MDE's Operating Curve Analysis

MDE's annual ozone season assessments of optimization of SCR and SNCR controls typically compares the unit's analytic year ozone season average NOx emission rate to its past-best ozone season average NOx emission rate. MDE identified the past-best ozone season average emission rate as a point of comparison for the current analytic year by calculating a percent deviation in NOx emission rate between the "best year" and the current analytic year. Any unit that shows a greater than 100% deviation in NOx emission rate (i.e., more than double) is identified as poorly utilizing controls. This is a clear indicator that utilization of SCR or SNCR control technology at these units appears questionable and, at minimum, requires further investigation. MDE has presented its technical analysis in the past to a variety of stakeholders, state agencies and the EPA, and has received feedback that many coal-fired EGUs with SCR or SNCR controls could not meet the emission rates consistent with what was achieved in their past-best year simply because they were operating at lower capacities. In September 2015, MDE developed a tool that examined optimization of SCR controls while also accounting for expected changes in NOx removal efficiency due to low-capacity operation. MDE has shared this tool and the results of the analysis with stakeholders, state agencies and the EPA.

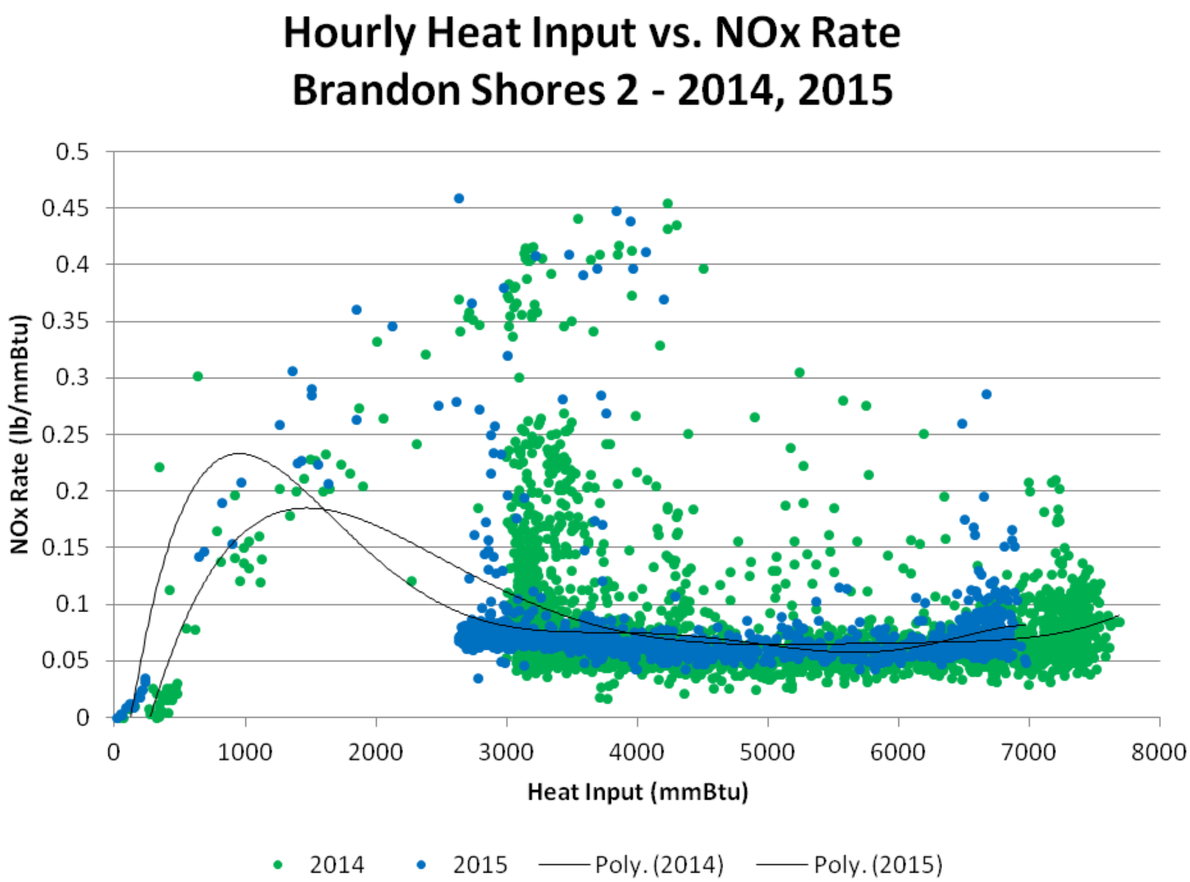
Feedback from stakeholders indicated that NOx emission rates associated with a unit's past-best average ozone season rate could not be achieved in recent years primarily due to changes in operating patterns. Coal-fired EGUs are operating at lower capacities in recent years, which in turn causes higher emission rates. MDE examined this claim by comparing NOx emission rates at various heat inputs to discern the unit-specific relationship between its heat inputs and its NOx rates. This analysis is completed at the unit level because each boiler and its emissions control components are unique to each installation; assuming the results based on the design of one boiler can be applied to a different boiler is likely inappropriate.

