EA

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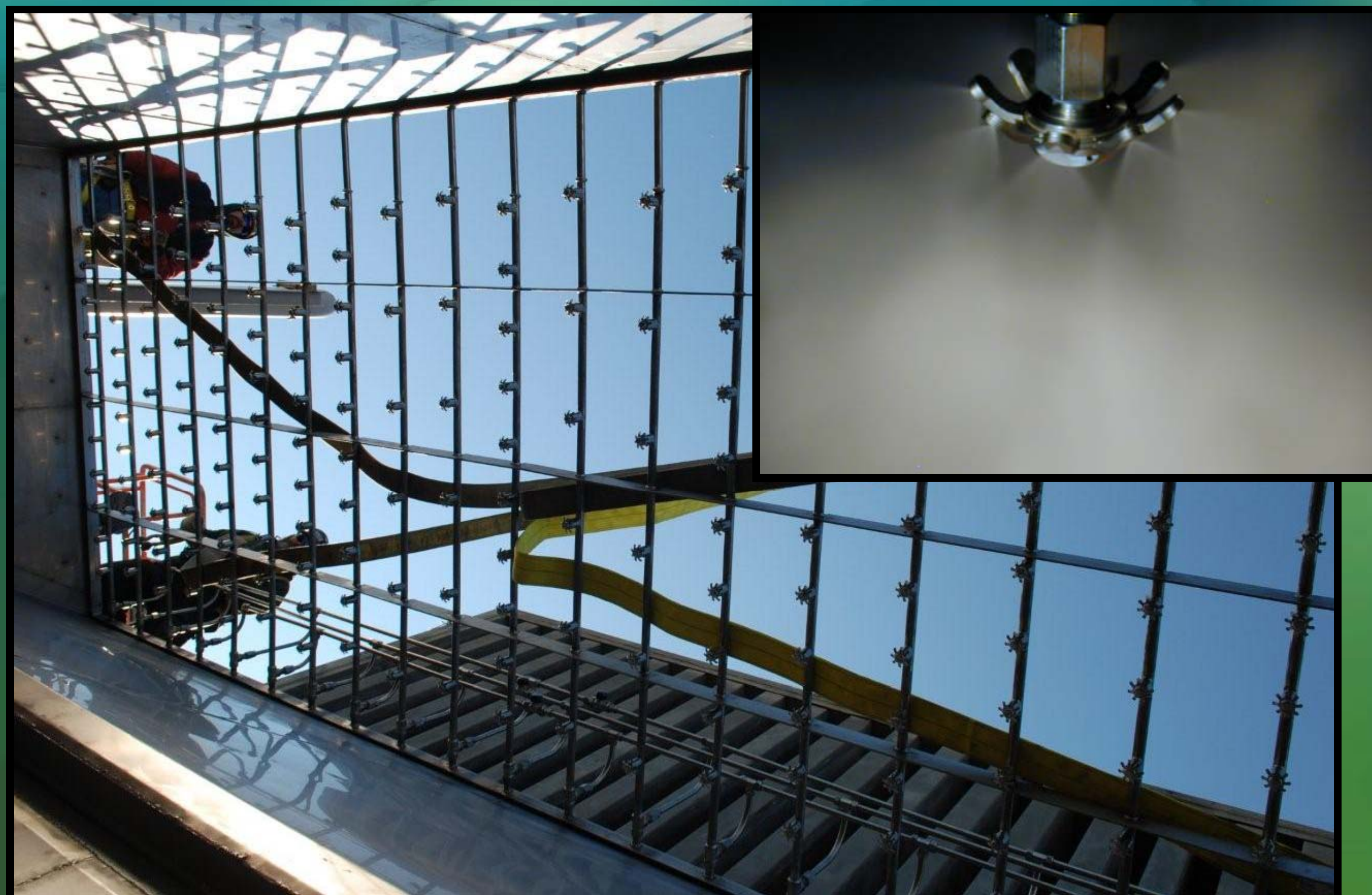
Manifold Installation



