

Software CEM[®]

Advanced Emissions Monitoring



Pavilion8[®] Software CEM[®] is a predictive emissions monitoring system (PEMS), developed on the Pavilion8 platform, which provides highly accurate measurements of NO_x, CO, O₂ and other emissions as an alternative to costly hardware based Continuous Emissions Monitors (CEM).

The Software CEM system continuously monitors emissions by developing an online model using historical and real-time data from existing plant sensors. The Rockwell Software Hybrid Modeling technology incorporates nonlinear empirical models as well as first principles models to provide the most accurate prediction models available in the industry. These models are executed online using the Pavilion8 Model Analytic Engine to provide real-time predictions of emissions from a wide range of sources and fuels. Model validation is a routine that applies known values to the sensor inputs and verifies the values against known outputs. Predetermined input values are applied to the PEMS and output values are then calculated. These values are compared to the known output values from known input values (developed during modeling and RATA). Values are compared and determined via the Software CEMS that confirms they are in accuracy compliance. This process is an equivalency to a EPA mandated Quarterly audit.

Software CEM Model Development

Software CEM has been certified and is in continuous operation monitoring NO_x, CO, O₂, and other emissions, at more than 270 sources in the US. Software CEM has been proven to meet the PEMS requirements of the EPA on boilers, furnaces, reciprocating engines, turbines, and other emissions sources.

A kick-off meeting to discuss the scope of the Software CEM project is held prior to initiating any onsite activities, and at this meeting the functional design of the Software CEM is established and the necessary process sensors are identified. Appendix A provides a list of typical sensors used for wood, oil or natural gas fired combustors.

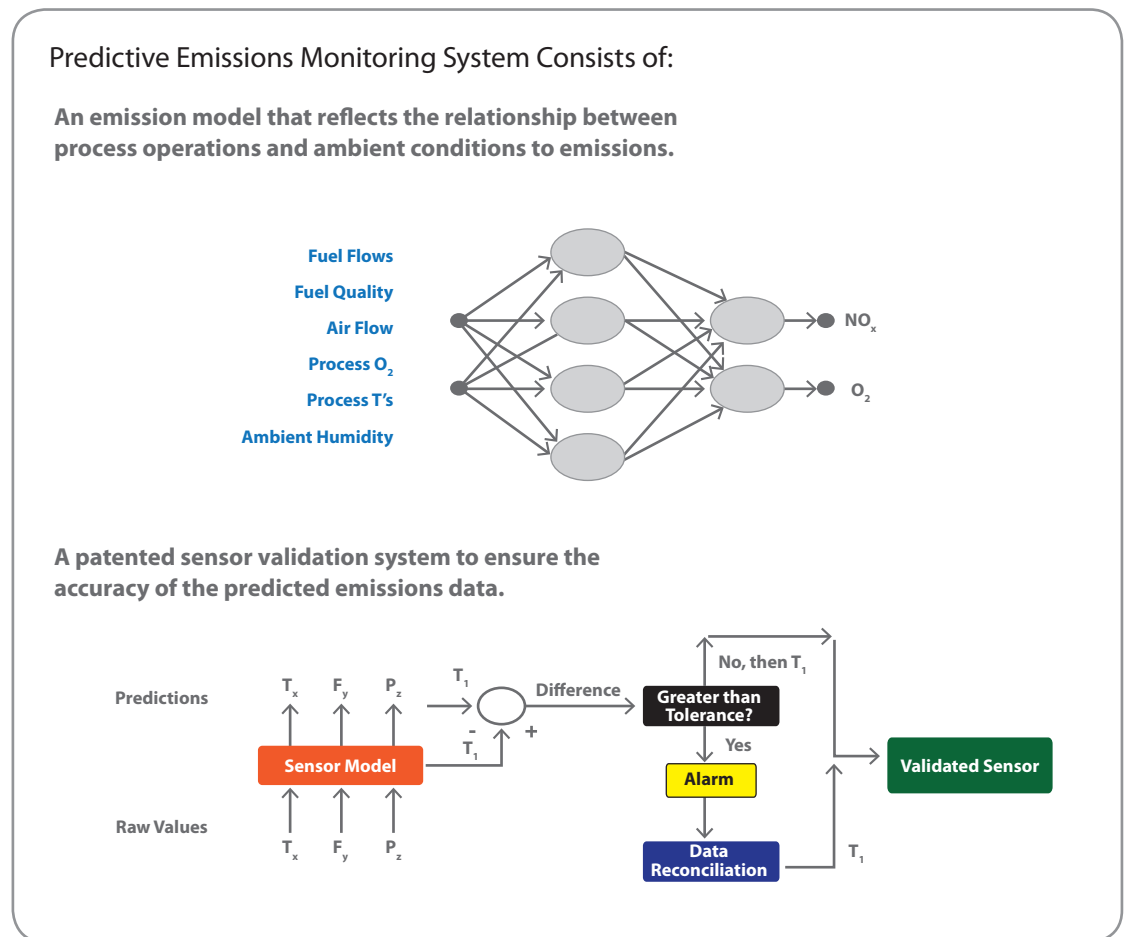
If no existing process is in place (i.e. hardware CEMS or other monitoring system), process data is obtained from the process's data historian or the Pavilion8 Data Logger. If no emissions data is available from existing hardware CEMS, stack emissions data is collected concurrently by an environmental testing firm.

