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Industrial Application of Gas Turbines

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Certification of a Statistical Hybrid Predictive Emission Monitoring System in the U.S.A. and Development of a Small Gas Turbine Class Model

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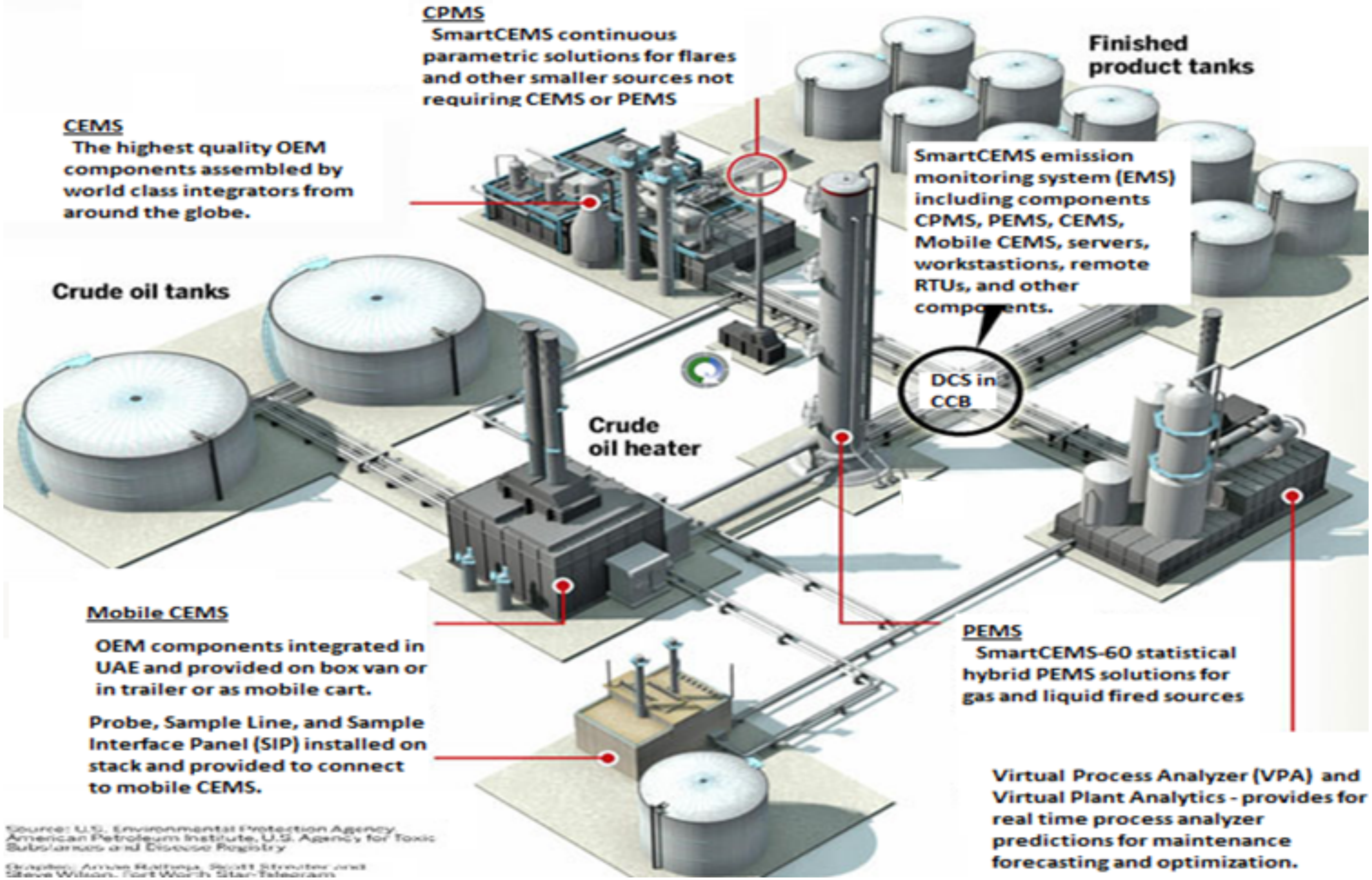
Objectives

- Summarize the methods used to certify a Predictive Emission Monitoring System (PEMS) using U.S. EPA 40 CFR Part 60
- Outline Class Model development process using the example of a small gas turbine
- Discuss applicability of PEMS as a multi-pollutant and process monitoring solution

Why consider PEMS?

- Adaptable, Flexible, and Configurable
- Has Met U.S. EPA Regulations
- Superior to a parametric method with accuracy levels as good as CEMS
- Minimal maintenance & operational costs
- Consistently achieves very high data availability

EMS Components

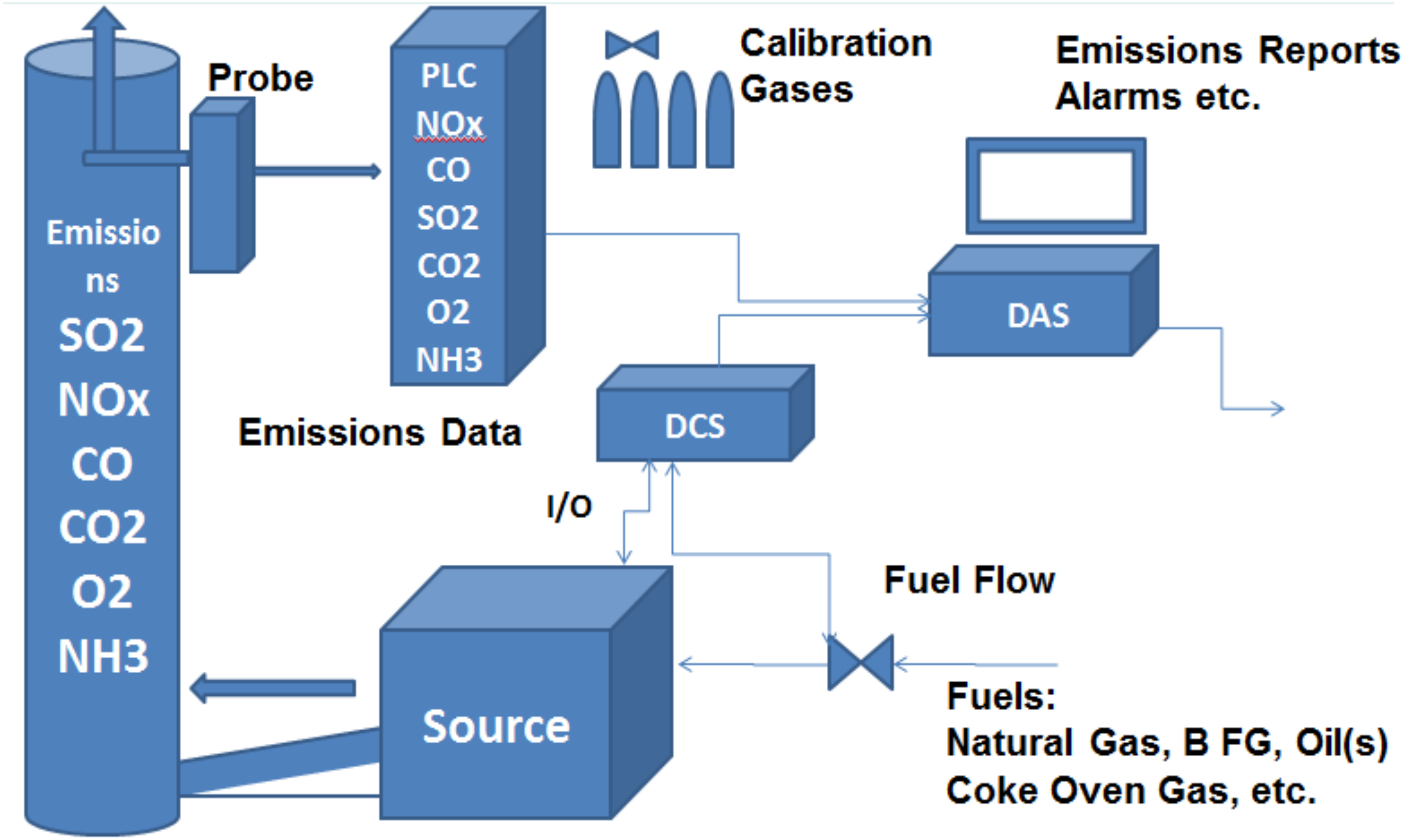


U.S. Regulatory Selection Criteria

Monitoring Primary Pollutants (NOx, SO_2, CO)