Heat input is the amount of energy entering the boiler; it follows that lower heat inputs leads to less electricity generated. Temperature is the measure of the intensity of heat in a substance. Heat input and temperature are not the same, but they are related. SCR efficiency is dependent on many factors, but one of the most important factors is the temperature of the flue gas exiting the boiler. NOx control efficiency is lowest at lower temperatures, and temperature is likely lower at lower heat input levels. However, as flue gas temperature is not available in the EPA's CAMD database, MDE's used heat input as a proxy for flue gas temperature. The theory follows that at lower heat input, NOx rate will be higher out of the SCR, because the flue gas temperature (and the amount of electricity generated) will be lower. Assuming all other factors remain constant, there should be a similar relationship between NOx emission rate and heat input between a unit's best ozone season and the analytic year ozone season. Any large increase in rate at the same heat input indicates that other factors, such as a decrease in ammonia or urea injection rate, may be the cause of NOx rate increases and that the SCR is not being optimized.

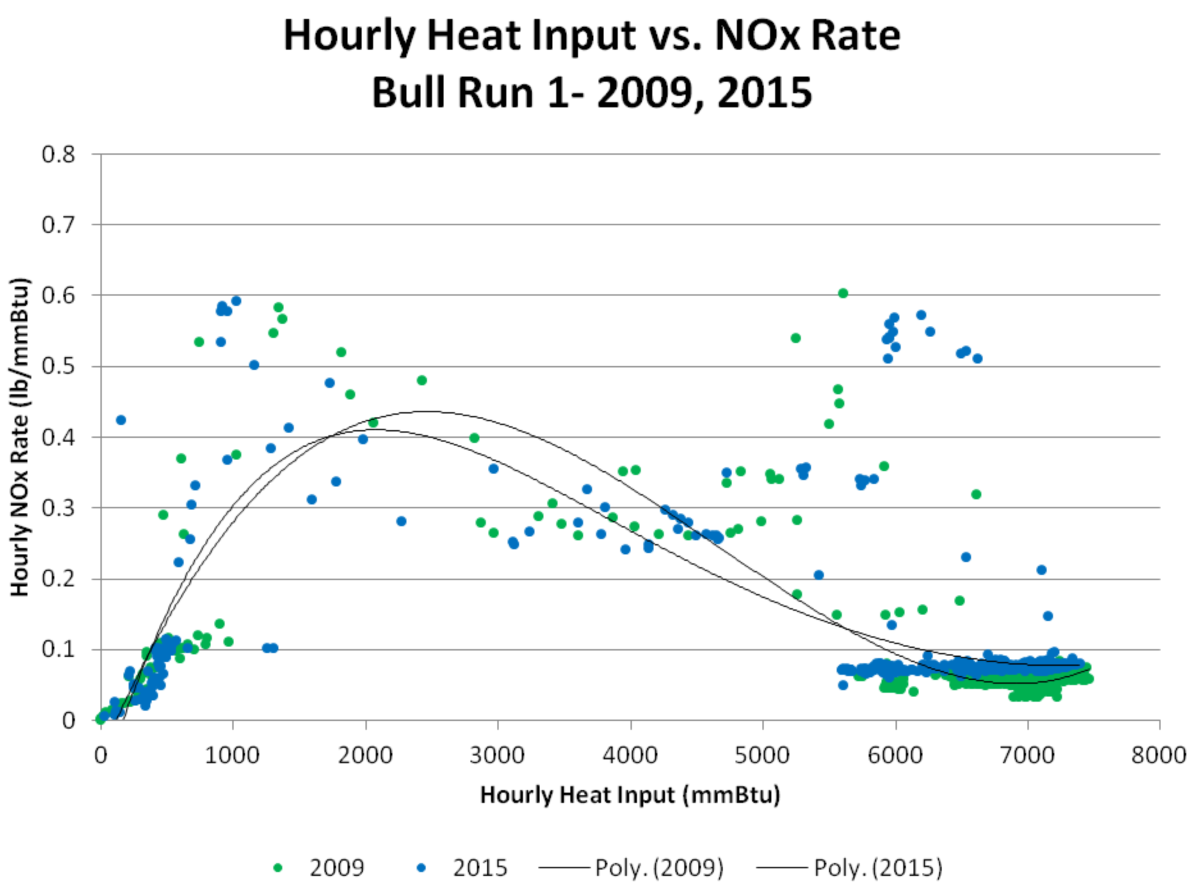
MDE's Operating Curve Tool uses the hourly NOx emissions data from EPA's CAMD database for each unit's past best ozone season and the current analytic year ozone season. The tool plots the hourly NOx emission rate as a function of hourly heat input for both ozone seasons. Comparison between the two "curves" gives insight into SCR optimization efforts in the analytic year.

