WEBINAR SERIES: Turbine Inlet Cooling Best Practices

WEBINAR #5:

Best Practices for Wet Compression

Sponsored by:

Turbine Inlet Cooling Association

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TURBINE INLET COOLING ASSOCIATION turbineinletcooling.org

Welcome & Introduction

- Webinar Series co-sponsored by
  - Turbine Inlet Cooling Association
- Industry (end users, developers, engineers, etc.) looking to optimize and improve power generation and efficiency of the turbine inlets.

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Welcome & Introduction
Agenda & Speakers

- Welcome
- Featured Topic
- Q&A

- Annette Dwyer
  - Chair, TICA
  - Munters Corporation

- Don Shepherd
  - TICA Board Member
  - Caldwell Energy Company

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Who Are We?

TURBINE INLET COOLING ASSOCIATION turbineinletcooling.org

- The Turbine Inlet Cooling Association (TICA) promotes the development and exchange of knowledge related to gas turbine inlet cooling (TIC) for enhancing power generation worldwide.
- TICA is a non-profit organization.
- Turbine Inlet Cooling provides a cost-effective, energy-efficient, and environmentally beneficial means to enhance power generation capacity and efficiency of combustion/gas turbines during hot weather.

www.turbineinletcooling.org

Who Are We?

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- The TICA website includes technical and other details including a publicly available version of the TICA database of TIC installations and other information.
- Members enjoy expanded access to technical information

Become a Member Today!!!

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Turbine Inlet Cooling Technologies

Webinar Schedule

- June 11, 2014
  - Best Practices for Wetted-Media Evaporative Cooling
- August 13, 2014
  - Best Practices for Fogging Evaporative Cooling
- October 8, 2014
  - Best Practices for Chiller Systems
- December 12, 2014
  - Best Practices for Thermal Energy Storage
- February 11, 2015
  - Best Practices for Wet Compression
- April 8, 2015
  - Best Practices for Hybrid Systems

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Webinar Procedures

- To avoid background noise, we will mute participants
- Please submit questions during the presentations by typing them into the “chat” window area of the screen
- After the featured presentation is complete, we will answer your submitted questions
- You may receive a online survey immediately following the webinar . We would appreciate your participation to:
  - Provide feedback on webinar series
  - Suggest other topics and speakers

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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

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)

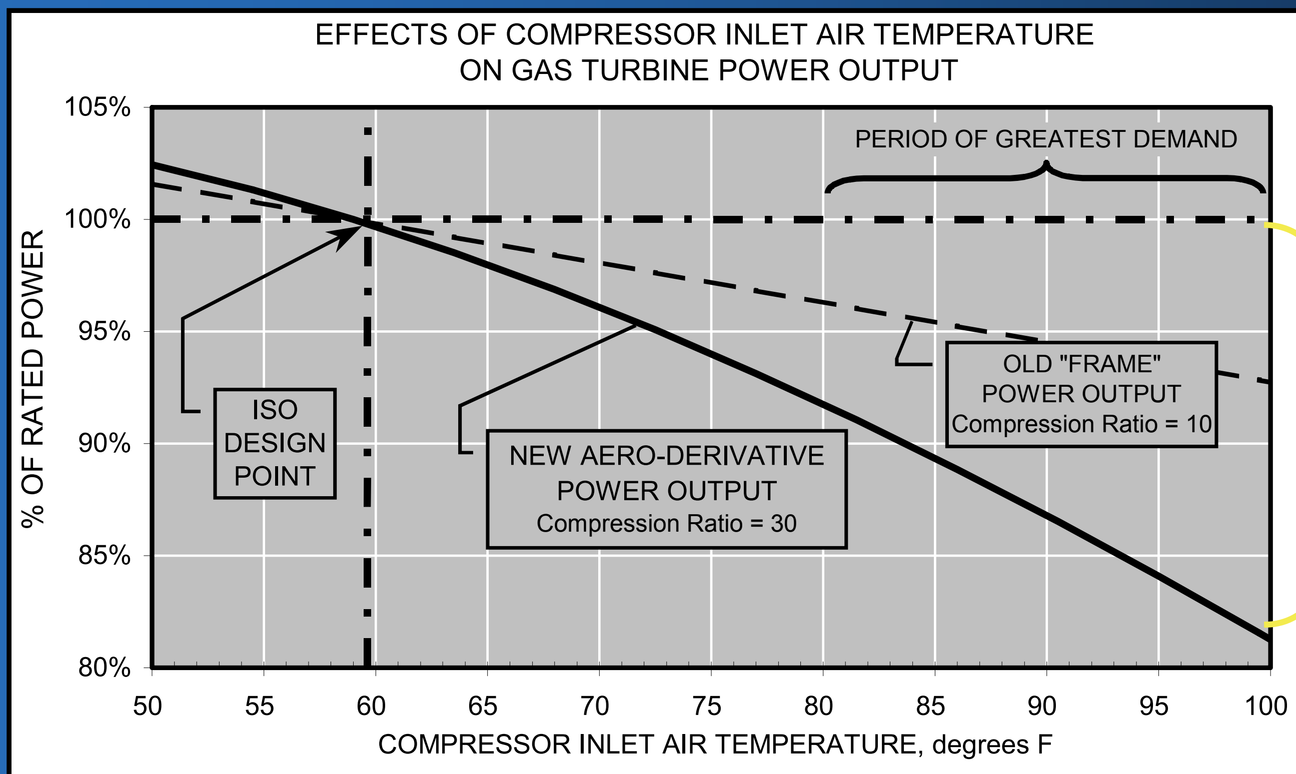
Why CT Power Output Capacity Decreases with Increase in Ambient Temperature?