- PEMS may be used as an alternative to CEMS for all gas or oil-fired boilers, for gas-fired heaters and simple or combined cycle turbines
- Parametric, PEMS, or CEMS approaches can be used for all smaller units (< 50 Tonnes/year)
- CEMS must be used on some units that fire solid fuels such as MWCs (> 50 Tonnes/year)
- Local agencies may require monitoring of specific pollutants in non-attainment (CO or HC)

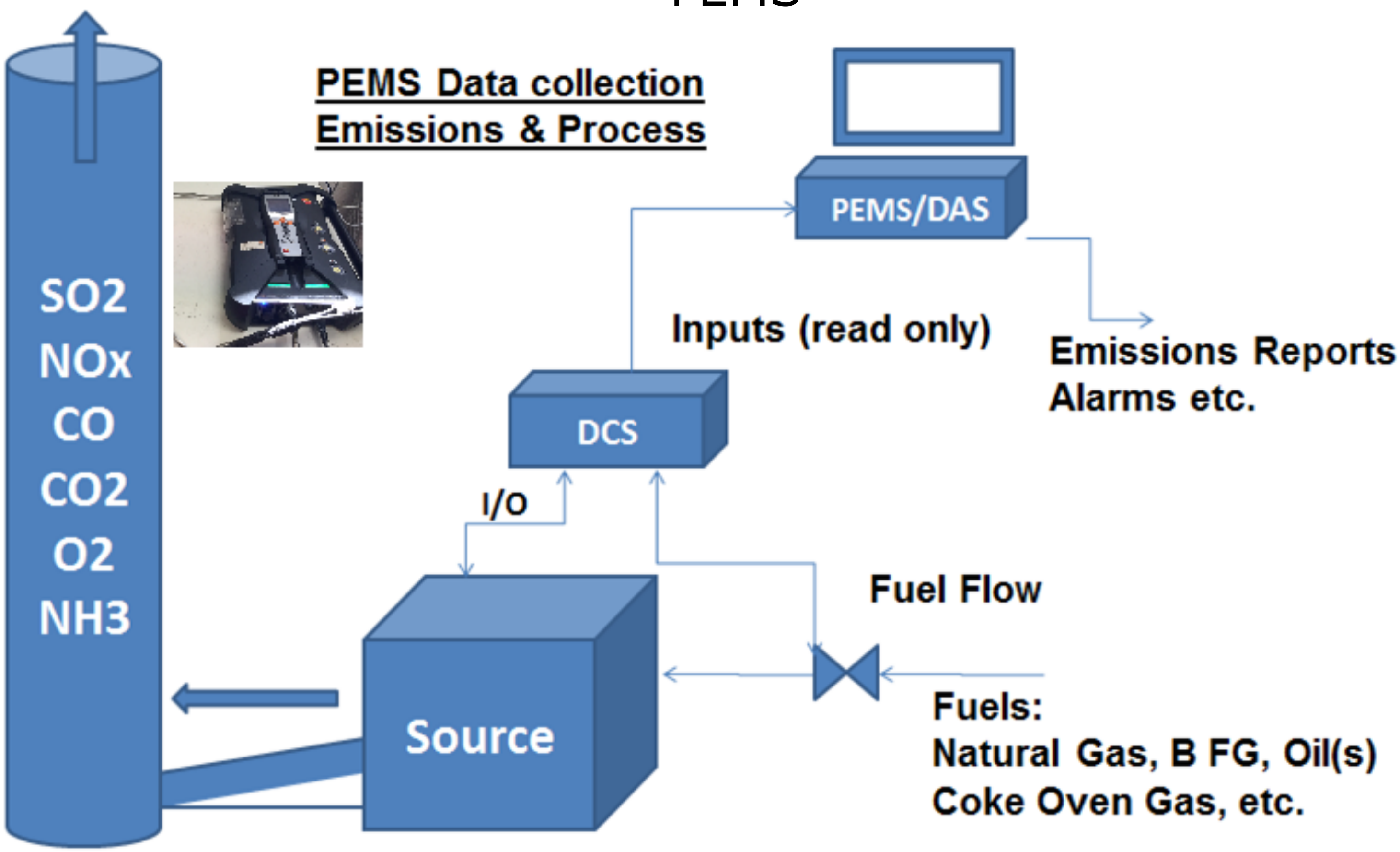
CEMS


Probe
PLC
NOx
CO
SO2
CO2
O2
NH3
Calibration
Gases
Emissions Reports
Alarms etc.
Emissio
ns
SO2
NOx
CO
CO2
O2
NH3
DAS
DCS
Emissions Data
I/O
Fuel Flow
Source
Fuels:
Natural Gas, B FG, Oil(s)
Coke Oven Gas, etc.

PEMS System Overview

- An advanced software model using existing instrumentation to predict emission rate
- Predicts accurately across the full load range of the unit including transitional states such as startup and shutdown
- Accepted by 40 CFR Part 60 or Part 75 where continuous monitoring is required