The emission unit is operated through its applicable range of operation over a 2 to 7 day period (depending upon the complexity of the unit) while data is collected. This process and stack data is then utilized to construct a highly accurate emissions model.

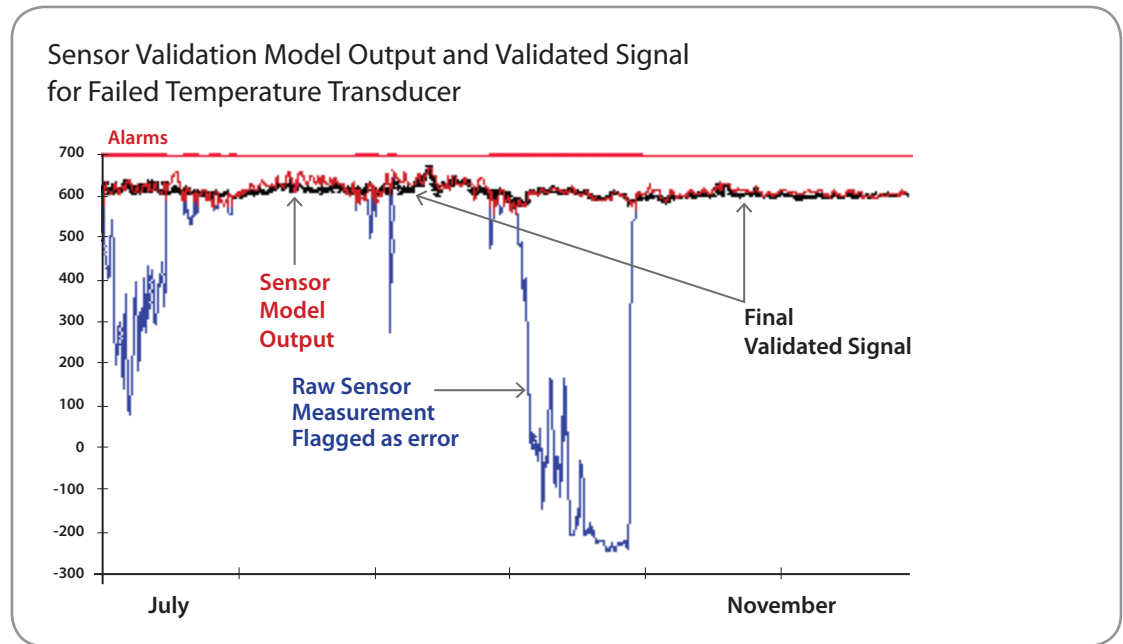
LISTEN.
THINK.
SOLVE.[®]