- 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?

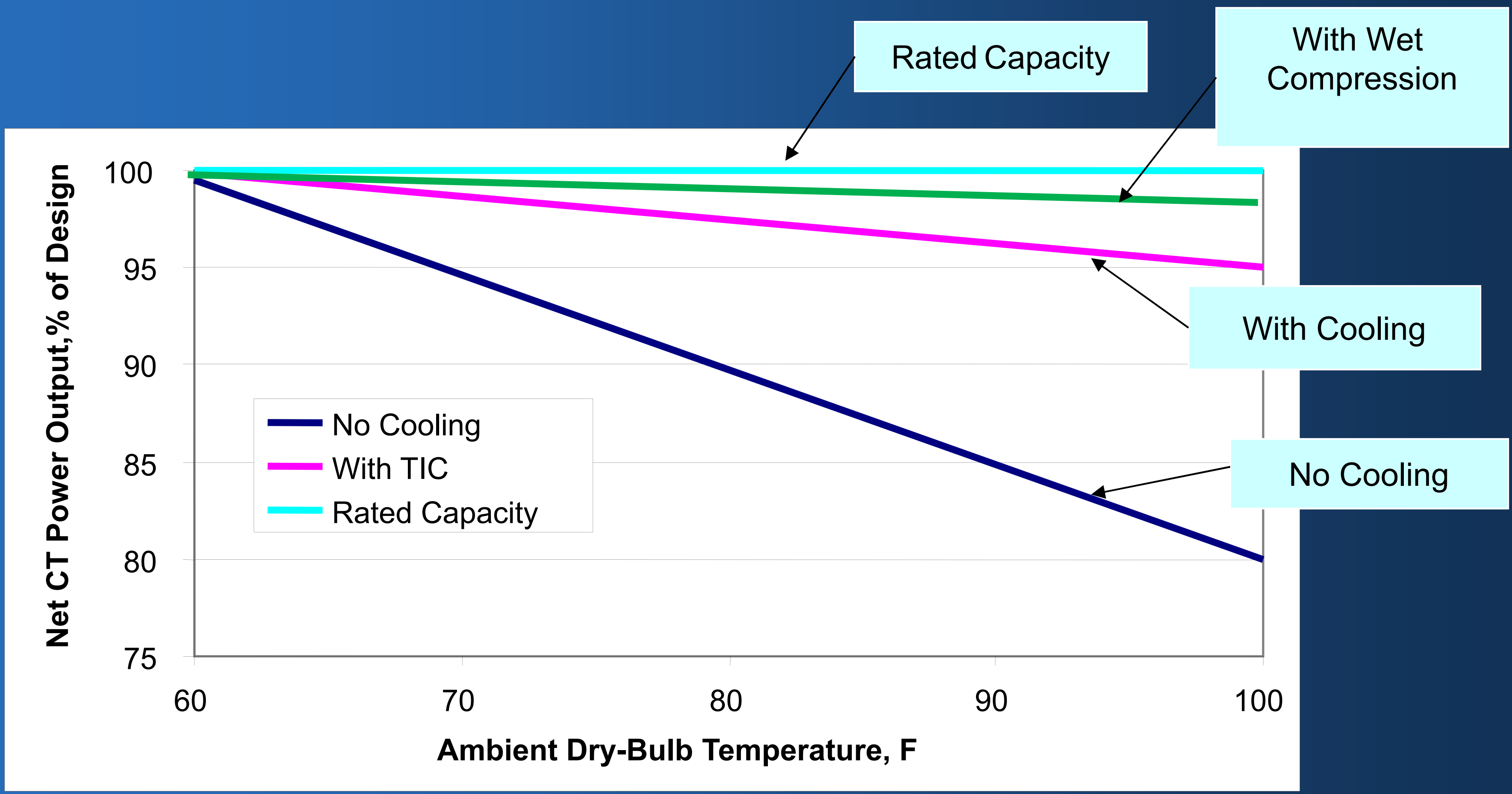
- Compressor of a CT system consumes almost two-third of the turbine's gross output
- Compressor requirement increases with increase in air temperature
- Increased power required by the compressor reduces the net electric power available from the CT system