PEMS

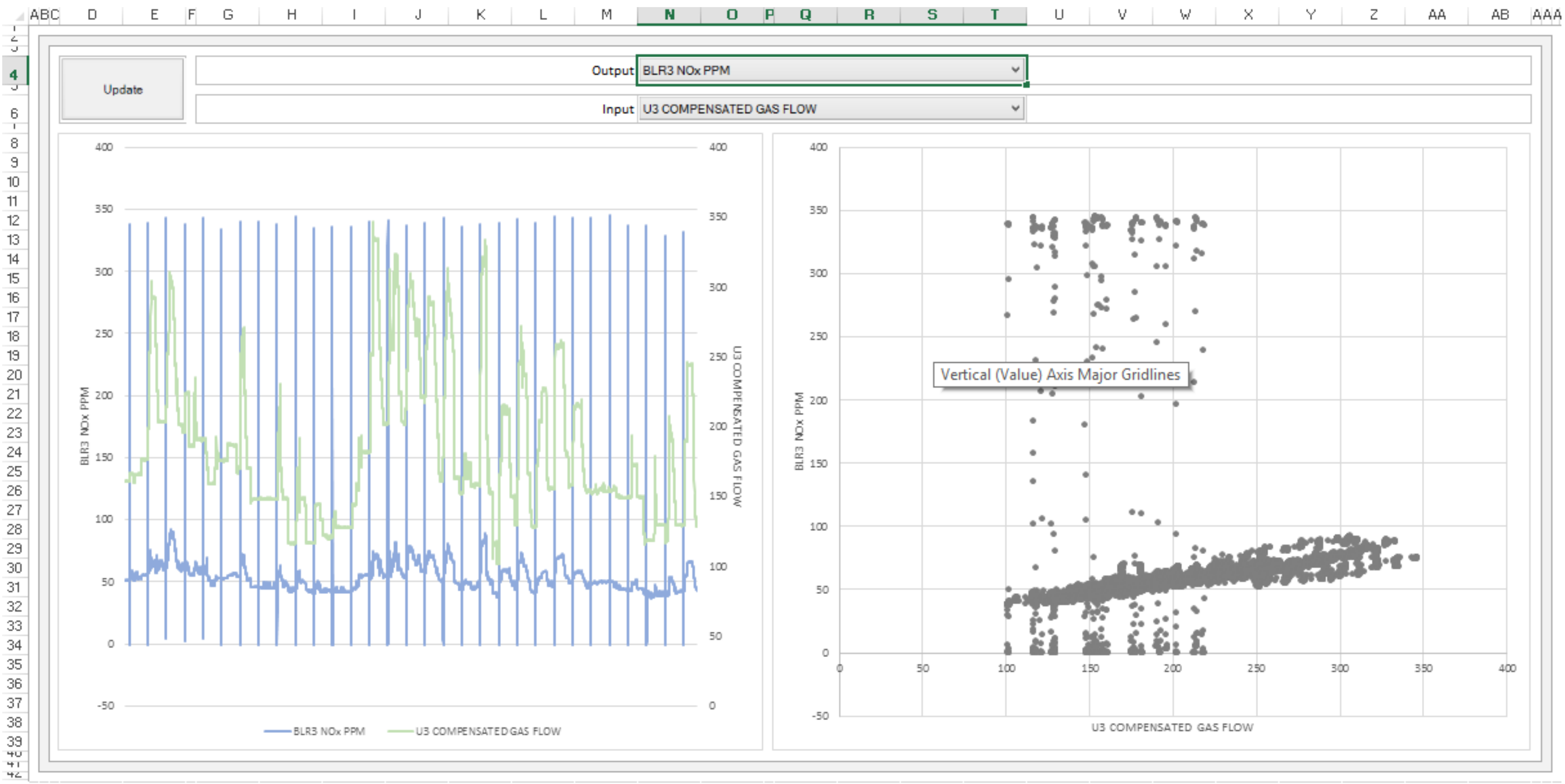

PEMS Data collection
Emissions & Process
SO2
NOx
CO
CO2
O2
NH3
PEMS/DAS
Inputs (read only)
Emissions Reports
Alarms etc.
DCS
I/O
Fuel Flow
Source
Fuels:
Natural Gas, B FG, Oil(s)
Coke Oven Gas, etc.

Technology and Type	No. of Subpart E	Cost	Advantages	Disadvantages	Accuracy	Reliability
First Principle PEMS - Theoretical PEMS	0	Medium	Accurate Measurement as long as process operations within the developed formula – not used extensively for compliance	High cost of maintenance, not resilient to input failure, proprietary, not flexible o adjustable	Fair, 10% to 20%	Good, 90 to 95%, but 0% if critical inputs fail
Neural Network PEMS - Empirical PEMS	1	High	Accurate Measurement across the full load range	High cost of model development, proprietary, needs expert onsite, high cost of maintenance	Good, < 10%	Very Good, near 100%, resilient to input failure
Statistical Hybrid PEMS - Empirical PEMS	27	Medium	Accurate Measurement across the full load range, can be retrained any time without expert onsite, flexible and adaptable	Model limited to load range established can be extrapolated and interpolated as required	Good, < 10%	Very Good, near 100%, resilient to input failure

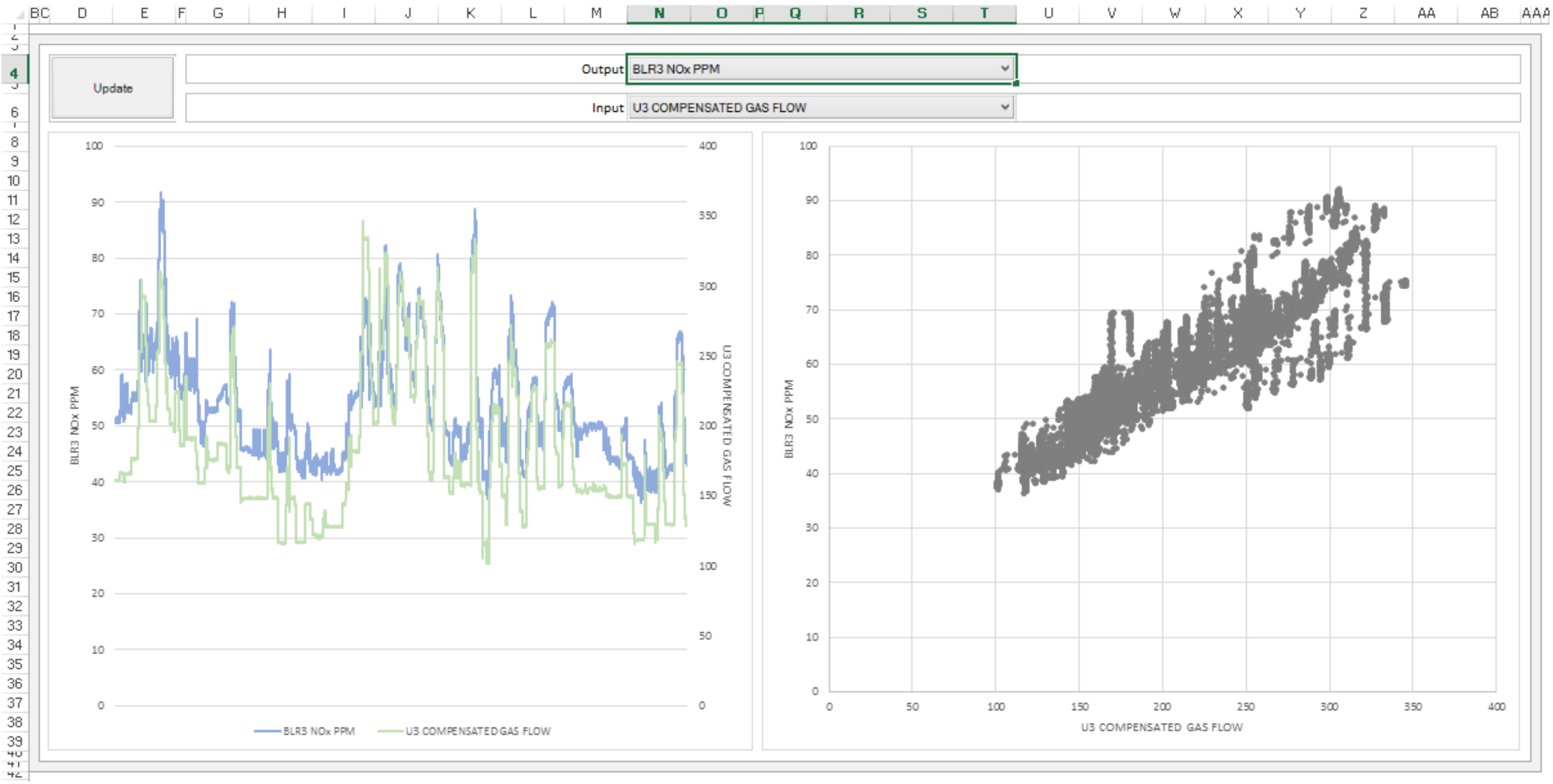
Empirical System Design

- Many inputs with correlation to emissions
- Collect Historical Training Dataset
  - Paired process and emission data for a period under normal operating conditions
  - Need to quality assure the model data
- Certification and Performance Testing
  - Periodic (annual or quarterly) testing to validate the emission levels at each load

Raw Historical Data



Quality Assurance of Data



Unit Description

- Combined Cycle
- 8 MW Solar Taurus 70 turbine
- Natural gas fired HRSG rated at 130 mmBTU/hr (137 GJ/hr)
- SCR for NOx

TAURUS 70 PG - GENERATOR SET

ISO Performance/Specifications

Power	7965	kWe
Heat Rate	10 505	kJ/kW-hr
Exhaust Flow	96 775	kg/hr
Exhaust Temperature	505	°C
Steam Production	16.5 - 72.3	tonnes/hr
Axial Exhaust	Yes	
SoLoNOx	Yes	

Figure 1: Gas Turbine Specifications

Figure 2:
Turbine HRSG Arrangement

US EPA PEMS Performance Specifications

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BILLING CODE 6560–50–P

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Parts 60 and 63

[EPA–HQ–OAR–2003–0074; FRL–8785–4]

RIN 2060–AG21

Performance Specification 16 for Predictive Emissions Monitoring Systems and Amendments to Testing and Monitoring Provisions

AGENCY: Environmental Protection Agency (EPA).