The following examples show the operating curve for three units - one where the percent deviation between the unit's past-best ozone season average emission rate and the unit's preliminary 2015 ozone season average emission rate (May and June only - as that is when the study was initiated) is less than 0%, one for a unit where the percent deviation is between 1-100% and one for a unit with a percent deviation is greater than 100%.

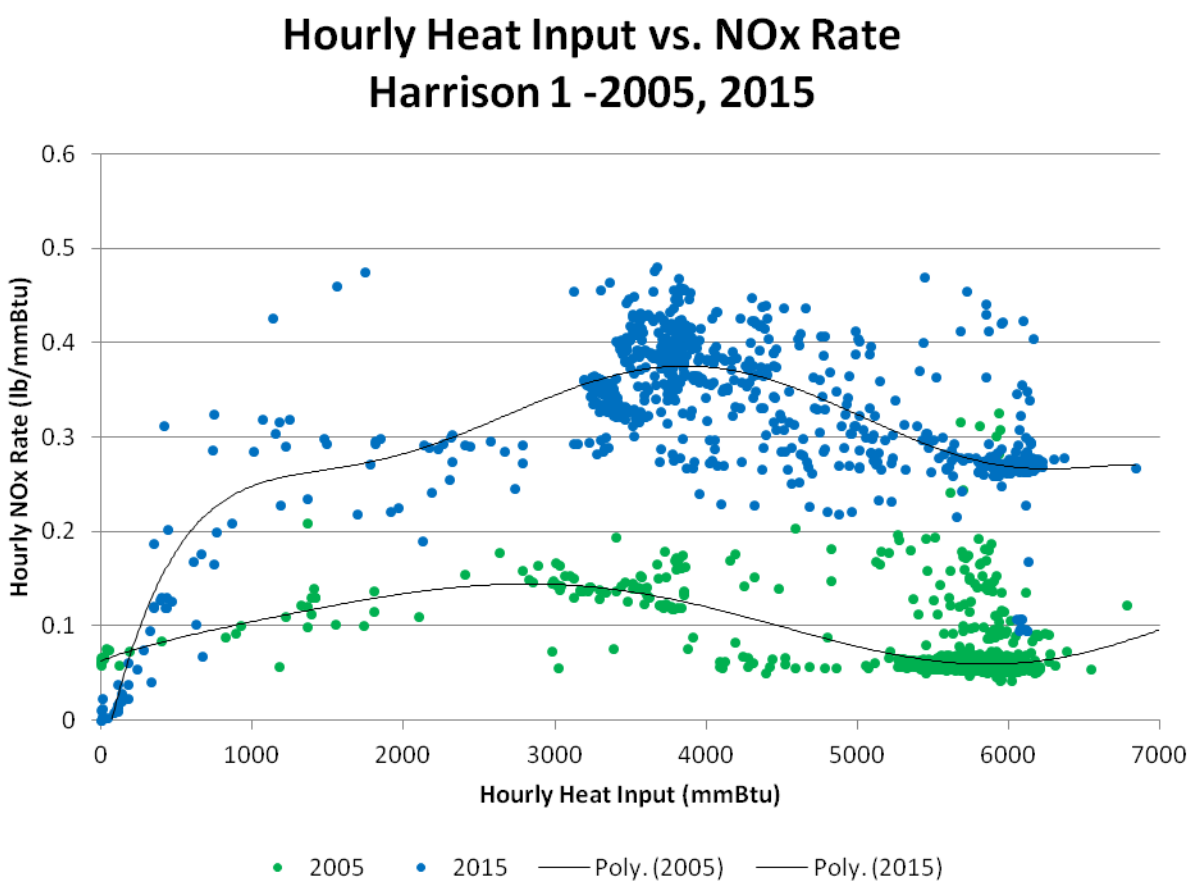
- Example 1: This unit's percent deviation between the past-best ozone season average NOx emission rate and the preliminary 2015 ozone season average emission rate is -7.17%. The "operating curve" for the unit shows that NOx rates at nearly every heat input level is either equal to or lower than the NOx emission rates achieved in this unit's past-best ozone season. The controls are likely fully optimized.



