

# REINHOLD ENVIRONMENTAL®



## **2022 Reinhold/PCUG Round Table Presentation**

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# Comparison of Heat Rate and CO<sub>2</sub> Emission Data

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## Project Objective

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- The intent of this study is to produce a methodology that can be adopted into an ASME Code that provides heat rate/CO<sub>2</sub> measurement results with the lowest reasonably achievable uncertainty consistent with the best engineering knowledge and practice in the industry, by employing accurate instrumentation and best possible measurement techniques and data validation methods available to determine the continuous power output and heat rate, as applicable to a specific generating facility.
- In addition, the methodology needs to provide procedures and techniques to design Relative Accuracy Test Audits (RATA) that ensure that the uncertainty reported is upheld.
- Can we measure a 1% annual heat rate improvement or degradation using permanent plant instrumentation?

# Technical Approach

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- **Task 1 – Project Management and Planning**
  - Managing the project to meet all technical, schedule and budget objectives and requirements
- **Task 2 – Problem Identification**
  - Problem will be defined, and problems/conflicts with current technology and test methods identified
- **Task 3 – Summary Report**
  - Meet with various organizations and agencies that have a stake in measuring or reporting EGU heat rate
  - Prepared summary report
- **Task 4 – Code Development**
  - Develop a methodology to determine changes in heat rate on an annual basis with low uncertainty and based in established commercial standards that will increase acceptance of results
  - Coordinate Performance Test Code with Codes & Standards

# Background

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- ASME ST LLC is under contract with DOE is in the process of developing a methodology that can be used in establishing a Standard or Code to measure annual heat rate and CO<sub>2</sub> emissions from coal-fired power plants. No consensus code exist.
- One measurement method is a Real Time algorithm that evaluates thermal losses, and determines performance assessments such as boiler efficiency, heat rate based on PTC-4.
- Second method is modified/calibrate F-factor at a given plant operating condition.

# Project Structure/Team

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- ASME and ASME ST-LLC
  - Project structure, communication system
  - Two PTC committees and staff to develop Code(s)/Standard
  - Principal investigator
- Licata Energy
  - Lead technical investigator, expert in power plant operations
  - Project management, literature research, interview with stakeholders
  - Data gathering and preparation of interim and final reports
- McHale & Associates
  - Data analysis, expert in power plant testing, drafting of methodology
  - Coordination with subcontractors to draft inputs to ASME PTC committee
  - Remote evaluation of plant operating data
  - Thermodynamic modeling and analysis of potential methodologies for inclusion in the recommended performance test code
- Tennessee Technological University
  - Collect data and develop models and calculations
  - Shakti Consultancy, LLC
  - Provided overview of development of statistical data
  - Problem Identification for technical approaches and industry practices

## Preliminary Results

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- Two ASME PTC Code Committees.
  - ASME RAP/PTC Joint Subcommittee on Heat Rate.
  - ASME PTC Committee on Control and Quality Improvement of Process Data.
- Power Generating Facilities: Continuous Power Output And Heat Rate.
  - The objective of this effort is to establish an industry-acceptable standard heat rate test method and annual heat rate calculation protocol for coal-fired electricity generating units.
  - DOE participation.
- Committee on Control and Quality Improvement of Process Data
  - Develop procedures and guidelines for using techniques such as data validation and reconciliation to assure determine the quality of measurements, quantify reduce the uncertainties, and assess reconciled results.

## Preliminary Results

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- McHale has identified potential concepts / methodologies / procedures that may be used in developing a Performance Test Code to determine annual heat rate for power plants that can achieve more consistent uncertainties of +/-1.5% to +/-3%.
- Each of the methods can evaluate measuring heat rate on an annual basis and on a rolling average basis.
  - One can readily be adopted on an online continuous basis.
- An approach for uncertainty analysis for the proposed method of annual heat rate will be recommended.
- Provided a sources for plant data.

# History Heat Rate/CO<sub>2</sub> Using CEMs Data

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- Dr. Jeff Quick reported “Annual CO<sub>2</sub> emission tallies for 210 coal-fired power plants during 2009 were more accurately calculated from fuel consumption records reported by the EIA than measurements from CEMS reported by the EPA. Results from these accounting methods for individual plants vary by **+/- 10.8%** comparing stoichiometric calculated CO<sub>2</sub> emission compared to EPA reported emissions”.
- The Department of Commerce’s National Institute for Standards and Technology (NIST) reported that CEMS measured CO<sub>2</sub> emissions versus the DOE/EIA calculation method to report CO<sub>2</sub> emissions, and “there was a **-10% to +15%** variation in the data.” One of the primary causes of the difference in the reported emissions is related to the flow measurement in the stack.

