Green Foundry Project 2005-02

Six Sigma PM (Particulate Matter) Emission Reduction

☒ Full Scale Implementation OR ☐ Pilot Scale/Study

1. Description of the project: What is the issue and how did you fix it?

Business Case: In May 2018 a particulate matter (PM) initial performance test resulted in 1.63 lb PM/ton iron poured on our department 804 mold line cooling shed (CBE). Without any changes, that rate created an emissions projection in excess of PSD thresholds, requiring the investment of a baghouse (filtration system) to lower the emissions.

To solve the problem a team was chartered with the goal to understand the impacts of variables affecting the overall PM emissions from the cooling shed at 95% confidence level, determine the correct emission rate and normalization factor to accurately report emissions, and deliver a proposal to reduce PM emissions by 50% from the cooling shed.

Emission measurement and analysis: To begin, the team needed a method to measure emissions. The regulatory test method of sampling the gas stream in each stack was too costly, expensive, and slow. We concluded a real-time measurement system was the only realistic option to test critical to emissions parameters. We initially felt we would need to install a continuous emission monitoring system to be successful, which are costly and time consuming to install. The cooling shed exhaust stacks had opacity meters installed during construction, which measures the amount of light blocked across the exhaust stream. These are typically considered far less sophisticated instruments, used to detect catastrophic failures in baghouses and not incremental changes in particulate loads. By analyzing the output form the opacity meter during various operating scenarios we used a time series analysis to show there is a structure to the data which we can use. This proved successful - it was the sensitivity determined necessary for the project. Team members recalled their experience as former trade electricians and maintenance supervisors; knowing the calibration procedure and hypothesized it could be modified. By contacting the manufacturer and discussing what we desired a commissioning procedure was modified to provide the improved resolution the project needed.

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To validate that we could use the meters we set up a 10-run engineering stack test to validate the model but also used the test to provide an added bonus of investigating fan speed changes. To determine the sensitivity needed environmental felt we needed to observe a 10% change in emissions in the PSD tracking for the 804 project. Because the project included many emissions sources and not just the 804 cooling shed this equated to +/- 2.5 lb/hr in cooling shed emissions. Using linear regression models we correlated the opacity meters to actual measured PM Emissions.

System block diagraming facilitated the identification of critical to emissions (CTE) parameters. Of 10 possible CTE's, 5 were selected for measurement and analysis: Supply Fan Duct Velocity (fan speed), Casting Temperature, Cooling Shed (CBE) Ambient Temperature, Measurement Uncertainty (sensors), and Cooling Shed Relative Pressure.

Air Quality Analysis: Members from the computational fluid dynamics (CFD) team at PEC (Product Engineering Center) in Waterloo were able to model the cooling shed enclosure based on boundary conditions in the cooling shed. The cooling shed operates based on pressure differentials between many systems. By providing this information to the CFD team we were able to analyze particulate motion between the exhaust and inlet in the CBE.

Using the equation for the terminal velocity of a spherical particle the boundary conditions in the cooling shed showed particles <50 microns will not settle out.

Emissions Test Program: The team employed the opacity meters in a test program to investigate effects of fan speed on the PM detector. Charted data was visible to the eye to have correlation and was confirmed using linear regression with the detector average as the dependent variable. During high fan speed PM increased dramatically and in low fan speed scenarios PM drops very low.

Revised PM Forecast: After much discussion and regression analysis, the team decided to stick with tons of iron poured as the normalizing factor for annual emissions reporting. We developed a revised 5-yr PM emissions forecast to ensure that the project goal would be met. The new strategy takes tractor volume forecast and converts it to a tons of iron poured forecast through: Net Molds Per Hour (nMPH), Average mold weight, and Hours of production planned.

Additional Efforts: The CBE is exhausted with 2 exhaust stacks. The team was never comfortable with how much Green Foundry Project 25 / 38 higher emissions from the south stack were when compared to the north. During a stack test in 2015 the 8 individual headers which now merge into the north and south stacks were tested.

Particulate emissions from one stack in particular was much higher. The team identified the root cause a position 19A/B. This position contained the transition from the cooling box enclosure to the shaker pans where manipulators hang the parts for cleaning. The transition was controlled by a baghouse but the collection point in was high in the ceiling. This resulted in the cooling box enclosure pulling those emissions back into the cooling shed. The capture system was re-designed and resulted in an additional PM reduction from the cooling shed.

Results: After implementing the new fan control scheme (lowering fan speeds) the PM emission rate was reduced by 42% from 1.63 lb/ton iron poured to 0.95 lb/ton iron poured. After completing the 19A/B project to isolate emissions from the cooling shed the PM emissions reduction was 52% or 0.78 lb/ton iron poured.

2. Environmental Benefits: Conservation of raw materials or energy, reduction or elimination of emissions, wastes, toxics, water discharges, etc.