Sensor Validation System

The Software CEM is utilized to construct a Sensor Validation System for the process sensors. This system is used to determine variable inputs (e.g. air flow, process O₂, etc.) and emissions output (NO_x, CO, O₂ and CO₂). The Sensor Validation System consists of models that can detect failed (or drifting) instruments and will automatically reconstruct an appropriate value to be used in place of the failed instrument by the Software CEM to determine accurate emissions. If during normal operation an input sensor fails, the Sensor Validation System has the capability to use information from the remaining sensors to reconstruct the value of the failed sensor. In addition to continuing to predict emissions accurately, the Software CEM will also issue an alarm alerting the operator of a failed sensor.

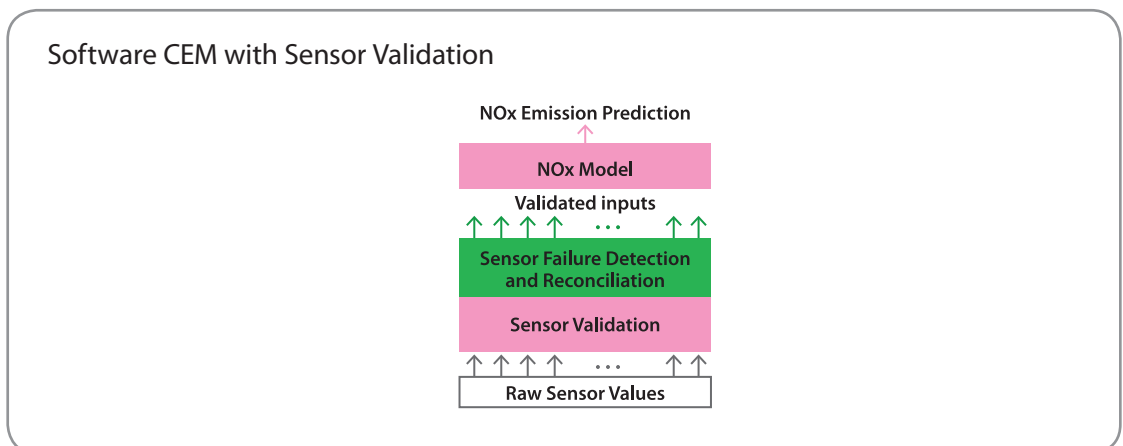


A key regulatory requirement for most PEMS is 95% uptime. The Software CEM typically achieves >99% uptime through the use of the Rockwell Software Sensor Validation System.



Emissions Prediction On-line

The Software CEM system (including the sensor validation routine) is initiated on-line by interfacing to the process distributed control system or data historian. The Software CEM acquires current process data, passes the data to the model for execution, and returns the emission prediction back in the form of a tag value. This approach allows existing operator console interfaces to be used to present information from the models to operations or engineering staff. The Software CEM can then be integrated with commercially available reporting packages.



Environmental Regulations and the Software CEM

The EPA and State agencies have approved the Software CEM to perform continuous emission monitoring of NO_x , CO , O_2 and other emissions on more than 270 emission units in the US. Environment Canada and Provisional agencies also accept Software CEM as a Predictive Emissions Monitoring System (PEMS).

EPA Emission Measurement Center's PEMS Evaluation

The EPA Emission Measurement Center has developed 5 PEMS Protocols and Performance Specifications that have been published on EPA's TTN website (www.epa.gov/ttn/emc/monitor.html) based on data from 5 Software CEM installations. The EPA hired an independent consultant to evaluate PEMS, and from this counsel, the EPA determined that PEMS requires sensor validation to eliminate the possibility of erroneous predictions due to failed sensor indications. The EPA also determined that expert personnel must construct a sensor validation system. The Emission Measurement Center now recognizes PEMS as a viable alternative to hardware CEMS and most states follow the EPA's recommendation.