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



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

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



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

How it works: Four-fold effect

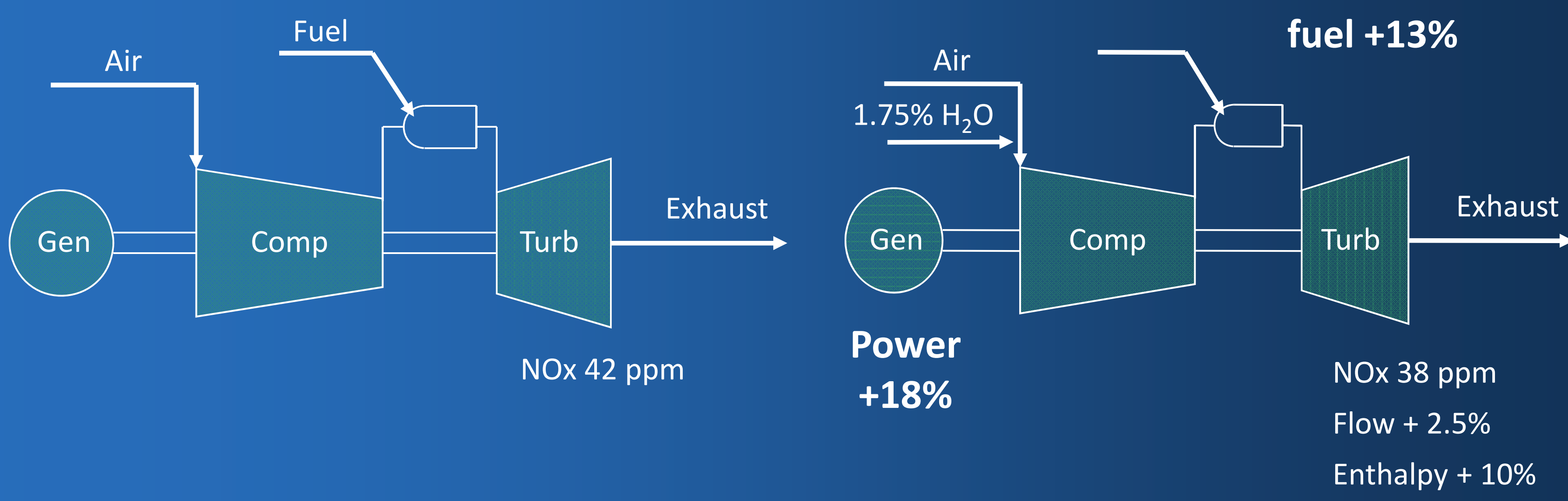
- COMPRESSOR EFFICIENCY DRAMATICALLY IMPROVED
  - Water Inter-cools the CT compressor
- Mass flow enhancement
- Lower CDT allows more fuel to be fired (at constant firing temperature)
- Cools air to very near WBT @ bell-mouth
  - Adiabatic Cooling of inlet air
  - Can be operated with an existing fogger,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