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Duct Work Treatment LM's

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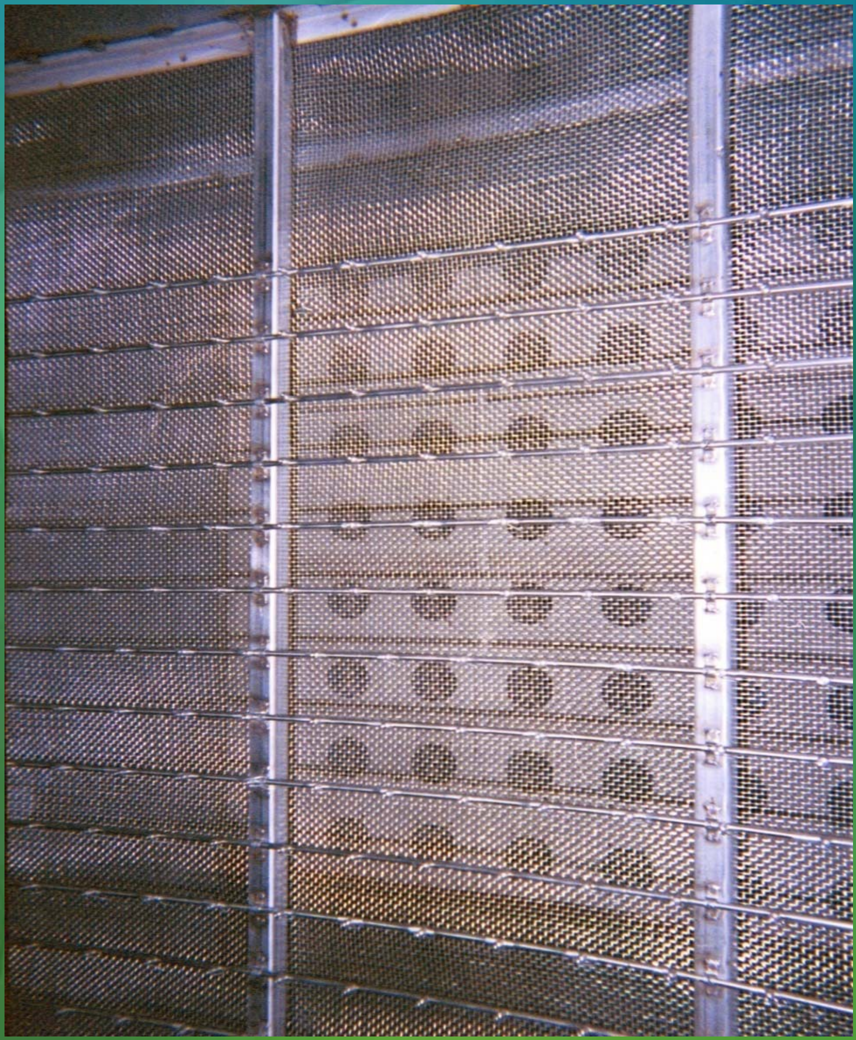
Wet Compression Arrays LM2500



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VFD Wet Compression Pump Skid

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VFD Wet Compression Skid

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Advantages With Nessie High Pressure Water Pumps PAH/PAHT 50-100/90

Axial piston pump:

- Based upon well know principle from oil hydraulics.
- Swash plate type with fixed displacement.
- Various displacements in same frame.
  - High efficiency
  - Compact design
  - 50 - 100 cc/rev
  - 68 – 145 litre/min output flow
  - 160 Bar Continuous pressure
  - AISI 316 Stainless Steel Housing

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Wet Compression Install Considerations

- Duct work condition
  - Materials of construction
  - Drain System
  - Obstructions
- Lube Oil System Capacity
- Generator Capacity

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Wet Compression Install Considerations

- Rotor Grounding
- Guide vane
- Water Source
- Control System Integration
- 18 years of patented WC experience shows no failures
- This is not “spray and pray”

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Inlet Icing

- Although power augmentation not required in cold ambient conditions, a WC system could operate down to ~41 F, without risk of bell-mouth icing.
  - Studies show maximum bell-mouth temperature drop is <9 degrees.

- Most operators use temperature-based permissive, such as 45, 50, 55, or 59 (F)
  - Caldwell provides this low-temp permissive at the time of controls commissioning.

Control System Integration

- HMI for normal system operation
  - Start-up, operation, shut down
- Emergency response
  - Hardwired CWCT Trip on CT Trip Signal
- Fuel step change to CT on CWCT Trip
- Emission control interface with injection systems or dry low NOx combustion

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How Wet Compression Compares

100 MW CT in Houston (98F/75F)

	Fog	Media	Mechanical Chilling	Wet Compression
Deg of Cooling	22 F	20 F	50 F	NA
Water Evaporated	28 GPM	25 GPM	95GPM (at Cooling Tower)	100 GPM
Blow Down	5 GPM	10 GPM	42 GPM	15 GPM
Parasitic Power Loss	45 kW	10 kW	4250 kW	150 kW
Insertion loss	0.1”wg	0.4”wg	1.2”wg	0.25 WG
Increased MW	5.2	4.8	12	14

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Table 1: Performance Comparison of Various Combustion Turbines							
Combustion Turbine	Siemens W501FC	Siemens V84.2	GE LM2500PE	GE Frame 6B	SWPC W501D5A	Alstom GT-24	GE Frame 7EA
Overspray, %	1.3	1.0	2	1	2	1.2	1.5%
Compressor Discharge Temperature Reduction, °F	90	50	Data not available	50	100	48	90
Fuel Flow Increase, %	N.D.	N.D.	4	8.2	13.2	5.5	11.5%
Change in Base Load Firing Temperature, ºF	No Change	No Change	No Change	No Change	No Change	No Change	No Change
CT Power Increase, MW	17	5.2	1.6	3.3	15	15.5	14.9
Steam Turbine Power Increase, MW	Simple Cycle	Simple Cycle	-.5	0.3 (est.)	2 (est.)	1.8(est.)	Simple Cycle
CT Heat Rate Improvement, %	N.D.	2	0	1	2	2	1.05%
NOx Info	-10%	N.D.	-14%	DLN	DLN	NoChange	-24%

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Why Use Wet Compression

- One of the most cost effective solutions
  - Lowest first install cost
  - Low operating costs
  - Low maintenance cost
  - Complementary to other cooling methods
  - 10% to 20% Increase in output
  - Better Heat Rate on Simple Cycle unit
- Simple
  - To understand
  - To maintain
- 100’s of successful installations Worldwide

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Low Maintenance

- Drain and protect from freezing – seasonally
- Clean filters once a year
- Change nozzles 4 to 5 yrs
- Replace or service pumps – 3 to 5 yrs
- Calibrate Instruments once a year

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Thank You

And Don’t Forget to Join

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