ACTION: Final rule.

SUMMARY: EPA is taking final action to promulgate Performance Specification (PS) 16 for predictive emissions monitoring systems (PEMS). Performance Specification 16 provides testing requirements for assessing the acceptability of PEMS when they are initially installed. Currently, there are no Federal rules requiring the use of PEMS; however, some sources have obtained Administrator approval to use PEMS as alternatives to continuous emissions monitoring systems (CEMS). Other sources may desire to use PEMS in cases where initial and operational costs are less than CEMS and process optimization for emissions control may be desirable. Performance Specification 16 will apply to any PEMS required in future rules in 40 CFR Parts 60, 61, or 63, and in cases where a source petitions the Administrator and receives approval to use a PEMS in lieu of another emissions monitoring system required under the regulation. We are also finalizing minor technical amendments.

DATES: This final rule is effective on April 24, 2009.

Certification Requirements 40 CFR Part 60

- Obtain data from a certified temporary CEMS for comparison with the PEMS data
- Pass an initial RATA and corresponding statistical analysis, including relative accuracy (RA), correlation, and F-test
- Must continue ongoing QA/QC program

Certification Procedure PS-16

- Collect data at these operating levels:
  - low (minimum to 50% of maximum load)
  - mid (between low and high load)
  - high (80% to maximum load)
- Perform a minimum of nine runs at each level and choose a total of twenty-seven runs for certification

Testing Results – Low Load

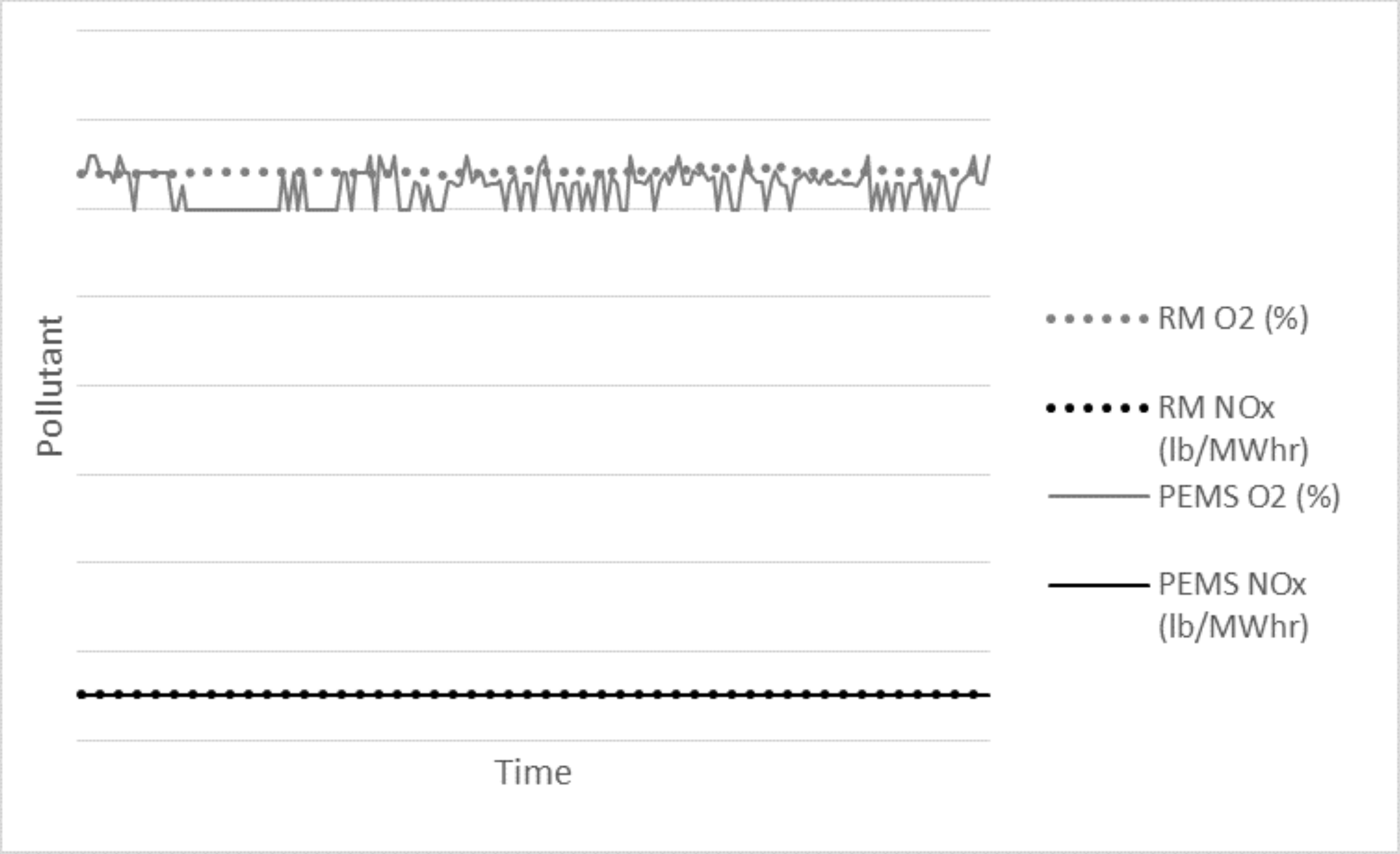


Figure 2: Certification RATA EMS Readings (Low Load)