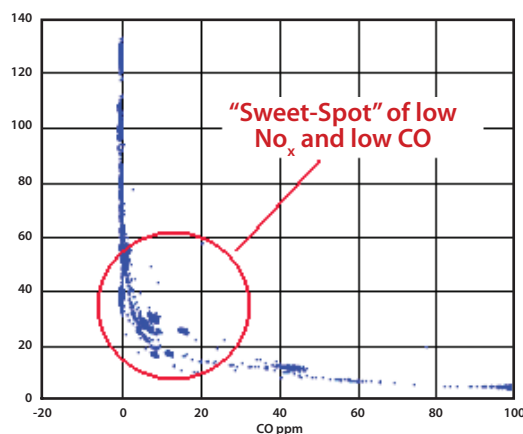
The basic EPA requirements for PEMS are:

- Initial 9 Test Run RATA:
 - 3 Test Runs at Low Emission Rates,
 - 3 Test Runs at Normal Emission Rates
 - 3 Test Runs at High Emission Rates
- Demonstration of Sensor Validation System
- Ability to Detect Failed and Drifted Sensors
- Ability to Reconcile Bad Sensor Values
- Quarterly "Golden Diskette" Check
- Annual 9 Test Run RATA

Emission Reduction and Process Optimization

In addition to the reduced costs of regulatory compliance, the Software CEM provides another cost saving benefit - the power to control the process to reduce emissions while optimizing production, thereby improving operations. The figure below depicts the inverse relationship between NO_x and CO for a gas turbine unit. While developing the Software CEM, the engineer using Pavilion8 located a "sweet-spot" where both NO_x and CO are low and operations are optimal to achieve reduced emissions and improved production. Reference Appendix B for details.

Emission Reduction: NO_x versus CO



Appendix A – Process Sensors Examples

Process Sensors

The following sensor inputs have been used to develop Software CEMs for natural gas, oil and wood fired combustors. All sensors available are evaluated for development of the Software CEM.

Boiler Sensors

- Feedwater Flow Rate
- Grate Temperature (if applicable)
- Steam Flow Rate
- Air Flow Rate
- Air Inlet Temperature
- Economizer Outlet Flue Gas Temperature
- Economizer Inlet Flue Gas Temperature
- Economizer Outlet Water Temperature
- Economizer Inlet Water Temperature

Fuel Conditions

- Natural Gas Flow Rate
- No. 2 Oil Flow Rate
- Wood Feeder Master Rate

Ambient Conditions

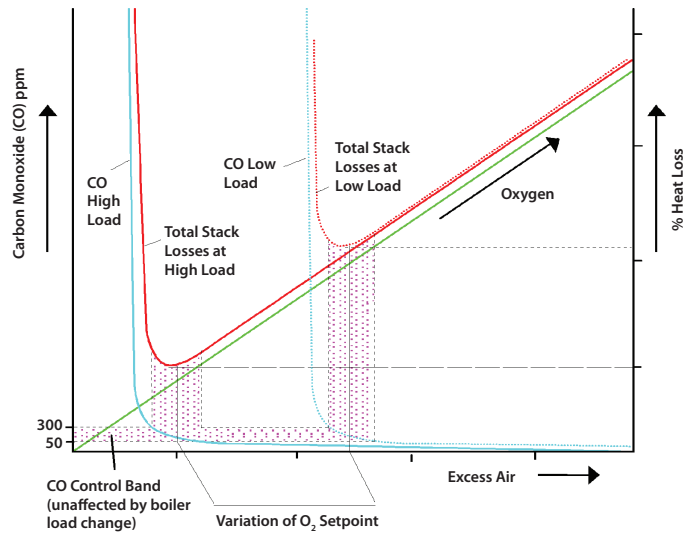
- Relative Humidity (testing firm required to monitor)
- Barometric Pressure (testing firm required to monitor)
- Temperature (air preheat temperature or after flue gas recirculation)

Appendix B – Combustor Optimization with Software CEM

Industrial/Commercial/Institutional (I/C/I) Combustors and Process Heaters (P/H) are fired via a carbon based fuel such as natural gas, oil, coal or some form of biomass that is continuously fed into the combustor chamber. During this process complete combustion of the fuel occurs. However, the use of these fuels can be minimized by optimizing burner efficiency, thus reducing fuel consumption and emissions output.