## Project Description

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- Calculates calibration factors for the Real Time algorithm method such as stack concentration of CO<sub>2</sub> and SO<sub>2</sub>, coal flow rate, and air preheater leakage. The algorithm calculates both heat rate and CO<sub>2</sub> emissions.
- Calibrate Real Time algorithm data from an ASME PTC-4 test was used and check against data reported by EPA's Clean Air Markets database.
- Test conducted on older supercritical boiler equipped with WFGD.

## PTC-4 test with data compared with the EPA Clean Air Markets database and the Real Time algorithm

- The average uncertainty between the Real-Time algorithm and the PTC-4 field test data was less than 1% for both the gross and net heat rates.
- The average heat rate difference between the EPA database and PTC-4 is about 20%.
- Real Time and PTC-4 CO<sub>2</sub> data are close, but EPA are high.
- Clean Markets only reports Gross Data.

Gross Load (MW)	Gross Heat Rate Btu/kWh				
	EPA CEMs Database	Real-Time Algorithm	PTC-4 Test	EPA/PTC-4	Real-Time/PTC-4
469	10,867	8,906	8,763	-24.0%	-1.6%
400	10,692	8,801	8,723	-22.6%	-0.9%
351	10,550	8,846	8,785	-20.1%	-0.7%
280	10,549	8,897	8,877	-18.8%	-0.2%
201	11,017	9,114	9,173	-20.1%	0.6%

Gross Load (MW)	CO <sub>2</sub> /MWh		
	EPA tons/MWh	Real Time Tons/MWh	PTC-4 Tons/MWh
469	1.11	0.90	0.90
400	1.10	0.90	0.89
351	1.08	0.90	0.91
280	1.08	0.90	0.91
201	1.13	0.90	0.93

# Analysis of Test Data - Validation

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- NIST reported variations in their evaluations of 20%, however, 10 to 15% variations are more commonly observed.
- New supercritical plant firing bituminous equipped with a wet scrubber should have a Net Heat Rate of  $\approx 9,058$  Btu/kWh and a net plant efficiency of 37.7%. The net heat rates reported by PTC-4 and Real-Time algorithm are in the “ballpark” of the S & L data considering this is an older boiler in operations for many years. The EPA CEMs data does not match the industry expected performance of the design of this unit based on a supercritical design.
- DOE report for a new supercritical boiler/WFGD of this design and fuel should have CO<sub>2</sub> emission between 1,600 (0.8 tons/MWh) and 1,900 (0.95 tons/MWh) lbs of CO<sub>2</sub> /MWh gross.

# Comparison of Net Heat Rates

Gross Load (MW)	Net Heat Rate		
	Real-Time	PTC-4	Real-Time/PTC-4
469	9,668	9,523	-1.5%
400	9,586	9,501	-0.9%
351	9,581	9,649	0.7%
280	9,892	9,907	0.2%
201	10,493	10,515	0.2%

EPA Clean Markets does not report net heat rates

DOE New boiler estimate Net Heat Rate of  $\approx 9,058$  Btu/kWh

# Evaluation

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- The PTC-4 and Real Time data was in this range of published data while the CEMs data was higher than predicted.
- Could not finding any significant data inputs that could result in this  $\approx 20\%$  variation, a search was made of the EPA's Field Audit Checklist Tool (FACT) database.
- EPA's data shows that a new CEMS flow monitor was installed on this unit about 6 weeks prior to the PTC-4 test program. **Passed annual RATA test.**
- Evaluated CEMs data prior to new flow monitor using curve fit analysis since no PTC-4 data available to validate data.