Testing Results – Mid Load

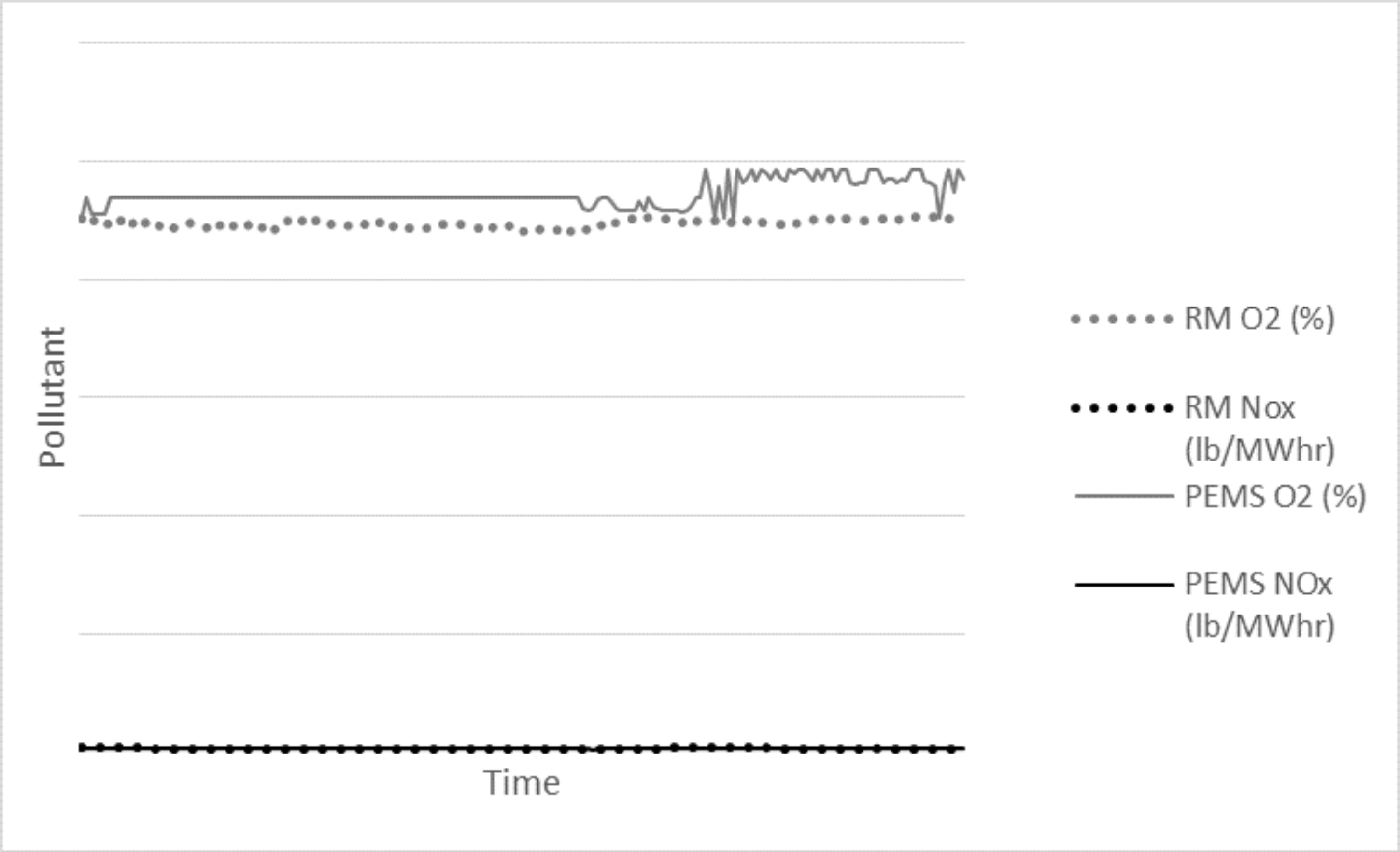


Figure 2: Certification RATA EMS Readings (Low Load)

Testing Results – High Load

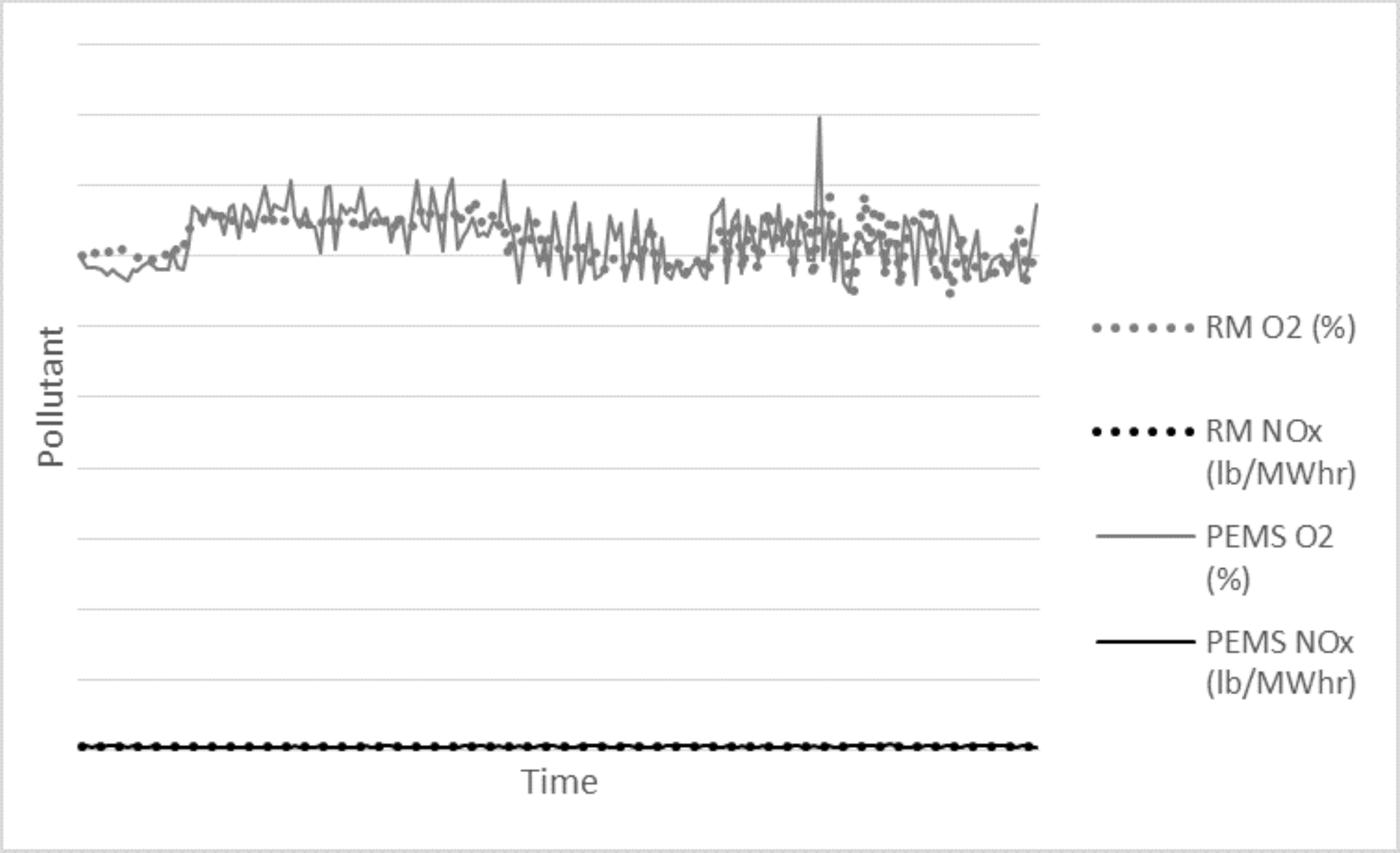


Figure 2: Certification RATA EMS Readings (Low Load)