Efficiency is a direct correlation of data derived from the measurement of flue gas temperature and oxygen (O_2). The combustion chamber of an Industrial/Commercial Boiler introduces the primary air and fuel. The fuel is introduced through a burner nozzle and is designed to produce a flame front over the full range of operating conditions. Complete combustion is a function of oxygen and temperature: the greater the amount of excess oxygen, the less fuel efficient the boiler will be. Reducing the excess oxygen improves efficiency. Conversely, as oxygen is reduced, CO can start to form. Excess levels of CO indicate incomplete combustion and increased emissions. The use of CO monitoring can help emission levels remain within limited parameters and maximize the efficiency of the burner operation. Monitoring O_2 and CO as a process application for burner/boiler control has been widely accepted in the utility and industrial source market and has played a strong role in optimization of burner/boiler efficiency. The figures included present a graphic representation of the relationship of O_2 and CO with efficiency.

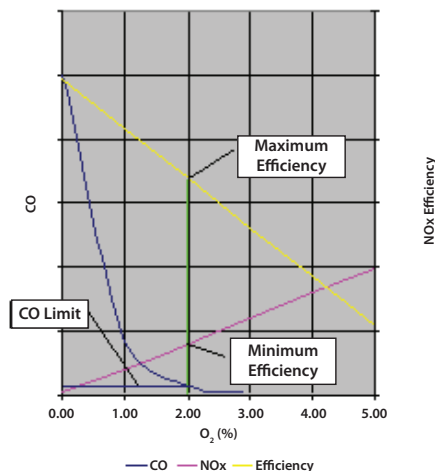
To Optimize Fuel/Air Ration and combustion Efficiency



Combustion Optimization

Figure 1 shows the formation of NO_x and CO as a function of excess O₂ in a typical combustion application. Efficiency is also shown as a function of excess O₂. As excess O₂ decreases, NO_x decreases while CO and efficiency increase. To minimize NO_x production and maximize efficiency, excess O₂ needs to be minimized. However, equipment safety limitations and environmental regulations limit the amount of CO that can be produced. As a result, excess O₂ can only be reduced until the CO constraint is reached. At this point, combustion has been optimized, with the unit operating at the maximum allowable CO production, which corresponds to the minimum NO_x production and maximum efficiency.

NO_x and CO Efficiency



Disturbances such as changes in fuel composition, equipment conditions, ambient conditions, and load cause these variables to shift. As a result, it is not possible to determine an optimal excess O₂ arch as a function of load. Most operators use an input that guarantees that the CO limit will not be exceeded, which respects the CO constraint but fails to minimize NO_x or maximize efficiency. Combustion optimization uses a real-time CO indication and a model of the combustion process to constantly update the excess O₂. The optimal curve is recalculated each time the software application runs (every 15 to 30 seconds).

In more complex units, other variables in addition to excess O₂ have a significant impact on NO_x and CO formation and can be useful in minimizing NO_x and maximizing efficiency. Examples of these manipulated variables include: burner and overfire air dampers, burner and overfire air tilts, and windbox to furnace differential pressure. Additionally, adjustments to the combustion optimization manipulated variables can affect other important unit variables such as flue gas exit temperature, steam temperature, or attemperating spray flows. It is important that the combustion optimization system respect constraints for these variables as well.

Modeled operating parameters applied to a well defined and verifiable Neural Network can be applied to the real-time operation of the combustor source and maximize the efficiency without additional hardware and maintenance costs. Typical (but not limited to) operating parameters (sensors) are:

- Operating O₂ values
- Outlet Temperature
- Ambient Air Temperature
- Windbox Differential Pressure
- Fuel Flow
- Combustion Air Flow
- Inlet Air Damper Position
- ID Fan Speed

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