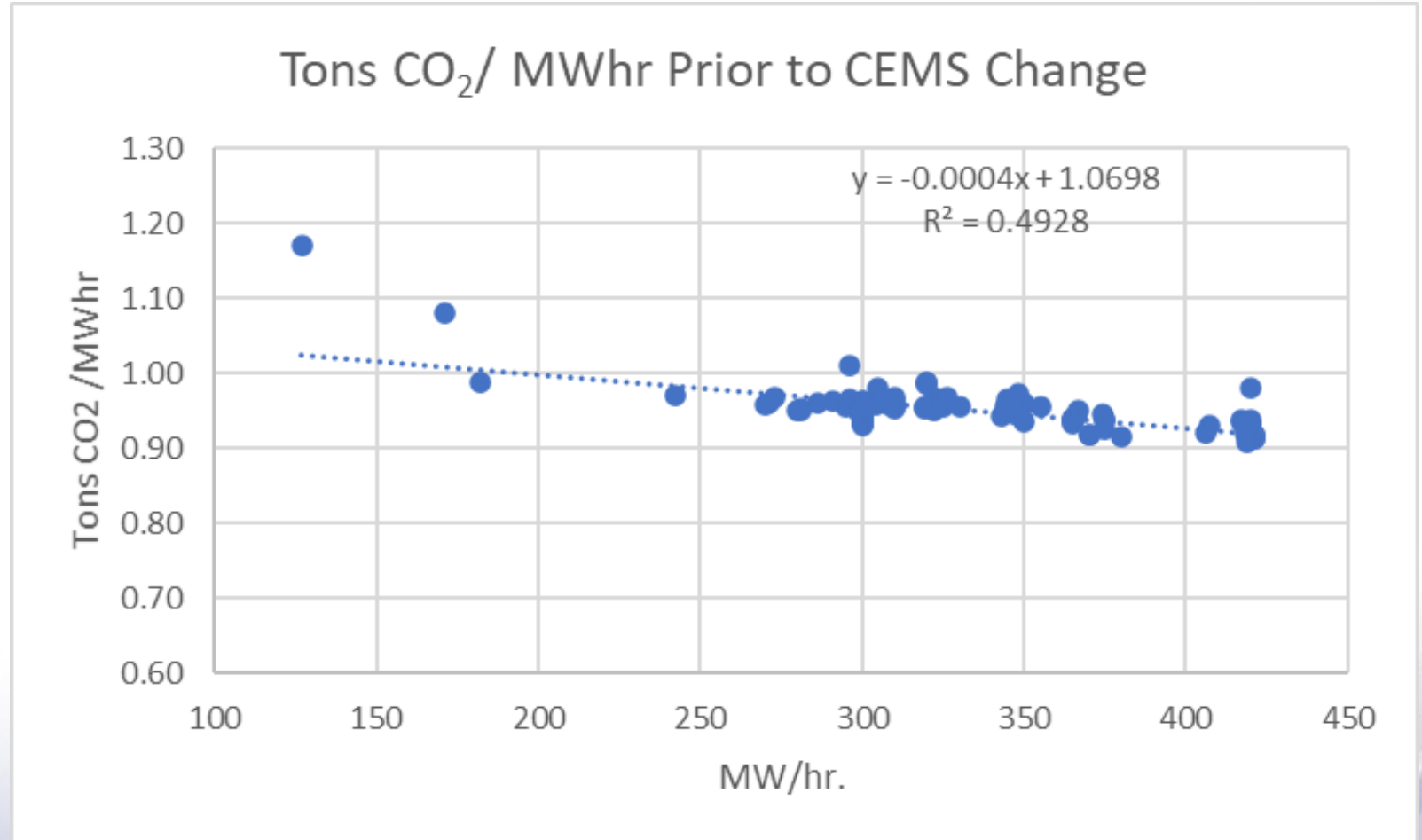
## Back Calculating For Old CEMs Data

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- The curve fit of EPA “FACT” data shows that at 400 MW the flue gas stack flow was 65,971,600 SCFH, however after the new CEM flow meter was changed the flow increased to 74,558,800 SCFH at 400 MW. This is about a 13% increase.
- Additional data on heat rate and CO<sub>2</sub> emissions was plotted and curve fit data was obtained for the range of 200 MW/hr to 480 MW/hr.

# Typical Curve Fit

Data was linear between  
200 & 400 MW/hr.



# Adjusted CEMs data Comparison

The data analysis shows the unit heat rate increased by about 14% after the new CEMS was installed. When the CEMS data was compared to the PTC-4 test the difference was 4%. This is a direct link between the 13% flue gas flow and the 14% heat rate post the CEMS change.

		Unit Heat Rate Summary				
	CEMS Heat Rate Prior to Change	CEMS Heat Rate After Change	Percent Change After/Prior	CEMS Heat Rate During Test	PTC-4 Test	Difference PTC-4/ CEMS Prior
MW/hr	Btu/kWh			Btu/kWh		
470	8,888	10,581	16.0%	10,867	8,763	1.4%
400	9,075	10,675	15.0%	10,616	8,723	3.9%
350	9,209	10,742	14.3%	10,550	8,785	4.6%
280	9,396	10,836	13.3%	10,549	8,877	5.5%
200	9,610	10,943	12.2%	11,017	9,173	4.5%

## Adjusted CEMs data Comparison

A similar analysis was made for the CO<sub>2</sub> emissions. The first **CEMs column** is from curve fit data before the new CEMs. The curve fit data in the second CEMs column matches the CEMs data recorded during the PTC-4 test program.