- Example 2: This unit's percent deviation between the past-best ozone season average NOx emission rate and the preliminary 2015 ozone season average emission rate is 69.2% indicating that this unit may have some optimization issues. The "operating curve" for the units shows that this unit is spending a higher proportion of hours in lower heat input ranges, indicating that it is likely operating at lower capacities or lower temperatures, which can lead to an increase in emission rate. However, the 2015 operating curve for this unit is very similar to its best year's curve. There may be some opportunity for greater optimization of the SCR, especially at higher heat input levels, but given likely changes in operating conditions, the SCR is likely optimized.



- Example 3: This unit's percent deviation between the past-best ozone season average NOx emission rate and the preliminary 2015 ozone season average emission rate to 416.25% indicating that this unit is likely operating the SCR in a sub-optimal manner. The number of data points and their heat input levels in 2015 indicates that there is likely a significant change in the operating pattern at this unit compared to its best year where it appears it operated for many more hours and at a consistent heat input level. However, at all levels of heat input, the operating curve indicates that there is a level of optimization that is not being achieved.



For each of these examples, the green plots, are the data associated with the unit's past-best ozone season. The data in the plot shows that as the unit increases in temperature and heat input, there is a precipitous increase in NOx emissions rate. This is expected as the boiler is likely not to a temperature that is not ideal for NOx removal. The emissions rates for these three units appear to plateau generally between 2,000 and 3,000 mmBtu, indicating that the boiler appears to have reached the lower threshold at which NOx removal becomes efficient, as is evident by the precipitous downward trend in emission rate as heat input increases. Generally, after about 3,000 mmBtu, the boiler is clearly at optimal temperature and NOx removal is maximized. The blue data points show the hourly operating and emissions data from 2015. The same relationship between heat input and NOx emission rate exists as it does in the unit's best ozone season. In some instances, it is also evident, based on (1) the number of data points and (2) the collection of data points at certain heat-input levels, that some units are likely operating less frequently and likely at lower temperatures than in their past- best ozone season. However, even accounting for those changes in operation, it is evident for some of the units in the 0-100% deviation range, and many in the 100%+ deviation range, that these units are likely operating their controls in a sub-optimal manner. At heat inputs generally above about 3,000 mmBtu, the heat input identified as being a point at which NOx reduction is at its maximum potential, these units emitted at a rate clearly above what should be expected had the SCR controls been optimized.

MDE recognizes that some units are spending more operating time at temperatures and heat inputs that are less conducive to NOx reduction. Clearly MDE could not expect that a unit could achieve maximum NOx reduction rates at those lower heat inputs. However, many units, even operating at lower temperatures and heat inputs are capable of achieving NOx emission rates lower than what they are currently emitting at.

As part of its annual study, MDE updated its methodology for calculating potential ozone season NOx savings, taking into consideration changes in operating patterns. The traditional methodology calculates the analytic year ozone season NOx mass if the units had met their past-best ozone season average emission rate. This assumes that a unit can meet its past-best ozone season average rate throughout the entire ozone season. It is calculated by multiplying the unit's best ozone season average NOx emission rate by the analytic year's ozone season heat input. The difference in NOx mass between what was actually emitted and what would have been emitted had they operated at that past best average rate are the potential avoidable NOx emissions. The updated methodology calculates NOx savings if the units had met rates associated with the past-best ozone seasons operating curve. This assumes that NOx rate is a function of heat input, and that a unit can follow the same curve as the past-best ozone season. First, the hourly data from the past-best ozone season is used to calculate the units average NOx emission rate for each 500 mmBtu heat input "bin". Next, the analytic year hourly heat inputs are matched to those best year 500 mmBtu heat input bins and multiplied by the average NOx rate calculated in the previous step. This gives hourly NOx emissions. Lastly, the NOx emissions are summed to determine how much NOx would have been emitted had each unit followed the past-best ozone season operating curve. For units that have experienced significant changes in their operating patterns from their past- best ozone season, this methodology gives a certain amount of leniency when calculating potential emissions reductions; it accounts for the increase in emissions due to low capacity operation. However, for many units, there tends to be a fairly close agreement in potential NOx reductions between the original methodology and the updated methodology.