Mass Emission Rate RATA

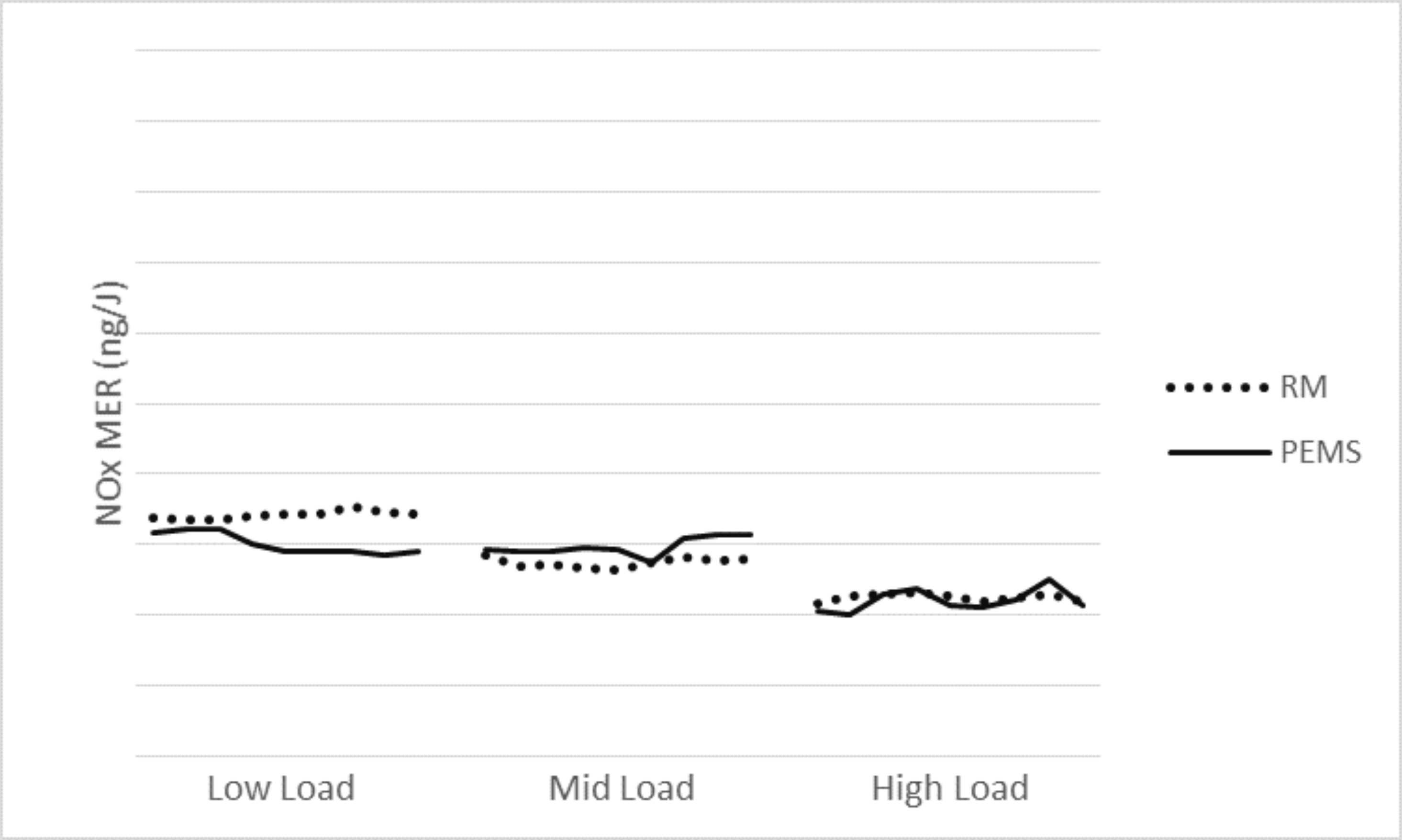


Figure 5: Certification RATA Mass Emission Rates

Relative Accuracy

- Per U.S. EPA Performance Specifications 16 (PS-16), the allowable RA is 10% when over 100 ppmv and 20% when under
- The maximum RA values were 6% and 12% for O_2 and NO_x, respectively, which are within the allowable limits

F-test

- The maximum F-value was 1.973
- The maximum F-value is less than the critical F-value of 3.438 given by PS-16

Correlation Analysis

- Correlation of CEMS and PEMS values were 0.961 in ppmvd (lbs/MWhr), and 0.970 in lb/hr (kg/hr), greater than the required 0.8 correlation

Performance Analysis

- Data availability from the PEMS was greater than the temporary CEMS and exceeded the minimum requirements
- PEMS provides compliance reports to meet the monitoring requirements and online emission data to the operators
- Details and tables of the data are in the paper along with detailed references

Quality Assurance (QA)

- A QA program is developed for the site
  - PS-16 minimum requirements
  - Air permit requirements
  - PEMS provider requirements
- Sensor input validation along with daily zero and span calibrations are automatically performed by the system

Quality Assurance (QA)

- Instruments critical to PEMS model accuracy are checked annually
- Periodic quality control activities are scheduled as required by PS-16
- The PEMS model is updated to respond to process or operational changes

PEMS Periodic Quality Control

• Zero and Span checks:	**Daily**
• Direct gas measurement:	**Quarterly**
• Relative Accuracy Test Audit:	**Annually**
• Input failure detection system:	**Before RATA**
• Bias Check:	**After RATA**
• Statistical Analysis:	**After RATA**
• Input failure alarms:	**After RATA**

Quality Audits (RAA)

- Portable Analyzer
- Quality control between RATA
- Quarterly first year and annually after

Annual Audits (RATA)

- RATA by third party using reference methods

Instrument QA

Input	Description	Interval	QC Activity
25	B-3 (HRSG) Duct Burner Natural Gas	Annual	Calibration Check
35	Gas Turbine Natural Gas (Retransmitted by GT	Annual	Calibration Check
82	B-3 (HRSG) Turbine Exhaust Temperature Entering HR	Annual	Calibration Check
30	B-3 (HRSG) Steam Flow	Annual	Calibration Check
63	Boiler Feedwater Header Pressure A	Annual	Calibration Check
64	Boiler Feedwater Header Pressure B	Annual	Calibration Check
22	APCU Ammonia Flow	Annual	Calibration Check
4	B-3 (HRSG) Stack O_2	Annual	Calibration Check
51	Deaerator Steam PRV Outlet Pressure	Annual	Calibration Check
62	Generic Analog Input	Annual	Calibration Check
48	Steam Main Pressure Transmitter A	Annual	Calibration Check

Class Model

- A statistical hybrid PEMS model can be applied to similar units and certified for compliance using PS-16 in the U.S.
- A separate PEMS is deployed for each unit to allow for adjustments and fine tuning over time
- Each unit undergoes certification testing and periodic audits