Energy Savings: As a result of our fan speed strategy we achieved 8.8 million kW-hr reduction to the cooling shed. Emissions Reduction: 52% of particulate from largest source at foundry.

3. Other Benefits: Productivity, health and safety, employee morale, etc.

Aligned teamwork from a project team of cross functional groups each having different experiences yielded an innovative solution. Environmental – wanted to have improved accuracy of emissions reporting Operations – did not want to invest in bag house, gained more in depth understanding of key foundry process (804 cooling shed) Factory Automation – provided expertise regarding data collection & interpretation, created solution that enabled the foundry to use existing sensors in a manner that was innovative Quality – the glue that allowed the team to succeed, also got exposure to solving a problem that was related to environmental, not the typical quality project

4. Cost Savings: Capital cost, operating cost, ROI or other pertinent cost information.

Energy Cost Savings: As a result of our fan speed strategy we achieved $563,000/yr savings from 2018 to 2019. Cost Avoidance: $12,000,000 for a new baghouse

5. Applicability to other foundries and additional Comments

Quality management tools such as six sigma are utilized across the industry. The only limitations are a management team willing to assign the resources to an environmental project, and committing to the analytical rigor necessary for success.

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6. Applicable Environmental Categories and Foundry Processes. Select all that apply.

Environmental Categories

☒ Carbon (GHG) Emissions Measurement and Reduction

☒ Air Quality ☐ Water Use and Discharge ☐ Waste Management

☐ Beneficial Use ☐ Stormwater ☐ Material and Resource Conservation

☐ Community Engagement

Foundry Process(es) Impacted

☐ Melt ☒ Pour ☒ Mold ☐ Core ☐ sand system/reclaim

☐ Shakeout ☐ Heat Treat ☐ Quench ☐ Finishing ☐Shipping

☐ Maintenance ☐ Pattern Shop ☐ Casting Design

☐ Management Systems and Metrics

☐ Other, explain: Click or tap here to enter text.

7. Add photos to enhance your application, if applicable.

See following Pages

Emissions Measurement and Analysis

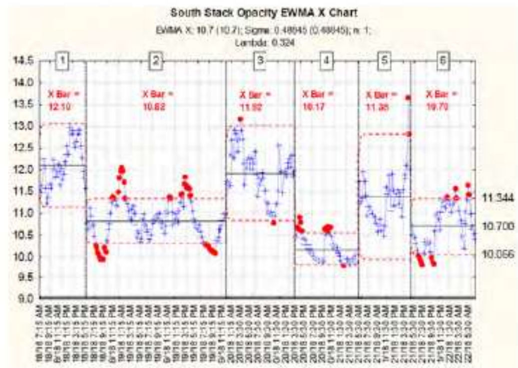
Measurement Systems

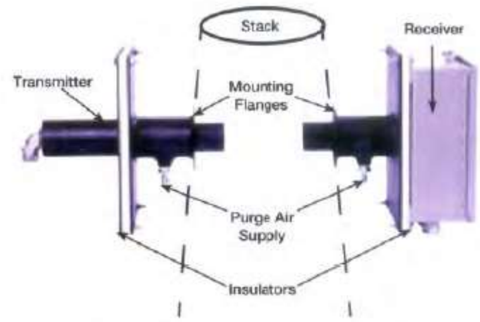
Needed real time measurement of emissions. We could not rely on repeated stack tests (cost and time). Existing opacity meters were reviewed for possible use as project instrumentation.

1. Time Series Analysis encouraged us to push forward (Signal/Noise Assessment)
2. Understanding the set up Standard Operating Procedure (SOP) yielded an opportunity for improvement

Opacity meter now had the sensitivity necessary to be qualified for this project.

Team was able to avoid the $40K expense of installing a CEMS system by utilizing existing opacity meters.





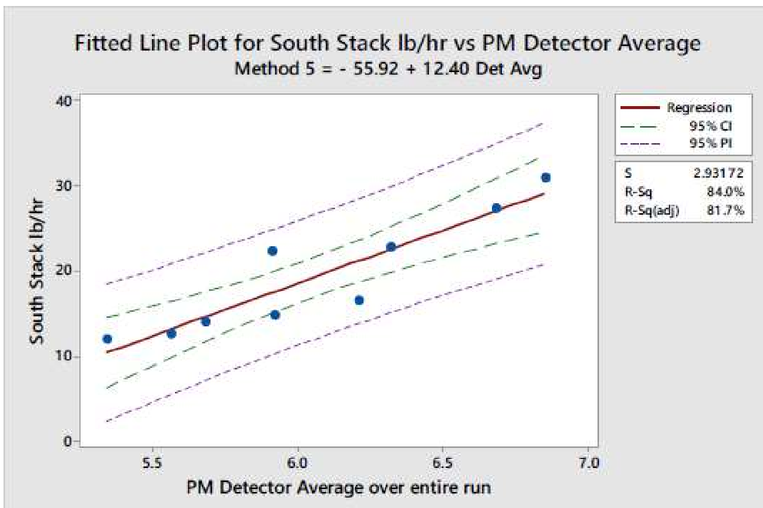
The receiver senses the signal modulation from the transmitter and the microprocessor converts it to a dust concentration reading.