		Revised Unit CO <sub>2</sub> Emission Comparison Summary				
	<b>CEMS CO<sub>2</sub> rate prior to change curve fit</b>	<b>CEMS CO<sub>2</sub> rate after change</b>	<b>Percent Change After/Prior</b>	<b>Real-Time CO<sub>2</sub> rate calculation</b>	<b>PTC-4 Test CO<sub>2</sub> rate</b>	<b>Difference PTC-4/CEMS Prior</b>
<b>MW/hr</b>	<b>CO<sub>2</sub> tons/MWh</b>	<b>CO<sub>2</sub> tons/MWh</b>		<b>CO<sub>2</sub> tons/MWh</b>	<b>CO<sub>2</sub> tons/MWh</b>	
470	<b>0.88</b>	1.07	-21.6%	0.90	0.90	2.11%
400	<b>0.91</b>	1.08	-18.7%	0.90	0.89	-2.25%
350	<b>0.93</b>	1.08	-16.1%	0.90	0.90	-2.54%
280	<b>0.96</b>	1.09	-13.5%	0.90	0.91	-5.49%
200	<b>0.99</b>	1.1	-11.1%	0.90	0.93	-6.00%

# Revised Data Summary

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- The data shows a 13.6% increase in CO<sub>2</sub> emissions after the new CEMS flow monitor was installed. Based on the curve fit data, there is a +2% to -6% difference between the PTC-4 test and the "old" CEMS results.
- The curve fitting data is a good tool to evaluate data in a limited range.

# Summary

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- The Real Time algorithm accurately calculates the following plant performance parameters when compared to PTC-4 and the gross and net unit heat rate with uncertainty less than the 3% goal and the CO<sub>2</sub> produced per MW/hr of gross plant generation.
- Additional evaluations need to be made on the heat rate and CO<sub>2</sub> emissions data comparing CEMs data that has been tested in accordance with Part 75. This is critical if there will be a carbon tax or CO<sub>2</sub> trading. There needs to be a more comprehensive evaluations on the relative accuracy of CEMS systems and their calibration and quality assurance.
- This also demonstrates that the Real-Time algorithm can be used to check on CEMs data for heat rate and CO<sub>2</sub> emissions. For example, if the algorithm reported 0.90 tons of CO<sub>2</sub>/MWh but the CEMs are reporting 1.07 tons it would serve as indicator that the difference should be investigated.

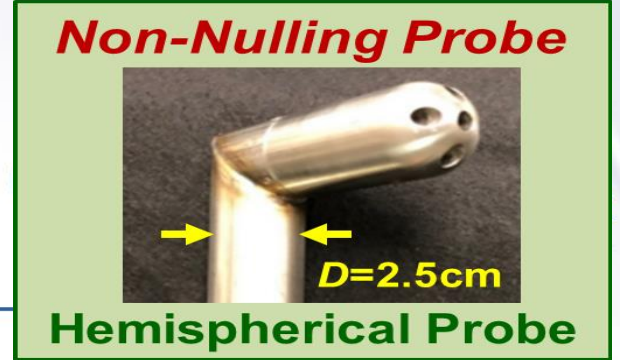
# Acknowledgements

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- Work on this project was conducted by additional team members including Joseph M. Staller, Robert P.M. Craven, & Stephen Idem, Ph.D. of Tennessee Tech University, Sastry Munukutla, Ph.D. of Shakti Consulting, Susan Eisenstadt, P.E., Karsten Kopperstad, Joe McHale, P.E. of McHale and Associates, and Dan Andrei of ASME.
- Project was formed when the US Department of Energy (DOE) retained the services of ASME ST-LLC to develop a standardized test method and calculation protocol for determining and reporting annual/long-term heat rate for coal-fueled plants electricity generating units.

## Side Note

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- Rick Himes of EPRI reported at the EPRI Heat Conference that a 12.7 % CEMs high biased velocity measurement would result in a \$16,400,000/yr. potential cost impact on an 869 MW unit, assuming future \$20/ton CO<sub>2</sub> charge.
- CEMS velocity data can have a negative impact on plant performance and economics.
- Operators and testing contractors should consider validation of flow measurements beyond Part 75.
- NIST and ASME working on a Code for the Non-Nulling velocity probe to reduce uncertainty.

The logo features the company name in a blue serif font, with a large, stylized blue 'C' shape that partially encircles the text from the left and bottom. The background is a light blue gradient with abstract, flowing white lines.

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