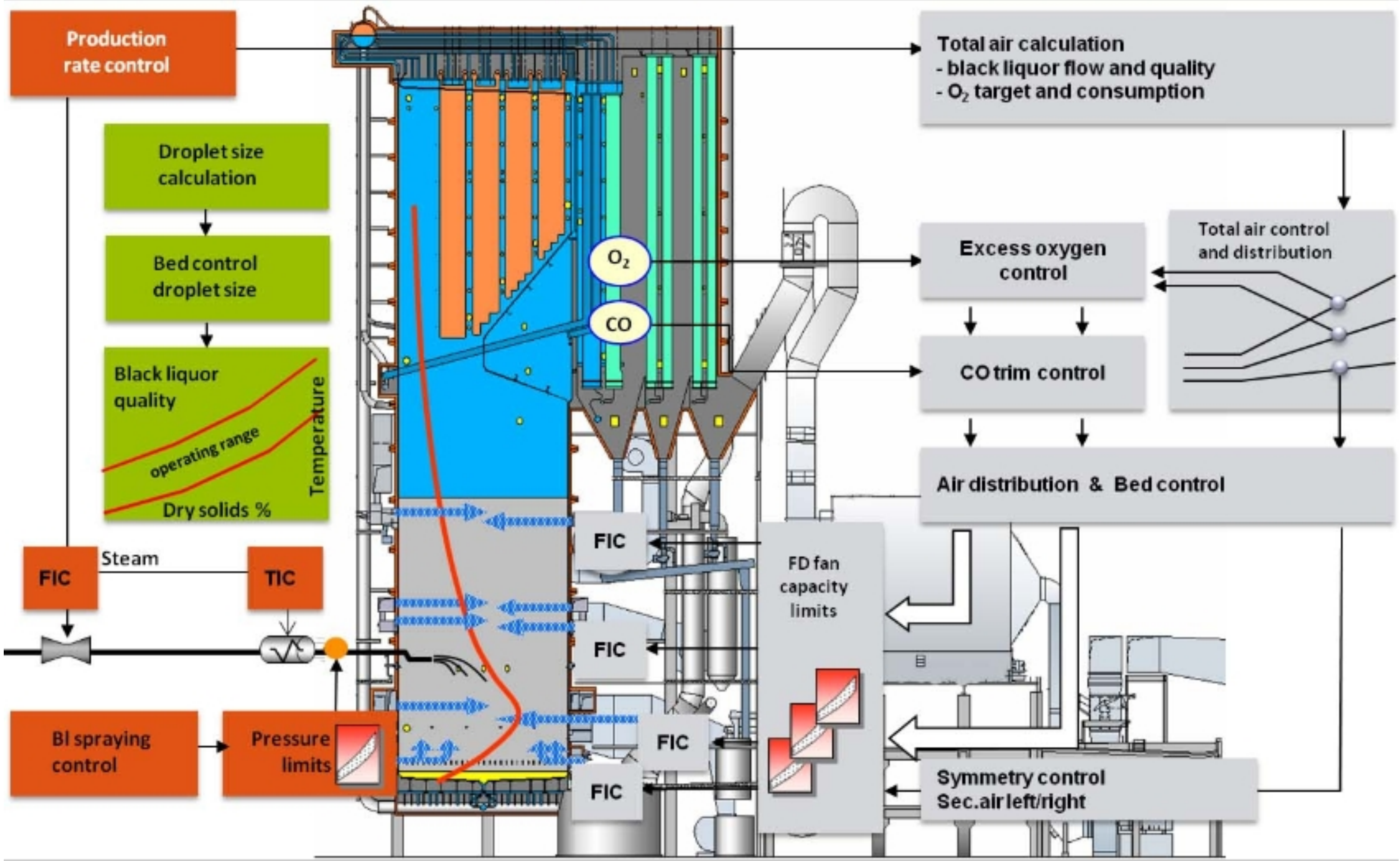
Process Optimization

- SCR injection tuning
- **Secondary air control and oxygen trim**
- Temperature control and calibration
- Predictive Maintenance
- Petroleum Refineries – process analysis
- Difficult to sample applications such as H2S and SO2 from NG production units