Emissions Measurement and Analysis

Measurement Validation

Team decided to set up and engineering stack test to build a linear regression model.

Through linear regression, we were able to correlate the opacity meters to actual measured particulate matter.



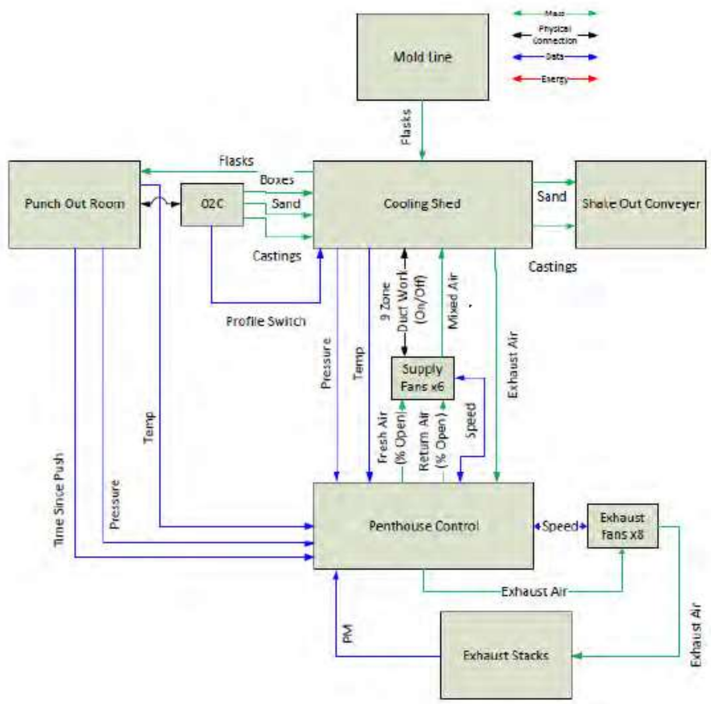
+/- 2.5 lb/hr resolution for the 95% confidence interval on regression meets the minimum resolution requirement set by Environmental Engineering

Identify Parameters Critical-to-Emissions

System Block Diagram

Rigorous application of Six Sigma tools enabled project variables critical to emissions to be identified and selected for measurement and analysis.

1. Supply Fan Duct Velocity (fan speed)
2. Casting Temperature
3. Cooling Shed (CBE) Ambient Temperature
4. Measurement Uncertainty (sensors)
5. Cooling Shed Relative Pressure



Team developed a new understanding of cooling shed operation

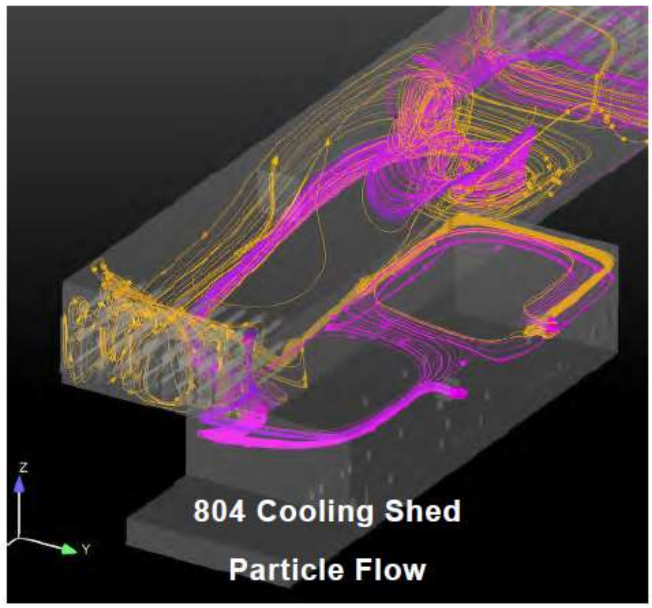
Air Quality Analysis

Computational Fluid Dynamics

Team experience and historical data led to the hypothesis that supply fan energy was causing unnecessary disturbance of dust. **After analyzing our system, the Computational Fluid Dynamics (CFD) team at PEC advised that if a particle less than 50 microns becomes air born, it will not settle out.**

Terminal velocity of a spherical particle:

$$V_t = \left[\frac{4gD}{3C_d}\left(\frac{\rho_s-\rho}{\rho}\right)\right]^{1/2}$$



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