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

WC Performance Effects

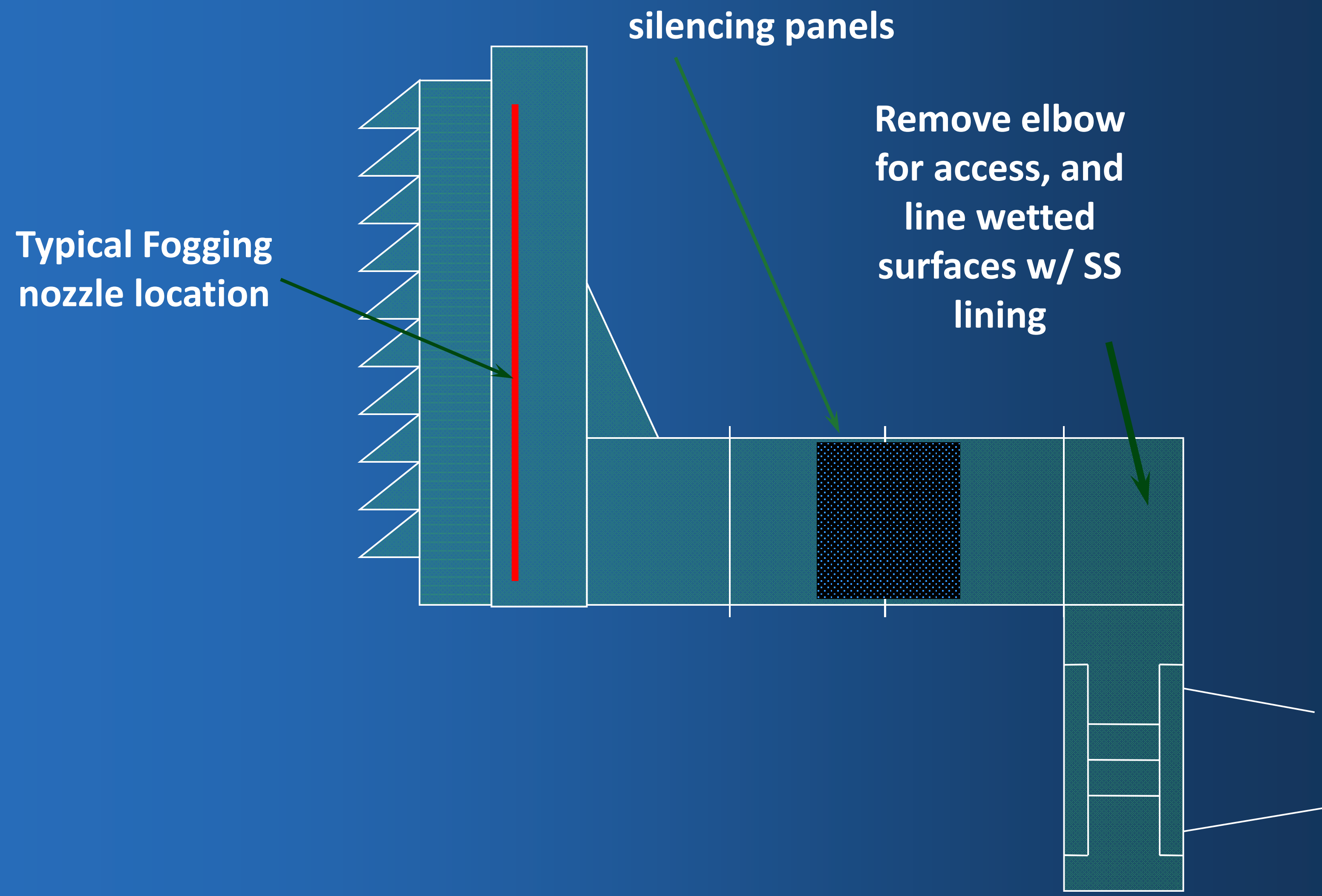
Base Case: 85% fogging @ 95 / 75°F

1.75% Wet Compression:



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

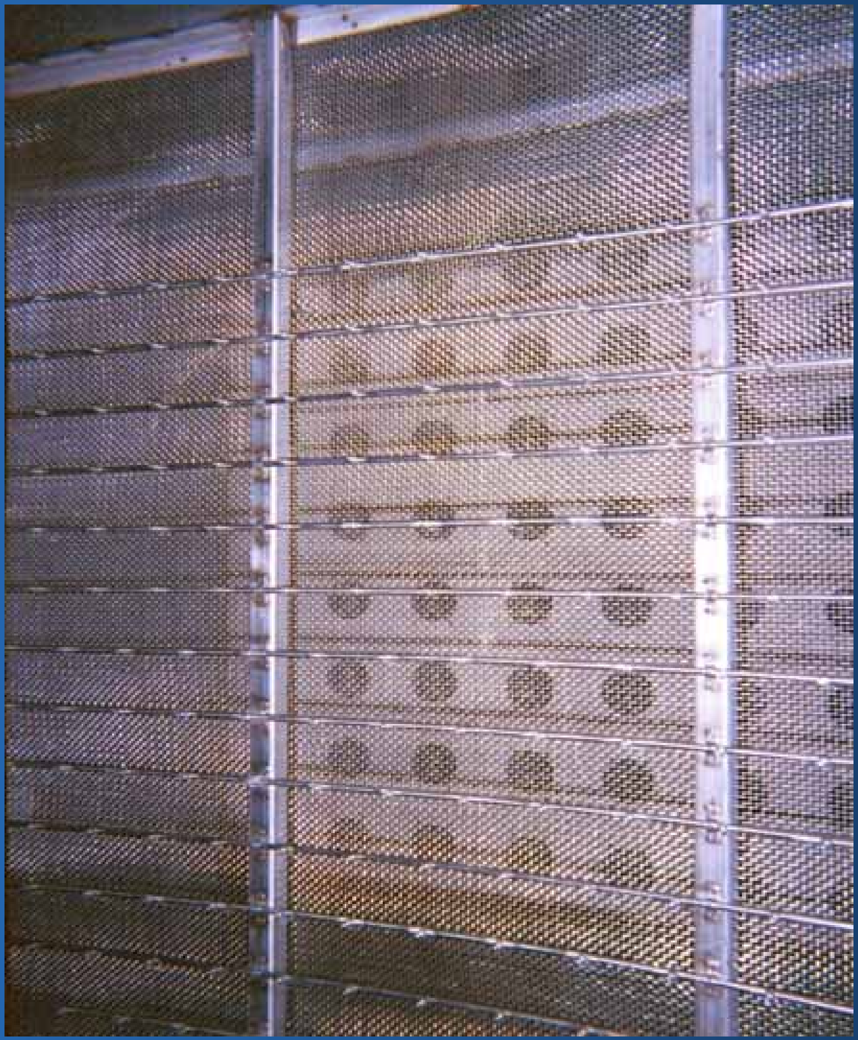


Array Manifold 7EA

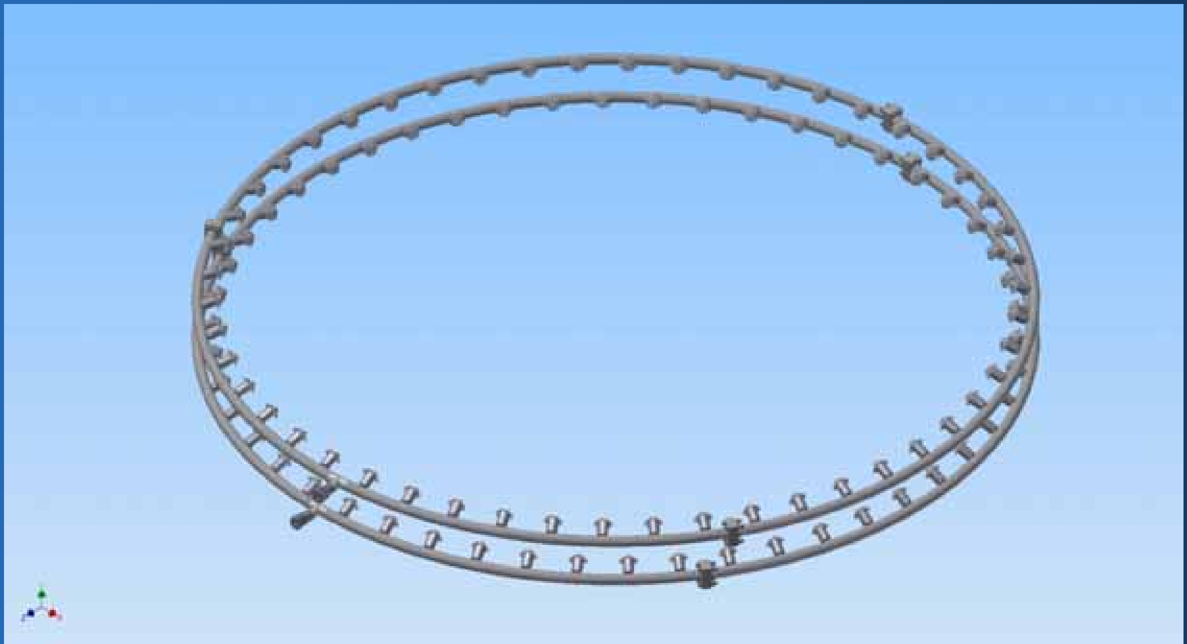
Manifold Installation

Duct Work Treatment LM's

Wet Compression Arrays LM2500



Wet Compression Arrays



VFD Wet Compression Pump Skid

VFD Wet Compression Skid

Wet Compression Install Considerations

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

Wet Compression Install Considerations

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

Inlet Icing

- Although power augmentation not required in cold ambient conditions, a WC systems have been operated down to ~42 F, without 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

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%

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

Low Maintenance

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

Thank You

And Don’t Forget to Join

TICA