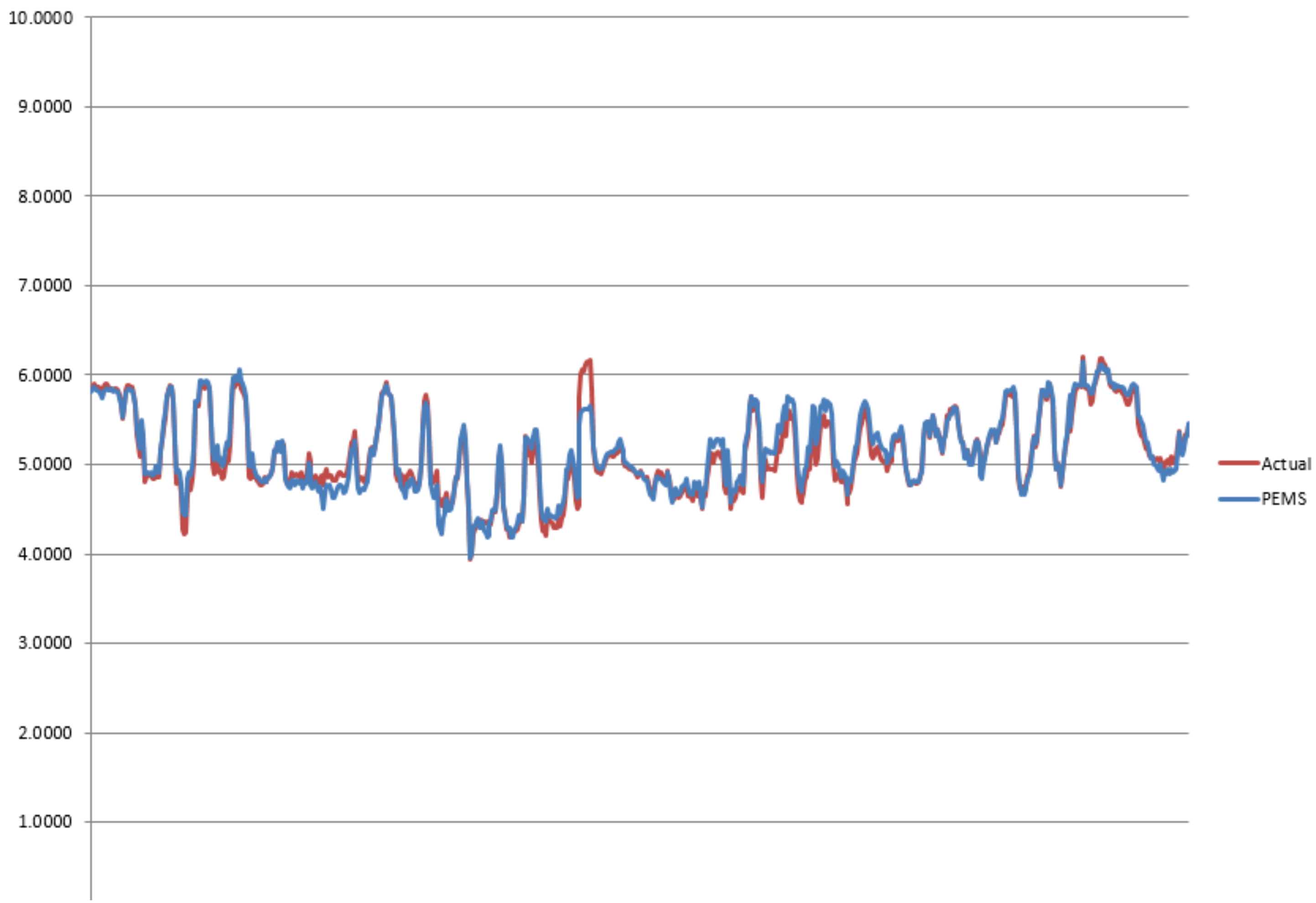
Other Process Applications

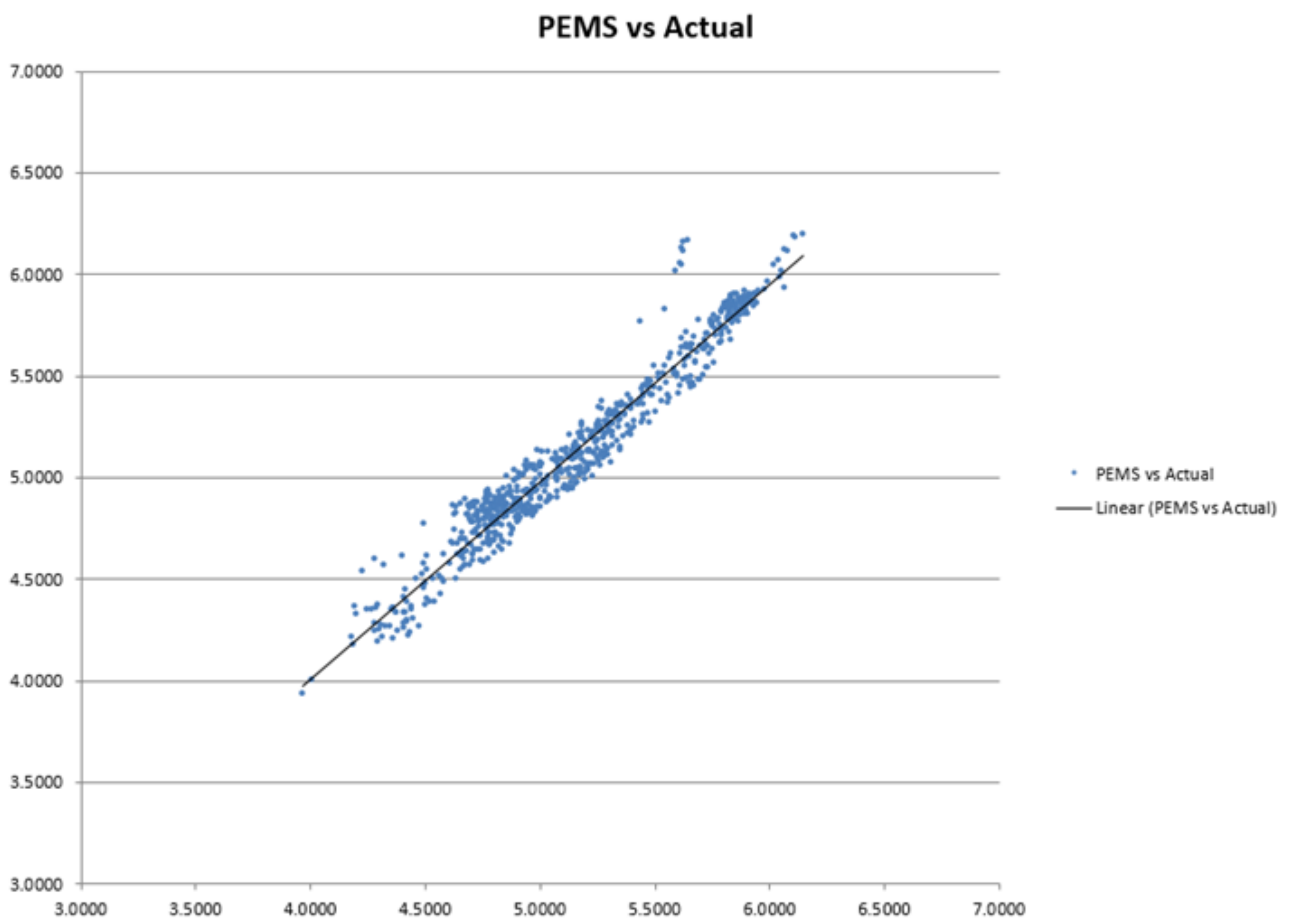
- Process Instrument replacement
- Process Instrument backup
- Preventive and Predictive Maintenance
- Process Optimization using class model
- Process Efficiency – unit by unit online
- Process Control tuning and validation
- Backup on Safety Devices

Oxygen Trim


Production rate control
Droplet size calculation
Bed control droplet size
Black liquor quality
operating range
Temperature
Dry solids %
FIC
Steam
TIC
Bl spraying control
Pressure limits
O_2
CO
FIC
FIC
FIC
FIC
FD fan capacity limits
Total air calculation
- black liquor flow and quality
- O_2 target and consumption
Excess oxygen control
Total air control and distribution
CO trim control
Air distribution & Bed control
Symmetry control
Sec.air left/right

Boiler Oxygen trim and control




PEMS vs Actual
7.0000
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6.0000
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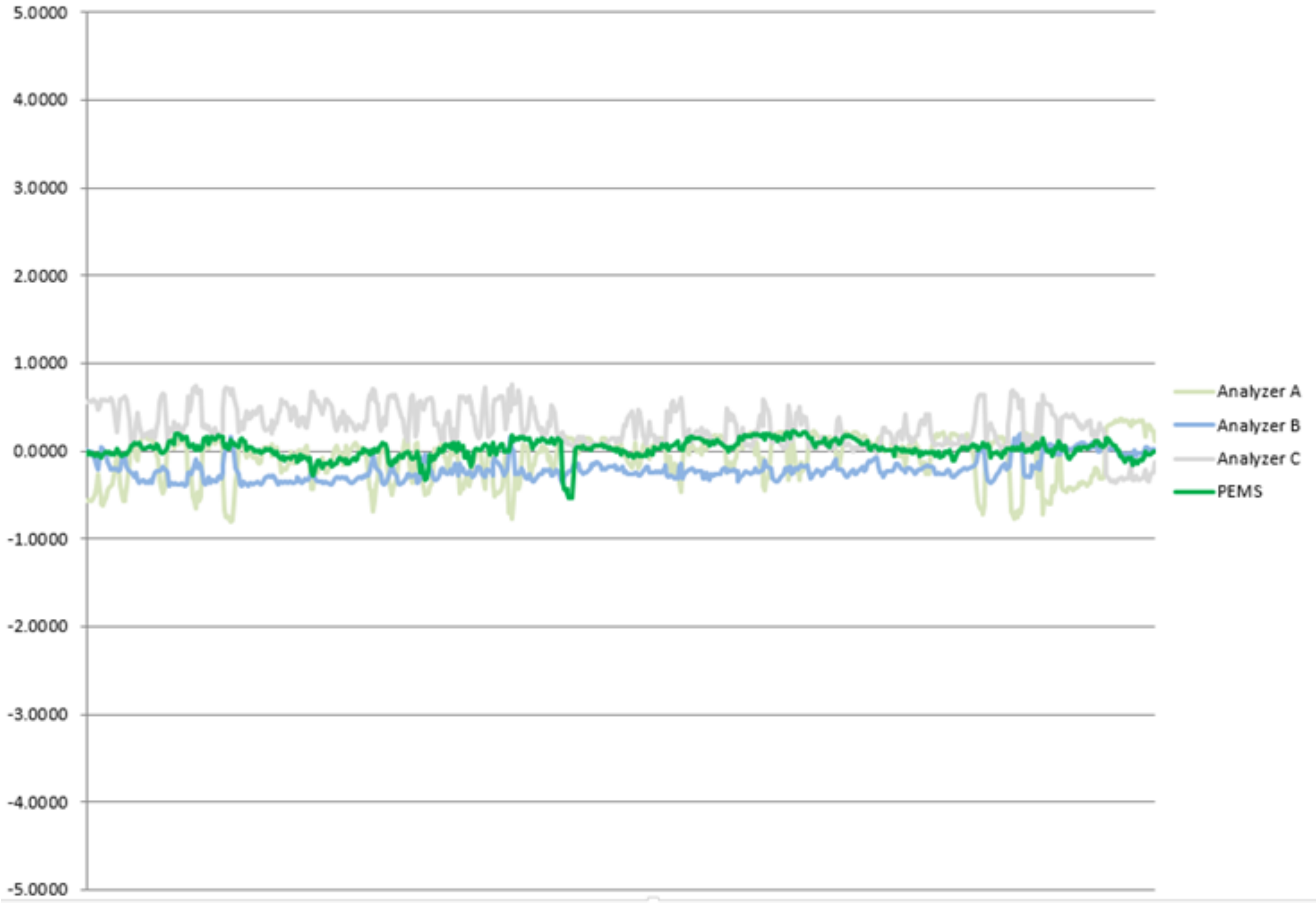
PEMS vs Actual
Linear (PEMS vs Actual)

Boiler Oxygen trim and control



Concluding Remarks

- A PEMS model can achieve accuracy comparable to a CEMS unit
- A statistical hybrid PEMS can be used as an alternative to CEMS under 40 CFR Part 60, PS-16 for the small gas turbine combined cycle application
- A class model can be developed that can be used for predictive maintenance and optimization